Some major school health problems in southern Ethiopia: Malnutrition, parasite infections, and skin problems

Hiwot Hailu Amare

Thesis for the degree of Philosophiae Doctor (PhD)
Hawassa University, Ethiopia and
University of Bergen, Norway
2022

HAWASSA UNIVERSITY

UNIVERSITY OF BERGEN

Some major school health problems in southern Ethiopia: Malnutrition, parasite infections, and skin problems

Hiwot Hailu Amare

Thesis for the degree of Philosophiae Doctor (PhD)
Hawassa University and University of Bergen

Date of defense: 02.12.2022

Year: 2022

Title: Some major school health problems in southern Ethiopia: Malnutrition, parasite infections, and skin problems

Name: Hiwot Hailu Amare

Print: Skipnes Kommunikasjon / University of Bergen

Dedication

To

Hailu, Zerfe,

Kenedi, Mara, and Kabrak

Scientific environment

This thesis is the product of a joint PhD programme between the University of Bergen in Norway and Hawassa University in Ethiopia. The research was funded by the Norwegian Programme for Capacity Development in Higher Education and Research for Development (NORHED) through the South Ethiopia Network of Universities in Public Health (SENUPH). The NORHED-SENUPH project aimed to increase women's participation in postgraduate studies through a joint PhD programme between the School of Public Health, College of Medicine and Health Sciences, Hawassa University, Hawassa, Ethiopia, and the Centre for International Health, Faculty of Medicine, University of Bergen, Bergen, Norway. The training component of the PhD work was carried out at both the University of Bergen in Norway and Hawassa University. The study was conducted in Ethiopia. The entire course work, scientific conference, and research work were funded by the NORHED-SENUPH project (ETH-13/0025).

Acknowledgments

It is with great pleasure that I would like to express my deepest gratitude to my supervisor, Professor Bernt Lindtørn, for his enthusiasm, expertise in supervision, prompt responses, dedication to technical and academic support, constructive criticism, and indispensable contribution to my research work. Professor Lindtjørn is exceptional at persuading and encouraging his students to be independent and confident. I learned a great deal from him throughout our collaboration as a doctoral student, including scientific research, academic communication, and critical thinking. The ideas he shared with me gave me a comprehensive guide to learning new ideas and methods. This thesis work would not have been realized without his exceptional support, mentoring, and guidance. I am deeply grateful for the help you have provided, and I am happy to be working under your guidance and supervision. Professor Bernt, thank you so much. I wish you and your family an abundance of good health.

I would like to express my sincere gratitude to Dr. Eskinder Loha for his support and encouragement. I would also like to thank Dr. Taye Gari for his support and encouragement.
I am very grateful to the schoolchildren, parents, and guardians who agreed to participate in this study. My sincere thanks also go to the data collectors and field supervisors who sacrificed their time to contribute to this study. My special thanks to the laboratory technicians and nurses who participated in the laboratory diagnoses and clinical examinations; your contributions to this study are highly appreciated.

I would also like to thank the Norwegian Programme for Capacity Development in Higher Education and Research for Development for funding this research work. I extend my gratitude to Hawassa University, Ethiopia, and the University of Bergen, Norway for providing me with a scholarship.

I am thankful to the staff members at Hawassa University, Ethiopia, and the University of Bergen, Norway, for your support and encouragement during my PhD journey. Your readiness to support and encourage are also highly appreciated. I would like to thank Gunhild Koldal and Daniel Gundersen for their administrative facilitation and support at the University of Bergen. I would like to thank the Norwegian Programme for Capacity Development in Higher Education and Research for Development for funding this research work. I thank Hawassa University, Ethiopia, and the University of Bergen, Norway for providing me with a scholarship.

I am grateful to the Dilla University Teaching and Referral Hospital and the Ethiopian Public Health Institute for their logistical support. I would also like to thank Gedeo Zone Health Department, Wonago District Education Office, school directors, and their teachers for facilitating the research work.

I am grateful to my loving and helpful husband, Kenedi Sisay, who supported me unconditionally throughout my doctoral research. My dear husband, you are unquestionably the best thing that has happened to my life. Your appreciation and encouragement have contributed immensely to my success. You are also a great father, always taking care of our two little kids, Mara and Kabrak, who joined us during my PhD. Keni, Mar, and Kab, thank you for your presence in my life; you are a true blessing to me. I love you so much!

Most of all, I would like to thank my father, Hailu Amare, and my mother, Zerfe Tiruneh. Their love, support, encouragement, and prayers accompany me through my ups and downs. Thank you, Aba and Ema, for teaching me the value of education as a child. God bless you with long life and good health, Aba and Ema. My heartfelt thanks go also to my beloved brothers and sisters Daniel, Tewodros, Seyoum, Abraham, Semegn, Tigist, Simret, and their families for their love, support, prayers, and encouragement.

Mr. Sisay Negash, Mrs. Abebech Surur, Lemlem, Mekdes, Hailemichael, and Melat deserve my appreciation for their love, support, encouragement, and prayers. Abuye, I do not want to call you a mother-in-law, but a second mother. For all your love, support, encouragement, and prayers, I cannot thank you enough. May God bless you with health and long life, Gashe and Abuye. I extend my heartfelt gratitude to Mr. Tsadiku Sisay, Mr. Yonas Alemayew, Mrs. Alem Tekle, and Mrs. Menen Bezabih for their hospitality, kindness, love, support, and encouragement, especially when I was in the United States of America for a scientific conference. For sharing their knowledge and skills during the academic communication process, I wish to thank my fellow PhD students, Samrawit Hailu, Sewhareg Belay, Hiwot Abera, Tsigereda Behailu, Dr. Alemselam Zebdewos, and Dr. Debritu Nane. I am thankful to my cousin

Mr. Gezachew Kefelew for his words of encouragement and prayers. My sincere gratitude is also due to my friend Yirefu Tefera for her love and encouragement.

Above all, I am grateful to God almighty and the Blessed Virgin Mary for accompanying me in every step of my life, for answering my prayers when I was in trouble, and for filling my life with blessings. Thank you, my Almighty God and blessed Virgin Mary—without your help I could never have completed this work. Thank you for allowing this to happen. (ያሳደከኝ መድኃኔዓለም የኔ ጌታ ስለረዳህኝ አምሰግንሀለው! የኔ እናት ቅድስት ድንግል ማርያም ሆይ ሁሌም ካጠገቤ ስለሆንሽ አመሰግንሻለው!)

Summary

Background: Even though the global enrolment of children in schools is increasing, school-aged children in Ethiopia are at risk of various health problems, including malnutrition, micronutrient deficiencies, infections with soil-transmitted helminths (STHs), and skin problems. Anemia and stunting are interlinked health problems and share common risk factors, but few studies have investigated their coexistence in Ethiopia. Although there are many school-aged children, few studies have been conducted on the nutritional status of school-aged children in rural southern Ethiopia. In addition, previous studies on helminth infections have focused mainly on urban northern Ethiopia, although southern Ethiopia is a region where access to clean water and sanitation facilities is poor at schools. Furthermore, despite improvements in reporting the prevalence of helminth infections, there are few studies on the intensity of helminth infections in rural southern Ethiopia. The risk factors for intensity of helminth infection were not reported in several previous studies, and the interpretation of helminth data was mainly done according to the categorical outcome (i.e., the presence or absence of helminth infection). Thus, the use of a count model considering helminth egg concentration as an outcome variable is rarely reported. In addition, helminth egg data are usually overly saturated with zeros, and the interpretation of such data requires specific statistical models. However, there have been no studies on helminth egg counts among schoolchildren in Ethiopia that account for excessive zeros and overdispersion. More than half of school-aged children in southern Ethiopia are affected by scabies and tungiasis. Tinea infections are also common skin diseases among school-aged children in

Ethiopia, especially tinea capitis, with approximately one-third of these children having experienced this infection at some point. Despite these facts, no compiled reports of such health conditions have been published. Moreover, there have been no studies that have investigated whether a Bayesian model could provide further evidence of these health conditions. Therefore, we applied both frequentist and Bayesian approaches to identify risk factors for scabies, tungiasis, and tinea infections. In our data, individuals were clustered within the same classroom, and classrooms within the same school. Thus, unlike previous studies, we applied a multilevel analysis to account for clustering effects.

General objective: The overall objective of this study was to investigate some of the prevalent health problems among schoolchildren aged 7–14 years in rural southern Ethiopia.

Specific objectives: 1) To assess the prevalence and risk factors for concurrent anemia and stunting (CAS) at the individual, household, and school levels among schoolchildren in rural southern Ethiopia using a multivariate, multilevel, mixed-effect model (Paper I); 2) to assess the prevalence and intensity of helminth infections and identify potential risk factors among schoolchildren in rural southern Ethiopia using a multivariate, multilevel, mixed-effect model and a zero-inflated negative binomial regression model (Paper II); and 3) to investigate the occurrence and risk factors of three parasitic skin diseases (scabies, tungiasis, and tinea) and their risk factors among schoolchildren in rural southern Ethiopia using both frequentist and Bayesian approaches (Paper III).

Methods: We conducted this study in the Wonago district of southern Ethiopia. Using a three-stage cluster sampling method, we randomly recruited 4 schools at the first stage, 24 classrooms with 2,384 children at the second stage, and 36 children from each classroom at the third stage, for a total of 864 children aged 7 to 14 years. We recorded weight, height, hemoglobin level, intestinal helminth infections, hygiene practices, dietary habits, household food insecurity, and sociodemographic information and conducted skin examinations. For Papers I and II, a multivariate, multilevel, mixed-effect, logistic regression model was constructed that accounted for random school and classroom effects and identified potential individual-, household-, and school-level risk factors for CAS, as well as any helminth or *Trichuris trichiura* or *Ascaris lumbricoides* infection (Papers I and II). A count model with zero-inflated negative binomial (ZINB) regression analysis was performed to estimate potential factors associated with infection intensity using fecal egg counts from *T. trichiura* and *A. lumbricoides* infections (Paper II). In Paper III, both frequentist and Bayesian multilevel, mixed-effect, logistic regression models were used to identify potential risk factors for any one of three skin diseases, namely scabies, tungiasis, and tinea, separately.

Results: In Paper I, CAS prevalence among schoolchildren was 10.5%, and risk factors for CAS were concentrated at the individual level. The clustering effects, as measured by the intra-cluster correlation coefficient (ICC), were 6.8% at the school level and 19% at the classroom level. Increased age, not washing hands with soap after latrine visits, walking barefoot, *T. trichiura* infection, and head lice infestation were associated with a high prevalence of CAS. Those using

treated drinking water were less likely to have CAS.

In Paper II, the prevalence of at least one helminth species was 56%, for while that of *T. trichiura* and *A. lumbricoides* was 42.4% and 18.7% among schoolchildren. School and classroom variables for helminth infections explained less than 5% of the variance and thus showed little influence. Being thin, anemic, children with a mother or guardian without formal education, and children in households using open containers for water storage were risk factors for helminths infection. In the ZINB model, older age and unclean fingernails increased the risk of *A. lumbricoides* infection. Handwashing with soap, deworming, and using water from protected sources reduced the risk of helminth infection.

In Paper III, nearly three-quarters of schoolchildren had at least one type of skin disease, with scabies at 5.5% (46/861), tungiasis at 54.4% (468/861), and tinea infections at 39.1% (337/861). In the frequentist model, the cluster effect was insignificant at the school level and 8.8% at the classroom level for each skin problem. In the Bayesian model, the effect was 5.3% at the school level and 16% at the classroom level. For all models, the measured effects were higher than the values in the frequentist model. In the Bayesian model, being a boy, having unclean fingernails, not washing the body and hair weekly with soap, sharing a bed, clothes, or combs, and living in a poor household were risk factors for skin problems, but washing the legs and feet daily with soap was preventative for skin problems.

Conclusions: Accounting for school- and classroom-level effects, this thesis identifies CAS as a moderate public health problem, as well as a high burden of helminth infections and skin problems among schoolchildren in southern Ethiopia. The risk of contracting CAS was high with age among those who did not always wash their hands with soap after visiting latrines, walked barefoot, and had *T. trichiura* infection, so educating children about personal hygiene and providing clean drinking water could reduce the burden of CAS among schoolchildren. Considering clustering at the school and classroom levels and the greater number of zeros in fecal egg counts, we observed associations between helminths and age, thinness, anemia, unclean fingernails, handwashing, deworming treatment, maternal education, household water source, and water storage protection. Therefore, strengthening the school deworming programme could reduce the burden of helminths in schoolchildren. The association between skin problems and most hygiene-related variables requires efforts to improve the personal hygiene of schoolchildren. The wide variation in skin problems across classrooms suggests that there are common risk factors in these locations and that transmission needs to be reduced by downsizing classrooms.

List of original papers

Paper I: Amare HH, Lindtjorn B. Concurrent anemia and stunting among schoolchildren in Wonago district in southern Ethiopia: A cross-sectional multilevel analysis. PeerJ. 2021;9: e11158. https://pubmed.ncbi.nlm.nih.gov/33996276/

Paper II: Hailu Amare H, Lindtjørn B. Helminth infections among rural schoolchildren in Southern Ethiopia: A cross-sectional multilevel and zero-inflated regression model. PLoS Negl Trop Dis. 2020;14(12): e0008002. https://pubmed.ncbi.nlm.nih.gov/33351816/

Paper III: Amare HH, Lindtjorn B. Risk factors for scabies, tungiasis, and tinea infections among schoolchildren in southern Ethiopia: A cross-sectional Bayesian multilevel model. PLoS Negl Trop Dis. 2021;15(10): e0009816. https://pubmed.ncbi.nlm.nih.gov/34613968/

Abbreviations

AOR	Adjusted odds ratio
AIC	Akaike information criterion
AUC	Area under the curve
CAS	Concurrent anemia and stunting
CI	Confidence interval
COR	Crude odds ratio
DACA	Drug administration and control authority
DALYs	Disability adjusted life years
DDS	Dietary diversity score
EPG	Eggs per gram
FAO	Food and Agriculture Organization
FEC	Formalin-ether concentration
HFIAS	Household food insecurity access scale
ICC	Intra-cluster correlation coefficient
IRB	Institutional review board
NB	Negative binomial
NORHED	Norwegian Programme for Capacity Development in Higher Education and Research for Development
NTDs	Neglected tropical diseases
OR	Odds ratio
PCR	Polymerase chain reaction
ROC	Receiver operating characteristic curve
SD	Standard deviation
SENUPH	South Ethiopia Network of Universities in Public Health

SPSS	Statistical package for social sciences
STATA	Statistical software package for statistics and data
STHs	Soil-transmitted helminths
SWASH	School water, sanitation, and hygiene
WASH	Water, sanitation, and hygiene
WHO	World Health Organization
ZINB	Zero-inflated negative binomial regression
ZIP	Zero-inflated Poisson

Table of contents

List of tables

Introduction

What is this thesis about?

It is well known that good health improves educational outcomes [1-3]. However, schoolchildren in Ethiopia are vulnerable to various health problems [4]. Although the health problems of school-aged children are broad [5, 6], we focused on some that are considered the most important, including malnutrition [7], infections with soil-transmitted helminths (STHs) [8], and skin problems [1]. Although school access and enrollment have improved significantly, a large number of school-aged children in Ethiopia live in areas of food insecurity [9] and high risk of STH infections [10]. Nevertheless, the health care of school-aged children can be improved through school health programmes [1, 3]. Although Ethiopia introduced the National Strategy for School Health and Nutrition in 2012 [4, 6], which includes interventions in nutrition [9], deworming [11], and water, sanitation, and hygiene [12], these health services are not adequately implemented [4]. Although regular screening for skin problems such as scabies, tungiasis, and fungal infections is mandated in school health programmes, implementation is limited [4].

Anemia and stunting are interlinked health problems and share common risk factors[13-15], yet few studies have investigated the co-existence of anemia and stunting in Ethiopia. The co-occurrence of anemia and stunting in children aged below five years was investigated using 2016 Ethiopian Demographic and Health Survey data, but there have been no similar studies on school-aged children. Moreover, previous studies on helminth infections concentrated mainly in urban northern Ethiopia [16-23]. Southern Ethiopia is among the regions in the country with inadequate school water supply [12] and poor sanitation practices, with more than half of schools still using open defecation [24]. Despite improvements in reporting the prevalence of helminth infections [18, 23, 24], there have been limited studies on the intensity of helminth infections in rural southern Ethiopia. Risk factors for helminth infection intensity were not reported in several previous studies, and interpretation of helminth data was mainly at the categorical level. Rarely have we seen count models with helminth egg concentration included as a variable. Additionally, helminth egg data are usually overly scattered with zeros [25] and require specific statistical models for interpretation. However, there are no studies on helminth egg counts among schoolchildren in Ethiopia that account for excessive nulls and overdispersion. Scabies and tungiasis affect more than half of school-aged children in southern Ethiopia [26, 27]. Tinea infections are also common skin diseases among schoolchildren in Ethiopia, especially tinea capitis [28], with approximately one-third of schoolchildren in southern Ethiopia being infected at some point [29]. Despite these facts, no summary reports of such health conditions have been published. Moreover, there have been no studies that have investigated whether a Bayesian model could provide further evidence of these health conditions. Therefore, we applied both frequentist and Bayesian approaches [30, 31] to identify risk factors for scabies, tungiasis, and tinea infections. In addition, our data clustered individuals within the same classroom, and classrooms within the same school. Therefore, unlike previous studies, we performed a multilevel analysis to account for cluster effects.

Therefore, in this thesis, we aimed to assess the following research questions:

1. What are the prevalence and risk factors for CAS among schoolchildren in rural areas? (Paper I)
2. What are the prevalence and intensity of helminth infections and their potential risk factors among schoolchildren in rural areas? (Paper II)
3. What are the prevalence and risk factors for scabies, tungiasis, and tinea among schoolchildren in rural areas? (Paper III)

To account for cluster effects, we used multilevel logistic regression analyses for Papers I, II, and III. In addition, for Paper II, we used a negative binomial regression model with zero inflation to identify risk factors for helminth egg intensity. In Paper III, we used both frequentist and Bayesian approaches for modeling.

In summary, these three papers provide new information about schoolchildren's health problems. The methods we used to analyze these three papers will also provide additional information for the diagnosis and management of health problems in schoolchildren.

School health and its problems in Ethiopia

As part of the effort to provide access to universal education, almost all children in Ethiopia have the opportunity to go to school, including poor children [32]. In recent years, more attention has been paid to the health needs of preschool-aged children in Ethiopia than to those of school-aged children [6]. Today, however, more children are in school than ever before, so health needs for survival have been superseded by needs for a better quality of life [6].

Ethiopia has recognized the impact of poor health and nutrition on the quality of education and children's achievement and presented a national strategy for school health and nutrition in 2008 [6]. Globally, several school health and nutrition programmes are led by health facilities, usually with nurses or mobile school health teams [32]. However, in Ethiopia, where a large number of schools are located in rural areas and the health sector has few resources, sustainability is lacking [33]. On the other hand, there are more teachers than health workers; thus, the education sector can take responsibility for school health services under the supervision of local health workers to reach a large school community [32]. Initiatives on school health and nutrition were launched and included as a cross-cutting theme in Education Sector Development Programme (ESDP) IV and V [5, 9]. All regions of Ethiopia have received training on the strategic activities of the national programme for health and nutrition in schools [9]. School health and nutrition are cost-effective means of promoting learning and quality education by reducing repetition and absenteeism, and raising achievement [32]. Improving the health of school-aged children not only supports learning but also increases long-term intergenerational and economic benefits [34]. However, in Ethiopia, the provision of school-based health services is a major challenge due to the rapid increase in the number of primary school students, the increasing number of students in rural areas, the lack of school-based health workers, the low involvement of parents and teachers in school-based health promotion, and inadequate funding [33]. Although approaches are not well standardized, individual clinical care, group-based health promotion, prevention, infectious disease control, screening, case management for chronic diseases, and referrals for further health services are the intended school health services in Ethiopia [33].

Schoolchildren are usually thought to be healthy, but studies have shown that schoolchildren in many areas of Ethiopia have numerous health problems [32]. In 2012, Ethiopia launched the National Strategy for School Health and Nutrition, which aims to improve the health of schoolchildren through nutrition, deworming, and water, sanitation, and hygiene interventions [4, 6, 9, 11, 12]. However, the implementation of these health services is inadequate [4]. Approximately 10 million school-aged children in Ethiopia live in food-insecure areas [9]. In 2015, water and sanitation facilities in schools were inadequate: only 11% of primary and 24% of secondary schools had appropriate water facilities, and only 3% of primary schools and 10% of secondary schools were fully equipped with water, sanitation, and hygiene (WASH) [35]. Despite school health and nutrition initiatives, a large proportion of schoolchildren in Ethiopia are still anemic or stunted [4, 6], infected with helminths [10], and have skin problems [12]. Although regular screening for skin problems such as scabies, tungiasis, and fungal infections is required in school health programmes, implementation of such programmes is limited [4].

School health in this thesis

Although health issues in Ethiopian schools span a broad spectrum of physical and psychological problems [5, 6], we have concentrated on malnutrition (the coexistence of anemia and stunting), intestinal parasite infections (helminths), and skin diseases (scabies, tungiasis, and tinea infections) in this thesis. This is because these issues directly affect the country's elementary-school-aged children.

Even though mortality rates in school-aged children are lower than in children under five years, nutritional deficiencies and diseases due to infections remain the major causes of death [36]. For example, both anemia and stunting can lead to impaired cognitive abilities, increased susceptibility to infections leading to morbidity and mortality, poor academic performance, and lower work productivity [37-40]. In addition, helminth infections can also impair physical and intellectual development, affect cognitive function [41-43], and impact school performance and economic productivity [43]. In addition, these skin diseases usually affect school-aged children [44], including their mental health, social relationships, and academic performance [45-47].

Malnutrition

Anemia and stunting

Globally

Globally, all forms of malnutrition are serious public health problems [48]. Malnutrition is an imbalance in nutrient intake, whether deficiency or excess [49]. It includes stunting, wasting, low weight gain, overweight, obesity, and micronutrient deficiencies [7]. One in nine people worldwide is undernourished, according to the Global Nutrition Report 2020 [50].

In 2019, anemia affected 1.8 billion people worldwide, causing an estimated 50.3 million years of life with a disability (YLD), with the highest YLDs reported in western and eastern Sub-

Saharan Africa [51]. Anemia is a condition in which the number of red blood cells and their oxygen-carrying capacity are insufficient to meet the physiological needs of the body [52]. Globally, anemia remains a considerable health burden [51, 53, 54]. Although there are few recent global reports of anemia in school-aged children, in 2008, WHO estimated that its prevalence in school-aged children was 25% [54]. Even though prevalence varies by population and setting, iron deficiency remains the leading cause of anemia worldwide [51, 53]. In a recent study of the global burden of disease, the YLDs of anemia attributable to iron deficiency in children aged 5–14 years was approximately 13% worldwide, 19% in low-income countries, and 1.85% in high-income countries [51]. Although iron deficiency is considered one of the most common causes of anemia, there are several other factors [55, 56], including folic acid, zinc, vitamin A, and vitamin B12 deficiencies, malaria, soil-transmitted helminths, chronic infections, and genetic disorders (hemoglobinopathies) [51, 55, 56]. In 2019, hemoglobinopathies were the second-most common cause of anemia worldwide [51]. Even though there are no global estimates for school-aged children, approximately 149 million children under five years were stunted in 2020 [50]. Stunting is a linear growth disorder, and chronic undernutrition and is defined as a height-for-age Z-score two standard deviations below the average [57].

Globally, of the 663 million enrolled children in low- and middle-income countries, an estimated 251 million live in communities where anemia and stunting are prevalent [58]. These problems can affect school performance [34, 59]. Anemia and stunting are interrelated health problems whose causes are complex and may share common risk factors [13-15, 55, 60]. Despite these facts, there are few published data on CAS in Ethiopia. Therefore, it is important to investigate the co-occurrence of anemia and stunting and its associated risk factors in school-aged children.

Ethiopia

In Ethiopia, the national prevalence of anemia among schoolchildren was 26% in 2016 [61], and similar findings were reported in southern Ethiopia [24, 62]. According to the 2016 National Micronutrient Survey Report, 20% of anemia among schoolchildren in Ethiopia was due to iron deficiency [61]. The Global Burden of Disease estimates for 2019 show that iron-deficiency anemia accounts for 13.9% of YLDs among children aged 5–14 years in Ethiopia [51]. Although the study did not include school-aged children, a recent study involving women and men aged 15–49 years and children aged less than five years shows that folate and iron deficiency and inflammation are the main causes of anemia in Ethiopia [63]. Iron-deficiency anemia can be caused by blood loss, poor nutrition, impaired absorption, high iron requirements in early childhood, malaria, and parasitic infections such as STHs [64].

The prevalence of stunting among school-aged children varies between 9% and 57% in different regions of Ethiopia, with the highest rate of 57% reported in the southern region [65, 66]. Ethiopia’s annual cost associated with child undernutrition is estimated at 55.5 billion Ethiopian Birr (ETB), which is equivalent to 16.5% of the country’s gross domestic product (GDP) [67]. The country can save an estimated 148 billion ETB in losses if it reduces the proportion of children under five suffering from stunting by 10% by 2025 [68]. Stunting is also associated with

16% of primary school class repetition and is a reason for 1.1 fewer years of schooling in Ethiopia [68].

Ethiopia has recognized the challenges of malnutrition and is committed to addressing all of its forms by 2030 [69, 70]. The country has developed several food and nutrition policies, strategies, and initiatives [71-74]— particularly, the National School Health and Nutrition Strategy for schoolchildren [6]. However, most anemia interventions focus on children under five years of age and pregnant women [72]. The country has also malaria and helminth infection controlling programmes that could reduce anemia associated with these cases [11, 75]. A school-based deworming programme has significantly reduced the burden of anemia [76]. However, school-based health services are fragmented and poorly implemented [77]. Despite various nutritional interventions, both anemia and stunting remain major public health problems [51, 60]. Identifying the specific causes of anemia and stunting is a major challenge [60, 78]. Despite the many factors that contribute to anemia, hemoglobin concentration has often been used as a surrogate indicator of iron status in surveys because it was assumed that anemia is always associated with iron deficiency [56]. However, iron deficiency is not always the main cause of anemia [79]. Although the early stages of life are considered a critical time for children's cognitive development, anemia-prevention efforts should continue for school-aged children [51].

Inter-linkage between anemia and stunting and contributing factors

The causes of anemia and stunting are complex [55, 60]. Stunting is often associated with anemia and recurrent infections in children [80]. At all stages of growth, anemia impairs linear growth [81]. For example, iron-deficiency anemia can cause low secretion of insulin-like growth factor-I (IGF-I), resulting in impaired linear growth [81]. Children with inadequate nutritional intake have weakened immune systems, are susceptible to infections, and are at increased risk for anemia and long-term developmental delays [78, 82]. In addition, inflammation also affects iron metabolism [83] and linear growth [84, 85]. Both anemia and stunting can lead to impaired cognitive abilities, increased susceptibility to infections leading to morbidity and mortality, poor academic performance, and lower work productivity [37-40]. Stunting can also become a generational problem [48, 86]. Poor living conditions, inadequate nutrient intake, poor nutrition, socio-demographic factors, infections, and poor hygiene are the most common risk factors for anemia and stunting [15, 60].

Anemia and stunting are interrelated health problems and share common risk factors [13-15], but few studies have examined the coexistence of anemia and stunting in Ethiopia. Although there are many school-aged children in rural areas, few studies have been conducted on the nutritional status of school-aged children in rural southern Ethiopia [24]. The CAS in children under five years of age was investigated using data from the 2016 Ethiopian Demographic and Health Survey, but there were no similar studies on school-aged children. To address this knowledge gap, we assessed the prevalence and risk factors of CAS at the individual, household, and school levels among rural school-aged children. In addition, our data clustered individuals within the same classroom, and classrooms within the same school. Thus, unlike previous studies, we conducted a multilevel analysis to account for cluster effects.

Parasite infections

Helminthes infections and their risk factors

Globally

Parasitic infections are caused by either helminths or protozoans [87]. STHs are parasitic infections and are among the 20 neglected tropical diseases (NTDs) prioritized by WHO [88]. Worldwide, more than 1.5 billion people, including over 568 million schoolchildren, are affected by these infections [8]. Roundworms (*Ascaris lumbricoides*), whipworms (*Trichuris trichiura*), and hookworms (*Ancylostoma duodenale* and *Necator americanus*) are the most common STH infections that chronically affect children [89]. Disability-adjusted life years (DALYs) attributable to these infections are estimated at 5.19 million [90]. STH infections are most common in tropical and subtropical areas, with the highest numbers in Sub-Saharan Africa [8]. The number of STH-endemic countries worldwide was estimated at 94 in 2018 [91, 92]. In 2018, an estimated 35 million children aged 5–14 years in Sub-Saharan Africa were infected with at least one STH species, and approximately 2.9 million still had moderate-to-severe-intensity infections [93]. These infections are transmitted by contact with a contaminated environment containing eggs or larvae produced by adult parasites in the gastrointestinal tract of the infected person [94]. STHs can survive for years in the human digestive tract [94] and are common among children in poor countries [43].

WASH interventions are critical to improving the prevention and control of STH infections and other NTDs. In 2015, WHO highlighted the integration of WASH as a global strategy to prevent STH infections and other NTDs, in addition to providing treatment [95]. Current global strategies to reduce STH infections in school-aged children include preventive chemotherapy with drugs such as albendazole or mebendazole against *A. lumbricoides*, *T. trichiura*, and hookworms twice a year for an STH prevalence of 50% or more, or once a year for an STH prevalence of 20% or more, and additional ivermectin medication for a *Strongyloides stercoralis* prevalence greater than 10% [88]. In addition, the provision of adequate sanitation, waste disposal facilities, and clean water in schools and households, improvements in hygiene practices, and behavioral education of at-risk groups can reduce these infections [88].

Although a decline in STH infections among children aged 5–14 years was observed in Sub-Saharan Africa as a result of the wide reach of preventive chemotherapy, access to improved sanitation, and economic development, there were still 25% of implementation sites with an estimated moderate-to-severe intensity of infection in 2018—well above the 2% target threshold [93]. These sites were mainly in nine countries, including Nigeria, the Democratic Republic of Congo, Ethiopia, Cameroon, Angola, Mozambique, Madagascar, Equatorial Guinea, and Gabon [93]. The target for the treatment of school-aged children was 75% [88]. However, by 2020, the coverage was only 59% [88]. Only 21 countries with an STH endemic area met the target of 75% by 2020 [88].

Despite various measures to reduce helminth infections in schoolchildren, the prevalence and intensity of infections remain high [93]. These infections can affect school attendance and performance [34, 59]. WHO has stated the minimum coverage target of 96% for the elimination of STH infections as a public health problem in children to achieve moderate-to-severe-intensity *A. lumbricoides*, *T. trichuria*, and hookworm infections below 2% by 2030 [88]. Although infection intensity is used to evaluate the elimination of helminth infections, there are few published reports on modeling helminth egg counts in schoolchildren. In particular, the use of count models that account for excessive zeros and too much dispersion is rare in helminth infection data. Therefore, it is important to determine the prevalence and intensity of helminth infections and possible risk factors in schoolchildren.

Ethiopia

Ethiopia is endemic to STH infections [96], and approximately 88 million people, including 28 million school-aged children, were at risk of these infections in 2015 [10]. The prevalence of helminth infections among schoolchildren ranges from 18% to 63% [16-23], with the highest infection rate (63%) recorded in southern Ethiopia [23]. According to 2018 estimates, Ethiopia is among the Sub-Saharan African countries with the highest burden of STH infections [93]. Ethiopia introduced a national deworming programmes for school-aged children in 2007 and treated nearly 13 million children as of 2015 [97]. The country has classified STH infections as one of the nine important NTDs [121] and mapped 721 endemic areas for these infections as of 2015 [97]. However, only 475 areas were selected for STH treatment because existing guidelines do not allow mass drug administration in areas with a low prevalence of these infections [97]. In addition, between 2008 and 2015, approximately 8 million children aged 2–5 years were dewormed against STH infections. The country also started STH treatment for adolescents aged 15–19 years in high-risk areas in 2015 [97].

Ethiopia has both short- and long-term programmes to combat STH infections [11]. The short-term plan was to treat 75% of school-aged children, maximize treatment of all adults in endemic areas, and reduce the intensity of infection in school-aged children by 65%–90% [11]. The long-term plan was to eliminate morbidity associated with STH in children by reducing the severe intensity of these infections to below 1% by 2020.

Adequate water, improved sanitation, and better hygiene practices help prevent re-infection [98]. Ethiopia launched the ONE WASH National Programme (OWNP) in 2013 and the school WASH (SWASH) in the strategic plan for 2016–2020 [99]. Although these interventions take place in a very similar community to improve the health and well-being of the population, both WASH and NTD programmes have not been integrated [11]. Ethiopia, however, recently established an integrated WASH and NTD programme at the national and regional levels and formulated a WASH-NTD framework to accelerate the reduction of STH infections and other NTDs [88, 100].

The health burden of STH infections is mainly attributed to their chronic and insidious effects on health and quality of life, as morbidity is significantly higher in the presence of severe infection than in its absence or the presence of less-severe infection [41, 89, 101]. Loss of appetite, malabsorption, anemia, impaired nutritional status, poor physical and intellectual development, and impaired cognitive function may occur with these infections [41-43]. In addition, these infections have an impact on school performance and economic productivity [43]. Risk factors for these infections include poverty [17], low maternal education level, unclean fingernails, walking barefoot, unhygienic toilet areas, lack of handwashing before eating or after latrine use, consumption of raw or inadequately cooked vegetables or meat, lack of hygiene facilities, and drinking water from unsafe sources [101, 102].

Despite ongoing efforts to eliminate STH infections as a public health problem among children [116], the burden of these infections among school-aged children in Ethiopia is still high [103]. The country is among 22 others with poor deworming rates among school-aged children (as of 2018) [104]. It is well known that deworming helps to reduce the prevalence and intensity of infections, but preventing re-infection is challenging due to poor water access, inadequate sanitation, and poor hygiene practices [11]. Despite the inclusion of the SWASH in the strategic plan for 2016–2020, progress has been slow due to poor underlying conditions [99]. Previous studies on helminth infections focused mainly on urban northern Ethiopia [16-23]. Southern Ethiopia is one of the regions of the country where the water supply in schools is inadequate [12], as 66% of schools do not have access to clean water [105], handwashing facilities are not available in most schools, hygiene behavior is poor [196], sanitation facilities are unsafe, and open defecation is common [24, 105].

Despite improvements in reporting the prevalence of helminth infections [18, 23, 24], there are few studies on the intensity of helminth infections in rural southern Ethiopia. Risk factors for helminth infection intensity were not reported in several previous studies, and interpretation of helminth data was mainly done using categorical outcomes. Rarely have we seen count models with helminth egg concentration included as a variable. Additionally, helminth egg data are usually overly scattered with zeros [25] and require specific statistical models for interpretation. However, there are no studies on helminth egg counts among schoolchildren in Ethiopia that account for excessive zeros and overdispersion. Therefore, this study aimed to fill the knowledge gap by assessing the prevalence and intensity of helminth infections and identifying potential risk factors at the individual, household, and school levels among rural schoolchildren.

Skin problems

The burden of scabies, tungiasis, and tinea infection and their risk factors

Globally

Skin problems are causes of disability, a condition that considerably affects mental health, social relationships, ability to work, and ultimately quality of life [45, 46]. In 2013, the estimated

DALYs for skin problems were 1.79% of the total global burden of disease, and in 2019, they were among the top six causes of disease burden in children aged 5–14 years [44].

The burden of scabies

Scabies is an ectoparasitic, highly pruritic skin problem caused by infestation with the mite *Sarcoptes scabiei var. hominis* [106, 107] and has recently been recognized as one of the world's NTDs by WHO [103]. It affects over 200 million people worldwide, with prevalence ranging from 0.2% to 71% [108], and 565 million cases occurring annually [109]. The most recent Global Burden of Disease study from 2019 shows that an estimated 0.19% of DALYs and 0.85% of DALYs in children aged 5–14 years are due to this infestation [44]. Scabies lesions can occur on various body sites, but the topographic distribution of scabies lesions can vary with age [106, 110-112]. In addition, superficial bacterial skin infection is also common as a result of scabies complications, and it can progress to severe infections, poststreptococcal glomerulonephritis, and possibly acute rheumatic fever and chronic kidney disease [113].

Scabies is transmitted through skin contact. It is endemic in areas where populations live in poor conditions and is often associated with living in crowded housing [114]. Scabies commonly occurs in the form of outbreaks [26, 115, 116], and closed residential communities and schools are at higher risk of this infestation [117].

Neglected parasitic skin diseases are a major medical challenge in poor areas [107, 118]. Scabies is a highly contagious parasitic skin disease that is challenging to treat and control because of its impact on underprivileged or poor communities with poor access to adequate health care [46].

WHO, the International Alliance for the Control of Scabies [119], and researchers such as the Sarcoptes-World Molecular Network (Sarcoptes-WMN) [120] are collaborating to control scabies worldwide [121]. Global scabies prevention strategies include mass treatment with oral ivermectin, case management with topical scabicides for all household contacts, and improving hygiene practices during outbreaks to reduce secondary infections [88]. WHO envisions 100% of countries integrating scabies treatment into general health care and aims for 25 countries to achieve mass drug administration in endemic areas by 2030—up from zero in 2020 [88]. Furthermore, WHO recommends integrating preventive chemotherapy programmes for scabies with five previously integrated health problems: STHs, schistosomiasis, onchocerciasis, lymphatic filariasis, and trachoma [88]. The recently developed and proposed scabies control framework also includes disease burden mapping, implementation of interventions, and establishment of adequate surveillance and evaluation [122, 123]. Elimination of scabies through treatment alone is not sufficient because of treatment non-adherence in resource-poor settings with inadequate health facilities and poor health behaviors [121]. Also, although it takes longer for scabies to manifest, asymptomatic people can transmit scabies, making treatment more difficult [121]. Other challenges in scabies control include detection of all scabies contacts during epidemics, resistance and toxicity associated with mass drug administration, poor living conditions, diagnostic methods, and lack of vaccination [121].

The burden of tungiasis

Tungiasis is also a neglected parasitic skin problem caused by the female sand flea *Tunga penetrans*, also known as the jigger flea, and is widespread in tropical and subtropical areas [124, 125]. According to estimates from 2020, approximately 668 million people in Sub-Saharan Africa live in areas favorable to jigger flea transmission, and nearly 304 million people in East Africa are at risk of this infection [126]. The disease is prevalent in all Sub-Saharan countries and often occurs in communities with poor living conditions [125]. The prevalence of tungiasis (jigger flea) infection in poor communities is estimated to be as high as 60%, with children being the most affected, accounting for up to 80% of infections [125]. The sites most commonly affected by tungiasis include the toes, lateral feet, and heel, and thus 99% of all lesions occur on the feet [125]. Acute manifestations of this infection include erythema, edema, tenderness, itching, and pain. In the chronic phase, the infection may be manifested by shiny skin, scaling, deformed nails and toes, or loss of nails [127]. It also has a socioeconomic burden that includes difficulty to walk, grip, or sleep, stigmatization, school absenteeism, or dropping out, all of which can affect quality of life [47, 127-129]. In addition, bacterial superinfections are also common and can cause tetanus, gangrene, and septicemia, which can lead to death [127, 128, 130].

Tungiasis is another poverty-related skin problem [131]; it commonly occurs in children aged 5–14 years, and boys, in particular, are at higher risk [125]. The type of flooring (earthen floor) in the home or school can affect the occurrence of jigger fleas [125]. Not wearing footwear, contact with animals such as cats, dogs, or pigs, and living in rural areas increase susceptibility to tungiasis infection [132].

Despite its burden, tungiasis has been neglected by health workers, policymakers, researchers, the pharmaceutical industry, and funders [133, 134]. Since there is no standard treatment for tungiasis [133], WHO recommends surgical removal of embedded jigger fleas from the skin in a health facility by medical personnel [125]. However, people in endemic areas usually use non-sterile procedures to remove the embedded fleas with sharp instruments such as needles, sticks, hairpins, or scissors [125]. These make them vulnerable to bacterial superinfection, and these instruments can carry the agents for the transmission of HIV, hepatitis B, and hepatitis C [125]. Coconut-oil-based repellent prevents jigger fleas from entering the skin [135]. The presence of various domestic animals as reservoirs, the long-term survival of jigger fleas in the environment, and the lack of controlled studies to ensure the efficacy of insecticides to kill jigger fleas in the environment are challenges in controlling tungiasis [107]. Behavioral changes such as wearing shoes or avoiding walking barefoot [27, 47], improving the environment, and avoiding contact with animal reservoirs can reduce morbidity associated with tungiasis [125, 136, 137].

The burden of tinea infection

Fungal skin diseases are caused by dermatophyte infection and are common worldwide [138]. They were responsible for 0.15% of DALYs due to skin problems in 2013 [139]. Dermatophytes are classified as anthropophilic (living on humans), zoophilic (living on an animal), and geophilic (living in the soil). All of these species are associated with human infections, but the anthropophilic species are the most common causative agents in humans [138]. Tinea is caused by fungus, is confined to keratinized areas of the body such as skin, hair, and nails, and is distinct from deep mycotic infections [140]. It usually occurs on the scalp, foot, hand, groin, nails, or face and does not penetrate deeper areas [138, 141]. It occurs in developed and developing countries, although the most common sites of infection are different. For example, tinea capitis is common in developing countries, whereas tinea pedis and onychomycosis are common in developed countries [138]. Recent evidence suggests that one in five children in Africa has tinea capitis, and more than 96% (132.6 million) of cases occur in Sub-Saharan Africa, mainly in Nigeria and Ethiopia [28].

Although antifungal agents are used for the treatment of tinea infection, other mimicking skin problems and affordability of treatment in poor areas, longer treatment duration, and poor treatment responses are challenges to controlling this infection [142, 143]. Tinea infection is also associated with immune factors [144-146]. Having no close contact with an infected person or animal, not sharing sources of infection, feet hygiene, not walking barefoot, and appropriate footwear all prevent tinea [142, 147-149].

Unfortunately, scabies, tungiasis, and tinea infections are strongly associated with poverty [45, 138]. These skin problems can affect all age groups, although they are most common in children [114]. However, there is little compiled evidence on the occurrence of these skin problems in school-aged children. Also, the use of a Bayesian model [30, 31] to study these problems is uncommon in previous studies. Therefore, it is important to study these problems using both frequentist and Bayesian models.

Ethiopia

In Ethiopia, the estimated prevalence rates of scabies among school-aged children range from 6% to 50% [26, 150]. The highest rate (50%) is reported in southern Ethiopia [26]. Ethiopia is a favorable area for jigger fleas, and tungiasis is also common in the country [126]; prevalence ranges from 35% to 60% in school-aged children in southern Ethiopia [27, 129]. Tinea infections are also common skin diseases among schoolchildren in Ethiopia, especially tinea capitis [28], and approximately one-third of schoolchildren in southern Ethiopia are infected [29]. These skin problems can affect all age groups, although they are most common in children [114]. In addition, the transmission of these skin diseases varies with the seasons, with cool climates being favorable for scabies [151-153], dry seasons for tungiasis [154-156], and humid weather for tinea infections [157]. In general, poor hygiene, large families, crowded conditions, shared fomites, poverty, and environmental conditions are important determinants of these three skin problems [45, 114]. Despite these facts, no compiled reports of such health conditions have been published. Moreover, no study has investigated whether a Bayesian model could provide further insights into these health conditions. Therefore, we applied both frequentist and Bayesian approaches [30, 31] to identify risk factors for scabies, tungiasis, and tinea infections. Thus, we investigated whether a Bayesian model that estimates credible intervals for unknown parameters from the posterior distribution [30, 31] could provide important and additional information for the evaluation and management of these diseases. Moreover, in our data, individuals were clustered within the same classroom, and classrooms were clustered within the same school. Therefore, unlike previous studies, we performed a multilevel analysis to account for cluster effects.

Ethiopia: Country profile

General country profile of Ethiopia

Ethiopia is a diverse country officially recognized as the Federal Democratic Republic of Ethiopia, with an estimated population of 118 million people in 2021 [158, 159]. It is a landlocked country in the Horn of Africa, bordered by Eritrea, Djibouti, Somalia, Sudan, South Sudan, and Kenya [158]. Ethiopia is one of the most populous countries in the world and the second-most populous country on the African continent [158]. The country has a total area of 1.1 million square kilometers, and its capital is Addis Ababa. The population of Ethiopia is 40% younger than 15 years, 57% between 15 and 64 years, and 3% older than 64 years [159]. As of 2019, the overall life expectancy is 66 years [160]. The level of urbanization is low, with only 17% of the population living in urban areas [158, 161]. Over 80 languages and 200 dialects are spoken in the country. Amharic is the official language, although the government encourages the teaching of local languages in schools [158]. The Oromo and English languages are also widely spoken [158].

Agriculture and services are the main economic sectors in Ethiopia [162]. In 2016, agriculture contributed 37% of the country's GDP, accounted for over 70% of exports, and employed 73% of the labor force [162]. Coffee alone accounts for over 60% of exports [158]. Ethiopia is one of the five Sub-Saharan African countries with the largest population, nearly 24% of whom live in extreme poverty [163]. Over the past 15 years, the country has experienced considerable economic growth, a decline in poverty, and progress in social development, but it remains one of the countries with the lowest human development [162]. In 2020, the Ethiopian economy grew by 6%, a decrease from the 8% rate in 2019, mainly due to the COVID-19 pandemic [164]. At present, the country is at a critical juncture, and further decline is expected in developmental aid for health care and government revenue due to the global COVID-19 pandemic and the weakening economy before COVID-19 [160]. Although our study was not affected, there was also social unrest or displacement of people in the study region in 2018 due to ethnic conflict in the Gedeo zone.

Health services in Ethiopia

The Ethiopian healthcare system consists of three tiers comprising primary, secondary, and tertiary levels [165]. The primary level includes primary hospitals, health centers, and health posts. A primary hospital has up to 50 beds, and it serves approximately 100,000 people, both inpatients and outpatients; it also provides emergency surgical services. Approximately 25,000 people in rural areas and 40,000 in urban areas receive preventive and curative services from a health center with about 20 staff and 5 inpatient beds. A health post is staffed by two health extension workers and serves approximately 5000 people in *Kebeles*, and it is the lowest administrative unit in the country. A general hospital belongs to the secondary level of care and serves 1–1.5 million people as inpatients and outpatients. A specialty hospital is a tertiary level of care hospital, serving approximately 3.5 to 5 million people.

Health centers are practical training centers for health extension workers, primary hospitals for nurses and other paramedical health workers, and general hospitals for health officers, nurses, and emergency surgeons. There is also a referral link within the health system. Health posts refer to health centers, health centers refer to primary hospitals, then to general hospitals, and finally to specialty hospitals [165].

School in Ethiopia

Ethiopia's education and training structure includes a three-year pre-primary kindergarten starting at age 4, the first cycle of primary education (grades 1–4) starting at age 7, the second cycle of primary education (grades 5–8), the first cycle of secondary education (9–10), preparatory secondary education (11–12) or technical and vocational education and training, and tertiary education with bachelor's, master's, and doctoral degrees.

Ethiopia has made remarkable progress in education over the last two decades [9]. The country is trying to expand the education system by increasing the number of trained teachers and school facilities and establishing mobile schools to meet the diverse needs of the population [5, 9]. As of

2016, the country has 32,048 primary schools with 18 million students and a net enrollment rate of 100% [9]. The expansion of secondary schools has also improved, although access is limited to urban areas. Ethiopia had nearly 2,333 secondary schools for over 2 million enrolled students in 2014 [9]. Despite improved access to education, ensuring quality education is a major challenge in Ethiopia. This is due to the low quality of education, large population, high number of pastoralists, special needs, challenges faced by girls, climatic conditions, conflicts, and weak capacity of systems [9, 166]. Although the education policy stipulates that no child should drop out of school at any stage of primary education, nearly 2.6 million primary-school-aged children are not enrolled in school, of which 43% are boys and 57% are girls [9]. In 2014, the repetition rate was 8%, and the dropout rate was 22% in the first grade and 11% in other grades [9]. Currently, more than 7,000 schools are damaged, and an estimated 2.7 million children are out of school due to the escalating conflict in northern Ethiopia [167]. The challenges of the COVID-19 pandemic have also been significant in Ethiopia, and school closures have affected the education system [168]. Although the Ministry of Education encouraged schools and parents to allow all children to learn from home through distance learning, limited facilities and the educational status of parents made it impossible to offer this to all children [168]. Moreover, there are significant concerns that the COVID-19 pandemic may increase the number of child marriages due to school closures in the country [169, 170].

The rationale for this thesis

Good health and nutrition are important prerequisites for, and outcomes of, good education [1-3]. Although many children are enrolled in schools worldwide [1], school-aged children in countries such as Ethiopia are at risk of various health problems [4], including malnutrition, micronutrient deficiencies [7], STH infections [8], and skin problems [1]. It is well known that poor health and nutritional deficiencies are related to poor attendance and concentration [32]. School health programmes are designed to meet the health needs of school-aged children [1, 3]. Although school access and enrollment have improved considerably in Ethiopia, approximately 10 million school-aged children live in nutritionally insecure areas [9], and 28 million children are at risk of STH infections [10].

In 2012, Ethiopia launched a national strategy for school health and nutrition, which aimed to improve the health of schoolchildren through interventions [4, 6], including nutrition [9], deworming [11], and water, sanitation, and hygiene [12]. However, the implementation of these health services was inadequate [4]. Despite school health and nutrition initiatives, a large proportion of schoolchildren in Ethiopia are still anemic or stunted [4, 6], infected with helminths [10], or have skin problems [12]. Despite the strategy of bi-annual deworming and improvement of water, sanitation, and hygiene facilities in the country [171], many school-aged children continue to be affected by helminth infections [172-174]. Generally, school health services in the country are fragmented and poorly implemented [77]. Although regular screening for skin diseases such as scabies, tungiasis, and fungal infections is mandatory as part of school health programmes, implementation of these programmes is limited [4].

Anemia and stunting are interrelated health problems and share common risk factors [13-15], but few studies have examined the coexistence of anemia and stunting among school-aged children in Ethiopia. There have been few studies on the nutrition status of school-aged children in rural southern Ethiopia, despite the large number of school-aged children living there [24]. A study looking at the co-occurrence of anemia and stunting in Ethiopian children under five years of age used data from the 2016 Ethiopian Demographic and Health Survey, but no such study was available for school-aged children. To address this gap, we examined the prevalence and risk factors of CAS at the individual, household, and school levels among rural schoolchildren (Paper I).

Moreover, previous studies on helminth infections focused mainly on urban northern Ethiopia [16-23]. Southern Ethiopia is one of the regions of the country where the water supply in schools is inadequate [12], handwashing facilities are often not available in schools, hygiene behavior is poor [196], and open defecation is common in schools [24]. In rural southern Ethiopia, few studies have investigated the intensity of helminth infections despite improvements in reporting helminth infection prevalence [18, 23, 24]. Risk factors for helminth infection intensity were not reported in several previous studies, and interpretation of helminth data was mainly done with categorical outcomes. Rarely have we seen count models with helminth egg concentration included as a variable. Additionally, helminth egg data are usually oversaturated with zeros [25] and require specific statistical models for interpretation. However, there are no studies on helminth egg counts among schoolchildren in Ethiopia that account for excessive zeros and overdispersion. Therefore, this study aimed to fill these knowledge gaps by assessing the prevalence and intensity of helminth infections and identifying potential risk factors at the individual, household, and school levels among rural schoolchildren (Paper II).

Scabies and tungiasis affect more than half of school-aged children in southern Ethiopia [26, 27]. Tinea infections are also common skin diseases among schoolchildren in Ethiopia, especially tinea capitis [28], which affects approximately one-third of schoolchildren in southern Ethiopia [29]. Moreover, no study has investigated whether a Bayesian model could provide further insights into these health conditions. Therefore, we applied both frequentist and Bayesian approaches [30, 31] to identify risk factors for scabies, tungiasis, and tinea infections. Thus, in Paper III, we investigated whether a Bayesian model that estimates credible intervals for unknown parameters from the posterior distribution [30, 31] could provide important and additional information for the evaluation and management of these diseases. Moreover, in our data, individuals were clustered within the same classroom, and classrooms were clustered within the same school. Therefore, unlike previous studies, we performed a multilevel analysis to account for cluster effects.

Objectives

General objective

The overall aim of this study was to assess some of the prevalent health problems among schoolchildren aged 7–14 years in rural southern Ethiopia.

Specific objectives

1. To assess the prevalence and risk factors of CAS at the individual, household, and school levels among rural schoolchildren in the Wonago district of southern Ethiopia (Paper I).
2. To assess the prevalence and intensity of helminth infection and identify potential risk factors at the individual, household, and school levels among rural schoolchildren in the Wonago district of southern Ethiopia (Paper II).
3. To examine the occurrence and risk factors of three parasitic skin diseases (scabies, tungiasis, and tinea) and their risk factors among rural schoolchildren in the Wonago district southern Ethiopia using both frequentist and Bayesian approaches (Paper III).

Methods and materials

Study area and period

The study area for this work was the Wonago district in the Gedeo zone in southern Ethiopia, which was conducted from February 2017 to June 2017. The district is located 377-km south of Addis Ababa, the capital of Ethiopia, and 13-km south of Dilla, the capital of the Gedeo zone. Wonago district consists of 17 rural and 4 urban *kebeles*, the smallest administrative units. The district was estimated to have a population of 143,989 in 2014 and is one of the most populous areas in Ethiopia, with a population density of 1,014 people per square kilometer of land area. Wonago district has 26 government-owned health facilities, including 6 health centers and 20 health posts, 2 private clinics, and 2 drugstores. The district has over 36,000 students in 3 urban and 22 rural schools at the primary level. Most residents live in rural areas and depend on coffee, fruit, and ensete (*Ensete ventricosum*) cultivation for their livelihoods.

Study design

A cross-sectional study was conducted to identify school health problems, including the co-occurrence of anemia and stunting and their risk factors in Paper I, helminth infections and their risk factors in Paper II, and the occurrence of skin problems and their risk factors in Paper III, all of them taking place in the Gedeo zone in southern Ethiopia.

This study was conducted on schoolchildren aged 7–14 years; their parents or guardians were contacted by visiting them at home. Our target population was primary-school-aged children in rural areas. Using a three-stage cluster sampling method, we recruited randomly from 22 rural primary schools in the study district: 4 schools at the first stage, 24 classrooms with 2,384 children at the second stage, and then 36 children from each classroom at the third stage, for a total of 864 schoolchildren. If more than one child in a class lived in the same household, one of them was selected by lottery. We randomly selected participants who left school after the selection process and replaced them with participants of the same grade, gender, and age

Sample size and participants

The sample size was determined using OpenEpi software based on a single proportion of the population [175, 176]. We considered several factors to calculate the maximum sample size for all three papers. We assumed a 95% confidence interval (CI), proportions of study variables from previous studies (anemia [27%], stunting [30%], thinness [37%], helminth infections [27%], and skin problems [50%]), a precision of 5%, and accounted for multistage sampling using a design effect of two [18, 177-180]. We also calculated the sample size using outcome-related variables such as under-nutrition (e.g., 32% prevalence of stunting in female participants) and helminth infections (50% in children who did not wash their hands before meals) [18, 177-180]. The maximum sample size was reached when 50% of children who did not wash their hands before meals had helminth infections, and 50% had skin infections. After adding a non-response rate of

10%, we reached a final sample size of 845, the minimum size required. Finally, 864 children were randomly recruited, and those younger than 7 years and older than 14 years were excluded from this study. Children who had physical malformations, especially for Paper I, and children with severe illnesses, could have been excluded from this study, but we did not observe any of these cases during data collection.

In this study, for the household data: 861 of 864 had complete weight and height data; 810 of 864 had a complete blood sample for the hemoglobin test; 850 of 864 had a complete stool sample for the helminth test, and 861 of 864 had complete skin examination data. In general, 3 children dropped out of skin examination, 11 refused to give a stool sample, 33 refused to give a blood sample, and 18 children were absent during blood sample collection. Therefore, 810 of 864 in Paper I, 850 of 864 in Paper II, and 861 of 864 in Paper III were included in the analysis.

Measurement and procedures

Measurement

Interviews were conducted by ten trained enumerators using a pretested structured questionnaire developed in English following previous studies [18, 181-183] and subsequently translated into the local Gedeo language. We conducted the interviews in schools with children and at home with parents or guardians. The household of the student's parent or guardian was identified using a local guide. Variables related to the individual, parent, household, and school levels were collected by interviewing children and their parents or guardians. Observations were made regarding the children's hygiene and the housing conditions in which the children lived.

In Paper I, hemoglobin was measured from capillary blood samples using standard procedures by trained and experienced laboratory technicians using a HemoCue analyzer Hb 301 (Angelholm, Sweden) at the children's schools. Hemoglobin levels were adjusted for altitude to estimate anemia according to WHO guidelines for school-aged children (values below 11.5 g/dL for those aged 5 to 11 years and below 12 g/dL for those aged 12 to 14 years) [52]. In addition, we measured the weight and height of the children. The children were measured in light clothing and without shoes using a digital portable scale (Seca 877, Seca GmbH, Germany) calibrated to the nearest 0.1 kg. The children's height was measured using a measuring board (Seca 213, Seca GmbH, Germany) calibrated to the nearest 0.1 cm [52]. We used the software WHO AnthroPlus 1.0.4 to calculate Z-scores for height for age, weight for age, and body mass index for age according to the standard reference for children aged 5–19 years. Children with height-for-age Z-scores below −2 SD were classified as stunted, Z-scores ≥ −3 to < −2 SD as moderately stunted, and Z-scores below −3 SD as severely stunted [57, 184].

Laboratory procedures

In Paper II, we used standard procedures to collect, prepare, and examine stool specimens to identify helminth infections [185, 186]. Stool samples were collected and stored in the early morning in labeled stool cups with a code that included the children's names, sex, age, and the date.

Samples were transported in a cooler with ice packs from the school to Dilla University Teaching and Referral Hospital. Stool tests were performed using two techniques: the Kato-Katz, and formalin ether concentration (FEC) methods. On the day of stool specimen collection, a single 41.7 g Kato-Katz smear was prepared from each stool specimen. One gram of stool was then preserved in 10% formalin solution and processed according to the FEC method [187]. Reading of the smears was performed by three experienced laboratory technicians. Examinations of all Kato-Katz slides were performed within one hour of preparation to reduce the risk of hookworm egg disappearance. Subsequently, all Kato-Katz slides were reexamined to identify and count eggs from other helminth infections. All helminth species identified by the two diagnostic methods were recorded separately.

To minimize measurement error and ensure reproducibility of results, 10% of the 850 randomly selected test results were rechecked in a blinded fashion. We performed quality control for the results of helminths detected based on WHO guidelines [188]. According to these guidelines, retesting is required if the expert finds a difference in egg count of more than 10% and more than four eggs between measurements and the expert then discusses the reasons for the discrepancy after re-reading [188]. However, there is no clear information in the WHO guidelines on how to deal with differences in the presence or absence of helminth eggs [189]. Therefore, we compared the number of helminth eggs in the first measurement with the second quality control. According to the WHO guidelines, the slides were re-examined by a third experienced laboratory technician if the difference in the number of helminth eggs was more than four eggs. If the results between the first measurement and the re-measurement did not agree, the third experienced laboratory technician confirmed the results. However, the quality control WHO guidelines mainly refer to quantitative diagnostic methods such as the Kato-Katz method. There are no guidelines for evaluating discrepancies in fecal egg counts obtained by the semi-quantitative FEC method for quality control. Therefore, we performed quality control for the FEC method based on the presence or absence of helminth eggs. For the FEC method, a result was considered non-concordant if there was a difference in the presence or absence of helminth eggs between the original measurement and the quality control. Results were considered false-positive if the first result was positive for a specific helminth infection, but the results of the second measurement and the third measurement were negative. Results were classified as false-negative if the original result was negative, but the quality control results, as well as the third measurement, were positive.

Skin examination procedures

In Paper III, a skin examination was performed to determine the presence or absence of skin problems such as scabies, tungiasis, or tinea infection in children. The examination was performed in a private place in daylight by one of three experienced nurses with clinical diagnoses of dermatologic cases—a male nurse for boys and a female nurse for girls. Tungiasis was diagnosed after the feet and hands were cleaned with soap and water. Depending on the affected area, all identified or suspected skin diseases were recorded. To minimize the risk of possible bias in the skin examination results and to ensure reproducibility, 10% (86) of the children were examined by two nurses. If the results did not agree, a third, experienced examiner was consulted to reach a consensus. Scabies was diagnosed based on clinical findings of typical skin lesions on the hands, interdigital sites, wrists, arms, elbows, axillae, abdomen, chest, mammillary or perimammillary areas, back, buttocks, genitals, legs, or feet, as well as a history of pruritus that increased at night [115, 190, 191]. Tinea infections were classified according to the body site affected [192-196]: tinea capitis (scalp), tinea corporis (trunk, arms, and legs), tinea pedis (feet), tinea cruris (groin), tinea unguium (nails), tinea faciei (face), and tinea manuum (hands). Tinea capitis was one or more scaly patches with broken hairs at the skin edge (black dots) and crusting. Tinea corporis presented as red or hyperpigmented lesions on skin sites other than the face, scalp, groin, hands, or feet. Tinea pedis presented as red, scaly cracks on the feet, macerations, and itching between the toes that extended to the edges of the soles and occasionally included the dorsum of the foot. Tinea cruris was diagnosed in cases involving the groin and thigh but omitting the scrotum and penis. Tinea unguium presented as yellow-brown to black discoloration in the distal portion of the nail, the proximal nail bed, or the underside of the nail plate. Tinea faciei presented as a typical red or pink hyperpigmentation or lesions on the face. Tinea manuum presented as red and scaly lesions on the palm or dorsum of the hand [192-196]. Tungiasis was diagnosed using the Fortaleza classification based on the clinical findings of invading jigger fleas: a small, dark, itchy spot in the epidermis with visible posterior parts of the parasite, with or without local pain; a brownish or black spot surrounded by erythema; a circular yellow-white spot with a central black spot representing the posterior segments of the parasite; or a circular brownish-black crust with or without surrounding necrosis of the epidermis. We also recorded manipulated lesions (i.e., a characteristic crater-like wound) and ulcerative lesions caused by non-sterile perforating instruments (i.e., needles) [197]. Table 1 summarizes the study design, participants, and data collection methods used in this thesis.

Table 1: Summary of study design, participants, and data collection methods

Paper	Study design	Participants and sample size	Data collection methods
I: Concurrent anemia and stunting among schoolchildren in Wonago district in southern Ethiopia: A cross-sectional multilevel analysis	Cross-sectional	Schoolchildren aged 7 to 14 years and their parents or guardians were included. Four schools, 24 classrooms, and 864 children were included. 810 children were included in the final analysis.	Interview with the child and the child's parents or guardians. Observation of the child's hygiene and the child's parents' or guardians' home conditions. Hemoglobin test for anemia. Measurement of weight and height.
II: Helminth infections among rural schoolchildren in Southern Ethiopia: A cross-sectional multilevel and zero-inflated regression model	Cross-sectional	Schoolchildren aged 7 to 14 years and their parents or guardians were included. Four schools, 24 classrooms, and 864 children were included.	Interview with the child and the child's parents or guardians. Observation of home conditions. Examination of stool by

		850 children were included in the final analysis.	an experienced laboratory technician for helminth eggs.
III: Risk factors for scabies, tungiasis, and tinea infections among schoolchildren in southern Ethiopia: A cross-sectional Bayesian multilevel model	Cross-sectional	Schoolchildren aged 7 to 14 years and their parents or guardians were included. Four schools, 24 classrooms, and 864 children participated. 861 children were included in the final analysis.	Interview with the child and the child's parents or guardians. Observation of home conditions. Physical examination of the skin by experienced nurses with clinical diagnoses of dermatological cases.

Assessment of exposure and outcome variables

Exposure variables at the individual, parent, household, and school levels were assessed for all three Papers in this thesis. The outcome and exposure variables with their respective definitions are described in detail in Tables 2 and 3.

Table 2: Definitions of outcome variables used for this thesis

Outcome variables	**Definitions**	**Paper**
Concurrent anemia and stunting (CAS)	Defined when a child was both anemic and stunted. Anemia was defined based on the WHO guidelines for school-aged children: hemoglobin < 11.5 g/dL for children aged 5 to 11 years and < 12 g/dL for children aged 12 to 14 years [52]. Categorized as anemic (yes) or non-anemic (no). WHO AnthroPlus 1.0.4 software was used to calculate Z-scores of height-for-age for stunting according to the standard reference for children aged 5–19 years. Stunting in children was classified as Z-scores of height-for-age below −2 SD and Z-scores ≥ −3 to < −2 SD as moderately stunted, or Z-scores below −3 SD as severely stunted [57, 184]. Categorized stunted (yes) or not-stunted (no).	I
The presence or absence of any helminth infections	Assessed by laboratory examinations of stool specimens with two techniques (Kato-Katz and FEC). The presence (yes) or absence (no) of *T. trichiura*, *A. lumbricoides*, *Taenia* species, hookworm species, *S. stercoralis*, and *Hymenolepis nana*.	II
The presence or absence of *T. trichiura*	The presence of *T. trichiura* (yes) or absence of *T. trichiura* (no).	II
The presence or absence of *A. lumbricoides*	The presence of *A. lumbricoides* (yes) or absence of *A. lumbricoides* (no).	II
Intensity of *T. trichiura* infection	Infection intensity was defined as light (for *T. trichiura*) or moderate (≥ 1,000 epg for *T. trichiura*) [198].	II
Intensity of *A. lumbricoides* infection	Infection intensity was defined as light (< 5,000 epg for *A. lumbricoides*) or moderate (≥ 5,000 epg for *A.*	II

	lumbricoides) [198].	
Any skin problem	The presence or absence of any one of three skin conditions such as scabies, tungiasis, and tinea (yes) and absence of any one of three skin conditions such as scabies, tungiasis, and tinea (no).	III
The presence or absence of scabies	The presence of scabies (yes) or absence of scabies (no).	III
The presence or absence of tungiasis	The presence of tungiasis (yes) or absence of tungiasis (no).	III
The presence or absence of tinea infection	The presence of tinea (yes) or absence of tinea (no).	III

Table 3: Definitions of exposure variables used for this thesis

Exposure variables	**Definitions**	**Paper**
Child individual-level factors		
Sex	Sex of the child categorized as girl and boy.	I, II, III
Age	Age of child in years (grouped as “7–9 years” and “10–14 years”).	I, II, III
Fingernails trimmed	Assessed by observation of the condition of the child's fingernails (categorized as “yes” or “no”).	I, II III
Unclean fingernails	Assessed by observing the state of cleanliness of the child's fingernails (categorized as “yes” or “no”).	II, III
Handwashing with soap before meals	The child’s habit of handwashing with soap before meals was assessed by interview (categorized as “yes” or “no”).	II

Handwashing with soap after latrine use	A habit of handwashing with soap after latrine use was assessed by interview (categorized as "always," "sometimes," or "never").	I, II
Frequency of washing body with soap	Child's habit of washing body with soap (categorized as "every week" or "every two weeks").	III
Frequency of washing legs and feet with soap	Child's habit of washing legs and feet with soap (categorized as "daily" or "sometimes").	III
Frequency of washing hair with soap	Child's habit of washing hair with soap (categorized as "every week" or "every two weeks").	III
Presence of footwear at time of examination	Assessed by observation of child's feet during skin examination (categorized as "yes" or "no").	III
Sharing of beds	Child's state of sharing a bed with other family members (categorized as "yes" or "no").	III
Sharing of combs	Child's state of sharing combs with other family members (categorized as "yes" or "no").	III
Sharing of clothes	Child's condition of sharing clothes with other family members (categorized as "yes" or "no").	III
Loss of appetite in the past month	Presence or absence of loss of appetite in the month before data collection (categorized as "yes" or "no").	II
Eating uncooked vegetable	Child's habit of eating undercooked vegetables (categorized as "yes" or "no").	II
A habit of walking barefoot	Child's habit of walking barefoot (categorized as "always barefoot," "sometimes barefoot," or "never barefoot").	I, III
Dietary intake	Based on a 24-hour recall method, the child's parent or guardian was asked to list the foods consumed, and the child was also asked if he or she ate outside in the past 24 hours to calculate the Dietary Diversity Score (DDS).	I

Meal habits before attending school (breakfast or lunch)	Child's condition of regularly eating a meal before going to school (breakfast or lunch) (categorized as "yes" or "no").	I
Reported illness in the month before data collection	The child's condition of being sick in the month before data collection, as reported by the child's parent or guardian (categorized as "yes" or "no").	I
Deworming treatment in the past 6 months	The condition of the child who received deworming treatment in the last 6 months before data collection was assessed by asking the child's parents or guardians and showing them deworming tablets (categorized as "yes" or "no").	I, II
The presence of *A. lumbricoides*	Assessed by laboratory testing of stool samples using two techniques: Kato-Katz and FEC (categorized as "yes" or "no").	I
The presence of *T. trichiura*	Assessed by laboratory testing of stool specimens using two techniques: Kato-Katz and FEC (categorized as "yes" or "no").	I
The presence of hookworm	Assessed by laboratory testing of stool specimens using two techniques: Kato-Katz and FEC (categorized as "yes" or "no").	I
Head lice (pediculosis) infestations	Diagnosed by observation of the child's hair. Presence of infestation with head lice (categorized as "yes" or "no").	I
Anemia	Anemia was defined based on WHO guidelines for school-aged children: hemoglobin < 11.5 g/dL for 5 to 11 years and < 12 g/dL for 12 to 14 years [52] (categorized as "yes" for anemic children and "no" for non-anemic children).	II
Stunting	WHO AnthroPlus 1.0.4 software was used to calculate Z-scores of height-for-age for stunting according to the standard reference for children aged 5–19 years.	II

	Stunting in children was classified as Z-scores of height-for-age below −2 SD and Z-scores ≥ −3 to < −2 SD as moderately stunted or Z-scores below −3 SD as severely stunted [57, 184] (categorized as "yes" for the stunted children and "no" for non-stunted children).	
Thinness	Thinness was defined as body mass index-for-age Z-scores < −2 SD [57, 184] (categorized as "yes" for thin children and "no" for non-thin children).	II
Child's parents' or guardians' individual-level factors		
Mother's education	Education level of the child's mother or guardian (categorized as "no formal education" or "primary and above").	I, II, III
Father's education	Education level attained by the father or guardian of the child (categorized as 'no formal education' or 'primary and above').	I, II, III
Household-level factors		
Wealth index	The wealth index was constructed using principal component analysis [199] based on 14 variables related to household assets. Then, households were classified into three groups ("poor", "middle-class," and "rich").	I, II, III
Family size	The number of people living in the same house sharing food, shelter, and other essentials was determined by interviewing the children's parents or guardians (categorized as "1-4" or "≥ 5").	II, III
Source of drinking water	The source of drinking water in the household where the child lived (categorized as "protected source" or "unprotected source").	II
A container used to store water	A container used to store water in the household where the child lived (categorized as "closed container" or "open container").	II

Use of treated drinking water	The use of treated drinking water at the household level (categorized as "yes" or "no").	II
Food insecurity	Assessed based on a 4-week recall period of 9 items on the HFIAS (household categorized as "food secure," "food insecure," "slightly food insecure," "moderately food insecure," and "severely food insecure." And also categorized as "yes" for food insecure and "no" for food secure.	I
Received food aid in the past 6 months	The household in which the child lives received food assistance in the 6 months before data collection (categorized as "yes" or "no").	I
School-level factors		
Participation in the school meal programme	Child's participation in the school meal programme at the time of data collection (categorized as "yes" or "no").	I, II
Access to health education on personal hygiene	Child's access to personal hygiene education at school (categorized as "yes" or "no").	II, III
Absence from school in the past month	The presence of missed classes by the child in the month before data collection (categorized as "yes" or "no").	II

Statistical analysis

Data were entered into a database using Epi-data version 3.1 software (EpiData Association; Odense Denmark, 2004) via the double-entry system. Data analyses for this thesis work were performed using SPSS version 20 (IBM Corp, 2011), STATA version 14 (StataCorp LP, College Station, TX, 2015), and STATA version 15 (StataCorp LLC, College Station, TX, 2017). WHO

AnthroPlus 1.0.4 software was used to calculate Z-scores for height-for-age and body mass index-for-age according to the standard reference for children aged 5–19 years [184].

All variables relevant to this work were analyzed primarily with descriptive statistics including frequency, percentage, mean, median, range, interquartile range, and standard deviation (SD). We then performed cross-tabulation to calculate the proportions of categorical variables relative to outcome variables: in Paper I for CAS; in Paper II for each helminth infection, for *T. trichiura* infection, and *A. lumbricoides* infection; and in Paper III for scabies, tungiasis, and tinea infections. For all three Papers, we performed bivariate analyses to assess the association between two different variables. We also performed multivariate analyses to determine the relationship between more than two different variables or to identify risk factors associated with the outcome variables. The wealth index was constructed using a principal component analysis [199] with 14 household variables: electricity, radio, television, mobile phone, table, chair, bed, separate kitchen, cooking area, own land, bank account, toilet facilities, floor type, and roof type [200].

For Paper I and II, STATA version 14 software was used to analyze a multivariate, multilevel, mixed-effects regression model that accounted for random school and classroom effects and identified potential individual-, household-, and school-level risk factors for CAS and any helminth, *T. trichiura,* or *A. lumbricoides* infections. To ensure the reproducibility of the anthropometric measurements, we performed a reliability test in Paper I to observe inter-observer and intra-observer variation in children's weight and height measurements and estimated these with the intraclass correlation coefficient. In Paper II, we performed kappa statistics in STATA version 14 to estimate the inter-rater agreement reliability between the two readers using 10% of the test results by either the Kato-Katz or the FEC method and applied a count model with a zero-inflated negative binomial (ZINB) regression analysis to estimate potential factors associated with infection intensity by estimating the number of fecal eggs of *T. trichiura* and *A. lumbricoides* infections. $P < 0.05$ was considered statistically significant for the kappa values [201].

In Paper III, we used STATA version 15 software to analyze both frequentist and Bayesian, multilevel, mixed-effect, logistic regression models and identified potential risk factors that may contribute to outcome variables such as any skin problems (presence or absence of any one of the three skin diseases, namely scabies, tungiasis, and tinea) and the presence or absence of scabies, tungiasis, and tinea.

In Papers I, II, and III, exposure variables with $P < 0.25$ in the bivariate, multilevel, mixed-effect, logistic regression model were included in all models. However, there were also covariate variables with $P > 0.25$ that we retained in the final multivariate model to control for the effects of confounding. We calculated the results as crude odds ratios (CORs) and adjusted odds ratios (AORs) with a 95% CI. Exposure variables with P values < 0.05 in the final multilevel multivariate regression model were reported as statistically significant.

Table 4: Summary of statistical methods used for data analysis

Statistical methods	Paper
Descriptive statistics	I, II, and III
Principal component analysis	I, II, and III
Reliability test	I
Kappa statistics	II
Anthropometric analysis (Z-scores)	I
Bivariate, multilevel, mixed-effect, logistic regression model	I, II, and III
Multivariate, multilevel, mixed-effect logistic, regression model	I, II, and III
Receiver operating characteristic curve (ROC) or area under the curve (AUC)	I
Zero-inflated negative binomial regression	II
Bayesian, multilevel, mixed-effect, logistic regression model	III

Ethical considerations

The institutional review board at the College of Medicine and Health Sciences, Hawassa University (IRB/005/09), and the Regional Ethics Committee of Western Norway (2016/1900/REK vest) granted ethical approval. The Gedeo Zone Health Authority and the District Education Department also provided permission letters. The principals and teachers of the schools were informed about the objectives and procedures of the study. We obtained written (signed) and verbal (thumbprint) informed consent from all parents or guardians of study participants and written consent (assent) from children 12 years of age and older before the interviews. Participant privacy and confidentiality of information were maintained during interviews and measurements. Children who had anemia, helminth infections, scabies, and tinea infections were referred to the nearby health institution for treatment according to standard national guidelines [202]. We distributed soap and Vaseline ointment to each child to encourage them to protect their legs and practice good foot hygiene at the end of the study. In addition, all children in each school received health education on personal hygiene.

Results

Paper I: Concurrent anemia and stunting among schoolchildren in Wonago district in southern Ethiopia: A cross-sectional multilevel analysis

In Paper I, a cross-sectional study of 864 schoolchildren aged 7–14 years in rural southern Ethiopia was conducted from February 2017 to June 2017. Our objective was to assess the prevalence and risk factors of CAS at the individual, household, and school levels among schoolchildren using a multivariate, multilevel, mixed-effect, logistic regression model. CAS prevalence was 10.5% (85/810) among schoolchildren, and risk factors for CAS were concentrated at the individual level. The effects of clustering, as measured by the ICC, were 6.8% at the school level and 19% at the classroom level. Increased age (adjusted odds ratio [AOR]: 1.39 [95% confidence interval: 1.13, 1.71]), not washing hands with soap after latrine visits (AOR: 4.30 [95% CI: 1.21, 15.3]), walking barefoot (AOR: 10.4 [95% CI: 2.77, 39.1]), infection with *T. trichiura* (AOR: 1.74 [95% CI:1.05, 2.88]), and infestation with head lice (AOR: 1.71 [95% CI: 1.01, 2.92]) were associated with a high prevalence of CAS. Those who used treated drinking water (AOR: 0.32 [95% CI: 0.11, 0.97]) were less likely to have CAS.

Paper II: Helminth infections among rural schoolchildren in Southern Ethiopia: A cross-sectional multilevel and zero-inflated regression model

In Paper II, a cross-sectional study was conducted with 864 schoolchildren aged 7–14 years. Our objective was to assess the prevalence and intensity of helminth infections and potential risk factors at the individual, household, and school levels among schoolchildren in rural southern Ethiopia using multivariate, multilevel, mixed-effect, logistic, and zero-inflated negative binomial regression models.

The prevalence of at least one helminth species was 56%, while that of *T. trichiura* and *A. lumbricoides* was 42.4% and 18.7%, respectively. School- and classroom-level variables for helminth infections calculated with the ICC explained less than 5% of the variance, showing little influence. Thinness (AOR: 1.73 [95% CI: (1.04, 2.90]), anemia (AOR: 1.45 [95% CI: 1.04, 2.03]), children with a mother or guardian without formal education (AOR: 2.08 [95% CI: 1.25, 3.47]), and children in households using open containers for water storage (AOR: 2.06 [95% CI: 1.07, 3.99]) were risk factors for any helminth infection. In the ZINB model, older age (AOR:

1.08 [95% CI: 1.01, 1.16]) and unclean fingernails (AOR: 1.47 [95% CI: 1.07, 2.03)] significantly increased the risk of *A. lumbricoides* infection intensity. Handwashing with soap (AOR: 0.68 [95% CI: 0.48, 0.95]), deworming (AOR: 0.57 [95% CI: 0.33, 0.98]), and use of water from protected sources (AOR: 0.46 [95% CI: 0.28, 0.77]) reduced the risk of helminth infection.

Paper III: Risk factors for scabies, tungiasis, and tinea infections among schoolchildren in southern Ethiopia: A cross-sectional Bayesian multilevel model

In Paper III, a cross-sectional study was conducted with 864 schoolchildren aged 7–14 years. Almost three-quarters of schoolchildren had at least one type of skin disease, such as scabies (5.5%, 46/861), tungiasis (54.4%, 468/861), or tinea infections (39.1%, 337/861).

The clustering effects calculated by the ICC at both school and classroom levels for any skin problem (scabies, tungiasis, or tinea) were significant in the Bayesian model, and the measured values were higher than those in the frequentist model. In the frequentist model, at the school and classroom levels, the clustering effect was not significant and 8.8% for any skin problem, 8% and 28% for scabies, not significant and 2.8% for tungiasis, and not significant and 4.9% for tinea, respectively. In the Bayesian model, at the school and classroom levels, the clustering effect was 5.3% and 16% for any skin problem, 31.2% and 49.3% for scabies, 3% and 8.5% for tungiasis, and 5.7% and 12.7% for tinea, respectively.

In the Bayesian model, being a boy (AOR: 1.55 [95% Bayesian credible interval, BCI]: 1.01, 2.28); having unclean fingernails (AOR :1.85 [95% BCI: 1.08, 2.97]); not washing one's body (AOR: 1.90 [95% BCI :1.21, 2.85]) and hair with soap every week (AOR: 3.07 [95% BCI: 1.98, 4.57]); sharing a bed (AOR: 1.97 [95% BCI: 1.27, 2.89]), clothes (AOR: 5.65 [95% BCI: 3.31, 9.21]), or combs (AOR: 3.65 [95% BCI: 2.28, 5.53]); and living in a poor household (AOR: 1.76 [95% BCI: 1.03, 2.83]) were risk factors for any skin problem, but washing legs and feet daily with soap (AOR: 0.23 [95% BCI: 0.15, 0.33]) was protective against skin problems.

Discussion

Methodological discussion

Study design

A cross-sectional study design was used for all three Papers in this thesis: Papers I, II, and III. In cross-sectional studies, all information, exposures, and outcomes are measured at the same time [203]. This design is useful in two ways: 1) descriptive studies help describe information or estimate the prevalence of the outcome or exposure; and 2) analytic studies help estimate the association between outcome and exposure using odds ratios [203, 204]. However, in cross-sectional studies, it is not possible to demonstrate a temporal relationship between outcome and exposure variables because it is difficult to determine whether the exposure occurred before, during, or after the occurrence of the outcome [203, 205]. The main focus of the studies in this thesis was to identify the health problems in schoolchildren. These included CAS and its risk factors in Paper I, helminth infections and its risk factors in Paper II, and the occurrence of skin problems and its risk factors in Paper III. Thus, we used both descriptive and analytical studies. However, the studies in this thesis could be improved if we had included other study designs. For example, repeated cross-sectional studies, such as our study in Paper III, could be influenced by seasonality, or cohort studies could help to assess the incidence of skin problems in this study and also show the temporal relationship between outcome and exposure variables.

Sample size

Sample size refers to the number of participants included in a study to represent a population [206], and its estimation is an important step in planning a study [207]. It helps determine a minimum sample size that is adequate to achieve a desired level of precision in an estimate and determine the level of statistical significance achieved by that desired effect size [207]. An adequate sample size improves the statistical power of a study, reduces the risk of false negatives (a type II error), and increases the chances of detecting a difference if there is one [206]. To estimate the appropriate sample size for this thesis, we assumed a CI of 95%, a precision of 5%, and a proportion of outcomes and outcome-related variables, and then calculated the maximum sample size with 50% of the proportion having skin problems (Papers I, II, and III). In addition, our data were clustered—individuals were clustered within classrooms and classrooms were clustered within schools—and multistage sampling was used. The similarity of responses within a cluster likely affects the statistical power of the study. Therefore, we used a design effect of two and accounted for these cluster effects. The estimated sample size was 845 children after we accounted for a 10% rate of non-response. Although the estimated sample size was sufficient to address our study objective, we included a total of 864 children. However, in this thesis, the nonsignificant findings of some exposure variables with their respective outcomes are likely due to low statistical power because of the small sample size, especially when doing sub-group analysis. For example, in Paper I, no association was found between CAS and hookworm infections. The null association between outcome and exposure variable may arise from at least two conditions: 1) the evidence in the study sample may not be sufficiently strong despite the presence of an effect, and it could have been missed, or 2) the effect is smaller than expected and can be considered negligible or absent [208]. Therefore, the nonsignificant association between CAS and hookworm infection are likely due to the low statistical power resulting from the small number of hookworm-infected children. Hence, in this thesis, to avoid reporting bias associated only with positive results, we reported both positive and negative findings. In addition, in Paper III, we used both frequentist and Bayesian approaches. A Bayesian approach, unlike a frequentist approach, is not affected by the sampling distribution [30]. A Bayesian approach is better able to control the type-I error related to the false rejection of the true null hypothesis [209].

Statistical methods

This thesis used standard statistical procedures as outlined in the methods section and in each of the three papers. However, the data in this thesis were clustered (i.e., individuals within classrooms, and classrooms within schools). In Papers I, II, and III, we ran a simple regression model and a random-effects model using a multilevel mixed-effects logistic regression analysis. Therefore, we presented the results of all papers using the random-effects model. In Paper I, we compared a simple regression model with a random effects model using a ROC or the AUC, and the random-effects model showed better performance. We also calculated the ICC to measure homogeneity within clusters at the school and classroom levels and reported this for all papers. In addition, we applied both frequentist and Bayesian mixed-effects logistic regression models in Paper III and reported the results of the two models. The estimates in both models were similar; however, the observed smaller standard errors in the Bayesian model indicated the better performance of this model than that of the frequentist model [30]. However, the similarity of the estimates of the frequentist and Bayesian models is likely due to the large sample size, especially in the frequentist method. Moreover, in Bayesian Markov Chain Monte Carlo simulations, we performed a large number of iterations to achieve convergence. In addition, the school- and classroom-level cluster-effect estimates showed a high cluster effect in the Bayesian model and confirmed the presence of common risk factors for skin problems, suggesting that the Bayesian model can better explain the variation in these similar.

Validity

The credibility of an epidemiological study is evaluated in terms of internal and external validity [210]. Both internal and external validity are important in improving the estimation of effects [211]. The internal validity of a study helps evaluate the conditions of the study design, conduct, and analysis in providing trustworthy results for the study questions [212]. External validity assesses the generalizability of the results and whether they can be generalized to other contexts [212].

Internal validity

Internal validity assesses the trustworthiness of observed results. Thus, the results of a study are internally valid if the estimated effect is not biased [211]. This can be affected by selection, measurement (information), confounding, and random chance (random error) [213]. Bias is a systematic error resulting from improper study methods in recruiting participants, collecting information, or taking measurements [213]. Although bias is unavoidable in the design of epidemiologic studies, it can be minimized through appropriate design, standardized data collection instruments, handling procedures, and precise definitions of exposure and outcome [213]. Bias is not affected by sample size or statistical significance, and its presence may underestimate or overestimate the true association [214].

Selection bias

Selection bias is a systematic error that occurs in the selection of study participants or is due to causes that affect participation in a study [213]. This can include sampling bias and non-participant or non-response bias [215]. Non-random sampling is the most common type of sampling error, which can lead to an unrepresentative sample due to the lack of accuracy of the sampling frame [215]. In this thesis, we randomly selected primary schools and classrooms and then recruited a representative sample of children to minimize sampling bias. Thus, all primary schools in the study area had an equal chance of being included through random selection. Nevertheless, we only included four schools because the rural schools are located in remote areas, resulting in selection bias. Additionally, there may have been selection bias in the recruitment of children due to our inclusion of only rural schools and children 7 to 14 years of age. The reason for this is that we assumed in our study that primary school-aged children were in the age range of 7 to 14 years old. Although we had planned to exclude children with a physical disability in Paper I, we did not identify such cases during data collection. In all three Papers, nonresponse or refusal bias may have occurred. However, we randomly selected participants who left school after the selection process and replaced them with participants of the same grade, gender, and age. Although we lost some participants due to refusal and unavailability during data collection, we achieved a response rate of 94% in Paper I, 98% in Paper II, and 99% in Paper III. Because of this, some variables may not have been complete. Thus, selection bias, including sampling and nonresponse bias, was minimal in all three papers of this thesis.

Information bias

Information bias is a type of systematic error that occurs in the collection of exposure and outcome information [213]; it includes self-reporting bias (social desirability and recall biases), measurement error (observer, interviewer, or recording errors), and confirmation bias [215, 216].

Self-reporting bias: Social desirability bias

Social desirability bias is one of the self-reporting biases and a source of systematic error. It is defined as a condition of participants to give information in a situation that is considered acceptable by social norms or favorable by the interviewer or others, where the information may be private or sensitive [216].

Some results in this thesis, particularly the exposure variables, could be affected by bias due to social desirability. For example, in Paper I, the questions on child dietary diversity and HFIAS may have been influenced by this bias. Dietary items may be under- or overreported when there is a tendency to respond in a manner that avoids criticism or seeks praise. In addition, in the HFIAS questions, there may have been overreporting if there was a desire to seek help, or underreporting if there was an uncertainty of disclosure due to cultural norms, especially when it came to questions assessing severe food insecurity. Exposure variables related to personal hygiene, including the habits of washing hands, legs, feet, hair, and walking barefoot, may also be influenced by social desirability bias. However, this bias can also be overemphasized by external influences if the confidentiality of the information is not ensured [216]. To minimize social desirability bias, we stated the study's purpose, used closed-ended questions for all variables except dietary-related questions, and conducted the study in a private location.

Self-reporting bias: Recall bias

Another self-reporting bias categorized as a systematic error is recall bias, which often occurs in epidemiological studies when study participants do not accurately recall previous exposures or outcomes [216]. However, the occurrence of this error depends in part on the length of the recall period [217]. In all three papers in this thesis, recall bias may occur when assessing some exposure variables. In Paper I, dietary diversity could be subject to recall bias because it was collected based on a 24-hour recall period. The repeatability of dietary habits in the study could minimize recall errors. Moreover, by probing, we attempted to minimize this bias to increase the accuracy of food recalls in the past 24 hours.

Paper I required accurate age records for calculating anthropometric indices. As a result, to accurately record children's ages and minimize recall bias, we trained interviewers to use memory aids based on past events in the local area, and we verified the age information obtained from the school register with the information provided by children's parents or guardians. In addition, in Paper II, a recall bias may have occurred when collecting information on past deworming treatment and the presence of appetite loss in the past month because we observed an association between helminths infection and history of deworming in the past six months and loss of appetite in the past month before data collection (Paper II).

Measurement bias

A form of systematic error that occurs in the measurement of exposures or outcomes, either because of inaccurate equipment or tools, environmental or laboratory conditions, or records (i.e., bias caused by an interviewer or observer or recorder bias) [216]. In this thesis, measurement errors could have occurred in conducting participant interviews, recording responses, or measuring. We attempted to minimize measurement error by training data collectors and supervisors in data collection, recording, and processing techniques and by closely monitoring them during the study period. We measured all exposures and outcomes using an adapted, validated, pretested, structured questionnaire. In addition, data completeness and consistency were checked during each instance of data collection.

However, in Paper I, bias may have occurred in the measurement or recording of hemoglobin, weight, and height values. To minimize these biases, we processed and performed all measurements (i.e., hemoglobin, weight, and height) according to standard procedures. We also applied a reliability test [218, 219], and estimated intra-and inter-observer variation using the intraclass correlation coefficient. More than 90% of the estimated intra-and inter-observer reliability tests for both weight and height were good [219], as reported in Paper I [220]. In addition, environmental conditions such as altitude may affect the estimation of anemia, which we considered [52]. Furthermore, there may also have been an underestimation of the prevalence of head lice in Paper I because of unobserved head lice, particularly in girls with much hair.

In Paper II, we collected, processed, and examined stool samples for helminth diagnosis using the Kato-Katz and FEC techniques according to standard procedures [185, 186]. To ensure the reproducibility of the test results, we also reexamined 10% of randomly selected test results blindly selected and applied a reliability test for inter-rater agreement [201]. To avoid inaccurate helminth results, we also controlled the quality of the results according to WHO guidelines [188].

Misclassification bias is a systematic error that occurs when the sensitivity or specificity of the measurement instrument is not perfect in accurately identifying the exposure or outcome [215]. In Paper II, the fact that there is no "gold standard" test with 100% accuracy for helminth detection may have led to this bias. A species-specific diagnostic method [221, 222] and the use of sensitive techniques, such as polymerase chain reaction (PCR) and the recently developed recombinase polymerase amplification, could have improved the detection rate of helminth infections [223, 224]. Unfortunately, PCR was not available for this study, as it requires resources and skilled personnel [224]. Moreover, the use of combined tests may also increase the detection rate of helminth infections [221, 225]. We used combined tests (i.e., the Kato-Katz test and FEC techniques) known to detect STHs [223]. In addition, the sensitivity of the Kato-Katz method may be affected by the duration of stool sample testing and the number of Kato-Katz smears [225]. Therefore, the prevalence of hookworms in our study may be underestimated, as the Kato-Katz method is not very sensitive to them. In addition, the prevalence of *S. stercoralis* was probably underestimated because neither the Kato-Katz nor the FEC methods are recommended methods for its detection. Furthermore, measurement of infection intensity requires accurate counting of helminth eggs, but mismatched results are not unexpected because eggs of the helminth species can be confused with others, and recording errors may also play a role [189, 225]. Consequently, we tried to minimize this error by re-reading 10% of the test results and found that they were in good agreement with the Kappa values reported in Paper II [200]. In addition, the ZINB model we used for helminth infection intensity (*T. trichiura* and *A. lumbricoides*) also helped in the analysis of true zeros (i.e., infection-free children) and false zeros (i.e., infection-free children despite the actual presence of infection due to sampling zero or diagnostic methods).

In Paper III, an error in outcomes measurement could have occurred during clinical diagnosis of skin problems without further laboratory confirmation testing, particularly for tinea infection, as fungal cultures were not available in our setting [226]; thus, under- or overestimation could have occurred. Nevertheless, nurses experienced in clinical diagnosis of dermatological cases diagnosed skin problems with well-defined clinical manifestations. In addition, to address this issue, 10% of children were examined by two nurses to confirm the reproducibility or consistency of clinically diagnosed skin problems.

Confirmation bias

Confirmation bias a systematic error caused by human judgment during diagnosis when a researcher infers evidence based on his or her preconceived opinions, beliefs, expectations, or preferences [216]. This bias is common in medical diagnoses. In this thesis, particularly in Paper III, the diagnosis of scabies infestation and tinea infection may have been subject to confirmation bias because we did not perform further confirmatory testing. However, the use of experienced nurses to diagnose skin problems and three experienced examiners to achieve agreement could minimize this bias.

Confounding

Confounding is defined as an extraneous variable introduced when a variable is associated with both the exposure and outcome variables, such that its presence affects the results [227]. It can occur in all epidemiologic studies but can be controlled for in the design phase or during analysis [215]. However, misclassification of confounders may hinder their control in the analysis. Moreover, it is impossible to account for unknown confounders in statistical analysis [215].

Stratification or multivariate analyses are techniques used to control confounding in the analysis phase. Therefore, in this thesis, to control for potential confounding factors in the analysis stage, we performed a multivariate, multilevel analysis using regression models. For example, we used a multivariate, multilevel mixed-effects logistic regression analysis (Papers I, II, and III), a ZINB regression model (Paper II), and a Bayesian regression model (Paper III). Estimated effect measures were reported as CORs and AORs.

For example, in Paper I, to identify potential predictors of CAS, we adjusted for sex, age, handwashing with soap after latrine use, walking barefoot, *T. trichiura* and head lice, mother's education, wealth, family size, use of treated water for drinking, access to food assistance in the past six months, and participation in the school feeding programme. In Paper II, to identify potential predictors of helminths, we adjusted for sex, age, loss of appetite in the past month, nail trimming, handwashing with soap before meals, thinness and anemia, mother's education, wealth, source of drinking water, water container, use of treated drinking water, and participation in the school feeding programme. For outcome *T. trichiura* infection, we adjusted for sex, age, loss of appetite in the past month, consumption of uncooked vegetables, thinness and anemia, mother's education, wealth, family size, container used to store water, and participation in the school feeding programme. For outcome *A. lumbricoides* infection, we adjusted for sex, age, nail trimming, unclean fingernails, loss of appetite in the last month, handwashing with soap after using the latrine, deworming treatment in the last six months, anemia, mother's education, wealth, source of drinking water, and participation in the school feeding programme.

When using ZINB to model infection intensity for *T. trichiura*, we adjusted for sex, age in years, nail trimming, loss of appetite in the past month, consumption of uncooked vegetables, hemoglobin concentration, thinness, mother's education, wealth, container used to store water, and participation in the school feeding programme; and for *A. lumbricoides*, sex, age in years, nail trimming, unclean fingernails, handwashing with soap after latrine use, deworming treatment in the last six months, hemoglobin concentration, mother's education, wealth, and participation in the school feeding programme.

Using the Bayesian model in Paper III, for each skin problem, we adjusted for the factors of sex, age, unclean fingernails, presence of footwear, frequency of washing with soap, sharing of beds, clothes, and combs, wealth, and access to health education about personal hygiene. For the scabies model, we adjusted for the factors of sex, age, frequency of washing with soap, sharing of beds, clothes, and combs, family size, wealth, and access to health education about personal hygiene. For the tungiasis model, we adjusted for sex, age, nail trimming, walking barefoot, presence of footwear, frequency of washing with soap, sharing of beds and clothes, family size, wealth, and access to health education about personal hygiene. For the tinea model, we adjusted for sex, age, unclean fingernails, walking barefoot, presence of footwear, frequency of washing with soap, sharing of beds and clothes, family size, wealth, and access to health education about personal hygiene.

Controlling for confounding variables, we identified *T. trichiura* infection as a confounding variable for the association between CAS and handwashing with soap after latrine use in Paper I. On the other hand, handwashing with soap after latrine use was also a confounding variable for the association between CAS and walking barefoot. Although we attempted to control for confounders in our analysis, there may be unknown or unmeasured confounders or effect modifiers in this thesis that could underestimate or overestimate our outcomes, which could be considered a limitation of our study. For example, in Paper I, we did not examine serum ferritin levels, dietary information over consecutive days, food quantity, or malaria. In Paper II, we did not consider possible risk factors for helminth infections such as altitude, soil type, rainfall, and land surface temperature. In Paper III, the nonsignificant effect of habitual barefoot walking in the Bayesian model could be due to unmeasured confounding factors such as footwear type. Although we did not account for climate variability in Paper III, the occurrence of skin problems such as scabies, tungiasis, and tinea could have been influenced by the seasonality. In addition, the immune factor, which we did not consider, could also be a possible risk factor, especially for tinea infections.

Chance (random error)

Random error is a non-systematic error resulting from sampling variability that can affect the precision of exposure and outcome measurements [213]. It is difficult to include the entire population in studies, and almost all researchers draw their conclusions from a sample of the entire population, so chance can lead to nonrepresentation of true values [228]. However, chance can be minimized by either increasing the sample size or decreasing the variation in measurements [213]. In this thesis, we used a large representative sample of schoolchildren, and, in addition, in Paper III, we used a large randomly generated Markov Chain Monte Carlo sample. Random error can be quantified using statistics through P-values and CIs [229]. However, according to a recent guide, a P-value is a measure of compatibility between the data and the overall model used to estimate them [230]. According to a statement from the American Statistical Association (ASA), a P-value is not the probability that chance produced the observed data, but a statement about the data in terms of a particular hypothesized explanation [231]. According to the explanation of ASA, we reported the effect size with 95% CIs and P-values for Papers I, II, and III [232]. Therefore, the observed smaller P-values in this thesis indicate greater statistical incompatibility with the null hypothesis in the data we used [231].

However, according to the frequentist approach, the interpretation of the 95% CI is based on the replication of a study. That is, if we replicate a study 100 times using a similar procedure and calculate the 95% confidence interval, we are 95% confident that the unknown or true estimate is within the estimated interval [30]. It is recommended to use a Bayesian approach to directly interpret the uncertainty or directly assess the correctness of the hypothesis, although this requires another assumption, namely the prior distribution [230, 231]. In Paper III, we applied Bayesian statistics and set a 95% credibility interval. Based on Bayesian estimation, the interpretation of the 95% credible interval refers to the probability that the unknown or true effect estimate is within the interval is 95% [30].

External validity

External validity refers to the ability to generalize results (i.e., whether the results can be generalized to the population at large or other settings) [212]. A study cannot be externally valid if internal validity is compromised. Therefore, the internal validity of a study is a prerequisite for the generalizability of the study results [210]. In addition, the representativeness of a study sample for the target population and the sample size can influence the external validity of the study [210].

In this thesis, we randomly recruited a large representative sample of rural primary school students from the Wonago district, which is typical of other primary school students in rural southern Ethiopia. However, we included only schoolchildren aged 7–14 years in the study and excluded the age groups below 7 and above 14 years. Thus, the studies in this thesis could be representative of schoolchildren within this age group. In addition, the fact that only school-aged children were included could affect generalizability by not being representative of children who do not attend school, although we assume that most school-aged children do attend school. Moreover, in Paper III, we conducted the analysis using Bayesian estimation and randomly generated Markov Chain Monte Carlo samples. Thus, the simulated data are large and close to the target population, which makes us confident that the results of Paper III can be generalized to school-aged children with similar socio-demographic and cultural conditions in rural southern Ethiopia. However, the generalizability of the results of Paper III could also be affected by the study period, as the skin problems in this study could be influenced by seasons or climatic variations. To the best of our knowledge, the studies in this thesis (i.e., the coexistence of anemia and stunting and the prevalence of helminth infections modeled with logistic multilevel regression, the intensity of helminth infections modeled with ZINB regression, and skin problems modeled with both frequentist and Bayesian multilevel approaches) are the first of their kind in Ethiopia. Thus, the use of different statistical models to estimate health problems in schools in this thesis could provide additional insights into reducing health problems in schools and improving the health of schoolchildren.

Discussion of the main findings

The general objective of this thesis was to investigate some of the prevalent health problems among schoolchildren aged 7–14 years in rural southern Ethiopia. In this thesis, CAS is identified as a moderate public health problem, as is the high burden of helminth infections and skin problems among schoolchildren in southern Ethiopia. Considering school- and classroom-level effects, the risk of contracting CAS was higher with increased age and among those who did not always wash their hands with soap after visiting latrines, always walked barefoot, and had *T. trichiura* infection and/or head lice infestation, but the use of treated drinking water proved protective against CAS. Considering the cluster effects at the school and classroom level and adjusting for the larger number of zeros in fecal egg counts, we observed associations between helminth infection and age, thinness, anemia, loss of appetite in the past month, unclean fingernails, handwashing with soap after latrine visits, deworming treatment, maternal education, household water source, and use of an uncovered water container at home. The cluster effects at the school and classroom levels for CAS were significant, but the cluster effect for helminth infections was minimal. Using the Bayesian model, we also showed that most hygiene-related factors and wealth were associated with skin problems, with large differences between classrooms, suggesting the presence of common risk factors at these sites.

Even though mortality rates in school-aged children are lower than in children under five years, nutritional deficiencies and diseases due to infections remain the major causes of death [36]. Though the health problems of school-aged children are diverse, the studies analyzed in this thesis focused primarily on the co-occurrence of anemia and stunting, helminth infections, and skin problems.

Although improving children's health is the goal of the National Strategy for School Health and Nutrition [6], through nutrition interventions [9], deworming [11, 97], and improving water, sanitation, and hygiene [12], we found anemia and stunting to be a moderate health problem in Paper I and a high burden of helminth infections among rural school-aged children in Paper II. Also, in Paper III, we found a high prevalence of skin problems despite national school health programmes aimed at detecting active cases of skin problems through regular screening [4].

CAS in this thesis refers to the co-occurrence of anemia and stunting, and we reported a lower rate of 10.5% in schoolchildren than recent reports of 24% for Ethiopia [15], 21% for India, and 30% for Peru [233] in children younger than 5 years. These differences could be due to the different ages of the participants and the study setting. The prevalence of anemia was 29.6%, which is higher than the 22% and 23% reported in other studies from southern Ethiopia [24, 62], although these results are lower than the 43% reported in southwestern Ethiopia [22]. Our reported moderately high prevalence of stunting of 32% is consistent with previous reports of 28% in southern Ethiopia [24], 31% in the town of Filtu [13], and 33% in the Fogera district [178].

As given in Paper II, the overall helminth prevalence of 56% found in this thesis is consistent with the results of 60% and 63% in southern Ethiopia [23, 62], but exceeds the 23% [24], and 28% [18] found in other studies. We reported a higher prevalence of *T. trichiura* infections (42%) than in previous studies in Ethiopia [22], the Democratic Republic of Congo, Kenya [234, 235], Burkina Faso [236], and globally [237]. We determined the prevalence of *A. lumbricoides* infection to be 18.7%, which is consistent with the global report of 20% [237] but higher than other reports from southern Ethiopia [18, 238]. The hookworm infection rate of 4% was in line with the national mapping [238] but low compared with studies from southern Ethiopia [24], other regions of Ethiopia [22, 239], and the global report [237]. The low intensity of helminth infections observed in this study [198] is comparable to other studies in Ethiopia [24, 240, 241], but the observed multiple helminth infections were high compared to other studies elsewhere in Ethiopia [242, 243]. The differences in helminth prevalence could be because our study used two diagnostic procedures, while other studies used only a single Kato-Katz procedure [24], and some studies used procedures with low sensitivity, such as wet mounting [18, 244]. In addition, ecological factors such as elevation, soil type, rainfall, and surface temperature could play a role in these differences [245].

In Paper I, we identified the risk factors associated with CAS. The odds of developing CAS increased significantly with increasing age, as previously reported in Ethiopia [66, 183, 246]. This may be related to the high nutritional needs of older children during the transition period to puberty [247]. Lack of handwashing with soap after latrine use was associated with an increased odds of CAS, as has been reported elsewhere [233, 248]. Good personal hygiene is crucial for the prevention of infections and, consequently, for the prevention of nutritional deficiencies caused by helminths. This is also confirmed by a finding in Paper II: handwashing with soap after latrine visits and trimming nails protect against helminths [200]. In addition, we also found an increased intensity of *A. lumbricoides* infection in children with unclean fingernails (Paper II), as has been reported by others [18, 21]. The observed high risk of CAS in children who always walked barefoot and in children infested with head lice is probably related to low socioeconomic levels and poor hygiene [249]. Moreover, even though we have not found studies that have evaluated the association between head lice infestation and CAS, evidence also showed an association between anemia and this infestation [250]. However, given the small number of children in our study who always washed their hands with soap after visiting the latrine and walked barefoot, these results must be interpreted with caution.

In addition, we found an association between *T. trichiura* infection and CAS, as described in previous studies [242, 251, 252]. This may be related to inflammatory responses to worm infection in the intestinal mucosa, leading to loss of appetite, decreased food intake, and impaired iron absorption [242, 252]. On the other hand, iron deficiency can cause low secretion of insulin-like growth factor-I (IGF-I), leading to growth failure [81]. Moreover, as shown in previous studies [251, 253, 254], we reported a high rate of helminth infections in anemic children (Paper II). In addition, our ZINB model in Paper II suggests that the probability of children remaining free of *T. trichiura* and *A. lumbricoides* infections increases with increasing hemoglobin concentration. The intensity of infection observed in Paper II was low, and although mild infections of *T. trichiura* and *A. lumbricoides* are not sufficient to cause significant blood loss, they may exacerbate the condition [255]. However, de Gier et al. found low hemoglobin concentrations in children with mild *T. trichiura* infection [251]. This finding could also be influenced by unmeasured factors such as low dietary iron intake and malaria. In Paper II, we also found that thin children were more frequently infected with helminths—an association that has been demonstrated in previous studies [237, 256]. This is because malnutrition can impair immunity, which can increase susceptibility to infection [256]. However, we did not find a significant difference between hookworm infection and CAS, possibly due to inadequate statistical power because the number of children infected with hookworm was small (Paper I). Further, in Paper II, the rate of helminth infections in children who reported a loss of appetite in the past month was also high. In Paper I, the use of treated drinking water in households reduced the odds of CAS in children, which also likely indicates a protective effect against intestinal parasitic infections [102, 234, 235].

In Paper I, neither dietary diversity nor household food security was associated with CAS, possibly due to the low level of severe food insecurity observed in this study. On the other hand, food insecurity could be related to dietary diversity. It has been previously reported that wealth is associated with CAS [15]. Although we found no significant association between wealth status and CAS (Paper I), the result is consistent with previous reports [183]. However, this result could be related to the presence of other unmeasured socioeconomic factors. Moreover, CAS rates did not differ between children who participated in a school feeding programme and those who did not, although the result can be considered borderline significant (P=0.08) (Paper I). Only cereals were served in the school. Therefore, the food served to the children at school contained micronutrient deficiencies, which may explain why we did not find a significant difference.

In the ZINB model, we observed an increased intensity of *A. lumbricoides* infection and a decrease in the probability that older children remained free of this infection (Paper II). Older children most likely engage in different activities and have contact with the environment, which makes them susceptible to helminth infection. In contrast, a previous study reported a lower risk of helminth infection in older age groups [257]. This lower risk could be due to immunologic and behavioral factors related to hygiene [258].

Our ZINB model showed an association between the probability of *T. trichiura* infection and consumption of raw vegetables, where those who ate raw vegetables were at increased risk for this infection (Paper II). Consumption of contaminated raw vegetables could play an important role in the transmission of helminth infections [257, 259]. It is well known that deworming reduces the prevalence and intensity of helminth infections [43]. In Paper II, deworming in the last six months significantly increased the probability that children remained free of *A. lumbricoides*, as was also observed in rural Bangladesh [260].

Helminth infections were more common in children whose mothers had no formal education (Paper II), similar to previous studies in Ethiopia [17, 18] and rural Mexico [261]. This could be related to inadequate home sanitation and hygiene as a result of poor knowledge. The use of treated drinking water in households reduced the odds of CAS in children (Paper I), which also likely indicates a protective effect against intestinal parasitic infections [102, 234, 235]. Moreover, piped water use has been shown to influence the prevalence of *A. lumbricoides* infection [102]. In this study, low rates of *A. lumbricoides* infection were observed in children who lived in households that used a protected water source. This suggests the possibility of contamination if water is not protected from STH eggs during transport and storage [262]. In the zero-inflation model, we also observed a high risk of helminth infections, particularly *T. trichiura* infection, among children in households that used open containers for water storage. Similar results were also observed in Kenya [234]. The high percentage of unimproved water sources and the practice of open defecation, especially in rural Ethiopia, support this finding [263]. Indeed, we observed a high percentage of unimproved toilet facilities in the households surveyed.

Children who participated in school feeding programmes had high rates of *T. trichiura* infection and increased intensity of *A. lumbricoides* infection. These findings suggest unsafe or unsanitary food preparation and poor sanitation at schools in the study setting. School sanitation and hygiene could influence this finding, although we were unable to demonstrate an association because of the similarity of these potential exposure variables. In addition, schools with nutrition programmes could be at high risk of food insecurity and susceptibility to infection.

In Paper III, similar to other studies in southern Ethiopia [129] and the national survey report on schoolchildren [150], we found a prevalence of 5% for scabies, but these findings are considerably lower than previous reports of 34% to 50% in the same region [26, 116]. These differences could be because of personal hygiene, socioeconomic factors, study settings, climate variability, and disease outbreaks. Scabies varies with the seasons [151-153]. In addition, we conducted this study in the dry season, which may have influenced scabies prevalence, as scabies is more common in cool and humid weather [151, 152]. In contrast, other studies have shown an association between increased temperature and high scabies prevalence [153]. However, a previous study in Ethiopia also showed that most scabies cases occur in drought-affected areas [115]. Although we did not examine seasonal variation in this study due to the nature of our study design, it could be related to overcrowding and close contact in cooler seasons. However, other studies have not shown significant differences depending on season [110, 264, 265].

The 54% tungiasis prevalence we found is consistent with other findings from rural southern Ethiopia [27] and Kenya [266], but higher than the 35% found in other areas of southern Ethiopia [129]. This discrepancy could be related to our study setting, which is rural and where most children live in houses with earthen floors and attend classrooms with poor hygiene facilities. It could also be related to seasonal variations, as our study took place during the dry season, when tungiasis is more common [154-156]. This could be explained by an indirect relationship with access to water in the dry season to protect personal hygiene. The prevalence of tinea infection was 39%, which is consistent with rates from other rural areas in southern Ethiopia [29] but exceeds those from urban areas in Ethiopia [129], Côte d'Ivoire [267], and Tanzania [180]. Conditions such as poverty, as well as hygiene, climate, and immune factors [144-146, 157], could explain the observed differences. In agreement with the findings of studies from Ethiopia [29, 268, 269] and other African countries [267, 270-272], we found a higher prevalence of tinea capitis in boys than in girls, which could be associated with the frequency of washing, shaving, or haircutting [157].

Paper III also identified several risk factors for skin problems. We found that children with unclean fingernails are at higher risk for skin problems, especially tinea. Nail hygiene is a known factor that prevents the spread of infection, as many pathogens can be shed from fingernails, leading to transmission [273]. Irregular washing of the body and hair with soap has also been associated with increased skin problems [266, 274-276]. Our results also show that daily washing of the feet with soap is a protective factor against both tungiasis and tinea. Sharing beds, clothes, or combs has also been associated with an increased risk of scabies and tinea infections, as shown in other studies in Ethiopia [26, 116] and other African countries [275-278].

Similar to previous reports from Ethiopia [27] and Rwanda [47], we observed no differences in tungiasis rates between boys and girls. Our bivariate frequentist model showed that boys had a slightly higher risk, possibly due to behavioral factors related to hygiene. The findings of Elson et al. [266] and Wiese et al. [279] also showed a higher risk of tungiasis in boys. Other findings suggest that the risk of acquiring tungiasis varies with age-specific behavioral patterns [266, 279] and is increased in children younger than 15 years [266] and the elderly [279]. We could not confirm these findings because our study did not include adolescents older than 14 years or older age groups. Previous reports suggest that poor hygiene, including a low frequency of washing with soap [279], is associated with increased rates of tungiasis [47, 280]. Transmission is also more likely in places where shoes are not worn, such as in sleeping rooms [134]. Our findings confirm that sharing beds and clothing increases the risk of tungiasis.

Appropriate footwear and foot hygiene are critical for protection [281] against tinea [148, 149] and tungiasis [136, 137]. Walking barefoot is a known risk factor for tungiasis [27, 47]. In this study, walking barefoot was not associated with skin problems in either the Bayesian or frequentist models. The nonsignificant effect in the Bayesian model could be due to other unmeasured factors, such as the type of footwear. However, the association between the presence of footwear at the time of the study and an increased risk of tungiasis was unexpected and should be interpreted with caution. A previous study showed an association between wearing closed footwear and an increased risk of tungiasis [129].

Poverty is a known factor influencing the occurrence of skin problems [45, 138, 282]. The observed association between children living in poor households and an increased risk of skin problems in Paper III perhaps indicates that these families cannot afford soap and other hygiene products. The construction material of the home [283], contact with pets [284, 285], and poor environmental hygiene [134, 280] may also be among the factors. Studies from Kenya [266, 283] and Nigeria [137] show that flooring type plays an important role in the transmission of tungiasis. Floor material was not included as a separate variable in our multivariate model because this variable was also used to construct the wealth index. However, we observed a high prevalence of tungiasis among children who lived in a home with a floor of natural soil or dung. Dry, loose soil or sand is a favorable environment for fleas causing tungiasis [137, 266]. There is evidence that family size is related to the risk of developing skin problems [286]. We found that children who lived in households with large families were at higher risk of skin problems, especially tinea infections, which was likely due to the close contact that results from overcrowding in the home.

Many school-aged children are not adequately covered by different programmes, despite improvements in interventions for mothers, newborns, and young children [36]. Although there are effective interventions for improving the health of children under five years of age, those programmes are not accessible to school-aged children. Effective interventions to improve the health of children under five exist; however, none are linked to programmes to support school-aged children [36]. Nevertheless, it is challenging to select appropriate preventive programmes and ensure programme sustainability across all age groups. Children's health is also affected by poverty and other factors in the household [36], as we found. Therefore, improving household conditions is also a critical preventive measure that benefits households as a whole, but especially children. However, school health programmes can provide opportunities for school-aged children by being either preventive, promotive, or supportive when linked to their communities [36]. Most importantly, school health programmes help identify nutritional disorders, anemia, and other health problems. However, school health services in Ethiopia are fragmented and poorly implemented [77]. The health services for young children need to be extended to school-aged children to ensure their full potential [36]. Moreover, in addition to strengthening health services in the health system, it is also necessary to establish and provide them in the school system to reduce the burden of health problems and improve children's health [36]. Also, we believe that assessing only some problems is not enough to improve children's health. Instead, regular assessments could provide compiled information and improve children's health.

Conclusions and recommendations

Conclusions

Based on the general objective of this thesis, which assessed some of the major health problems among schoolchildren aged 7–14 years in rural southern Ethiopia, we concluded that the observed CAS prevalence is a moderate public health problem, and the burden of helminth infections and skin problems is high among schoolchildren in southern Ethiopia; in addition, individual-, household-, and school-level factors were also found to contribute to the risk of developing these health conditions. The conclusions from the main findings of the specific objective are as follows:

Objective 1: To assess the prevalence and risk factors of CAS at the individual, household, and school levels among rural schoolchildren in the Wonago district, southern Ethiopia (Paper I). The conclusions for this specific objective are as follows:

- We found that the prevalence of CAS is a moderate public health problem among rural schoolchildren in the Wonago district, southern Ethiopia.
- We observed significant cluster effects at the school and classroom levels for CAS; most identified risk factors were concentrated at the individual level, including age, not always washing hands with soap after using a latrine, walking barefoot, presence of *T. trichiura* infection, and head lice infestation.
- The use of treated water for drinking was a protective factor against CAS.

Objective 2: To assess the prevalence and intensity of helminth infections and identify potential risk factors at the individual, household, and school levels among rural schoolchildren in the Wonago district, southern Ethiopia (Paper II). Our conclusions for this specific objective are as follows:

- We observed a high burden of helminth infections, *T. trichiura,* and *A. lumbricoides* infections, but the intensity of infection was low among rural schoolchildren in the Wonago district, southern Ethiopia.
- Most risk factors for helminth infections were concentrated at the individual level, and observed cluster effects at the school and classroom levels were minimal.
- Lack of appetite in the past month, thinness, anemia, having a mother or guardian without formal education, and using open containers for water storage were associated with increased risk of helminth infection.
- Eating raw vegetables and using open containers for water storage increased the probability of *T. trichiura* infection.
- We also observed an association between *T. trichiura* and *A. lumbricoides* infections and hemoglobin concentration.
- We found that the intensity of *A. lumbricoides* infection increased in older children and those with unclean fingernails.

- Trimming nails, washing hands with soap after latrine visits, deworming, and using protected water sources reduced the risk of *A. lumbricoides* infection.
- Children who participated in school feeding programmes had high rates of *T. trichiura* infection and higher intensity of *A. lumbricoides* infection.

Objective 3: To examine the occurrence and risk factors of three parasitic skin diseases (scabies, tungiasis, and tinea) and their risk factors in rural schoolchildren in the Wonago district, southern Ethiopia, using a frequentist and a Bayesian approach (Paper III). For this specific objective, our conclusions are as follows:

- We observed a high burden of skin problems in rural schoolchildren in the Wonago district of southern Ethiopia.
- The Bayesian model performed better than the frequentist model in indicating the presence of common risk factors for skin problems at the classroom level.
- Sharing beds or clothes was associated with an increased risk of scabies, tungiasis, and tinea, and comb-sharing was also linked with a high risk of scabies and tinea.
- Unclean fingernails and living in large families were associated with an increased risk of skin problems, especially tinea infections, but washing legs and feet daily with soap was found to be protective for both tungiasis and tinea.
- Living in poor households was associated with an increased risk of skin problems.

Recommendations

Our recommendation for the general objective is that policymakers should focus on integrated programmes that improve the health status of individuals, households, and schools to minimize the major health problems in school-aged children in rural Ethiopia. Based on the findings of the studies in this thesis, we have also presented operational, policy, and research recommendations for each specific objective as follows:

Operational recommendations

Objective 1: To assess the prevalence and risk factors of CAS at the individual, household, and school levels among rural schoolchildren. Our recommendations are as follows:

- Implementation of more effective nutrition programmes to address CAS in schoolchildren.
- Interventions to improve personal hygiene, including the provision of safe water and education on personal hygiene protection in households and schools, can help reduce CAS associated with poor hygiene among schoolchildren.

Objective 2: To assess the prevalence and intensity of helminth infections and identify potential risk factors at the individual, household, and school levels among rural schoolchildren in the Wonago district, southern Ethiopia (Paper II). Our recommendations for this specific objective are as follows:

- Integrated intervention efforts focused on the individual, the household, and the school will reduce the burden of helminth infections.

- Deworming must be supplemented by hygiene programmes at school and at home to improve the health of schoolchildren in the study area.
- Avoiding eating raw vegetables or washing vegetables appropriately before consumption could reduce the risk of helminth infection.
- The observed high rates of helminth infections in children participating in school feeding programmes could be due to unsafe or unsanitary food preparation and poor sanitation in schools, which also require attention.

Objective 3: To investigate the occurrence and risk factors of three parasitic skin diseases (scabies, tungiasis, and tinea) among rural schoolchildren in the Wonago district, southern Ethiopia, using both frequentist and Bayesian approaches (Paper III). Our recommendations for this specific objective are as follows:

- Integrated intervention efforts that focus on the individual, home, and school levels can help reduce the burden of skin problems in school-aged children.
- Ensure that adequate water and soap are available in all schools, promote the importance of washing legs and feet daily with soap and appropriate footwear, and encourage those schoolchildren who care about their hygiene.
- Train schoolteachers to detect active cases of skin problems in children through regular checkups at schools.

Policy recommendations

Our recommendation for the general objective is that, in addition to strengthening health services in the health system, policymakers should focus on improving the implementation of school-based health services to minimize the major health problems among schoolchildren in rural Ethiopia. Policy recommendations for each specific objective are as follows:

- Reducing major health problems among schoolchildren requires strengthening school health programmes, which requires policy attention.
- Efforts of the Ministry of Health and Education are required to address the major gaps in school health services implementation and to improve the health of rural school-aged children. For objectives 1, 2, and 3, efforts of the Ministry of Health and Education are required to ensure adequate water and soap in schools for hygiene protection.
- For objective 1: School-based nutrition programmes should be strengthened.
- For objective 2: A periodic deworming programme must be strengthened.
- For objective 3: The Ministry of Education should emphasize rural school settings, including the building material of the classrooms, and also take measures to standardize classroom sizes to reduce highly transmissible skin problems.
- The link between skin problems and poverty also requires policy measures to improve the socioeconomic level of the households.

Future research

- Further studies in the region should investigate micronutrient levels and malaria in schoolchildren.
- The observed high rates of helminth infections in children participating in school feeding programmes may also require further investigation.
- Further investigation should include possible causes of the clustered occurrence of skin problems (e.g., building materials of floors and classroom size).
- Future studies should investigate the role of climate in skin problems, as well as the health-seeking behavior of parents for children with skin problems at the community level.
- Future studies should investigate the causes of tinea in the setting by applying skin scraping, particularly for tinea capitis.
- Future interventional studies are needed for high-risk schoolchildren with skin problems.

References

1. WHO guideline on school health services. Geneva: World Health Organization; 2021.
2. Kolbe LJ. School health as a strategy to improve both public health and education. Annu Rev Public Health. 2019;40(1): 443-63. doi: 10.1146/annurev-publhealth-040218-043727.
3. World Food Programme. Global mapping of initiatives in school health and nutrition with emphasis on health education 2010. Available from: https://healtheducationresources.unesco.org/index.php/library/documents/global-mapping-initiatives-school-health-and-nutrition-emphasis-health-education.
4. Federal Democratic Republic of Ethiopia Ministry of Health. School Health Programme Framework. Addis Ababa, Ethiopia: Ministry of Health; 2017.
5. Federal Democratic Republic of Ethiopia Ministry of Education. Education Sector Development Programme IV (ESDP IV) 2010/2011 - 2014/2015: Program action plan. Addis Ababa, Ethiopia: Ministry of Education; 2010.
6. Federal Democratic Republic of Ethiopia. National School Health and Nutrition Strategy. Addis Ababa, Ethiopia: Ministry of Education; 2012.
7. International Food Policy Research Institute. Global Nutrition Report 2015: Actions and accountability to advance nutrition and sustainable development. Washington, DC, 2015.
8. World Health Organization. Soil-transmitted helminth infections 2020. Available from: https://www.who.int/news-room/fact-sheets/detail/soil-transmitted-helminth-infections.

9. Federal Democratic Republic of Ethiopia Ministry of Education. Education Sector Development Programme V (ESDP V) 2015/16 - 2019/20: Programme action plan. Addis Ababa, Ethiopia: Ministry of Education; 2015.

10. World Health Organization Ethiopia. Ethiopian school-based deworming campaign targets 17 million children. Addis Ababa, Ethiopia: WHO Ethiopia; 2015. Available from: https://who.insomnation.com/news/ethiopian-school-based-deworming-campaign-targets-17-million-children.

11. Negussu N, Mengistu B, Kebede B, Deribe K, Ejigu E, Tadesse G, et al. Ethiopia schistosomiasis and soil-transmitted helminthes control programme: Progress and prospects. Ethiop Med J. 2017;55(Suppl 1): 75-80.

12. Federal Democratic Republic of Ethiopia Ministry of Education. National School Water Supply, Sanitation and Hygiene (SWASH) Strategy and Implementation Action Plan. Addis Ababa, Ethiopia: Ministry of Education; 2017.

13. Gutema B, Adissu W, Asress Y, Gedefaw L. Anemia and associated factors among school-age children in Filtu Town, Somali region, Southeast Ethiopia. BMC Hematol. 2014;14(1): 13. doi: 10.1186/2052-1839-14-13.

14. Getaneh Z, Enawgaw B, Engidaye G, Seyoum M, Berhane M, Abebe Z, et al. Prevalence of anemia and associated factors among schoolchildren in Gondar town public primary schools, northwest Ethiopia: A school-based cross-sectional study. PLoS One. 2017;12(12): e0190151. doi: 10.1371/journal.pone.0190151.

15. Mohammed SH, Larijani B, Esmaillzadeh A. Concurrent anemia and stunting in young children: Prevalence, dietary and non-dietary associated factors. Nutrition journal. 2019;18(1): 10. doi: 10.1186/s12937-019-0436-4.

16. Amare B, Ali J, Moges B, Yismaw G, Belyhun Y, Gebretsadik S, et al. Nutritional status, intestinal parasite infection and allergy among schoolchildren in northwest Ethiopia. BMC Pediatr. 2013; 13:7. doi: 10.1186/1471-2431-13-7.

17. Asemahagn MA. Parasitic infection and associated factors among the primary schoolchildren in Motta Town, Western Amhara, Ethiopia. Am J Public Health Res. 2014;2(6): 248-54. doi: 10.12691/ajphr-2-6-6.

18. Haftu D, Deyessa N, Agedew E. Prevalence and determinant factors of intestinal parasites among schoolchildren in Arba Minch town, Southern Ethiopia. American Journal of Health Research. 2014;2(5): 247-54. doi: 10.11648/j.ajhr.20140205.15.

19. Tulu B, Taye S, Amsalu E. Prevalence and its associated risk factors of intestinal parasitic infections among Yadot primary schoolchildren of South Eastern Ethiopia: A cross-sectional study. BMC Res Notes. 2014;7: 848. doi: 10.1186/1756-0500-7-848.

20. Gelaw A, Anagaw B, Nigussie B, Silesh B, Yirga A, Alem M, et al. Prevalence of intestinal parasitic infections and risk factors among schoolchildren at the University of Gondar Community School, Northwest Ethiopia: A cross-sectional study. BMC Public Health. 2013;13: 304. doi: 10.1186/1471-2458-13-304.

21. Mahmud MA, Spigt M, Mulugeta Bezabih A, Lopez Pavon I, Dinant GJ, Blanco Velasco R. Risk factors for intestinal parasitosis, anemia, and malnutrition among schoolchildren in

Ethiopia. Pathog Glob Health. 2013;107(2): 58-65. doi: 10.1179/2047773213y.0000000074.

22. Desalegn Wolide A, Mossie A, Gedefaw L. Nutritional iron deficiency anemia: Magnitude and its predictors among school-age children, southwest Ethiopia: A community based cross-sectional study. PLoS One. 2018;13(8): e0202380. doi: 10.1371/journal.pone.0202380.
23. Abossie A, Seid M. Assessment of the prevalence of intestinal parasitosis and associated risk factors among primary schoolchildren in Chencha town, Southern Ethiopia. BMC Public Health. 2014;14: 166. doi: 10.1186/1471-2458-14-166.
24. Grimes JET, Tadesse G, Gardiner IA, Yard E, Wuletaw Y, Templeton MR, et al. Sanitation, hookworm, anemia, stunting, and wasting in primary schoolchildren in southern Ethiopia: Baseline results from a study in 30 schools. PLoS Negl Trop Dis. 2017;11(10): e0005948. doi: 10.1371/journal.pntd.0005948.
25. Alexander N. Review: analysis of parasite and other skewed counts. Trop Med Int Health. 2012;17(6): 684-93. doi: 10.1111/j.1365-3156.2012.02987.x.
26. Wochebo W, Haji Y, Asnake S. Scabies outbreak investigation and risk factors in Kechabira district, Southern Ethiopia: Unmatched case-control study. BMC Res Notes. 2019;12(1): 305. doi: 10.1186/s13104-019-4317-x.
27. Girma M, Astatkie A, Asnake S. Prevalence and risk factors of tungiasis among children of Wensho district, southern Ethiopia. BMC Infect Dis. 2018;18(1): 456. doi: 10.1186/s12879-018-3373-5.

28. Bongomin F, Olum R, Nsenga L, Namusobya M, Russell L, de Sousa E, et al. Estimation of the burden of tinea capitis among children in Africa. Mycoses. 2021;64(4): 349-63. doi: 10.1111/myc.13221.

29. Leiva-Salinas M, Marin-Cabanas I, Betlloch I, Tesfasmariam A, Reyes F, Belinchon I, et al. Tinea capitis in schoolchildren in a rural area in southern Ethiopia. Int J Dermatol. 2015;54(7): 800-5. doi: 10.1111/ijd.12691.

30. Hespanhol L, Vallio CS, Costa LM, Saragiotto BT. Understanding and interpreting confidence and credible intervals around effect estimates. Braz J Phys Ther. 2019;23(4): 290-301. doi: 10.1016/j.bjpt.2018.12.006.

31. Kruschke JK, Liddell TM. The Bayesian new statistics: Hypothesis testing, estimation, meta-analysis, and power analysis from a Bayesian perspective. Psychon Bull Rev. 2018;25(1): 178-206. doi: 10.3758/s13423-016-1221-4.

32. WHO guideline on school health services: Web annex B: Brief exploratory review of school health services globally: Methodology and select findings. Geneva: World Health Organization; 2021.

33. Federal Democratic Republic of Ethiopia Ministry of Health. National Reproductive Health Strategy 2016-2020. Addis Ababa, Ethiopia: Ministry of Health; 2016.

34. Pradhan N, Karmaliani R, Gulzar S. Health problems among school-age children and proposed model for school health promotion. J Public Health Dev Ctries. 2016;2(3): 285-90.

35. Federal Democratic Republic Of Ethiopia. One WASH National Programme. A multi-sectoral SWAp: Phase II program document. Addis Ababa, Ethiopia, September 2018.
36. Vaivada T, Lassi ZS, Irfan O, Salam RA, Das JK, Oh C, et al. What can work and how? An overview of evidence-based interventions and delivery strategies to support health and human development from before conception to 20 years. Lancet. 2022;399(10337): 1810-29. doi: 10.1016/S0140-6736(21)02725-2.
37. Galler JR, Bringas-Vega ML, Tang Q, Rabinowitz AG, Musa KI, Chai WJ, et al. Neurodevelopmental effects of childhood malnutrition: A neuroimaging perspective. Neuroimage. 2021;231:117828. doi: 10.1016/j.neuroimage.2021.117828.
38. Meera S, Jakub K, Julia DE, Dylan W. An Investment Framework for Nutrition: Reaching the global targets for stunting, anemia, breastfeeding, and wasting. Directions in Development-Human Development. Washington, DC: World Bank; 2017.
39. Perignon M, Fiorentino M, Kuong K, Burja K, Parker M, Sisokhom S, et al. Stunting, poor iron status and parasite infection are significant risk factors for lower cognitive performance in Cambodian school-aged children. PLoS One. 2014;9(11): e112605. doi: 10.1371/journal.pone.0112605.
40. Doom JR, Georgieff MK. Striking while the iron is hot: Understanding the biological and neurodevelopmental effects of iron deficiency to optimize intervention in early childhood. Curr Pediatr Rep. 2014;2(4): 291-8. doi: 10.1007/s40124-014-0058-4.

41. Tchuem Tchuenté L-A. Control of soil-transmitted helminths in Sub-Saharan Africa: Diagnosis, drug efficacy concerns and challenges. Acta Trop. 2011;120 Suppl 1: S4-S11. doi: 10.1016/j.actatropica.2010.07.001.

42. Kassebaum NJ. The Global burden of anemia. Hematol Oncol Clin North Am. 2016;30(2): 247-308. doi: 10.1016/j.hoc.2015.11.002.

43. Bethony J, Brooker S, Albonico M, Geiger SM, Loukas A, Diemert D, et al. Soil-transmitted helminth infections: Ascariasis, trichuriasis, and hookworm. Lancet. 2006;367(9521): 1521-32. doi: 10.1016/S0140-6736(06)68653-4.

44. Institute for Health Metrics and Evaluation. Global Burden of Disease Study 2019. University of Washington: IHME; 2021. Available from: https://vizhub.healthdata.org/gbd-compare/.

45. Seth D, Cheldize K, Brown D, Freeman EF. Global burden of skin disease: Inequities and innovations. Curr Dermatol Rep. 2017;6(3): 204-10. doi: 10.1007/s13671-017-0192-7.

46. Karimkhani C, Colombara DV, Drucker AM, Norton SA, Hay R, Engelman D, et al. The global burden of scabies: A cross-sectional analysis from the global burden of disease study 2015. Lancet Infect Dis. 2017;17(12): 1247-54. doi: 10.1016/S1473-3099(17)30483-8.

47. Nsanzimana J, Karanja S, Kayongo M, Nyirimanzi N, Umuhoza H, Murangwa A, et al. Factors associated with tungiasis among primary schoolchildren: A cross-sectional study in a rural district in Rwanda. BMC Public Health. 2019;19(1): 1192. doi: 10.1186/s12889-019-7481-y.

48. World Health Organization. Global Nutrition Policy Review 2016-2017: Country progress in creating enabling policy environments for promoting healthy diets and nutrition. Geneva: WHO; 2018.

49. Saunders J, Smith T. Malnutrition: Causes and consequences. Clin Med. 2010;10(6): 624-7. doi: 10.7861/clinmedicine.10-6-624.

50. Development Initiatives. Global Nutrition Report: Action on equity to end malnutrition. Bristol, UK: Development Initiatives; 2020.

51. Safiri S, Kolahi A-A, Noori M, Nejadghaderi SA, Karamzad N, Bragazzi NL, et al. Burden of anemia and its underlying causes in 204 countries and territories, 1990–2019: Results from the global burden of disease study 2019. J Hematol Oncol. 2021;14(1): 185. doi: 10.1186/s13045-021-01202-2.

52. World Health Organization. Hemoglobin concentrations for the diagnosis of anemia and assessment of severity: Vitamin and mineral nutrition information system. Geneva: WHO/NMH/NHD/MNM/11.1; 2011.

53. Kassebaum NJ. The global burden of anemia. Hematol Oncol Clin North Am. 2016;30(2): 247-308. doi: 10.1016/j.hoc.2015.11.002.

54. De Benoist B, Cogswell M, Egli I, McLean E. Worldwide prevalence of anemia 1993-2005: WHO global database of anemia. Geneva, Switzerland: World Health Organization; 2008.

55. WHO guideline: Use of multiple micronutrient powders for point-of-use fortification of foods consumed by infants and young children aged 6–23 months and children aged 2–12 years. Geneva: World Health Organization; 2016.

56. McLean E, Cogswell M, Egli I, Wojdyla D, de Benoist B. Worldwide prevalence of anemia, WHO vitamin and mineral nutrition information system, 1993–2005. Public Health Nutr. 2008;12(4): 444-54. doi: 10.1017/S1368980008002401.

57. de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. Bull World Health Organ. 2007;85(9): 660-7. doi: 10.2471/blt.07.043497.

58. Drake LJ, Lazrak N, Fernandes M, Chu K, Singh S, Ryckembusch D, et al. Establishing global school feeding programme targets: How many poor children globally should be prioritized, and what would be the cost of implementation? Front Public Health. 2020;8: 530176. doi: 10.3389/fpubh.2020.530176.

59. WHO, UNESCO. Making every school a health-promoting school: Global standards and indicators for health-promoting schools and systems. Geneva: World Health Organization and the United Nations Educational, Scientific and Cultural Organization; 2021.

60. Raiten DJ, Bremer AA. Exploring the nutritional ecology of stunting: New approaches to an old problem. Nutrients. 2020;12(2): 371. doi: 10.3390/nu12020371.

61. Ethiopian Public Health Institute. Ethiopian national micronutrient survey report. Addis Ababa, Ethiopia: Ministry of Health; 2016.

62. Shaka MF, Wondimagegne YA. Anemia, a moderate public health concern among adolescents in South Ethiopia. PLoS One. 2018;13(7): e0191467. doi: 10.1371/journal.pone.0191467.

63. Andersen CT, Tadesse AW, Bromage S, Fekadu H, Hemler EC, Passarelli S, et al. Anemia etiology in Ethiopia: Assessment of nutritional, infectious disease, and other risk factors in a population-based cross-sectional survey of women, men, and children. The Journal of Nutrition. 2021;00:1-12. doi: 10.1093/jn/nxab366.

64. Stoltzfus RJ, Chwaya HM, Tielsch JM, Schulze KJ, Albonico M, Savioli L. Epidemiology of iron deficiency anemia in Zanzibari schoolchildren: The importance of hookworms. Am J Clin Nutr. 1997;65(1): 153-9. doi: 10.1093/ajcn/65.1.153.

65. Assefa S, Mossie A, Hamza L. Prevalence and severity of anemia among schoolchildren in Jimma Town, Southwest Ethiopia. BMC Hematol. 2014;14(1): 3. doi: 10.1186/2052-1839-14-3.

66. Bogale TY, Bala ET, Tadesse M, Asamoah BO. Prevalence and associated factors for stunting among 6-12 years old school-age children from rural community of Humbo district, Southern Ethiopia. BMC Public Health. 2018;18(1): 653. doi: 10.1186/s12889-018-5561-z.

67. World Food Programme. The Cost of HUNGER in Ethiopia: Implications for the Growth and Transformation of Ethiopia: WFP; 2013.

68. Federal Democratic Republic of Ethiopia. Seqota Declaration. Implementation plan 2016 - 2030: Summary programme approach document. Addis Ababa, Ethiopia, March 2016.

69. Ethiopian Public Health Institute and World Food Programme. Fill the nutrient gap, Ethiopia. Addis Ababa, Ethiopia: EPHI, WFP; 2021.

70. Federal Democratic Republic of Ethiopia. Food and Nutrition Policy. Addis Ababa, Ethiopia, November 2018.

71. Federal Democratic Republic of Ethiopia. Seqota Declaration Innovation Phase Investment Plan 2017–2020. Addis Ababa, Ethiopia, January 2018.

72. Federal Democratic Republic of Ethiopia. National Nutrition Programme 2016-2020. Addis Ababa, Ethiopia, 2016.

73. Nutrition-Sensitive Agriculture Strategy. Addis Ababa, Ethiopia: Ministry of Agriculture and Natural Resource (MoANR), Ministry of Livestock and Fisheries (MoLF); 2016.

74. Ethiopia's Productive Safety Net Programme (PSNP): Integrating disaster and climate risk management. 2013.

75. Taffese HS, Hemming-Schroeder E, Koepfli C, Tesfaye G, Lee M-c, Kazura J, et al. Malaria epidemiology and interventions in Ethiopia from 2001 to 2016. Infectious diseases of poverty. 2018;7(1): 103. doi: 10.1186/s40249-018-0487-3.

76. Girum T, Wasie A. The effect of deworming schoolchildren on anemia prevalence: A systematic review and meta-analysis. Open Nurs J. 2018;12(1): 155-61. doi: 10.2174/1874434601812010155.

77. Federal Democratic Republic of Ethiopia Ministry of Health. National Adolescent and Youth Health Strategy 2016-2020. Addis Ababa, Ethiopia: Ministry of Health; 2016.

78. Chaparro CM, Suchdev PS. Anemia epidemiology, pathophysiology, and etiology in low- and middle-income countries. Ann N Y Acad Sci. 2019;1450(1): 15-31. doi: 10.1111/nyas.14092.

79. Petry N, Olofin I, Hurrell RF, Boy E, Wirth JP, Moursi M, et al. The proportion of anemia associated with iron deficiency in low, medium, and high human development index countries: A systematic analysis of national surveys. Nutrients. 2016;8(11): 693. doi: 10.3390/nu8110693.

80. Gupta A. Nutritional anemia in preschool children. Singapore: Springer Nature, Pte Ltd; 2017. Available from: https://doi.org/10.1007/978-981-10-5178-4_2.

81. Soliman AT, De Sanctis V, Kalra S. Anemia and growth. Indian J Endocrinol Metab. 2014;18(Suppl 1): S1-S5. doi: 10.4103/2230-8210.145038.

82. Bourke CD, Berkley JA, Prendergast AJ. Immune dysfunction as a cause and consequence of malnutrition. Trends Immunol. 2016;37(6): 386-98. doi: 10.1016/j.it.2016.04.003.

83. Cassat JE, Skaar EP. Iron in infection and immunity. Cell Host Microbe. 2013;13(5): 509-19. doi: 10.1016/j.chom.2013.04.010.

84. Millward DJ. Nutrition, infection and stunting: the roles of deficiencies of individual nutrients and foods, and of inflammation, as determinants of reduced linear growth of children. Nutr Res Rev. 2017;30(1): 50-72. doi: 10.1017/s0954422416000238.

85. Syed S, Manji KP, McDonald CM, Kisenge R, Aboud S, Sudfeld C, et al. Biomarkers of systemic inflammation and growth in early infancy are associated with stunting in young Tanzanian children. Nutrients. 2018;10(9): 1158. doi: 10.3390/nu10091158.

86. Prendergast AJ, Humphrey JH. The stunting syndrome in developing countries. Paediatr Int Child Health. 2014;34(4): 250-65. doi: 10.1179/2046905514Y.0000000158.

87. Haque R. Human intestinal parasites. J Health Popul Nutr. 2007;25(4): 387-91.

88. Ending the neglect to attain the sustainable development goals: A road map for neglected tropical diseases 2021–2030. Geneva: World Health Organization; 2020.

89. Johnston EA, Teague J, Graham JP. Challenges and opportunities associated with neglected tropical disease and water, sanitation and hygiene intersectoral integration programmes. BMC Public Health. 2015;15: 547. doi: 10.1186/s12889-015-1838-7.

90. Pullan R, Smith J, Jasrasaria R, Brooker S. Global numbers of infection and disease burden of soil-transmitted helminth infections in 2010. Parasit Vectors. 2014;7: 37. doi: 10.1186/1756-3305-7-37.

91. World Health Organization. Soil-transmitted helminthiases: Number of children treated in 2010. Geneva: WHO; 2012.

92. World Health Organization. Schistosomiasis and soil-transmitted helminthiases: Number of people treated in 2018. Geneva: WHO; 2019.

93. Sartorius B, Cano J, Simpson H, Tusting LS, Marczak LB, Miller-Petrie MK, et al. Prevalence and intensity of soil-transmitted helminth infections of children in sub-Saharan Africa, 2000-18: A geospatial analysis. Lancet Glob Health. 2021;9(1):e52-e60. doi: 10.1016/S2214-109X(20)30398-3.

94. Hotez PJ, Bundy DAP, Beegle K, Brooker S, Drake L, de Silva N, et al. Helminth Infections: Soil-transmitted Helminth Infections and Schistosomiasis. In: Jamison DT,

Breman JG, Measham AR, Alleyne G, Claeson M, Evans DB, et al., editors. Disease Control Priorities in Developing Countries. 2 ed. Washington (DC): The International Bank for Reconstruction and Development / The World Bank: Oxford University Press, New York; 2006.

95. World Health Organization. Water, sanitation and hygiene for accelerating and sustaining progress on neglected tropical diseases: A global strategy 2015-2020. Geneva: WHO; 2015.

96. Leta GT, Mekete K, Wuletaw Y, Gebretsadik A, Sime H, Mekasha S, et al. National mapping of soil-transmitted helminth and schistosome infections in Ethiopia. Parasit Vectors. 2020;13(1):437. doi: 10.1186/s13071-020-04317-6.

97. Federal Democratic Republic of Ethiopia Ministry of Health. Second Edition of National Neglected Tropical Diseases Master Plan 2015/16 – 2019/20. Addis Ababa, Ethiopia: Ministry of Health; 2016.

98. Strunz EC, Addiss DG, Stocks ME, Ogden S, Utzinger J, Freeman MC. Water, sanitation, hygiene, and soil-transmitted helminth infection: A systematic review and meta-analysis. PLoS Med. 2014;11(3):e1001620. doi: 10.1371/journal.pmed.1001620.

99. Federal Democratic Republic of Ethiopia Ministry of Education. National school water, sanitation and hygiene (swash) implementation guideline. Addis Ababa, Ethiopia: Ministry of Education; 2017.

100. Elimination of Neglected Tropical Diseases (NTDs) in Ethiopia: Woreda level coordination toolkit for the wash and NTD sectors. Addis Ababa, Ethiopia: Ethiopian Federal Ministry of Health, WHO, NALA Foundation, Sightsavers; 2019.

101. World Health Organization. Soil-transmitted helminthiases: Eliminating as public health problem soil-transmitted helminthiases in children: Progress report 2001-2010 and strategic plan 2011-2020. Geneva: WHO; 2012. Available from: https://apps.who.int/iris/handle/10665/44804.

102. Strunz EC, Addiss DG, Stocks ME, Ogden S, Utzinger J, Freeman MC. Water, sanitation, hygiene, and soil-transmitted helminth infection: a systematic review and meta-analysis. PLoS Med. 2014;11(3): e1001620-e. doi: 10.1371/journal.pmed.1001620.

103. Hailegebriel T, Nibret E, Abaineh M. Prevalence of soil-transmitted helminth infection among school-aged children of Ethiopia: A systematic review and meta-analysis. Infect Dis. 2020;13:1178633720962812. doi: 10.1177/1178633720962812.

104. Montresor A, Mupfasoni D, Mikhailov A, Mwinzi P, Lucianez A, Jamsheed M, et al. The global progress of soil-transmitted helminthiases control in 2020 and World Health Organization targets for 2030. PLoS Negl Trop Dis. 2020;14(8):e0008505. doi: 10.1371/journal.pntd.0008505.

105. Appleby LJ, Tadesse G, Wuletawu Y, Dejene NG, Grimes JET, French MD, et al. Integrated delivery of school health interventions through the school platform: Investing for the future. PLoS Negl Trop Dis. 2019;13(1): e0006449. doi: 10.1371/journal.pntd.0006449.

106. Stamm LV, Strowd LC. Ignoring the "Itch": The global health problem of scabies. Am J Trop Med Hyg. 2017;97(6): 1647-9. doi: 10.4269/ajtmh.17-0242.

107. Heukelbach J, Walton SF, Feldmeier H. Ectoparasitic infestations. Curr Infect Dis Rep. 2005;7(5): 373-80. doi: 10.1007/s11908-005-0012-2.

108. World Health Organization. Scabies. Geneva: WHO; 2020. Available from: https://www.who.int/news-room/fact-sheets/detail/scabies.

109. Institute for Health Metrics and Evaluation. Global Health Metrics. Scabies: Level 3 cause. University of Washington, Seattle: IHME; 2021. Available from: https://www.healthdata.org/results/gbd_summaries/2019/scabies-level-3-cause.

110. Jackson A, Heukelbach J, Filho AFDS, Campelo Júnior EDB, Feldmeier H. Clinical features and associated morbidity of scabies in a rural community in Alagoas, Brazil. Trop Med Int Health. 2007;12(4): 493-502. doi: 10.1111/j.1365-3156.2006.01809.x.

111. McCarthy JS, Kemp DJ, Walton SF, Currie BJ. Scabies: More than just an irritation. Postgrad Med J. 2004;80(945): 382. doi: 10.1136/pgmj.2003.014563.

112. Johnston G, Sladden M. Scabies: Diagnosis and treatment. BMJ. 2005;331(7517): 619-22. doi: 10.1136/bmj.331.7517.619.

113. Engelman D, Cantey PT, Marks M, Solomon AW, Chang AY, Chosidow O, et al. The public health control of scabies: Priorities for research and action. Lancet. 2019;394(10192):81-92. doi: 10.1016/s0140-6736(19)31136-5.

114. World Health Organization. Recognizing neglected tropical diseases through changes on the skin: A training guide for front-line health workers. Geneva: WHO; 2018.

115. Enbiale W, Ayalew A. Investigation of a scabies outbreak in drought-affected areas in Ethiopia. Trop Med Infect Dis. 2018;3(4): 114. doi: 10.3390/tropicalmed3040114.

116. Ejigu K, Haji Y, Toma A, Tadesse B. Factors associated with scabies outbreaks in primary schools in Ethiopia: A case-control study. Res Rep Trop Med. 2019;10: 119-27. doi: 10.2147/RRTM.S214724.

117. Cox V, Fuller LC, Engelman D, Steer A, Hay RJ. Estimating the global burden of scabies: What else do we need? Br J Dermatol. 2021;184(2): 237-42. doi: 10.1111/bjd.19170.

118. Heukelbach J, Feldmeier H. Scabies. Lancet. 2006;367(9524): 1767-74. doi: 10.1016/S0140-6736(06)68772-2.

119. Engelman D, Kiang K, Chosidow O, McCarthy J, Fuller C, Lammie P, et al. Toward the Global Control of Human Scabies: Introducing the International Alliance for the Control of Scabies. PLoS Negl Trop Dis. 2013;7(8): e2167. doi: 10.1371/journal.pntd.0002167.

120. Alasaad S, Walton S, Rossi L, Bornstein S, Abu-Madi M, Soriguer RC, et al. Sarcoptes-World Molecular Network (Sarcoptes-WMN): Integrating research on scabies. Int J Infect Dis. 2011;15(5): e294-e7. doi: 10.1016/j.ijid.2011.01.012.

121. El-Moamly AA. Scabies as a part of the World Health Organization roadmap for neglected tropical diseases 2021-2030: What we know and what we need to do for global control. Trop Med Health. 2021;49(1): 64. doi: 10.1186/s41182-021-00348-6.

122. Engelman D, Marks M, Steer AC, Beshah A, Biswas G, Chosidow O, et al. A framework for scabies control. PLoS Negl Trop Dis. 2021;15(9):e0009661. doi: 10.1371/journal.pntd.0009661.

123. Engelman D, Yoshizumi J, Hay RJ, Osti M, Micali G, Norton S, et al. The 2020 International Alliance for the Control of Scabies Consensus Criteria for the Diagnosis of Scabies. Br J Dermatol. 2020;183(5): 808-20. doi: 10.1111/bjd.18943.

124. Heukelbach J. Tungiasis. Rev Inst Med Trop Sao Paulo. 2005;47(6): 307-13. doi: 10.1590/s0036-46652005000600001.

125. World Health Organization. Tungiasis 2020. Available from: https://www.who.int/news-room/fact-sheets/detail/tungiasis.

126. Deka MA. Mapping the geographic distribution of tungiasis in Sub-Saharan Africa. Trop Med Infect Dis. 2020;5(3): 122. doi: 10.3390/tropicalmed5030122.

127. Feldmeier H, Eisele M, Sabóia-Moura RC, Heukelbach J. Severe tungiasis in underprivileged communities: Case series from Brazil. Emerg Infect Dis. 2003;9(8): 949-55. doi: 10.3201/eid0908.030041.

128. Feldmeier H, Sentongo E, Krantz I. Tungiasis (sand flea disease): A parasitic disease with particular challenges for public health. Eur J Clin Microbiol Infect Dis. 2013;32(1): 19-26. doi: 10.1007/s10096-012-1725-4.

129. Walker SL, Lebas E, De Sario V, Deyasso Z, Doni SN, Marks M, et al. The prevalence and association with health-related quality of life of tungiasis and scabies in schoolchildren in southern Ethiopia. PLoS Negl Trop Dis. 2017;11(8): e0005808. doi: 10.1371/journal.pntd.0005808.

130. Feldmeier H, Heukelbach J, Eisele M, Sousa AQ, Barbosa LMM, Carvalho CBM. Bacterial superinfection in human tungiasis. Trop Med Int Health. 2002;7(7): 559-64. doi: 10.1046/j.1365-3156.2002.00904.x.

131. Heukelbach J, Ariza L, Adegbola RQ, Ugbomoiko US. Sustainable control of tungiasis in rural Nigeria: A case for One Health. One Health Implement Res. 2021;1(1): 4-13. doi: 10.20517/ohir.2021.01.

132. Obebe OO, Aluko OO. Epidemiology of tungiasis in Sub-Saharan Africa: A systematic review and meta-analysis. Pathog Glob Health. 2020;114(7): 360-9. doi: 10.1080/20477724.2020.1813489.

133. Abrha S, Heukelbach J, Peterson GM, Christenson JK, Carroll S, Kosari S, et al. Clinical interventions for tungiasis (sand flea disease): A systematic review. Lancet Infect Dis. 2021;3099(20): 30853-7. doi: 10.1016/S1473-3099(20)30853-7.

134. Feldmeier H, Heukelbach J, Ugbomoiko US, Sentongo E, Mbabazi P, von Samson-Himmelstjerna G, et al. Tungiasis: A neglected disease with many challenges for global public health. PLoS Negl Trop Dis. 2014;8(10): e3133. doi: 10.1371/journal.pntd.0003133.

135. Feldmeier H, Keysers A. Tungiasis: A Janus-faced parasitic skin disease. Travel Med Infect Dis. 2013;11(6): 357-65. doi: 10.1016/j.tmaid.2013.10.001.

136. Tomczyk S, Deribe K, Brooker SJ, Clark H, Rafique K, Knopp S, et al. Association between footwear use and neglected tropical diseases: A systematic review and meta-analysis. PLoS Negl Trop Dis. 2014;8(11): e3285. doi: 10.1371/journal.pntd.0003285.

137. Ugbomoiko US, Ariza L, Ofoezie IE, Heukelbach J. Risk factors for tungiasis in Nigeria: Identification of targets for effective intervention. PLoS Negl Trop Dis. 2007;1(3): e87. doi: 10.1371/journal.pntd.0000087.

138. Achterman RR, White TC. A foot in the door for dermatophyte research. PLoS Pathog. 2012;8(3): e1002564. doi: 10.1371/journal.ppat.1002564.

139. Karimkhani C, Dellavalle RP, Coffeng LE, Flohr C, Hay RJ, Langan SM, et al. Global skin disease morbidity and mortality: An update from the global burden of disease study 2013. JAMA Dermatol. 2017;153(5): 406-12. doi: 10.1001/jamadermatol.2016.5538.

140. Duldulao PM, Ortega AE, Delgadillo X. Mycotic and bacterial infections. Clin Colon Rectal Surg. 2019;32(5): 333-9. doi: 10.1055/s-0039-1687828.

141. Ely JW, Rosenfeld S, Seabury Stone M. Diagnosis and management of tinea infections. Am Fam Physician. 2014;90(10): 702-10.

142. Leung AK, Lam JM, Leong KF, Hon KL. Tinea corporis: An updated review. Drugs Context. 2020;9:2020-5-6. doi: 10.7573/dic.2020-5-6.

143. Hay R. Therapy of skin, hair and nail fungal infections. J Fungi (Basel). 2018;4(3): 99. doi: 10.3390/jof4030099.

144. Blutfield MS, Lohre JM, Pawich DA, Vlahovic TC. The immunologic response to Trichophyton Rubrum in lower extremity fungal infections. J Fungi 2015;1(2): 130-7. doi: 10.3390/jof1020130.

145. García-Romero MT, Arenas R. New insights into genes, immunity, and the occurrence of dermatophytosis. J Invest Dermatol. 2015;135(3): 655-7. doi: 10.1038/jid.2014.498.

146. Hay RJ. Tinea capitis: Current status. Mycopathologia. 2017;182(1-2): 87-93. doi: 10.1007/s11046-016-0058-8.

147. Sentamilselvi G, Janaki C, Murugusundram S. Trichomycoses. Int J Trichology. 2009;1(2): 100-7. doi: 10.4103/0974-7753.58552.

148. Hospenthal DR, Rinaldi MG. Diagnosis and treatment of fungal infections. 2nd ed. ed. Cham: Springer International Publishing: Imprint: Springer; 2015.

149. Russell JJ, Ryan Jr EF. Common dermatologic conditions in primary care. 1st ed. 2019. ed. Cham: Springer International Publishing : Imprint: Humana; 2019.

150. Hall A, Kassa T, Demissie T, Degefie T, Lee S. National survey of the health and nutrition of schoolchildren in Ethiopia. Trop Med Int Health. 2008;13(12): 1518-26. doi: 10.1111/j.1365-3156.2008.02168.x.

151. Liu J-M, Wang H-W, Chang F-W, Liu Y-P, Chiu F-H, Lin Y-C, et al. The effects of climate factors on scabies.: A 14-year population-based study in Taiwan. Parasite. 2016;23: 54. doi: 10.1051/parasite/2016065.

152. Mimouni D, Ankol OE, Davidovitch N, Gdalevich M, Zangvil E, Grotto I. Seasonality trends of scabies in a young adult population: A 20-year follow-up. Br J Dermatol. 2003;149(1): 157-9. doi: 10.1046/j.1365-2133.2003.05329.x.

153. Kim J-H, Cheong H-K. Epidemiologic trends and seasonality of scabies in South Korea, 2010-2017. Korean J Parasitol. 2019;57(4): 399-404. doi: 10.3347/kjp.2019.57.4.399.

154. Heukelbach J, Wilcke T, Harms G, Feldmeier H. Seasonal variation of tungiasis in an endemic community. Am J Trop Med Hyg. 2005;72(2): 145-9. doi: 10.4269/ajtmh.2005.72.145.

155. Karunamoorthi K. Tungiasis: A neglected epidermal parasitic skin disease of marginalized populations-a call for global science and policy. Parasitol Res. 2013;112(10): 3635-43. doi: 10.1007/s00436-013-3551-8.

156. Pilger D, Schwalfenberg S, Heukelbach J, Witt L, Mencke N, Khakban A, et al. Controlling tungiasis in an impoverished community: An intervention study. PLoS Negl Trop Dis. 2008;2(10): e324. doi: 10.1371/journal.pntd.0000324.

157. Coulibaly O, Kone AK, Niaré-Doumbo S, Goïta S, Gaudart J, Djimdé AA, et al. Dermatophytosis among schoolchildren in three eco-climatic Zones of Mali. PLoS Negl Trop Dis. 2016;10(4): e0004675. doi: 10.1371/journal.pntd.0004675.

158. Expogroup: Ethiopia country information 2020. Available from: https://www.expogr.com/ethiopia_country_information.php.

159. United Nations Population Fund: Ethiopia-Overview: UNFPA; 2021. Available from: https://www.unfpa.org/data/world-population/ET.

160. Realizing universal health coverage through primary health care: A roadmap for optimizing the Ethiopian Health Extension Programme 2020-2035. Addis Ababa, Ethiopia: Ministry of Health Ethiopia; 2020.

161. United Nations, Department of Economic and Social Affairs, Population Division. World Urbanization Prospects 2018: Highlights (ST/ESA/SER.A/421). New York: United Nations; 2019.

162. UNDP Ethiopia. National Human Development Report 2018: Industrialization with a Human Face. Addis Ababa, Ethiopia: United Nations Development Programme; 2018.

163. United Nations. World Economic Situation Prospects 2020. New York: United Nations; 2020.

164. Ethiopia Economic Outlook: African Development Bank Group; 2021. Available from: https://www.afdb.org/en/countries/east-africa/ethiopia/ethiopia-economic-outlook.

165. Federal Democratic Republic of Ethiopia Ministry of Health. Health Sector Transformation Plan (HSTP) 2015/16 - 2019/20. Addis Ababa, Ethiopia: Ministry of Health; 2015.

166. UNICEF Ethiopia. Learning and Development Programme. Addis Ababa, Ethiopia: United Nations Children's Fund; 2018. Available from: https://www.unicef.org/ethiopia/learning-and-development.

167. OCHA. Ethiopia-Northern Ethiopia Humanitarian Update Situation Report, November 2021. Available from: https://reliefweb.int/report/ethiopia/ethiopia-northern-ethiopia-humanitarian-update-situation-report-11-nov-2021.

168. Tiruneh DT. COVID-19 school closures may further widen the inequality gaps between the advantaged and the disadvantaged in Ethiopia. 2020. doi: 10.13140/RG.2.2.11243.57120.

169. Jones N. Child marriage risks in the context of Covid-19 in Ethiopia 2020. Available from: https://odi.org/en/publications/child-marriage-risks-in-the-context-of-covid-19-in-ethiopia/.

170. United Nations Children's Fund, COVID-19: A threat to progress against child marriage. New York: UNICEF; 2021.

171. Government of the Federal Democratic Republic of Ethiopia. National Nutrition ProgrammeJune 2013 – June 2015. Available from: https://www.usaid.gov/documents/1867/government-federal-democratic-republic-ethiopia-national-nutrition-programme.

172. Ethiopia Ministry of Health. Health Sector Transformation Plan 2015/16 - 2019/20. 2015: 31-157.

173. Ethiopia Ministry Of Health. National Hygiene and Sanitation Strategic Action Plan for Rural, Per-Urban and Informal Settlements in Ethiopia. Addis Ababa, Ethiopia. 2011-2015.

174. Ministry of Education and UNICEF Ethiopia. Global Out of School Children Initiative. Study on Situation of Out of School Children (OOSC) in Ethiopia. 2012.

175. Sullivan KM, Dean A, Soe MM. OpenEpi: a web-based epidemiologic and statistical calculator for public health. Public Health Rep. 2009;124(3): 471-4.

176. Daniel WW. Biostatistics: A foundation for analysis in the health sciences. New York: John Willey and Sons.1999.

177. Mesfin F, Berhane Y, Worku A. Anemia among primary schoolchildren in Eastern Ethiopia. PLoS One. 2015;10(4): e0123615. doi: 10.1371/journal.pone.0123615.

178. Mekonnen H, Tadesse T, Kisi K. Malnutrition and its correlates among rural primary schoolchildren of Fogera District, Northwest Ethiopia. J Nutr Disord Ther. 2013: 2-7. doi: 10.4172/2161-0509.S12-002.

179. Ali J, Yifru S, Woldeamanuel Y. Prevalence of tinea capitis and the causative agent among schoolchildren in Gondar, North West Ethiopia. Ethiop Med J. 2009;47(4): 261-9.

180. Komba EV, Mgonda YM. The spectrum of dermatological disorders among primary schoolchildren in Dares Salaam. BMC Public Health. 2010;10: 765. doi: 10.1186/1471-2458-10-765.

181. Coates J, Swindale A, Bilinsky P. Household Food Insecurity Access Scale (HFIAS) for Measurement of Household Food Access: Indicator guide (v.3). Washington, DC: Food and Nutrition Technical Assistance Project, Academy for Educational Development; 2007.

182. Gebreyesus SH, Lunde T, Mariam DH, Woldehanna T, Lindtjørn B. Is the adapted Household Food Insecurity Access Scale (HFIAS) developed internationally to measure food insecurity valid in urban and rural households of Ethiopia? BMC Nutrition. 2015;1: 2.

183. Alelign T, Degarege A, Erko B. Prevalence and factors associated with undernutrition and anemia among schoolchildren in Durbete Town, northwest Ethiopia. Archives of Public Health. 2015;73(1): 34. doi: 10.1186/s13690-015-0084-x.

184. WHO AnthroPlus for Personal Computers Manual. Software for assessing growth of the world's children and adolescents. Geneva: WHO; 2009.

185. Montresor A, Crompton DWT, Hall A, Bundy DAP, Savioli L. Guidelines for the evaluation of soil-transmitted helminthiasis and schistosomiasis at community level: A guide for managers of control programmes. Geneva: World Health Organization; 1998.

186. WHO. Basic laboratory methods in medical parasitology. Geneva: World Health Organization; 1991.

187. Manser MM, Saez ACS, Chiodini PL. Faecal parasitology: Concentration methodology needs to be better standardized. PLoS Negl Trop Dis. 2016;10(4): e0004579. doi: 10.1371/journal.pntd.0004579.

188. WHO. Assessing the efficacy of anthelminthic drugs against schistosomiasis and soil-transmitted helminthiases. Geneva: World Health Organization; 2013.

189. Speich B, Ali SM, Ame SM, Albonico M, Utzinger J, Keiser J. Quality control in the diagnosis of *Trichuris trichiura* and *Ascaris lumbricoides* using the Kato-Katz technique: Experience from three randomized controlled trials. Parasit Vectors. 2015;8(1): 82. doi: 10.1186/s13071-015-0702-z.

190. Federal Democratic Republic of Ethiopia. Interim-guideline for multi-sectorial scabies outbreak emergency response. Addis Ababa, Ethiopia: Ministry of Health; 2015.

191. Engelman D, Fuller LC, Steer AC. Consensus criteria for the diagnosis of scabies: A Delphi study of international experts. PLoS Negl Trop Dis. 2018;12(5): e0006549. doi: 10.1371/journal.pntd.0006549.

192. Ely JW, Rosenfeld S, Seabury Stone M. Diagnosis and management of tinea infections. Am Fam Physician. 2014;90(10): 702-10.

193. Gulgun M, Balci E, Karaoglu A, Kesik V, Babacan O, Fidanci M, et al. Prevalence and risk factors of onychomycosis in primary schoolchildren living in rural and urban areas in Central Anatolia of Turkey. Indian J Dermatol Venereol Leprol. 2013;79(6): 777-82. doi: 10.4103/0378-6323.120724.

194. Parker J. Management of common fungal infections in primary care. Nurs Stand. 2009;23(43): 42-6. doi: 10.7748/ns2009.07.23.43.42.c7060.

195. de Berker D. Clinical practice: Fungal nail disease. N Engl J Med. 2009;360(20): 2108-16. doi: 10.1056/NEJMcp0804878.

196. Noble SL, Forbes RC, Stamm PL. Diagnosis and management of common tinea infections. Am Fam Physician. 1998;58(1): 163-74.

197. Eisele M, Heukelbach J, Van Marck E, Mehlhorn H, Meckes O, Franck S, et al. Investigations on the biology, epidemiology, pathology and control of Tunga penetrans in Brazil: I. Natural history of tungiasis in man. Parasitol Res. 2003;90(2): 87-99. doi: 10.1007/s00436-002-0817-y.

198. WHO. Prevention and control of schistosomiasis and soil-transmitted helminthiasis: Report of a WHO expert committee. Geneva; 2002. WHO Technical Report Series, 912.

199. Vyas S, Kumaranayake L. Constructing socio-economic status indices: How to use principal components analysis. Health Policy Plan. 2006;21(6): 459-68. doi: 10.1093/heapol/czl029.

200. Hailu Amare H, Lindtjørn B. Helminth infections among rural schoolchildren in Southern Ethiopia: A cross-sectional multilevel and zero-inflated regression model. PLoS Negl Trop Dis. 2020;14(12): e0008002. doi: 10.1371/journal.pntd.0008002.

201. Kirkwood BR, Sterne JAC. Essential Medical Statistics. 2 ed. Australia: Blackwell Publishing Ltd; 2003.

202. Drug Administration and Control Authority (DACA) of Ethiopia. Standard Treatment Guideline for Health Centers. Addis Ababa, Ethiopia: The Drug Administration and Control Authority (DACA) of Ethiopia; 2010.

203. Rothman KJ. Epidemiology: An introduction. 2 ed. Oxford, New York: Oxford University Press; 2012.

204. Setia MS. Methodology series module 3: Cross-sectional studies. Indian J Dermatol. 2016;61(3): 261-4. doi: 10.4103/0019-5154.182410.

205. Wang X, Cheng Z. Cross-sectional studies: Strengths, weaknesses, and recommendations. Chest. 2020;158(1s): S65-s71. doi: 10.1016/j.chest.2020.03.012.

206. Kadam P, Bhalerao S. Sample size calculation. Int J Ayurveda Res. 2010;1(1): 55-7. doi: 10.4103/0974-7788.59946.

207. Bujang MA. A step-by-step process on sample size determination for medical research. Malays J Med Sci. 2021;28(2): 15-27. doi: 10.21315/mjms2021.28.2.2.

208. Mehler D, Edelsbrunner P, Matić K. Appreciating the significance of non-significant findings in psychology. 2019;10: 1-7. doi: 10.5334/e2019a.

209. Kelter R. Analysis of type I and II error rates of Bayesian and frequentist parametric and nonparametric two-sample hypothesis tests under preliminary assessment of normality. Comput Stat. 2021;36(2): 1263-88. doi: 10.1007/s00180-020-01034-7.

210. Carlson MDA, Morrison RS. Study design, precision, and validity in observational studies. J Palliat Med. 2009;12(1): 77-82. doi: 10.1089/jpm.2008.9690.

211. Westreich D, Edwards JK, Lesko CR, Cole SR, Stuart EA. Target validity and the hierarchy of study designs. Am J Epidemiol. 2019;188(2): 438-43. doi: 10.1093/aje/kwy228.

212. Andrade C. Internal, external, and ecological validity in research design, conduct, and evaluation. Indian J Psychol Med. 2018;40(5): 498-9. doi: 10.4103/IJPSYM.IJPSYM_334_18.

213. Tripepi G, Jager KJ, Dekker FW, Zoccali C. Selection bias and information bias in clinical research. Nephron Clin Pract. 2010;115(2): c94-c9. doi: 10.1159/000312871.

214. Pannucci CJ, Wilkins EG. Identifying and avoiding bias in research. Plast Reconstr Surg. 2010;126(2): 619-25. doi: 10.1097/PRS.0b013e3181de24bc.

215. Delgado-Rodríguez M, Llorca J. Bias. J Epidemiol Community Health. 2004;58(8): 635-41. doi: 10.1136/jech.2003.008466.

216. Althubaiti A. Information bias in health research: Definition, pitfalls, and adjustment methods. J Multidiscip Healthc. 2016;9: 211-7. doi: 10.2147/jmdh.s104807.

217. Khare SR, Vedel I. Recall bias and reduction measures: An example in primary health care service utilization. Fam Pract. 2019;36(5): 672-6. doi: 10.1093/fampra/cmz042.

218. McHugh ML. Interrater reliability: The kappa statistic. Biochem Med. 2012;22(3): 276-82.

219. Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. J Chiropr Med. 2016;15(2): 155-63. doi: 10.1016/j.jcm.2016.02.012.

220. Amare HH, Lindtjorn B. Concurrent anemia and stunting among schoolchildren in Wonago district in southern Ethiopia: A cross-sectional multilevel analysis. PeerJ. 2021;9: e11158. doi: 10.7717/peerj.11158.

221. Knopp S, Salim N, Schindler T, Karagiannis Voules DA, Rothen J, Lweno O, et al. Diagnostic accuracy of Kato-Katz, FLOTAC, Baermann, and PCR methods for the detection of light-intensity hookworm and *Strongyloides stercoralis* infections in Tanzania. Am J Trop Med Hyg. 2014;90(3): 535-45. doi: 10.4269/ajtmh.13-0268.

222. Mbong Ngwese M, Prince Manouana G, Nguema Moure PA, Ramharter M, Esen M, Adégnika AA. Diagnostic techniques of soil-transmitted helminths: Impact on control measures. Trop Med Infect Dis. 2020;5(2): 93. doi: 10.3390/tropicalmed5020093.

223. Meurs L, Polderman AM, Vinkeles Melchers NVS, Brienen EAT, Verweij JJ, Groosjohan B, et al. Diagnosing polyparasitism in a high-prevalence setting in Beira, Mozambique: Detection of intestinal parasites in fecal samples by microscopy and Real-Time PCR. PLoS Negl Trop Dis. 2017;11(1): e0005310. doi: 10.1371/journal.pntd.0005310.

224. Cantera JL, White HN, Forrest MS, Stringer OW, Belizario VY, Jr., Storey HL, et al. Sensitive and semiquantitative detection of soil-transmitted helminth infection in stool using a recombinase polymerase amplification-based assay. PLoS Negl Trop Dis. 2021;15(9): e0009782. doi: 10.1371/journal.pntd.0009782.

225. Tarafder MR, Carabin H, Joseph L, Balolong E, Jr., Olveda R, McGarvey ST. Estimating the sensitivity and specificity of Kato-Katz stool examination technique for detection of hookworms, *Ascaris lumbricoides* and *Trichuris trichiura* infections in humans in the

absence of a 'gold standard'. Int J Parasitol. 2010;40(4): 399-404. doi: 10.1016/j.ijpara.2009.09.003.

226. Yee G, Al Aboud AM. Tinea corporis. In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2020.
227. Pourhoseingholi MA, Baghestani AR, Vahedi M. How to control confounding effects by statistical analysis. Gastroenterol Hepatol Bed Bench. 2012;5(2): 79-83.
228. Zaccai JH. How to assess epidemiological studies. Postgrad Med J. 2004;80(941): 140-7. doi: 10.1136/pgmj.2003.012633.
229. Janszky I, Bjørngaard JH, Romundstad P, Vatten L. A novel approach to quantify random error explicitly in epidemiological studies. Eur J Epidemiol. 2011;26(12): 899-902. doi: 10.1007/s10654-011-9605-2.
230. Greenland S, Senn SJ, Rothman KJ, Carlin JB, Poole C, Goodman SN, et al. Statistical tests, P-values, confidence intervals, and power: A guide to misinterpretations. Eur J Epidemiol. 2016;31(4): 337-50. doi: 10.1007/s10654-016-0149-3.
231. Wasserstein RL, Lazar NA. The ASA statement on P-values: Context, process, and purpose. The American Statistician. 2016;70(2): 129-33. doi: 10.1080/00031305.2016.1154108.
232. Wasserstein RL, Schirm AL, Lazar NA. Moving to a world beyond “P< 0.05”. The American Statistician. 2019;73(sup1): 1-19. doi: 10.1080/00031305.2019.1583913.

233. Gosdin L, Martorell R, Bartolini RM, Mehta R, Srikantiah S, Young MF. The co-occurrence of anemia and stunting in young children. Matern Child Nutr. 2018;14(3): e12597. doi: 10.1111/mcn.12597.
234. Worrell CM, Wiegand RE, Davis SM, Odero KO, Blackstock A, Cuéllar VM, et al. A cross-sectional study of water, sanitation, and hygiene-related risk factors for soil-transmitted helminth infection in urban school, and preschool-aged children in Kibera, Nairobi. PLoS One. 2016;11(3): e0150744-e. doi: 10.1371/journal.pone.0150744.
235. Matangila JR, Doua JY, Linsuke S, Madinga J, Inocêncio da Luz R, Van Geertruyden J-P, et al. Malaria, schistosomiasis and soil-transmitted helminth burden and their correlation with anemia in children attending primary schools in Kinshasa, Democratic Republic of Congo. PLoS One. 2014;9(11): e110789-e. doi: 10.1371/journal.pone.0110789.
236. Erismann S, Diagbouga S, Odermatt P, Knoblauch AM, Gerold J, Shrestha A, et al. Prevalence of intestinal parasitic infections and associated risk factors among schoolchildren in the Plateau Central and Centre-Ouest regions of Burkina Faso. Parasit Vectors. 2016;9(1): 554. doi: 10.1186/s13071-016-1835-4.
237. Alum A, Rubino JR, Ijaz MK. The global war against intestinal parasites: should we use a holistic approach? Int J Infect Dis. 2010;14(9): e732-8. doi: 10.1016/j.ijid.2009.11.036.
238. Grimes JET, Tadesse G, Mekete K, Wuletaw Y, Gebretsadik A, French MD, et al. School water, sanitation, and hygiene, soil-transmitted helminths, and schistosomes: National mapping in Ethiopia. PLoS Negl Trop Dis. 2016;10(3): e0004515. doi: 10.1371/journal.pntd.0004515.

239. Yimam Y, Degarege A, Erko B. Effect of anthelminthic treatment on helminth infection and related anemia among school-age children in northwestern Ethiopia. BMC Infect Dis. 2016;16(1): 613. doi: 10.1186/s12879-016-1956-6.

240. Gashaw F, Aemero M, Legesse M, Petros B, Teklehaimanot T, Medhin G, et al. Prevalence of intestinal helminth infection among schoolchildren in Maksegnit and Enfranz Towns, northwestern Ethiopia, with emphasis on *Schistosoma mansoni i*nfection. Parasit Vectors. 2015;8(1): 567. doi: 10.1186/s13071-015-1178-6.

241. Habtamu K, Degarege A, Ye-Ebiyo Y, Erko B. Comparison of the Kato-Katz and FLOTAC techniques for the diagnosis of soil-transmitted helminth infections. Parasitol Int. 2011;60(4): 398-402. doi: 10.1016/j.parint.2011.06.020.

242. Stephenson LS, Holland CV, Cooper ES. The public health significance of *Trichuris trichiura*. Parasitology. 2000;121 Suppl: S73-S95. doi: 10.1017/s0031182000006867.

243. Hailegebriel T. Undernutrition, intestinal parasitic infection and associated risk factors among selected primary schoolchildren in Bahir Dar, Ethiopia. BMC Infect Dis. 2018;18(1): 394. doi: 10.1186/s12879-018-3306-3.

244. Yimer M, Hailu T, Mulu W, Abera B. Evaluation performance of diagnostic methods of intestinal parasitosis in school-age children in Ethiopia. BMC Res Notes. 2015;8(1): 820. doi: 10.1186/s13104-015-1822-4.

245. Schüle SA, Clowes P, Kroidl I, Kowuor DO, Nsojo A, Mangu C, et al. Ascaris lumbricoides infection and its relation to environmental factors in the Mbeya region of

Tanzania, a cross-sectional, population-based study. PLoS One. 2014;9(3): e92032. doi: 10.1371/journal.pone.0092032.

246. Tariku EZ, Abebe GA, Melketsedik ZA, Gutema BT. Prevalence and factors associated with stunting and thinness among school-age children in Arba Minch Health and Demographic Surveillance Site, Southern Ethiopia. PLoS One. 2018;13(11): e0206659. doi: 10.1371/journal.pone.0206659.

247. Soliman A, De Sanctis V, Elalaily R. Nutrition and pubertal development. Indian J Endocrinol Metab. 2014;18(Suppl 1): S39-S47. doi: 10.4103/2230-8210.145073.

248. Mahmud MA, Spigt M, Bezabih AM, Pavon IL, Dinant G-J, Velasco RB. Efficacy of handwashing with soap and nail clipping on intestinal parasitic infections in school-aged children: a factorial cluster randomized controlled trial. PLoS Med. 2015;12(6): e1001837. doi: 10.1371/journal.pmed.1001837.

249. Liao C-W, Cheng P-C, Chuang T-W, Chiu K-C, Chiang IC, Kuo J-H, et al. Prevalence of Pediculus capitis in schoolchildren in Battambang, Cambodia. Journal of Microbiology, Immunology and Infection. 2017;52(4): 585-91. doi: 10.1016/j.jmii.2017.09.003.

250. Ronsley R, Ling F, Rehmus W, Dmytryshyn A. Lice infestation causing severe anemia in a 4-year-old child. Can Fam Physician. 2019;65(7): 473.

251. de Gier B, Nga TT, Winichagoon P, Dijkhuizen MA, Khan NC, van de Bor M, et al. Species-specific associations between soil-transmitted helminths and micronutrients in Vietnamese schoolchildren. Am J Trop Med Hyg. 2016;95(1): 77-82. doi: 10.4269/ajtmh.15-0533.

252. Shang Y, Tang L-H, Zhou S-S, Chen Y-D, Yang Y-C, Lin S-X. Stunting and soil-transmitted helminth infections among school-age pupils in rural areas of southern China. Parasit Vectors. 2010;3: 97. doi: 10.1186/1756-3305-3-97.

253. Degarege A, Animut A, Medhin G, Legesse M, Erko B. The association between multiple intestinal helminth infections and blood group, anemia and nutritional status in human populations from Dore Bafeno, southern Ethiopia. J Helminthol. 2014;88(2): 152-9. doi: 10.1017/S0022149X12000855.

254. Suchdev PS, Davis SM, Bartoces M, Ruth LJ, Worrell CM, Kanyi H, et al. Soil-transmitted helminth infection and nutritional status among urban slum children in Kenya. Am J Trop Med Hyg. 2014;90(2): 299-305. doi: 10.4269/ajtmh.13-0560.

255. Wani SA, Ahmad F, Zargar SA, Dar ZA, Dar PA, Tak H, et al. Soil-transmitted helminths in relation to hemoglobin status among schoolchildren of the Kashmir Valley. Parasitol. 2008;94(3): 591-3.

256. Katona P, Katona-Apte J. The interaction between nutrition and infection. Clin Infect Dis. 2008;46(10): 1582-8. doi: 10.1086/587658.

257. Feleke BE. Nutritional status and intestinal parasite in school age children: A comparative cross-sectional study. Int J Pediatr. 2016; 1962128. doi: 10.1155/2016/1962128.

258. O'Lorcain P, Holland CV. The public health importance of Ascaris lumbricoides. Parasitol. 2000;121 Suppl: S51-S71.

259. Mulambalah C, Ruto J. Prevalence and infection intensity of geohelminthiases among schoolchildren as an environmental health indicator to guide preventive activities in Nandi County, Kenya. Trop J Med Res. 2016;19(2): 131-7. doi: 10.4103/1119-0388.185439.

260. Benjamin-Chung J, Nazneen A, Halder AK, Haque R, Siddique A, Kopor MSUK, et al. The interaction of deworming, improved sanitation, and household flooring with soil-transmitted helminth infection in rural Bangladesh. PLoS Negl Trop Dis. 2015;9(12): e0004256.

261. Quihui L, Valencia ME, Crompton DWT, Phillips S, Hagan P, Morales G, et al. Role of the employment status and education of mothers in the prevalence of intestinal parasitic infections in Mexican rural schoolchildren. BMC Public Health. 2006;6: 225. doi: 10.1186/1471-2458-6-225.

262. Khairy AE, El Sebaie O, Abdel Gawad A, El Attar L. The sanitary condition of rural drinking water in a Nile Delta village. I. Parasitological assessment of 'zir' stored and direct tap water. J Hyg. 1982;88(1): 57-61. doi: 10.1017/s0022172400069898.

263. WHO, UNICEF. Progress on sanitation and drinking water. 2015 update and MDG assessment. Geneva: World Health Organization. https://apps.who.int/iris/handle/10665/177752

264. Feldmeier H, Jackson A, Ariza L, Lins Calheiros CM, de Lima Soares V, Oliveira FA, et al. The epidemiology of scabies in an impoverished community in rural Brazil: Presence and severity of disease are associated with poor living conditions and illiteracy. J Am Acad Dermatol. 2009;60(3): 436-43. doi: 10.1016/j.jaad.2008.11.005.

265. Armitage EP, Senghore E, Darboe S, Barry M, Camara J, Bah S, et al. High burden and seasonal variation of pediatric scabies and pyoderma prevalence in the Gambia: A cross-sectional study. PLoS Negl Trop Dis. 2019;13(10): e0007801. doi: 10.1371/journal.pntd.0007801.

266. Elson L, Wiese S, Feldmeier H, Fillinger U. Prevalence, intensity and risk factors of tungiasis in Kilifi County, Kenya II: Results from a school-based observational study. PLoS Negl Trop Dis. 2019;13(5): e0007326. doi: 10.1371/journal.pntd.0007326.

267. Yotsu RR, Kouadio K, Vagamon B, N’guessan K, Akpa AJ, Yao A, et al. Skin disease prevalence study in schoolchildren in rural Côte d'Ivoire: Implications for integration of neglected skin diseases (skin NTDs). PLoS Negl Trop Dis. 2018;12(5): e0006489. doi: 10.1371/journal.pntd.0006489.

268. Figueroa JI, Fuller LC, Abraha A, Hay RJ. Dermatology in southwestern Ethiopia: Rationale for a community approach. Int J Dermatol. 1998;37(10): 752-8. doi: 10.1046/j.1365-4362.1998.00425.x.

269. Pérez-Tanoira R, Marín I, Berbegal L, Prieto-Pérez L, Tisiano G, Cuadros J, et al. Mycological profile of tinea capitis in schoolchildren in rural southern Ethiopia. Med Mycol. 2017;55(3): 262-8. doi: 10.1093/mmy/myw061.

270. Oke OO, Onayemi O, Olasode OA, Omisore AG, Oninla OA. The prevalence and pattern of superficial fungal infections among schoolchildren in Ile-Ife, South-Western Nigeria. Dermatol Res Pract. 2014;2014: 842917. doi: 10.1155/2014/842917.

271. Moto JN, Maingi JM, Nyamache AK. Prevalence of tinea capitis in school going children from Mathare, informal settlement in Nairobi, Kenya. BMC Res Notes. 2015;8(1): 274. doi: 10.1186/s13104-015-1240-7.

272. Kechia FA, Kouoto EA, Nkoa T, Nweze EI, Fokoua DCM, Fosso S, et al. Epidemiology of tinea capitis among school-age children in Meiganga, Cameroon. J Mycol Med. 2014;24(2): 129-34. doi: 10.1016/j.mycmed.2013.12.002.

273. Ford C, Park LJ. Hand hygiene and handwashing: Key to preventing the transfer of pathogens. Br J Nurs. 2018;27(20): 1164-6. doi: 10.12968/bjon.2018.27.20.1164.

274. Dagne H, Dessie A, Destaw B, Yallew WW, Gizaw Z. Prevalence and associated factors of scabies among schoolchildren in Dabat district, northwest Ethiopia, 2018. Environ Health Prev Med. 2019;24(1): 67. doi: 10.1186/s12199-019-0824-6.

275. Kouotou EA, Nansseu JRN, Kouawa MK, Zoung-Kanyi Bissek A-C. Prevalence and drivers of human scabies among children and adolescents living and studying in Cameroonian boarding schools. Parasit Vectors. 2016;9(1): 400. doi: 10.1186/s13071-016-1690-3.

276. Afolabi O, Oninla O, Funmito F. Tinea capitis: A tropical disease of hygienic concern among primary schoolchildren in an urban community in Nigeria. J Public Health Epidemiol. 2018;10: 313-9. doi: 10.5897/JPHE2018.1050.

277. Ugbomoiko US, Oyedeji SA, Babamale OA, Heukelbach J. Scabies in resource-poor communities in Nasarawa State, Nigeria: Epidemiology, clinical features and factors

associated with infestation. Trop Med Infect Dis. 2018;3(2): 59. doi: 10.3390/tropicalmed3020059.

278. Chikoi R, Nyawale HA, Mghanga FP. Magnitude and associated risk factors of superficial skin fungal infection among primary schoolchildren in Southern Tanzania. Cureus. 2018;10(7): e2993. doi: 10.7759/cureus.2993.

279. Wiese S, Elson L, Reichert F, Mambo B, Feldmeier H. Prevalence, intensity and risk factors of tungiasis in Kilifi County, Kenya: I. Results from a community-based study. PLoS Negl Trop Dis. 2017;11(10): e0005925. doi: 10.1371/journal.pntd.0005925.

280. Wafula ST, Ssemugabo C, Namuhani N, Musoke D, Ssempebwa J, Halage AA. Prevalence and risk factors associated with tungiasis in Mayuge district, Eastern Uganda. Pan Afr Med J. 2016;24: 77. doi: 10.11604/pamj.2016.24.77.8916.

281. Emi W, Colleen MM, Abebayehu T, Desta AA, David F, Gail D. Use of footwear and foot condition among rural Ethiopian schoolchildren. J Epidemiol Glob Health. 2014;4(4): 323-5. doi: 10.1016/j.jegh.2014.06.001.

282. Feldmeier H, Heukelbach J. Epidermal parasitic skin diseases: A neglected category of poverty-associated plagues. Bull World Health Organ. 2009;87(2): 152-9. doi: 10.2471/blt.07.047308.

283. Mwangi JN, Ozwara HS, Gicheru MM. Epidemiology of T*unga penetrans* infestation in selected areas in Kiharu constituency, Murang'a County, Kenya. Trop Dis Travel Med Vaccines. 2015;1: 13. doi: 10.1186/s40794-015-0015-4.

284. Linardi PM, de Avelar DM. Neosomes of tungid fleas on wild and domestic animals. Parasitol Res. 2014;113(10): 3517-33. doi: 10.1007/s00436-014-4081-8.

285. Mutebi F, Krücken J, Feldmeier H, Waiswa C, Mencke N, Sentongo E, et al. Animal reservoirs of zoonotic tungiasis in endemic rural villages of Uganda. PLoS Negl Trop Dis. 2015;9(10): e0004126. doi: 10.1371/journal.pntd.0004126.

286. Gunathilaka N, Chandrasena N, Udayanga L. Prevalence of ectoparasitic infections and other dermatological infections and their associated factors among schoolchildren in Gampaha District, Sri Lanka. Can J Infect Dis Med Microbiol. 2019;2019: 5827124. doi: 10.1155/2019/5827124.

Original articles Paper I- III, Supplementary information and Appendices

Original articles Paper I- III

Paper-I

PeerJ

Concurrent anemia and stunting among schoolchildren in Wonago district in southern Ethiopia: a cross-sectional multilevel analysis

Hiwot Hailu Amare[1,2,3] and Bernt Lindtjorn[1,2]

[1] School of Public Health, College of Medicine and Health Sciences, Hawassa University, Hawassa, Ethiopia
[2] Centre for International Health, University of Bergen, Bergen, Norway
[3] Department of Public Health, College of Health Sciences and Medicine, Dilla University, Dilla, Ethiopia

ABSTRACT

Background. Even if many schoolchildren in Ethiopia are anemic and stunted, few have studied the co-existence of anemia and stunting among schoolchildren in Ethiopia. In addition, multilevel analysis to explore the variation in prevalence of concurrent anemia and stunting (CAS) across schools and classes is rarely applied. Thus, we aimed to assess the prevalence and risk factors of CAS at the individual, household, and school level among schoolchildren in southern Ethiopia.

Methods. We recruited 864 students aged 7–14 years from the Wonago district in southern Ethiopia using a three-stage random sampling, assigning four schools to level one, 24 classes to level two. We then randomly selected 36 children from each class, and recorded their weight, height, haemoglobin, intestinal helminthic infections, hygienic practices, dietary practices, household food insecurity, and socio-demographic information. A multivariate, multilevel logistic regression model was applied to detect potential risk factors for CAS.

Results. The prevalence of CAS was 10.5% (85/810) among schoolchildren, which increased with age in years (adjusted odds ratio [aOR] 1.39 [95% confidence interval 1.13, 1.71, $P = 0.002$]) and among children who always did not wash their hands with soap after use of latrine (aOR 4.30 [1.21, 15.3, $P = 0.02$]). Children who walked barefoot (aOR 10.4 [2.77, 39.1, $P = 0.001$]), were infected with *Trichuris trichiura* (aOR 1.74 [1.05, 2.88, $P = 0.03$]), or had head lice infestation (aOR 1.71 [1.01, 2.92, $P = 0.04$]) had higher CAS prevalence. Prevalence rates of CAS were low in those using treated drinking water (aOR 0.32 [95% CI 0.11, 0.97, $P = 0.04$]). Most of the risk factors for CAS were identified at the individual level. The clustering effect measured by the intra-cluster correlation coefficient was 6.8% at school level and 19% at class.

Conclusion. CAS prevalence is a moderate public health problem among schoolchildren in southern Ethiopia and varies across classes and schools. After controlling for clustering effects at the school and class levels, we found an association between CAS and increasing age, not always washing hands with soap after using latrine, walking barefoot, and *T. trichiura* infection. Using treated water for drinking was found to have a protective effect against CAS. Thus, educating children on personal hygiene and provision of safe drinking water could reduce the CAS burden in schoolchildren in rural areas of southern Ethiopia.

Submitted 10 November 2020
Accepted 4 March 2021
Published 6 May 2021

Corresponding author
Hiwot Hailu Amare,
hiwothailu14@yahoo.com

Academic editor
Abhijit Pakhare

Additional Information and Declarations can be found on page 13

DOI 10.7717/peerj.11158

How to cite this article Amare HH, Lindtjorn B. 2021. Concurrent anemia and stunting among schoolchildren in Wonago district in southern Ethiopia: a cross-sectional multilevel analysis. *PeerJ* 9:e11158 http://doi.org/10.7717/peerj.11158

Subjects Global Health, Hematology, Nutrition, Pediatrics, Public Health
Keywords Children, Concurrent, Anemia, Stunting, Rural, School, Multilevel, Southern, Ethiopia

INTRODUCTION

Nearly half of all countries worldwide face the multiple burdens of malnutrition, including stunting, wasting, poor weight gain, and micronutrient deficiencies (*International Food Policy Research Institute, 2015*). Ethiopia has a school nutrition program designed to improve students' nutritional status (*Federal Democratic Republic of Ethiopia Ministry of Education, 2012*; *Federal Democratic Republic of Ethiopia Ministry of Health, 2017*). Despite school health and nutrition initiatives, a large proportion of schoolchildren in Ethiopia are still anemic or stunted (*Federal Democratic Republic of Ethiopia Ministry of Education, 2012*; *Federal Democratic Republic of Ethiopia Ministry of Health, 2017*). In Ethiopia, even though school access and enrolment have improved, about 10 million school-age children live in food-insecure areas (*Federal Ministry of Education, 2015*). Southern Ethiopia is among the regions in the country with inadequate school water supply (*Federal Democratic Republic of Ethiopia Ministry of Education, 2017*), and with poor sanitation practice with more than half of the schools still using open defecation (*Grimes et al., 2017*).

Anemia affects about one-third of the population worldwide. Although the prevalence varies across different population groups and settings, the most common cause is iron deficiency (*Kassebaum et al., 2014*). Although there are few recent global reports for anemia among school-aged children, WHO estimated in 2008 a 25% prevalence among school-aged children (*De Benoist et al., 2008*). In 2016, the national prevalence of anemia among schoolchildren was 26% in Ethiopia, 20% with iron deficiency anemia (*Ethiopian Public Health Institute, 2016*) and similar results are found in southern Ethiopia (*Grimes et al., 2017*; *Shaka & Wondimagegne, 2018*). Stunting is also common among schoolchildren in southern Ethiopia with prevalence rates ranging from 15% to 57% (*Bogale et al., 2018*; *Shaka & Wondimagegne, 2018*). Both anemia and stunting are preventable or treatable (*Kakietek et al., 2017*).

Studies indicate a link between anemia and stunting (*Getaneh et al., 2017*; *Gutema et al., 2014*). Stunting is often associated with anemia and recurrent infections among children (*Gupta, 2017*). Children with poor nutrient intake have weakened immunity, are susceptible to infections, and are at increased risk of anemia and long-term developmental delays (*Bourke, Berkley & Prendergast, 2016*; *Chaparro & Suchdev, 2019*). Despite these complex and interconnected health problems, few studies have investigated the co-existence of anemia and stunting in Ethiopia. Apart from the 2016 Ethiopian Demographic and Health Survey which demonstrated a prevalence rate of 24% of the co-morbidity of anemia and stunting among children aged under-5 years (*Mohammed, Larijani & Esmaillzadeh, 2019*), we are not aware of similar studies on schoolchildren. However, several factors can contribute to the varied prevalence of anemia and stunting at both the individual (age, sex, nutritional deficiency, food consumption, poor hygiene, intestinal helminthic infections, parents' education) and household (wealth, family income and size, food insecurity, and access to hand-washing facilities) level (*Assefa, Mossie & Hamza, 2014*; *Getaneh et al., 2017*;

Gutema et al., 2014; *Mesfin, Berhane & Worku, 2015*). Furthermore, most previous studies did not consider the nested structure of school data (i.e., individuals nested within the same class and classes nested within the same school) in their analysis. Few have assessed the nutritional status of schoolchildren in rural southern Ethiopia (*Grimes et al., 2017*), even if most school-aged children live in this rural area. This paper is part of a larger study on school health problems that include the co-existence of anemia and stunting (CAS), intestinal helminthic infections (*Hailu Amare & Lindtjørn, 2020*), and skin problems in the Gedeo area of southern Ethiopia. Therefore, we aimed to assess the prevalence and risk factors of CAS at the individual, household, and school level among schoolchildren in the rural Wonago district in southern Ethiopia.

METHODS

Study area, design, and participants

The study was conducted in the Wonago district of the Gedeo zone in Southern Ethiopia. The district is 377 km south of Addis Ababa. The district has 17 rural and four urban *kebeles*, the smallest administrative units. In 2014, Wonago's population was estimated to be 143,989 people, with 1,014 people per square kilometer of land area. The district has 26 government health facilities (six health centers and 20 health posts), two private clinics, and two drug stores, along with more than 36,000 students in three urban and 22 rural primary schools. Most residents depend on cash crops of coffee, fruit, and *ensete* (*Ensete ventricosum)*.

We conducted this cross-sectional survey from February 2017 to June 2017. The study population was schoolchildren and their parents or guardians. Students aged 7–14 years were recruited in schools and their parents or guardians were contacted by visiting their homes.

Sample size estimation

Since this study was part of a large project aiming to identify school health problems, we considered multiple factors to calculate the sample size using OpenEpi software (*Sullivan, Dean & Soe, 2009*) based on single population proportion (*Daniel, 1999*). Assuming a 95% confidence interval (CI), the maximum sample size was calculated using proportions of different variables from previous studies (e.g., anemia [27%] (*Mesfin, Berhane & Worku, 2015*), stunting [30%], and thinness [37%] (*Mekonnen, Tadesse & Kisi, 2013*); intestinal parasites infections [27%] (*Haftu, Deyessa & Agedew, 2014*), and skin tinea infection [50%] (*Ali, Yifru & Woldeamanuel, 2009*); 5% precision, and a design effect of 2 to account for multistage sampling.

To maximize the sample size, we used a prevalence of 50%. After adding a 10% non-response rate, we calculated a sample size of 845 schoolchildren.

This study targeted rural primary school-aged children. There are 22 rural primary schools in the study district. Using a three-stage cluster sampling method, we randomly assigned 4 schools to level one, 24 classes with 2,384 children to level two. We then randomly selected 36 children from each class. When more than one child in a class was living together in the same household, one of them was selected randomly by a lottery method. In total, we randomly recruited 864 schoolchildren.

Children aged below 7 years and those older than 14 years were excluded from this study. Children who had a physical deformity and serious illness could have been excluded from this study, but we did not observe any of these cases during the data collection process.

The household of the student's parents or guardian was identified through a local guide. We randomly selected and replaced participants who dropped out of school after the selection process with participants from the same class, sex, and age by a lottery method. The recruitment process is shown in Fig. S1.

Outcome variables

We assessed the prevalence and risk factors of concurrent anemia and stunting (CAS) among schoolchildren. CAS among children was defined when a child was both anemic and stunted. Anemia was recorded according to the WHO guidelines for school-aged children: haemoglobin <11.5 g/dl for those aged 5–11 years and <12 g/dl for those aged 12–14 years. Anemia was estimated using the haemoglobin value adjusted for altitude (*World Health Organization (WHO), 2011*). Stunting among children was defined as height-for-age Z scores <-2 SD. Children with height-for-age Z scores ≥ -3 to <-2 SD were classified as moderately stunted, whereas those with <-3 SD were classified as severely stunted (*De Onis et al., 2007*; *World Health Organization (WHO), 2009*).

Independent variables

The independent variables at the individual level for the children were sex, age, hygienic practices: nail trimming, hand washing with soap after latrine use, and walking barefoot; and dietary *intake*, meal habit before attending school (breakfast or lunch), reported illness in the month prior to data collection, de-worming treatment in the past 6 months, and the presence of *Ascaris lumbricoides, Trichuris trichiura*, hookworm, or head lice (pediculosis) infestations. Parent individual level variables included the educational level of the mother and father.

Household factors included the wealth index, which was constructed using principal component analysis (*Vyas & Kumaranayake, 2006*) based on household assets and included electricity, radio, television, mobile phone, table, chair, bed, separate room for kitchen, cooking place, land ownership, bank account, toilet facility, floor, and roof materials; family size; the level of food insecurity; using clean drinking water; and household access to food aid in the past 6 months. School factor included participation in the school meal programme.

Data collection tools and procedures

Ten trained enumerators conducted the interviews using a pretested and structured questionnaire that was adapted and developed in English from previous published literature (*Alelign, Degarege & Erko, 2015*; *Coates, Swindale & Bilinsky, 2007*; *Gebreyesus et al., 2015*; *Haftu, Deyessa & Agedew, 2014*) and then translated into the local *Gedeooffa* language. Children were interviewed at their schools and parents at their homes.

Information related to the child's personal hygiene was collected from the children. Measurements, such as weight, height, and haemoglobin, were taken from children in the school. To measure weight, a digital portable scale (Seca 877, Seca GmbH, Germany) was calibrated to the nearest 0.1 kg. Children were weighed in light clothing and no shoes. To measure height, a measuring board (Seca 213, Seca GmbH, Germany) was calibrated to the nearest 0.1 cm. Children were measured while standing barefoot with parallel feet, heels, buttocks, and shoulders, with their heads held upright, the backs of their heads touching the measuring board, and their hands hanging by their sides. Capillary blood samples were taken for haemoglobin measurement by trained and experienced laboratory technicians using a HemoCue Analyser Hb 301 (Angelholm, Sweden).

Stool samples were collected, processed, and examined using standard procedures (*Montresor et al., 1998*; *WHO, 1991*). Samples were collected at school in the early morning, and stored in stool cups labelled with an identification code, name, sex, age, and date. The specimens were transported in a cold-box to Dilla University Teaching and Referral Hospital, where Kato-Katz and formalin-ether concentration (FEC) techniques were used to identify helminthic infections (*Montresor et al., 1998*; *WHO, 1991*). The result of each helminthic species from two diagnostic techniques was recorded separately. We also examined the child's hair for external parasites, such as head lice.

Household information was collected from the children's parents or guardians during home visits through interviews and observations of the housing conditions. Information related to socio-demographic characteristics, household assets, household food insecurity, use of treated drinking water, access to food aid, child dietary intake, and illness in the past month were collected from the parents or guardians at each household. Information related to the habit of taking a meal regularly before school (breakfast if the child attended school in the morning and lunch if the child attended classes in the afternoon) and the reason for not eating, was also collected from the parents. Information related to de-worming treatment was collected from parents by showing them the de-worming tablet and asking, "In the past 6 months, was your child given any de-worming treatment?"

Dietary intake was measured using a 24-hour dietary recall method (*Swindale & Bilinsky, 2006*). The children's parents were asked to list the food items that the children consumed within the past 24 h, and the children were asked if they ate outside the home the *day before the survey*. We calculated the child Dietary Diversity Score (DDS) using the following nine food groups: cereals, roots, or tubers; vitamin A-rich plant foods; other fruits; other vegetables; meat, poultry, fish; eggs; pulses or legumes; milk and milk products; and food cooked in oils or fats. The food items were classified based on FAO definition (*Kennedy, Ballard & Dop, 2011*). A value of 1 was recorded if any of the disaggregated food group items were consumed, and 0 if none of the disaggregated food group items were consumed (*Swindale & Bilinsky, 2006*). DDSs were computed by summing the previously mentioned food groups, with the score ranging from 0 to 9, and the mean DDS calculated for each child.

We assessed household food insecurity based on a 4-week recall period using nine items of the Household Food Insecurity Access Scale (HFIAS) (*Coates, Swindale & Bilinsky, 2007*; *Gebreyesus et al., 2015*): (Q1) worrying about food, (Q2) unable to eat preferred foods, (Q3) eating a limited variety of foods, (Q4) eating unwanted foods, (Q5) eating small meals, (Q6) eating fewer meals in a day, (Q7) having no food of any kind in the household, (Q8) going to sleep at night hungry, (Q9) going a whole day and night without eating anything. 'No' responses were coded as 0 and 'Yes' responses as 1. Responses for frequency of occurrence items are coded as 1 for 'rarely', 2 for 'sometimes', 3 for 'often'. Households with no affirmative responses or 1 for Q1 and 'No' responses for the other items were considered food secure, whereas those reporting 2 or 3 for Q1 or 1, 2, or 3 for Q2 or 1 for Q3 or Q4 and no affirmative responses for Q5 to Q9 were considered mildly food insecure; 2 or 3 for Q3 or Q4 or 1 or 2 for item Q5 or Q6 and 0 for Q7 to Q9 were considered as moderately food insecure; 3 for Q5 or Q6 or 1, 2, or 3 for Q7 to Q9 were categorized as severely food insecure. The score was computed by summing the responses for the frequency of occurrence for the nine items (range 0 to 27).

Data quality control

Training was provided for all personnel participating in *data collection*, supervision, and data entry. To minimize potential bias and validate the measurement tools prior to data collection, a pre-test was conducted on 42 primary school-aged children in other schools not selected for this study. Hence, we conducted a reliability test to observe inter- and intra-observer variations and ensure reproducibility for anthropometric measurements. Observers measured the weights and heights of 10 children twice. The intra-class correlation coefficient was used to estimate the reliability of the continuous measurements (*McHugh, 2012*) (intra-observer reliability for weight: 0.94 [95% CI 0.78, 0.98], and height: 0.94 [95% CI 0.78, 0.98]; inter-observer reliability for weight: 0.92 [95% CI 0.81, 0.97], and height: 0.91 [95% CI 0.78, 0.97]). More than 90% of the intra- and inter-observer measurements show good reliability (*Koo & Li, 2016*).

To record an accurate age for the children, we cross-checked information from the school registry with the age information provided by the children's parents. The supervisors checked data for completeness and consistency.

Statistical methods

Data were entered into a database using the double-entry system in Epi-data version 3.1 (EpiData, Odense Denmark, 2004). Inconsistencies were cleaned and missing values were addressed before analysis. After validation, the data were exported to SPSS version 20 (IBM Corp; 2011) and STATA 15 software (StataCorp LLC, College Station, TX, USA; 2017) for analysis.

The primary focus of this paper is to identify risk factors for CAS among school children. However, earlier papers have shown that CAS share risk factors for stunting and anemia among younger children. To assess this possibility, we provide separate risk estimates for anemia and for stunting as Supplemental Information. We have summarised the shared risk factors for CAS, anemia, and stunting at the end of the results section.

Descriptive statistics, frequency, percentage, mean, range, and standard deviation (SD) were calculated to describe relevant variables. The proportions were determined for categorical variables in relation to CAS. We used WHO AnthroPlus 1.0.4 software to calculate height-for-age, weight-for-age, and body mass index-for-age Z scores according to the standard reference for children aged 5–19 years (*World Health Organization (WHO), 2009*). The WHO AnthroPlus software allows Z scores for weight-for-age to be calculated only for children up to 10 years of age (*De Onis et al., 2019*; *World Health Organization (WHO), 2009*). Therefore, children aged >10 years were excluded from the estimation of underweight prevalence.

Household asset variables were categorized and coded as either 0 for absent or 1 for present. A wealth index was then constructed using principal component analysis (*Vyas & Kumaranayake, 2006*). The internal consistency of the 14 variables was determined using a Cronbach alpha of 0.78 and Kaiser-Meyer-Olkin sampling adequacy measure of 0.8. Socioeconomic indicators (poor, middle-class, and rich) were categorized based on the first component explaining 28.3% of the data variance, with an Eigen value of 4.1.

We used three data hierarchies: school level, class level, and individual level (child or parent). Students were clustered within the same class, and classes were nested within schools. We included school- and class-level data during the analysis, and assessed potential confounding and effect modifications using multivariate, multilevel regression and stratified analysis. 'Washing hands with soap after latrine use sometimes or not always and never' were all categorized under 'not washing hands always'. 'Walking barefoot always and sometimes' were all categorized under 'walking barefoot always'. Children with no CAS and yes CAS were stratified by the categories of T. trichiura and not washing hands always.

Prior to the multivariate regression, we checked the collinearity among independent variables. Both a bivariate logistic regression without considering random effects, and a multilevel logistic regression model with random school and class effects were applied for assessment of *potential risk factors*.

Using a multivariate, multilevel logistic regression model, we identified individual-, household-, and school-level factors that may contribute to CAS. Six separate models were constructed for CAS. Model I (empty) had no covariate indicating whether to consider the random-effect model. Independent variables with $P < 0.25$ in the bivariate multilevel logistic regression model were introduced concurrently in each model. The variables with $P < 0.25$ in each independent model were also maintained in the final model. Covariate variables; sex and wealth were with $P > 0.25$ in the bivariate model were retained in the final model to control for confounding. The final model for CAS included individual child (sex, age, hand washing with soap after latrine use, walking barefoot, *T. trichiura*, and head lice), parent (mother's education), household (wealth status, family size, using treated water for drinking, access to food aid in the past 6 months), and school (participation in school meal programme) factors.

Results were calculated as crude odds ratios (cORs) and adjusted odds ratios (aORs) with 95% CIs. Independent variables with $P \leq 0.05$ in the final model were considered significant. Model fitness was checked using −2 log likelihood (deviance) and the Akaike information criterion (AIC). The model with the lowest deviance and AIC value was used as the final model (*Twisk, 2006*). A receiver operating characteristic (ROC) curve or area under the curve (AUC) was used to compare simple regression models with models considering a random effect. An AUC ≥ 0.7 was considered acceptable (*Merlo et al., 2016*). In this study, the AUC for the CAS model considering a random effect was >0.80, whereas the AUC with a simple regression model was <0.7, suggesting that the *model* with a random effects is *better than* the model with a simple regression model for this outcome. *Homogeneity* within clusters at the school- and class-level was measured using the intra-cluster correlation coefficient (ICC).

Ethics statement

The institutional review board of Hawassa (IRB/005/09) and Regional Ethical Committee of Western Norway (2016/1900/REK vest) provided ethical clearance. The Gedeo Zone Health Department (2/572/110) and District Education Office provided a letter of permission (435). School directors and teachers participated in discussions. We obtained informed verbal (thumb print), and written (signed) consent from study participants' parents or guardians and permission (assent) from children aged 12 years and older before the interviews. The interviews and measurements were conducted in a private place for each participant. Confidentiality of the participant's information was maintained. Children diagnosed as anemic and who tested positive for intestinal helminthic infections were referred to the nearest health institution for treatment according to standard guidelines (*Drug Administration and Control Authority (DACA) of Ethiopia, 2010*).

RESULTS

Background information of study subjects

The 861 schoolchildren (483 boys and 378 girls) in this study were aged 7 to 14 years, with mean [SD] age of 11.4 [1.9] years. All of the recruited children's parents or guardians participated in the household survey. The majority (89.2%; $n = 768$) of children lived with their biological parents. The father's average age was 41 years and the mother's average age was 34 years. Among heads of households, 91.4% (787/861) were men, and 8.6% (74/861) were women. The family size ranged from 3 to 14 persons (mean 6.7). Among parents, 88.4% (761/861) of mothers and 48.8% (420/861) of fathers had never attended school. More than half of the mothers (54.0%; $n = 463$) were housewives, and most fathers (77.4%; $n = 619$) were farmers. Among the participants, 33.3% ($n = 287$) lived in poor households. Table S1 summarizes the demographic and socioeconomic statuses of the schoolchildren and their parents.

Dietary habits and food insecurity

The day before the survey, cereals, roots, or tubers (100%; $n = 861$) were consumed by all children; vitamin A-rich plant foods by 9.9% ($n = 85$); other fruits by 18.6% ($n = 160$); other vegetables by 22.6% ($n = 195$); meat or fish by 4% ($n = 35$); eggs by 17% ($n = 147$); pulses or legumes by 46.9% ($n = 404$); milk and milk products by 15% ($n = 129$); and food cooked in oil or fat by 3.7% ($n = 32$). Coffee or tea was also consumed by 87% ($n = 749$) of children a day prior to the survey. The median and interquartile range of DDS was 2 (1–3), with a range of 1 to 8 food groups consumed. The food items comprising each food group are found in the Supplementary Information (Table S2).

The median and interquartile range of HFIAS score was 2 (0–6), and scores ranged from 0 to 19. Among the 861 children, 50.7% ($n = 437$; 245 [56.1%] boys, 192 [43.9%] girls) lived in food-insecure households; 29% ($n = 253$) in mildly food insecure households, 18% ($n = 155$) in moderately food insecure households, and 3.5% ($n = 30$) in severely food insecure households. The household food-insecurity item responses are presented in the Supplementary Information (Table S3).

School sanitation and hygiene facilities

All schools had no access to drinking water and handwashing facilities. In all schools there were pit latrines covered with cement. However, we observed that there were defections on the latrine floors, and no toilet paper were available in the toilets room.

Prevalence and risk factors for CAS

The prevalence of CAS was 10.5% ($n = 85/810$ [95% CI 8.4, 12.6] among schoolchildren; 9.6%, $n = 44$ boys and 11.6%, $n = 41$ girls (Table 1, Tables S4 and S5). The results of the bivariate analysis for CAS are provided in Table S6.

We observed a clustering effect at the school- and class-level for CAS prevalence. The calculated ICC indicated that 6.8% of the variability in CAS among children was attributable to school-level factors and 19% to class-level factors (Table S7).

All significant variables in the bivariate were significant in the multivariate model (Tables S6 and Table S7). As shown in Table 1 and Table S7, in the multivariate analysis, the odds of CAS increased with increasing age [aOR] 1.39 [95% confidence interval 1.13, 1.71, $P = 0.002$]). Children who always did not wash their hands with soap after use of latrine (aOR 4.30 [1.21, 15.3, $P = 0.02$]), children who always walked barefoot (aOR 10.4 [2.77, 39.1, $P = 0.001$]), children infected with *T. trichiura* (aOR 1.74 [1.05, 2.88, $P = 0.03$]), or had head lice infestation (aOR 1.71 [1.01, 2.92, $P = 0.04$]) had higher CAS rates. Children using treated drinking water at their houses (aOR 0.32 [95% CI 0.11, 0.97, $P = 0.04$]) were less likely to be affected by CAS. However, we did not find significant differences between CAS and sex, nail trimming, infection with *A. lumbricoides*, mother's education, wealth, family size, access to food aid in the past 6 months, and participation in the school meal programme (Table S7).

The crude and adjusted odds ratio estimates for variables, such as hand-washing habit, and walking barefoot, were different. The association between CAS and washing hands with soap after latrine use was confounded by *T. trichiura* infection (Table 1). In addition, the association between CAS and walking barefoot was also confounded by hand washing with soap after latrine use (Table 1).

Prevalence of anemia and stunting

Anemia alone occurred among 29.6% ($n = 240/810$) and stunting occurred in 32.3% ($n = 278/861$) of children (Tables S4 and Tables S5). Commonly shared risk factors for stunting and CAS include age, not always washing hands with soap after use of latrine, and head lice infestation. Using treated water for drinking was also found to have a protective factor against stunting and CAS (Tables S8, S9 and S10).

Table 1 Bivariate and multivariate, multilevel, mixed-effect, regression analysis of CAS among schoolchildren in the Wonago district of southern Ethiopia, 2017.

Variables		CAS		Crude odds ratio (COR) (95% CI)	*P*-value	Adjusted OR (95% CI)	*P*-value
		Yes (%)	No (%)				
Individual child factors							
Sex	Boys	44 (9.6)	412 (90.4)	0.81 (0.50, 1.29)	0.37	0.84 (0.51, 1.39)	0.499
	Girls	41 (11.6)	313 (88.4)	1.0		1.0	
Age in years (continuous)	Mean (SD)			1.36 (1.13, 1.65)	0.001	1.39 (1.13, 1.71)	0.002
Hand washing with soap after use of latrine	Always	6 (6.2)	91 (93.8)	1.0		1.0	
	Sometimes or not always	45 (9.6)	422 (90.4)	1.74 (0.68, 4.44)	0.24	4.30 (1.21, 15.3)	0.02
	Never	34 (13.8)	212 (86.2)	1.67 (0.58, 4.81)	0.34	3.10 (0.82, 11.8)	0.09
Walking barefoot	Always	6 (30.0)	14 (70.0)	5.36 (1.74, 16.5)	0.003	10.4 (2.77, 39.1)	0.001
	Sometimes	40 (10.5)	341 (89.5)	1.16 (0.70, 1.91)	0.57	1.18 (0.68, 2.05)	0.55
	Never	39 (9.5)	370 (90.5)	1.0		1.0	
Head lice	Yes	42 (13.3)	273 (86.7)	1.69 (1.05, 2.74)	0.03	1.71 (1.01, 2.92)	0.04
	No	43 (8.7)	452 (91.3)	1.0		1.0	
T. trichiura	No	41 (8.8)	424 (91.2)	1.0		1.0	
	Yes	42 (12.4)	298 (87.6)	1.59 (0.99, 2.55)	0.05	1.74 (1.05, 2.88)	0.03
Household factors							
Using treated drinking water	Yes	4 (4.1)	94 (95.9)	0.28 (0.10, 0.80)	0.01	0.32 (0.11, 0.97)	0.04
	No	81 (11.4)	631 (88.6)	1.0		1.0	
School factor							
Participates in school meal programme	No	55 (13.7)	345 (86.3)	1.0		1.0	
	Yes	30 (7.3)	380 (92.7)	0.48 (0.22, 1.03)	0.06	0.29 (0.07, 1.17)	0.08

Notes.
CAS, concurrent anemia and stunting; CI, confidence interval; OR, odds ratio

DISCUSSION

Based on a standard definition, CAS was found to be a moderate public health problem among schoolchildren in southern Ethiopia (De Benoist et al., 2008; De Onis et al., 2019). Increasing age, not always washing hands with soap after using latrine, walking barefoot, *T. trichiura* infection, and head lice infestation were found to be associated with CAS. Using treated water for drinking was found to have a protective effect against CAS. Stunting and CAS share some of the same risk factors, including age, not washing hands with soap after use of latrine, and head lice infestation. Using treated drinking water was also a common shared protective factor for stunting and CAS. Significant clustering effect was observed at the school- and class-level for CAS prevalence.

The rate of CAS was 10.5% among schoolchildren. This rate is lower than the recent report of 23.9% for Ethiopia (Mohammed, Larijani & Esmaillzadeh, 2019), 21.5% for India, and 30.4% for Peru (Gosdin et al., 2018) among children under the age of 5 years. These variations could be due to different study settings and participant ages. Moreover, unlike most studies, we conducted our study in rural areas, which could also have influenced prevalence rates.

Using age as a continuous variable, we observed significantly increased odds of CAS with increasing age, as described previously in Ethiopia (Alelign, Degarege & Erko, 2015; Bogale et al., 2018; Tariku et al., 2018). This could be explained by the older school-age children are in the transition period to puberty, which increases nutritional demands (Soliman, De Sanctis & Elalaily, 2014).

Our results revealed an increased risk of CAS among children who always not washed their hands with soap after using the latrine compared to children who always washed their hands. This finding is supported by previous studies (Gosdin et al., 2018; Mahmud et al., 2015). Good hygiene is important to avoid acquiring infections and, thus, avoid CAS caused by helminthic infections. Moreover, walking barefoot may partly be indicative of low socio-economic status and poor hygiene. Relative to children who never walk barefoot, children who always walk barefoot had 5-times the risk of CAS in the bivariate analysis; introducing the habit of hand washing in the multivariate analysis, the risk of CAS was 10-times higher, potentially indicating the confounding effect of hand washing. Furthermore, these findings should be interpreted with caution as the number of children who always washed hands with soap after the use of latrine and walked barefoot were few in this study.

Species-specific analysis of intestinal helminthic infections revealed that *T. trichiura* is significantly associated with CAS. This finding was also consistent with the previous findings (De Gier et al., 2016; Shang et al., 2010; Stephenson, Holland & Cooper, 2000). The link between intestinal helminthic infections and CAS could be due in part to the inflammatory reactions to worm infection in the intestinal mucosa, resulting in a loss of appetite, reduced food intake, and impaired iron absorption (Shang et al., 2010; Stephenson, Holland & Cooper, 2000). No significant association was found between CAS and hookworm infections, probably due to low statistical power because the number of children with hookworm infection was low.

The significant effect of head lice infestation on risk of CAS may be associated with low socio-economic status and poor hygiene (*Moosazadeh et al., 2015*). We found lower odds of CAS among children using treated drinking water, suggesting a protective effect against intestinal helminthic infections (*Matangila et al., 2014*; *Strunz et al., 2014*; *Worrell et al., 2016*). Wealth status was also associated with CAS among children (*Mohammed, Larijani & Esmaillzadeh, 2019*), but we found no difference in any of these odds across poor, middle-class, and rich households, findings in agreement with *Alelign, Degarege & Erko (2015)*. There could be other socio-economic factors not investigated in this study.

In this study, neither dietary diversity nor household food security was associated with CAS. The lack of association may be due to similarities in the dietary diversity score and mild food insecurity in the area. A study from Kenya reported that participation in a school meal programme lowers the risk of anemia, and stunting (*Neervoort et al., 2013*). Consistent with the previous finding in southern Ethiopia (*Shaka & Wondimagegne, 2018*), our study did not find a significant difference in the rates of CAS among children participating in a school meal programme and those children who did not participate, although the observed association could be described as borderline significant ($P = 0.08$). Only cereals were served at school; therefore, the food being served to the children at school was deficient in micronutrients and may explain why we failed to detect a significant difference.

The strengths of this study include: we used a large representative sample of schoolchildren and applied a multilevel, mixed-effect model to identify risk factors for CAS. We also reported the risk factors for anemia, and stunting. We diagnosed helminthic infections using two standard techniques, the Kato-Katz and formalin-ether concentration. Data were clustered. Thus, individual within-school and within-class dependencies (similarities) were identified and measured using intra-cluster correlation coefficient.

Our study has some limitations. First, we used a cross-sectional design; thus, causality between the outcome and independent variables cannot be determined with certainty. Second, due to homogeneity issues, most school factors in this study (e.g., sanitation and hygiene facilities at the schools) were not modelled. Third, we did not measure serum ferritin levels to assess iron status, and we did not assess the presence of malaria. Recording dietary information for consecutive days and measuring the quantity of food consumed could have improved the dietary information. Unfortunately, we collected dietary information using only 24-hour dietary recall, and we did not measure the quantity of the food. Further study in the area should assess the micronutrient levels in schoolchildren. Our findings related to food insecurity could also be affected by over- or under-reporting on the HFIAS questions. Over-reporting could arise if responses were related to intentions to get food aid. Under-reporting of the last three HFIAS questions could also occur due to fear of disclosing severe food insecurity related to cultural perceptions (*Kabalo et al., 2019*). The results of hand washing may be affected by self-reported bias. Children who had their head shaved could have been affected by head lice, but we did not observe any with these characteristics during the examination. However, head lice could have been under-estimated. Furthermore, including only children at rural schools may affect the external validity of this study. However, we think that most school-aged children attended school. Thus, the findings can be generalized to rural school-aged children in the same region where culture and living standards are similar.

CONCLUSIONS

Our findings suggest the need for more effective nutrition programmes to tackle CAS among schoolchildren in rural areas of Ethiopia. Interventions that improve hygiene can reduce the morbidity caused by intestinal helminthic infections. Provision of safe drinking water and promotion of treated water could also reduce comorbidities in schoolchildren. School teachers should work with health workers to provide health education about personal hygiene protection. Therefore, individual-, household-, and school-level intervention activities must be integrated to improve the health of schoolchildren.

ACKNOWLEDGEMENTS

We are grateful to the schoolchildren, parents, and guardians who participated in this study. We also thank the data collectors, supervisors, Gedeo Zone Health Department, Wonago District Education Office, school directors, and teachers. We are also grateful to the Ethiopian Public Health Institute for providing the Kato-Katz template. We would like to thank Dilla University Teaching and Referral Hospital for providing us with a laboratory examination room.

ADDITIONAL INFORMATION AND DECLARATIONS

Funding

Norwegian Programme for Capacity Development in Higher Education and Research for Development/South Ethiopia Network of Universities in Public Health (NORHED/SENUPH) project provided funding in the form of a grant awarded to Bernt Lindtjorn (ETH-13/0025). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Grant Disclosures

The following grant information was disclosed by the authors:
Norwegian Programme for Capacity Development in Higher Education and Research.
Development/South Ethiopia Network of Universities in Public Health (NORHED/SENUPH).
Bernt Lindtjorn: ETH-13/0025.

Competing Interests

The authors declare there are no competing interests.

Author Contributions

- Hiwot Hailu Amare and Bernt Lindtjorn conceived and designed the experiments, performed the experiments, analyzed the data, prepared figures and/or tables, authored or reviewed drafts of the paper, analysis tools, and approved the final draft.

Human Ethics

The following information was supplied relating to ethical approvals (i.e., approving body and any reference numbers):

The institutional review board of Hawassa (IRB/005/09) and Regional Ethical Committee of Western Norway (2016/1900/REK vest) provided ethical clearance. The Gedeo Zone Health Department (2/572/110) and District Education Office provided a letter of permission (435/ወ/ወ/አስ/ማ). School directors and teachers participated in discussions. We obtained informed verbal (thumb print), and written (signed) consent from study participants' parents or guardians and permission (assent) from children aged 12 years and older before the interviews. The interviews and measurements were conducted in a private place for each participant. Confidentiality of the participant's information was maintained. Children diagnosed as anemic and who tested positive for intestinal helminthic infections were referred to the nearest health institution for treatment according to standard guidelines (*Drug Administration and Control Authority, DACA)of Ethiopia(2010*).

Field Study Permissions

The following information was supplied relating to field study approvals (i.e., approving body and any reference numbers):

The Gedeo Zone Health Department (2/572/110) and District Education Office (435/ወ/ወ/አስ/ማ) provided letters of permission.

Data Availability

The following information was supplied regarding data availability:

Data are available in the Supplemental Files.

Supplemental Information

Supplemental information for this article can be found online at http://dx.doi.org/10.7717/peerj.11158#supplemental-information.

REFERENCES

Alelign T, Degarege A, Erko B. 2015. Prevalence and factors associated with undernutrition and anaemia among schoolchildren in Durbete Town, northwest Ethiopia. *Archives of Public Health* **73(1)**:Article 34 DOI 10.1186/s13690-015-0084-x.

Ali J, Yifru S, Woldeamanuel Y. 2009. Prevalence of tinea capitis and the causative agent among schoolchildren in Gondar, North West Ethiopia. *Ethiopian Medical Journal* **47(4)**:261–269.

Assefa S, Mossie A, Hamza L. 2014. Prevalence and severity of anemia among school children in Jimma Town, Southwest Ethiopia. *BMC Hematology* **14(1)**:3 DOI 10.1186/2052-1839-14-3.

Bogale TY, Bala ET, Tadesse M, Asamoah BO. 2018. Prevalence and associated factors for stunting among 6-12 years old school age children from rural community of Humbo district, Southern Ethiopia. *BMC Public Health* **18(1)**:653 DOI 10.1186/s12889-018-5561-z.

Bourke CD, Berkley JA, Prendergast AJ. 2016. Immune dysfunction as a cause and consequence of malnutrition. *Trends in Immunology* **37(6)**:386–398 DOI 10.1016/j.it.2016.04.003.

Chaparro CM, Suchdev PS. 2019. Anemia epidemiology, pathophysiology, and etiology in low- and middle-income countries. *Annals of the New York Academy of Sciences* **1450(1)**:15–31 DOI 10.1111/nyas.14092.

Coates J, Swindale A, Bilinsky P. 2007. Household Food Insecurity Access Scale (HFIAS) for Measurement of Household Food Access: indicator guide (v.3). Washington, D.C.: Food and Nutrition Technical Assistance Project, Academy for Educational Development.

Daniel WW. 1999. *Biostatistics: a foundations for analysis in the health sciences.* New York: John Wiley & Sons, Ltd.

De Benoist B, Cogswell M, Egli I, McLean E. 2008. *Worldwide prevalence of anaemia 1993-2005; WHO global database of anaemia.* Geneva: World Health Organization.

De Gier B, Nga TT, Winichagoon P, Dijkhuizen MA, Khan NC, Van de Bor M, Ponce MC, Polman K, Wieringa FT. 2016. Species-specific associations between soil-transmitted helminths and micronutrients in Vietnamese schoolchildren. *American Journal of Tropical Medicine and Hygiene* **95(1)**:77–82 DOI 10.4269/ajtmh.15-0533.

De Onis M, Borghi E, Arimond M, Webb P, Croft T, Saha K, De-Regil LM, Thuita F, Heidkamp R, Krasevec J, Hayashi C, Flores-Ayala R. 2019. Prevalence thresholds for wasting, overweight and stunting in children under 5 years. *Public Health Nutrition* **22(1)**:175–179 DOI 10.1017/S1368980018002434.

De Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. 2007. Development of a WHO growth reference for school-aged children and adolescents. *Bulletin of the World Health Organization* **85(9)**:660–667 DOI 10.2471/blt.07.043497.

Drug Administration and Control Authority (DACA) of Ethiopia. 2010. Standard treatment guideline for health centers. Addis Ababa, Ethiopia: The Drug Administration and Control Authority (DACA) of Ethiopia.

Ethiopian Public Health Institute. 2016. Ethiopian national micronutrient survey report. Addis Ababa, Ethiopia: Ministry of Health.

Federal Democratic Republic of Ethiopia Ministry of Education. 2012. National school health and nutrition strategy. Addis Ababa, Ethiopia.

Federal Ministry of Education. 2015. Education Sector Development Programme V (ESDP V) 2015/16-2019/20: programme action plan. Addis Ababa, Ethiopia.

Federal Democratic Republic of Ethiopia Ministry of Education. 2017. National school water supply, sanitation and hygiene (SWASH) strategy and implementation action plan.

Gebreyesus SH, Lunde T, Mariam DH, Woldehanna T, Lindtjørn B. 2015. Is the adapted Household Food Insecurity Access Scale (HFIAS) developed internationally to measure food insecurity valid in urban and rural households of Ethiopia? *BMC Nutrition* **1**:2.

Getaneh Z, Enawgaw B, Engidaye G, Seyoum M, Berhane M, Abebe Z, Asrie F, Melku M. 2017. Prevalence of anemia and associated factors among schoolchildren in

Gondar town public primary schools, northwest Ethiopia: a school-based cross-sectional study. *PLOS ONE* **12(12)**:e0190151 DOI 10.1371/journal.pone.0190151.

Gosdin L, Martorell R, Bartolini RM, Mehta R, Srikantiah S, Young MF. 2018. The co-occurrence of anaemia and stunting in young children. *Maternal & Child Nutrition* **14(3)**:e12597 DOI 10.1111/mcn.12597.

Grimes JET, Tadesse G, Gardiner IA, Yard E, Wuletaw Y, Templeton MR, Harrison WE, Drake LJ. 2017. Sanitation, hookworm, anemia, stunting, and wasting in primary schoolchildren in southern Ethiopia: baseline results from a study in 30 schools. *PLOS Neglected Tropical Diseases* **11(10)**:e0005948 DOI 10.1371/journal.pntd.0005948.

Gupta A. 2017. *Nutritional anemia in preschool children*. Singapore: Springer Nature, Pte Ltd.

Gutema B, Adissu W, Asress Y, Gedefaw L. 2014. Anemia and associated factors among school-age children in Filtu Town, Somali region, Southeast Ethiopia. *BMC Hematology* **14(1)**:13 DOI 10.1186/2052-1839-14-13.

Haftu D, Deyessa N, Agedew E. 2014. Prevalence and determinant factors of intestinal parasites among schoolchildren in Arba Minch town, Southern Ethiopia. *American Journal of Health Research* **2(5)**:247–254 DOI 10.11648/j.ajhr.20140205.15.

Hailu Amare H, Lindtjørn B. 2020. Helminth infections among rural schoolchildren in Southern Ethiopia: a cross-sectional multilevel and zero-inflated regression model. *PLOS Neglected Tropical Diseases* **14(12)**:e0008002 DOI 10.1371/journal.pntd.0008002.

Federal Democratic Republic of Ethiopia Ministry of Health. 2017. School Health Programme Framework. Addis Ababa, Ethiopia.

International Food Policy Research Institute. 2015. Global nutrition report: actions and accountability to advance nutrition and sustainable development. Washington, D.C.: International Food Policy Research Institute.

Kabalo BY, Gebreyesus SH, Loha E, Lindtjørn B. 2019. Performance of an adapted household food insecurity access scale in measuring seasonality in household food insecurity in rural Ethiopia: a cohort analysis. *BMC Nutrition* **5(1)**:54 DOI 10.1186/s40795-019-0323-6.

Kakietek J, Eberwein JD, Walters D, Shekar M. 2017. *Unleashing gains in economic productivity with investments in nutrition*. Washington, D.C.: World Bank Group.

Kassebaum NJ, Jasrasaria R, Naghavi M, Wulf SK, Johns N, Lozano R, Regan M, Weatherall D, Chou DP, Eisele TP, Flaxman SR, Pullan RL, Brooker SJ, Murray CJL. 2014. A systematic analysis of global anemia burden from 1990 to 2010. *Blood* **123(5)**:615–624 DOI 10.1182/blood-2013-06-508325.

Kennedy G, Ballard T, Dop M. 2011. Guidelines for measuring household and individual dietary diversity. Nutrition and Consumer Protection Division, Food and Agriculture Organization of the United Nations. Rome, Italy: FAO.

Koo TK, Li MY. 2016. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *Journal of Chiropractic Medicine* **15(2)**:155–163 DOI 10.1016/j.jcm.2016.02.012.

Mahmud MA, Spigt M, Bezabih AM, Pavon IL, Dinant G-J, Velasco RB. 2015. Efficacy of handwashing with soap and nail clipping on intestinal parasitic infections in school-aged children: a factorial cluster randomized controlled trial. *PLOS Medicine* **12(6)**:e1001837–e1001837 DOI 10.1371/journal.pmed.1001837.

Matangila JR, Doua JY, Linsuke S, Madinga J, Inocêncio da Luz R, Van Geertruyden J-P, Lutumba P. 2014. Malaria, schistosomiasis and soil transmitted helminth burden and their correlation with anemia in children attending primary schools in Kinshasa, Democratic Republic of Congo. *PLOS ONE* **9(11)**:e110789–e110789 DOI 10.1371/journal.pone.0110789.

McHugh ML. 2012. Interrater reliability: The kappa statistic. *Biochemia Medica* **22(3)**:276–282.

Mekonnen H, Tadesse T, Kisi K. 2013. Malnutrition and its correlates among rural primary schoolchildren of Fogera District, Northwest Ethiopia. *Journal Nutritional Disorders & Therapy* **S12**:002 DOI 10.4172/2161-0509.S12-002.

Merlo J, Wagner P, Ghith N, Leckie G. 2016. An original stepwise multilevel logistic regression analysis of discriminatory accuracy: the case of neighbourhoods and health. *PLOS ONE* **11(4)**:e0153778 DOI 10.1371/journal.pone.0153778.

Mesfin F, Berhane Y, Worku A. 2015. Anemia among primary schoolchildren in Eastern Ethiopia. *PLOS ONE* **10(4)**:e0123615 DOI 10.1371/journal.pone.0123615.

Mohammed SH, Larijani B, Esmaillzadeh A. 2019. Concurrent anemia and stunting in young children: prevalence, dietary and non-dietary associated factors. *Nutrition Journal* **18(1)**:Article 10 DOI 10.1186/s12937-019-0436-4.

Montresor A, Crompton DWT, Hall A, Bundy DAP, Savioli L. 1998. *Guidelines for the evaluation of soil-transmitted helminthiasis and schistosomiasis at community level: a guide for managers of control programmes.* Geneva: World Health Organization.

Moosazadeh M, Afshari M, Keianian H, Nezammahalleh A, Enayati AA. 2015. Prevalence of head lice infestation and its associated factors among primary school students in Iran: a systematic review and meta-analysis. *Osong Public Health and Research Perspectives* **6(6)**:346–356 DOI 10.1016/j.phrp.2015.10.011.

Neervoort F, Von Rosenstiel I, Bongers K, Demetriades M, Shacola M, Wolffers I. 2013. Effect of a school feeding programme on nutritional status and anaemia in an urban slum: a preliminary evaluation in Kenya. *Journal of Tropical Pediatrics* **59(3)**:165–174 DOI 10.1093/tropej/fms070.

Shaka MF, Wondimagegne YA. 2018. Anemia, a moderate public health concern among adolescents in South Ethiopia. *PLOS ONE* **13(7)**:e0191467 DOI 10.1371/journal.pone.0191467.

Shang Y, Tang L-H, Zhou S-S, Chen Y-D, Yang Y-C, Lin S-X. 2010. Stunting and soil-transmitted helminth infections among school-age pupils in rural areas of southern China. *Parasites & Vectors* **3**:Article 97 DOI 10.1186/1756-3305-3-97.

Soliman A, De Sanctis V, Elalaily R. 2014. Nutrition and pubertal development. *Indian Journal of Endocrinology and Metabolism* **18(Suppl 1)**:S39–S47 DOI 10.4103/2230-8210.145073.

Stephenson LS, Holland CV, Cooper ES. 2000. The public health significance of Trichuris trichiura. *Parasitology* **121 Suppl**:S73–S95 DOI 10.1017/s0031182000006867.

Strunz EC, Addiss DG, Stocks ME, Ogden S, Utzinger J, Freeman MC. 2014. Water, sanitation, hygiene, and soil-transmitted helminth infection: a systematic review and meta-analysis. *PLOS Medicine* **11(3)**:e1001620–e1001620 DOI 10.1371/journal.pmed.1001620.

Sullivan KM, Dean A, Soe MM. 2009. OpenEpi: a web-based epidemiologic and statistical calculator for public health. *Public Health Reports* **124(3)**:471–474 DOI 10.1177/003335490912400320.

Swindale A, Bilinsky . 2006. Household Dietary Diversity Score (HDDS) for measurment of household food access: indicator guide (v.2). Washington, D.C.: FHI 360/FANTA.

Tariku EZ, Abebe GA, Melketsedik ZA, Gutema BT. 2018. Prevalence and factors associated with stunting and thinness among school-age children in Arba Minch Health and Demographic Surveillance Site, Southern Ethiopia. *PLOS ONE* **13(11)**:e0206659 DOI 10.1371/journal.pone.0206659.

Twisk JWR. 2006. Applied multilevel analysis. In: *A practical guides to biostatistics and epidemiology*. Cambridge: Cambridge University Press.

Vyas S, Kumaranayake L. 2006. Constructing socio-economic status indices: how to use principal components analysis. *Health Policy and Planning* **21(6)**:459–468 DOI 10.1093/heapol/czl029.

World Health Organization (WHO). 1991. Basic laboratory methods in medical parasitology. Geneva: World Health Organization.

World Health Organization (WHO). 2009. Software for assessing growth of the world's children and adolescents. Geneva: WHO.

World Health Organization (WHO). 2011. Haemoglobin concentrations for the diagnosis of anaemia and assessment of severity. Vitamin and mineral nutrition information system. Geneva: World Health Organization.

Worrell CM, Wiegand RE, Davis SM, Odero KO, Blackstock A, Cuéllar VM, Njenga SM, Montgomery JM, Roy SL, Fox LM. 2016. A cross-sectional study of water, sanitation, and hygiene-related risk factors for soil-transmitted helminth infection in urban school, and preschool-aged children in Kibera, Nairobi. *PLOS ONE* **11(3)**:e0150744–e0150744 DOI 10.1371/journal.pone.0150744.

Paper-II

RESEARCH ARTICLE

Helminth infections among rural schoolchildren in Southern Ethiopia: A cross-sectional multilevel and zero-inflated regression model

Hiwot Hailu Amare[1,2,3]*, **Bernt Lindtjørn**[1,2]

1 School of Public Health, College of Medicine and Health Sciences, Hawassa University, Hawassa, Ethiopia, **2** Centre for International Health, University of Bergen, Bergen, Norway, **3** Department of Public Health, College of Health Sciences and Medicine, Dilla University, Dilla, Ethiopia

* hiwothailu14@yahoo.com

Abstract

Although the prevalence of helminths infection among schoolchildren is known, there has been little progress in the application of count model for modelling the risk factors of helminths egg. Only a few studies applied multilevel analysis to explore the variation in helminths prevalence across schools and classes. This study aimed to assess the prevalence, intensity of helminths infection, and identify risk factors at the individual-, household-, and school-level among schoolchildren in Southern Ethiopia. Using multistage random sampling, we recruited 864 students in the Wonago District. We applied multilevel-logistic and zero-inflated negative binomial regression models (ZINB). Risk factors were concentrated at the individual level; school-level and class-level variables explained less than 5% of the variance. The overall helminths prevalence was 56% (479/850); *Trichuris trichiura* prevalence was 42.4% (360/850); and *Ascaris lumbricoides* prevalence was 18.7% (159/850). The rate of any helminths increased among thin children (AOR: 1.73 [95% CI: (1.04, 2.90]), anemic (AOR: 1.45 [95% CI: 1.04, 2.03]), mothers who had no formal education (AOR: 2.08 [95% CI: 1.25, 3.47]), and those in households using open containers for water storage (AOR: 2.06 [95% CI: 1.07, 3.99]). In the ZINB model, *A. lumbricoides* infection intensity increased with increasing age (AOR: 1.08 [95% CI: 1.01, 1.16]) and unclean fingernails (AOR: 1.47 [95% CI: 1.07, 2.03]). Handwashing with soap (AOR: 0.68 [95% CI: 0.48, 0.95]), de-worming treatment [AOR: 0.57 (95% CI: 0.33, 0.98)], and using water from protected sources [AOR: 0.46 (95% CI: 0.28, 0.77)] were found to be protective against helminths infection. After controlling for clustering effects at the school and class levels and accounting for excess zeros in fecal egg counts, we found an association between helminths infection and the following variables: age, thinness, anemia, unclean fingernails, handwashing, de-worming treatment, mother's education, household water source, and water storage protection. Improving hygiene behavior, providing safe water at school and home, and strengthening de-worming programs is required to improve the health of schoolchildren in rural Gedeo.

Check for updates

OPEN ACCESS

Citation: Hailu Amare H, Lindtjørn B (2020) Helminth infections among rural schoolchildren in Southern Ethiopia: A cross-sectional multilevel and zero-inflated regression model. PLoS Negl Trop Dis 14(12): e0008002. https://doi.org/10.1371/journal.pntd.0008002

Editor: De'Broski R. Herbert, University of Pennsylvania School of Veterinary Medicine, UNITED STATES

Received: December 13, 2019

Accepted: October 20, 2020

Published: December 22, 2020

Data Availability Statement: All relevant data are within the manuscript and its Supporting Information files.

Funding: Norwegian Programme for Capacity Development in Higher Education and Research for Development/ South Ethiopia Network of Universities in Public Health (NORHED/SENUPH) project provided funding in the form of a grant awarded to BL (ETH-13/0025). URL: https://www.uib.no/en. The sponsors or funders have no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Competing interests: The authors have declared that no competing interests exist.

Author summary

Helminth infections are common among school-aged children in Ethiopia. Several cross-sectional studies have investigated the risk factors of these helminths infection. However, most were conducted in an urban setting in Northern Ethiopia. Many of these studies did not report the intensity of helminth infections; and they restricted helminths infection data to binary outcomes. There has been limited report related to zero-inflated model for helminths count data with excess zeros and over-dispersion. Multilevel analysis for nested structure of school data has also been rarely applied. Therefore, we aimed to assess the prevalence and intensity of helminths infection and the related individual-, household-, and school-level risk factors among rural schoolchildren in Southern Ethiopia. Using count model, we modelled the risk factors of helminths egg. Using a multivariate, multi-level, mixed-effect, logistic regression model, we found minimal variation across class- and school-level factors for helminths infection prevalence. We found associations between helminths infection and most individual-, and some household-level factors. Therefore, interventions focusing on the individual, household, and school should be implemented to reduce the prevalence of infection and worm load among schoolchildren.

Introduction

More than 1.5 billion people around the world are infected by soil-transmitted helminths (STHs), including over 568 million schoolchildren who are at risk [1]. In 2015, an approximately 88 million individuals, including 28 million school-aged children, were at risk for STH infections in Ethiopia [2]. Roundworm (*Ascaris lumbricoides)*, whipworm (*Trichuris trichiura*), and hookworm (*Ancylostoma duodenale* and *Necator americanus*) are the most common STH infections that chronically infect children [3]. There were an estimated 5.19 million disability adjusted life years (DALYs) attributable to these infections [4]. The health burdens of STH infections is mainly attributed to their chronic and insidious impact on the health and quality of life because morbidity is considerably high in heavy infection intensity rather than the absence or presence of infection [3, 5, 6]. Loss of appetite, malabsorption, anemia, impaired children's nutrition, poor physical and intellectual development, and impaired cognitive function can occur with these infections [6, 7]. Some of the risk factors of these infections include poverty [8], mothers' education, untrimmed fingernails, walking barefoot, unsanitary toilet areas, not washing hands before eating or after visiting the toilet, eating raw or undercooked vegetables or meat, lack of hygiene facilities, and drinking water from unsafe sources [5, 9]. In developing countries, control measures can be difficult to implement due to water and sanitation problems [10].

In Ethiopia, the prevalence of helminths infection among schoolchildren ranges between 18% and 63% [8, 11–17], with the highest rate of infection (63%) recorded in the Southern region [17]. The government of Ethiopia is expanding schooling to make education more relevant to all children and meet their nutritional and health needs [18]. This strategy includes facilitating and implementing a de-worming service every six months and improving water, hygiene, and sanitation facilities [19]. However, many school-aged children continue to be affected by helminthic infections [20–22]. Moreover, most schools have no handwashing facilities, and hygienic behavior is inadequate [23]. Evidence of open defecation is observed in 53% of schools in Southern Ethiopia [24].

Previous studies from Ethiopia are mainly from urban areas in Northern Ethiopia [8, 11–17]. Only a few studies have assessed the prevalence and intensity of helminths infection among schoolchildren in Southern Ethiopia [12, 17, 24], and even fewer from rural areas. Many of previous studies did not report the risk factors of helminths intensity; most interpreted the helminths infection data in terms of binary outcomes. Despite various studies on helminths infection prevalence, there has been little progress in the application of count model for modelling the risk factors of helminths egg concentration in the stool specimen. However, the data related with helminthic egg counts are usually over-dispersed and zero-inflated [25]. Interpretation of such data can be problematic, as these data require the use of specific statistical models during the analysis process. To the best of our knowledge, no study has considered the two generating process for excess zeros and over-dispersion in the distribution of helminths egg count among schoolchildren in Ethiopia. Furthermore, most previous studies did not considered the nested structure of school data (i.e., individuals nested within the same class and classes nested within the same school) in their analysis. This paper is part of a larger study, which aimed to identify school health problems such as anemia, and stunting co-existence and helminth infections and skin problems and the risk factors associated with these problems in the Gedeo area in Southern Ethiopia. Therefore, this paper aimed to report the prevalence and intensity of helminths infection and identifies potential risk factors at the individual-, household-, and school-level among rural schoolchildren in the Wonago district of Southern Ethiopia. Using a multivariate, multilevel, regression model, we identified factors contributing to variations in the prevalence of helminths infection in this population. We also identified factors related with helminths egg intensity using zero-inflated count model.

Methods

Ethics statement

The institutional review board at the College of Medicine and Health Sciences of Hawassa University (IRB/005/09) and the Regional Ethical Committee of Western Norway (2016/1900/REK vest) provided ethical clearance. The Gedeo Zone Health Department and District Education Office provided a letter of permission. School directors and teachers participated in discussions. We obtained informed written (signed) and verbal (thumb print) consent from study participants' parents or guardians and permission (assent) from children aged 12 years and older before the interviews. The participants' privacy and confidentiality were maintained. Children diagnosed as anemic and who tested positive for helminths infections were referred to the nearest health institution for treatment according to the standard national guidelines [26].

Study area, design, and participants

The study was conducted in the Wonago district of the Gedeo zone in the Southern Ethiopia. The district is 377 km south of Addis Ababa, the capital city of Ethiopia, and 13 km South of Dilla, the capital city of the Gedeo zone. The district has 17 rural and 4 urban *kebeles*, which is the smallest administrative units. In 2014, Wonago's population was estimated to be 143,989 people: 71,663 (49.8%) men and 72,326 (50.2%) women. The district is among the most densely populated areas in Ethiopia, with 1,014 people per square kilometre of land area. The district has 26 government health facilities (6 health centers and 20 health posts), 2 private clinics, and 2 drug stores, and more than 36,000 students in 3 urban and 22 rural primary schools. Most residents depend on cash crops of coffee, fruit, and *ensete* (*Ensete ventricosum)*.

We conducted this cross-sectional survey from February 2017 to June 2017. The study population was schoolchildren and their parents or guardians. Students aged 7–14 years were

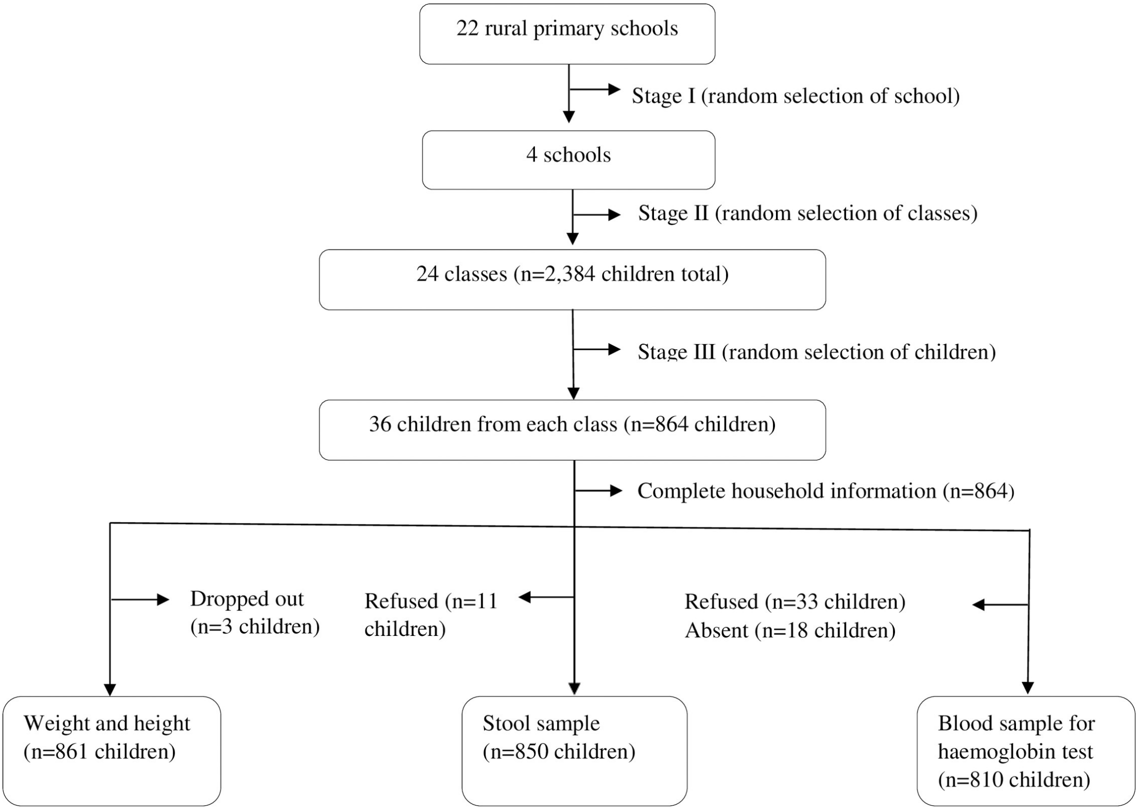

Fig 1. Flowchart of study inclusion.

https://doi.org/10.1371/journal.pntd.0008002.g001

recruited in schools and their parents or guardian contacted by visiting their homes. Using a three-stage cluster sampling method, we randomly assigned 4 schools to level one, 24 classes (comprising 2,384) to level two, and 864 students to level three. We then randomly included 36 children from each class. When more than one child in a class was living together in the same household, one of them was selected randomly by a lottery method. The household of the student's parents or guardian was identified through a local guide. The study participants' parents or guardians consented and children assented before enrolment. We replaced participants who dropped out of school after the selection process with participants of the same class, sex, and age. The recruitment process is shown in Fig 1.

Sample size

Since this study was part of a large project aiming to identify school health problems, we considered multiple factors to calculate the sample size using OpenEpi software [27] based on single population proportion [28]. Assuming a 95% confidence interval (CI), the maximum sample size was calculated using proportions of different variables from previous studies (e.g., anemia [27%], stunting [30%], thinness [37%], helminths infection [27%], and skin infection [50%]), 5% precision, and a design effect of 2 to account for multistage sampling [12, 29–32]. We also calculated the sample size using outcome-associated variables, such as under-nutrition (32% prevalence of stunting among female participants), and helminths infection (50% among children who did not wash their hands before meals) [12, 29–32]. Finally, we obtained the maximum sample size using 50% of helminths infection among children who did not wash their hands before meals, and 50% of skin infection. The reason that we included skin infection in the sample size calculation was that this problem was one of our studies planned for a subsequent paper. After adding a 10% non-response rate, we reached a final sample size of 845, the minimum required sample size. We then randomly recruited 864 students.

Data collection tools and procedures

Ten trained enumerators conducted the interviews using a pretested, structured questionnaire that was adapted and developed in English and then translated into the local *Gedeooffa* language. The interviews were done with children at their schools and with parent at their homes. Training was provided for all personnel participated in data collection, supervision, and data entry process. To minimize potential bias and validate the measurement tools prior to actual data collection, a pre-test was conducted on 42 primary school-aged children in other schools not selected for this study. The supervisors checked data for completeness and consistency onsite.

We assessed individual, parent, household, and school level exposure variables. Individual and household factors were collected from the child or the child's parents or guardians via interviews and observations of the housing conditions. The individual child factors included sex, age, hygiene behavior, loss of appetite in the past month, de-worming treatment in the past 6 months. Measurements such as weight, height, and haemoglobin were done for children in the school. To measure weight, a digital portable scale (Seca 877, Seca GmbH, Germany) was calibrated to the nearest 0.1 kg. Children were weighed in light clothing and no shoes. To measure height, a measuring board (Seca 213, Seca GmbH, Germany) was calibrated to the nearest 0.1 cm. Children were measured while standing barefoot with parallel feet, heels, buttocks, and shoulders, with their heads held upright, the backs of their heads touching the measuring board, and their hands hanging by their sides. Capillary blood samples were taken for haemoglobin measurement, processed, and examined using standard procedures by trained and experienced laboratory technicians using a HemoCue Analyser Hb 301 (Angelholm, Sweden). Parent factors included the educational level of the mother and father. Household factors included the wealth index, which was constructed using principal component analysis of 14 household assets (electricity, radio, television, mobile phone, table, chair, bed, separate kitchen, cooking place, own land, bank account, toilet facility, floor type, and roof type); family size; source of drinking water; container used to store water; and use of treated water. School factors included access to health education on personal hygiene, absence from school in the past month, and participation in the school food program.

Laboratory procedures

Stool samples were collected, processed, and examined using standard procedures [33, 34]. Samples were collected at school in the early morning and stored in stool cups labelled with an identification code, name, sex, age, and date. The specimens were transported in a cold-box with frozen ice-packs to the nearest health facility, Dilla University Teaching and Referral Hospital, where Kato-Katz and formalin-ether concentration (FEC) techniques were used to conduct stool tests. Single, 41.7-mg thick, Kato-Katz smears were prepared from each stool sample on the same day of specimen collection. Then, 1 g of stool was preserved in 10% formalin solution and processed using the FEC technique [35]. All Kato-Katz slides were examined within one hour of preparation to minimize the risk of hookworm egg disappearance, and then the reading of slides were re-performed to detect and count egg of other helminth infections. The slides were examined by three experienced laboratory technicians. The result of each helminths species from two diagnostic techniques was recorded separately. To reduce possible bias introduced during outcome measurement, 10% of 850 of the test results of Kato-Katz and FEC were randomly selected and re-examined in a blinded fashion to ensure reproducibility of the results. To ensure accuracy of helminth results, the quality control was performed based on World Health Organization (WHO) guideline [36]. According to WHO guideline, re-reading is required if the expert identifies a difference in the egg count of more than 10% and more than four eggs between the readings and discuss the reasons for the discrepancy [36]. However, in the WHO guideline, there is no clear information how to handle differences in presence or absence of helminth eggs [37]. Therefore, we compared the helminths egg count of initial reading with second quality control reading. According to WHO guideline, when the difference in helminths egg count exceed four eggs, re-reading of slides was performed by the third senior laboratory technician. In case of a discordant results between the initial reading and re-reading were confirmed by the third senior laboratory technician. However, the WHO quality control guideline is mainly for quantitative diagnostic methods such as Kato-Katz method, there is no guideline for judging discrepancy of faecal egg counts obtained by the FEC semi-quantitative method for quality control. Hence, we performed the quality control for the FEC method based on the presence or absence of helminth eggs. For the FEC method, a discordant result was considered when there is difference in the presence or absence helminths egg from initial reading to the quality control reading. Results were classified as false-positive if the original result was positive for a specific helminths infection, but the results from the second reading, as well as from the third reading, were negative. Results were classified as false-negative if the original result was negative, but the quality control as well as the result from the third reading, were positive.

Statistical analysis

The data were entered into a database using the double-entry system in Epi-data version 3.1 (EpiData Association; Odense Denmark, 2004). Inconsistencies were cleaned and missing values addressed before analysis. After validation, the data were exported to SPSS version 20 (IBM Corp, 2011) and STATA 14 software (StataCorp LP, College Station, TX, 2015) for analysis.

Descriptive statistics including frequency, percentage, mean, median, range, interquartile range (IQR), and standard deviation (SD) were calculated to describe relevant variables. Cross tabulation was used to calculate the proportions of categorical variables in relation to outcome variables for any helminths infection, for *T*. *trichiura* infection, and for *A*. *lumbricoides* infection. A wealth index was constructed by using principal component analysis [38] to code the previously listed 14 household assets as 0 (absent) or 1 (present). The internal consistency of the 14 variables was determined (Cronbach alpha of 0.78 and Kaiser-Meyer-Olkin sampling adequacy of 0.8). The socioeconomic indictors (poor, middle, and rich) were categorized based on the first component explaining 28.3% of the variance in the data with an Eigen value of 4.1. We used WHO AnthroPlus 1.0.4 software to calculate height-for-age, weight-for-age, and body mass index-for-age Z scores according to the standard reference for children aged 5–19 year [39]. Stunting was defined as height-for-age Z scores $<$ -2 SD, and thinness was defined as body-mass-index-for-age Z scores $<$ -2 SD [40]. Anaemia was recorded according to the WHO guidelines for school-aged children: haemoglobin < 11.5 g/dl for those aged 5–11 years and < 12 g/dl for those aged 12–14 years. Anaemia was estimated using the haemoglobin value adjusted for altitude [41].

Kappa statistics were used to estimate reliability of the inter-rater agreement of the two readers using 10% of the test results in either Kato-Katz or FEC method. Kappa values were defined as follows: poor = 0.01–0.2; fair = 0.21–0.4; moderate = 0.41–0.6; good = 0.61–0.8; and perfect = 0.81–1 [42]. Kappa values were considered statistically at $P < 0.05$.

We used a multivariate, multilevel, mixed-effect, logistic regression model to analyze three separate binary outcome variables: the presence or absence of any helminth infections, the presence or absence of *T*. *trichiura*, and the presence or absence of *A*. *lumbricoides*. Any helminth infections in this study includes (*T*. *trichiura*, *A*. *lumbricoides*, *Taenia* species, hookworm species, *Strongyloides stercoralis*, and *Hymenolepis nana*). In addition, the eggs detected per Kato-Katz slide (41.7 mg of faeces) was multiplied by a factor 24 to obtain a standard measure of eggs per gram (epg) of stool [43]. The epg was then used as a proxy for estimation of helminths infection intensity. Infection intensity was defined as light ($<$ 5,000 epg for *A*. *lumbricoides;* $<$ 1,000 epg for *T*. *trichiura;* and $<$ 2,000 epg for hookworm) or moderate ($\geq$ 5,000 epg for *A*. *lumbricoides*; $\geq$ 1,000 epg for *T*. *trichiura*; and $\geq$ 2,000 epg for hookworm) [44]. Two separate count models also were constructed for the *T*. *trichiura* and *A*. *lumbricoides* fecal egg counts. Thus, using a zero-inflated negative binomial (ZINB) regression model, we performed two part model; the first part has an interpretation as binary outcome model and the second part as a count model. The association between the over-dispersed count outcome with excess zeros and the potential predictors of *T*. *trichiura* and *A*. *lumbricoides* infection was determined using a ZINB regression model [25].

Multilevel, mixed-effect, logistic regression for modelling infection risk

We used three data hierarchies: school-level, class-level, and individual-level (child or parent). Student participants were clustered within the same class, and classes were nested within schools. We included school and class levels during the analysis and assessed potential confounding and effect modifications using a multivariate, multilevel, mixed-effect, logistic regression model and stratified analysis. Prior to the multivariate regression, we checked the collinearity among exposure variables. We used the presence and absence of any helminths, of *T*. *trichiura* infection, and of *A*. *lumbricoides* infection as separate outcome variables and conducted the analysis using a multilevel logistic regression model. For all predictors, we applied a simple, bivariate, logistic regression without considering random effects, and a multilevel, logistic regression model with random school and class effects. We also estimated the intracluster correlation coefficient for each model within school and class.

Five models were constructed for each outcome variable (any helminths or *T*. *trichiura*, or *A*. *lumbricoides* infection). Model 1 (empty) had no covariate indicating whether to consider the random-effect model. Model II contained the individual child factors. Model III contained the individual child and individual parent factors. Model IV contained household, individual child, and parent factors. Finally, Model V used multilevel, multivariate, logistic regression to assess individual, household, and school factors. Exposure variables with P values $< .25$ in the bivariate multilevel logistic regression model were introduced into the model II, model III and model IV.

Variables in model V for any helminths included individual child factors (sex, age, loss of appetite in past month, nail trimming, handwashing with soap before meals, thinness, and anemia), individual parent factors (mother's educational status), household factors (wealth, source of drinking water, container used to store water, treated water), and school factors (participation in school feeding program). Covariate variables (e.g., sex, age, nail trimming, handwashing with soap before meals, wealth, source of drinking water, using treated water, and participation in a school feeding program) with P values $>.25$ in the bivariate regression model were retained in the final model to control for confounding.

Variables in model V for *T*. *trichiura* infection included individual child factors (sex, age, loss of appetite in past month, eating uncooked vegetable, thinness, and anemia), individual parent factors (mother's educational status), household factors (wealth, family size, and container used to store water), and school factors (participation in school feeding program). Covariate variables (e.g., sex, age, and wealth) with P values $>.25$ in the bivariate regression model were retained in the final model to control for confounding.

Variables in model V for *A*. *lumbricoides* infection included individual child factors (sex, age, nail trimming, dirt in fingernail, loss of appetite in past month, handwashing with soap after using latrine, de-worming treatment in past 6 months, and anemia), individual parent factors (mother's educational status), household factors (wealth and source of drinking water), and school factors (participation in school feeding program). Covariate variables (e.g., sex, nail trimming, and wealth) with P values $>.25$ in the bivariate regression model were retained in the final model to control for confounding.

Zero-inflated negative binomial regression for modelling infection intensity

To examine potential factors associated with infection intensity, a count model was applied using the fecal egg counts for *T*. *trichiura* and *A*. *lumbricoides* infections. A Poisson model was appropriate for count data, but the assumption of equal variance and mean did not fit to our data, because the mean of *A*. *lumbricoides* and *T*. *trichiura* eggs was higher than the variance. We have evidence of over-dispersion for *T*. *trichiura A*. *lumbricoides* egg counts. Moreover, zero fecal egg counts for these two infections were more than expected if a Poisson distribution was used [45]. Furthermore, excess number of zeros in our data exceeded those expected under a standard negative-binomial (NB) distribution [45]. Thus, one-part models tend to underestimate the frequencies of zeros and to bias estimation of the covariate effect size [46]. The Vuong test favors ZINB over NB for *T*. *trichiura* (Z = 17.5; $P < .001$), and for *A*. *lumbricoides* (Z = 9.4; $P < .001$) eggs count model, indicating the presence of excess zeroes to be accounted. We thus choose ZINB as the best fitting model. The ZINB model is a two-part model that models an over-dispersed count outcomes with inflated zeros [47, 48]. The ZINB model assumes that the excess zero counts come from a logit model and the counts from a negative binomial model [49]. In other words, the excess zeros in *T*. *trichiura* and *A*. *lumbricoides* egg count among participants were generated from two separate process. The first process produced only zero counts, corresponds to participants that are free of *T*. *trichiura* and *A*. *lumbricoides* egg, zero counts for these group of participants considered as true zeros. The second process consisted of participants where *T*. *trichiura* and *A*. *lumbricoides* egg is actually present but not reported due to sampling zeros or diagnostic technique, zero counts for these group of participants considered as false zeros.

Measure of effect and model fitness

Results were calculated as crude odds ratios and adjusted odds ratios with a 95% CI. Predictors with P values $< .05$ in the final multilevel, multivariate regression model were reported as statistically significant. The Vuong test was used to compare the ZINB model with a standard negative binomial model and a likelihood ratio test to compare ZINB with a zero-inflated Poisson (ZIP) regression model. The Vuong and likelihood ratio tests with $P < .05$ favored the ZINB model [46]. Model fitness was checked using -2 log likelihood (deviance) and Akaike information criterion (AIC). The model with the lowest deviance and AIC was used as the final model [46, 50].

Result

The mean age of the 861 schoolchildren (483 boys and 378 girls) was 11.4 (95% CI: 11.3–11.5) years, ranging from 7 to 14 years. The majority (89.2%; 768) of children lived with their biological parents. About 88.4% (761/861) of mothers and 48.8% (420/861) of fathers never attended school. More than half of the mothers (54.0%; 463) were housewives, and most (77.4%; 619) fathers were farmers. Among heads of households, 91.4% (787/861) were men, and 8.6% (74/861) were women. Family size ranged from 3 to 14 (mean 6.7). Among the participants, 33.3% (287) lived in poor households (S1 Table). About 32% (278/861, 95% CI: 29.2–35.4) of children were stunted, and 9.9% (85, 95% CI: 7.9, 11.9] were thin. Anemia was also occurred in 29.6% (240/810, 95% CI: 26.5–32.8) of children; 85% (204) had mild anemia, 15% (36) had moderate anemia, but none had severe anemia (S2 Table).

As shown in Table 1, more than half (470/850) of any helminths cases were detected using Kato-Katz method, and 44.9% (382/850) of cases were detected using FEC method. Overall, helminths infection were detected in 56.4% (479/850) of children using these two methods. The most frequent helminths were *T. trichiura* (42.4%; 360/850), followed by *A. lumbricoides* (18.7%; 159/850), *Taenia* species (10.2%; 87/850), hookworm species (4.4%; 37/850), *S. stercoralis* (2.5%; 21/850), and *H. nana* (0.2%; 2/850). The mean egg intensity was 156.4 epg for *T. trichiura* (95% CI: 127.1–185.7), 284.7 epg for *A. lumbricoides* (95% CI: 119.5–449.9), 134.4 epg for *Taenia* species (95% CI: 117.4–151.4), 83.7 epg for hookworm (95% CI: 68.3–99.1). Almost all diagnosed infections were light intensity. Only two children had moderate intensity of infection for *T. trichiura* and one child for A. lumbricoides. Infection with a single helminth infection was more common 39.6% (337/850) than multiple infections 16.7% (142/850). About 12% (101) of children had double infections and 4.4% (37) had triple infections. We observed *T.trichiuria* and *A. lumbricoides* co-infection in 10.6% (90) of children (S3 Table).

As indicated in Table 2, the proportion of any helminths infection were 57.6% (276/479) among boys, and 55.8% (387) were among children aged 10–14 years. Anemia occurred among 63% (150) of children infected with any helminths. More than two-thirds (68.7%) of thin children were infected with any helminths. The S4 Table of supplementary data shows the proportions of children infected with any helminths, *T. trichiura* and *A. lumbricoides* in relation to individual, household, and school factors.

Table 1. Helminths species detected by Kato-Katz and FEC method among schoolchildren in the Wonago district, Southern Ethiopia, 2017 (n = 850).

Helminths species	Kato-Katz	Kato-Katz	FEC	Either Kato-Katz or FEC
	Positive	Positive	Positive	Positive
	n (%)	Mean (SD) of EPG	n (%)	n (%)
T.trichiuria	342 (40.2)	156.4 (275.3)	278 (32.7)	360 (42.4)
A.lumbricoides	145 (17.1)	284.7 (1006.3)	130 (15.3)	159 (18.7)
Taenia species	85 (10.0)	134.4 (78.9)	44 (5.2)	87 (10.2)
Hookworm species	37 (4.4)	83.7 (46.2)	11 (1.3)	37 (4.4)
S.stercoralis	12 (1.4)		21 (2.5)	21 (2.5)
H.nana	0		2 (0.2)	2 (0.2)
Any helminths	470 (55.3)		382 (44.9)	479 (56.4)

EPG: Egg per gram of stool; FEC: Formalin-ether concentration

Any helminths: *T. trichiura*, *A. lumbricoides*, *Taenia* species, hookworm species, *S. stercoralis*, *H. nana*

https://doi.org/10.1371/journal.pntd.0008002.t001

Table 2. Distribution of helminths infection in relation to age, sex, nutritional statuses and anemia among schoolchildren in the Wonago district, Southern Ethiopia, 2017.

Variables		*T. trichiura*	*A. lumbricoides*	*Taenia* species	Hookworm species	Any helminths
Individual child factors	**N**	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**
Boys	479	206 (43.0)	96 (20.0)	57 (11.9)	26 (5.4)	276 (57.6)
Girls	371	154 (41.5)	63 (17.0)	30 (8.1)	11 (3.0)	203 (54.7)
7–9	157	72 (45.9)	22 (14.0)	11 (7.0)	12 (7.6)	92 (58.6)
10–14	693	296 (41.6)	137 (19.8)	76 (11.0)	25 (3.6)	387 (55.8)
Not stunted	578	241 (41.7)	110 (19.0)	65 (11.3)	25 (4.3)	326 (56.4)
Stunted	272	119 (43.7)	49 (18.0)	22 (8.1)	12 (4.4)	153 (56.3)
Not thin	767	314 (40.9)	141 (18.4)	79 (10.3)	34 (4.4)	422 (55.0)
Thin	83	46 (55.4)	18 (21.7)	8 (9.6)	3 (3.6)	57 (68.7)
Non anemic	567	225 (39.7)	92 (16.2)	55 (9.7)	20 (3.5)	306 (54.0)
Anemic	238	115 (48.3)	64 (26.9)	30 (12.6)	17 (7.1)	150 (63.0)
Total		360 (42.4)	159 (18.7)	87 (10.2)	37 (4.4)	479 (56.4)

Any helminths: *T. trichiura*, *A. lumbricoides*, *Taenia* species, hookworm species, *S. stercoralis*, *H. nana;*
N: children examined; n: children positive with helminths infection

https://doi.org/10.1371/journal.pntd.0008002.t002

A large proportion of children 81.3% (691/850) for *A. lumbricoides*, and 57.6% (490/850) for *T. trichiura* were "zero egg excretors." The median and interquartile range (IQR) of eggs per gram (epg) of stool was 120 (72–168) for *T. trichiura*. According to gender, either boys or girls 120 (72–168) had equal median (IQR) of epg for *T. trichiura*. Among the age groups, the median (IQR) of epg for *T. trichiura* was 120 (72–192) in children aged 7–9 years. The median (IQR) of epg was 120 (72–216) for *A. lumbricoides*. The median (IQR) of epg for *A. lumbricoides* was 120 (96–216) among boys, and 120 (72–144) in children aged 7–9 years. The S5 and S6 Tables summarize the mean, median, standard deviation, and interquartile range of *T. trichiura* and *A. lumbricoides* infections for each exposure variable. The S1 Dataset of supplementary data shows the raw data for continuous variables.

Inter-rater agreement for helminths data

We performed reliability test using 10% of 850 sample. The inter-rater agreement of the two readers either Kato-Katz or FEC was checked with Kappa statistics. In case of discordant results, a third reader was used to confirm the analysis. We observed a good agreement between the initial reading and re-reading in either Kato-Katz or FEC method ($P < .001$). The Kappa values in the Kato-Katz reading were as follows: *A. lumbricoides*, 0.83 [95% CI: 0.72–0.95]; *T. trichiura*, 0.88 [95% CI: 0.78–0.98]; *Taenia species*, 0.87 [95% CI: 0.76–0.98]; and hookworm, 0.86 [95% CI: 0.74–0.98]. Among discordant results between the two readers, 7 were for *A. lumbricoides*, 5 for *T. trichiura*, 5 for *Taenia*, and 5 for hookworm. The proportion of false positive results in the Kato-Katz smear, 1.2% (1/85) were for *A. lumbricoides*, 5.9% (5/85*)* for *T. trichiura*, 3.5% (3/85) for *Taenia*, and 2.4% (2/85) for hookworm. The proportion of false negative results in the Kato-Katz smear, 7.1% (6/85) were for *A. lumbricoides*, 0 for *T. trichiura*, 2.4% (2/85) for *Taenia*, 3.5% (3/85) for hookworm. According to the WHO guideline, in the Kato-Katz smear, helminth egg counts between initial reading and second quality control reading was compared. Discrepancies in helminth egg counts in the Kato-Katz smear were detected, 8.2% (7/85) for *A. lumbricoides*, 5.9% (5/85) for *T. trichiura*, and 5.9% (5/85) for *Taenia* species. For hookworm, the observed differences in egg counts did not exceed 4 eggs per slide (S7 Table).

The Kappa values in the FEC reading were as follows: *A*. *lumbricoides*, 0.91 [95% CI: 0.82–0.99]; *T*. *trichiura*, 0.86 [95% CI: 0.75–0.98]; *Taenia* species, 0.84 [95% CI: 0.71–0.97]; hookworm, 0.86 [95% CI: 0.67–1.00]; and *S*. *stercoralis*, 0.81 [95% CI: 0.62–0.99]. Among discordant results between the two readers, 4 were for *A*. *lumbricoides*, 5 for *T*. *trichiura*, 5 for *Taenia*, 2 for hookworm, and 4 for *S*. *stercoralis*. The proportion of false positive results in the FEC method, 2.4% (2/85) were for *A*. *lumbricoides*, 3.5% (3/85) for *T*. *trichiura*, 2.4% (2/85) for *Taenia*, 1.2% (1/85) for hookworm, and 2.4% (2/85) for *S*. *stercoralis*. The proportion of false negative results in the FEC method, 2.4% (2/85) were for *A*. *lumbricoides*, 2.4% (2/85) for *T*. *trichiura*, 3.5% (3/85) for *Taenia*, 1.2% (1/85) for hookworm, and 2.4% (2/85) for *S*. *stercoralis* (S8 Table).

Variation and risk factors for any helminths infection

Predictors of any helminths infection were estimated using a multivariate, multi-level, mixed-effect, logistic regression analysis. The intra-cluster correlation coefficient (ICC) value, calculated in the empty model with no covariate, was 1.2% at the school and class levels and 0.1% in the final model, indicating unexplained variations of any helminths infection prevalence at the school- and class-levels. See the S10 Table of supplementary data for the results of subsequent multilevel models.

In the bivariate, multi-level, mixed-effect, logistic regression model; the following factors had significant associations with any helminths infection: loss of appetite in the past month, thinness, anemia, having a mother or guardian with no formal education, and using an open container for water storage (S9 Table). In the multivariate, multi-level, mixed-effect, logistic regression model analysis, the risk of any helminths infection was higher among children with loss of appetite in the past month (AOR: 1.89 [95% CI: 1.16, 3.08]), thinness (AOR: 1.73 [95% CI: (1.04, 2.90]), anemia (AOR: 1.45 [95% CI: 1.04, 2.03]), a mother or guardian with no formal education (AOR: 2.08 [95% CI: 1.25, 3.47]), and open containers for water storage (AOR: 2.06 [95% CI: 1.07, 3.99]). However, no significant differences were observed between any helminths infection and sex, age, nail trimming, handwashing before meals, eating undercooked vegetables, wealth, source of drinking water, using treated water at home, or participation in a school feeding program. Table 3 and S10 Table shows the details.

Variation and risk factors for *T. trichiura* and *A. lumbricoides* infections

The intra-cluster correlation value calculated in Model V for *T*. *trichiura* was low and insignificant, indicated that the variability in this infection prevalence was not attributable to class or school factors. The S11 Table of supplementary data shows the results of these tests. Similarly, the variability in *A*. *lumbricoides* prevalence at the school-level was insignificant. However, the intra-cluster correlation value calculated in Model V for *A*. *lumbricoides* infection indicated that 3.2% of the variability in this infection prevalence was attributable to class factors. The S12 Table of supplementary data shows the results of these tests.

For *T*. *trichiura* model, all significant variables in the bivariate, multilevel, mixed-effect model also were significant in the multivariate model. The risk of *T*. *trichiura* infection was higher among children with loss of appetite in the past month (AOR: 1.76 [95% CI: 1.15, 2.71]), thinness (AOR: 1.73 [95% CI: 1.07, 2.78]), anemia (AOR: 1.53 [95% CI: 1.11, 2.12]), a mother or guardian with no formal education (AOR: 1.94 [95% CI: 1.18, 3.19]), and participation in the school food program (AOR: 1.55 [95% CI: 1.13, 2.12]). Furthermore, there were no statistically significant differences between *T*. *trichiura* infection and sex, age, nail trimming, handwashing, eating uncooked vegetable, receiving de-worming treatment in the past 6 months, or wealth (S9 and S11 Tables).

Table 3. Multivariate, multilevel, mixed-effect, logistic regression analysis of any helminths infection among schoolchildren in the Wonago district of Southern Ethiopia, 2017.

Variables		Any helminths	Adjusted OR (95% CI)				
Individual child factors		**Yes (%)**	**Model I**	**Model II**	**Model III**	**Model IV**	**Model V**
Sex	Boys	276 (57.6)	-	1.0	1.0	1.0	1.0
	Girls	203 (54.7)	-	0.96 (0.72, 1.28)	0.97 (0.72, 1.30)	0.98 (0.74, 1.32)	0.98 (0.74, 1.32)
Age in years	7–9	92 (58.6)	-	1.19 (0.82, 1.74)	1.17 (0.81, 1.71)	1.13 (0.77, 1.65)	1.13 (0.77, 1.65)
	10–14	387 (55.8)	-	1.0	1.0	1.0	1.0
Loss of appetite in past month	Yes	82 (67.8)	-	1.77 (1.10, 2.85)*	1.89 (1.18, 3.04)*	1.89 (1.16, 3.08)*	1.89 (1.16, 3.08)*
	No	397 (54.5)	-	1.0	1.0	1.0	1.0
Thinness	No	422 (55.0)	-	1.0	1.0	1.0	1.0
	Yes	57 (68.7)	-	1.73 (1.04, 2.88)*	1.68 (1.01, 2.79)*	1.73 (1.04, 2.90)*	1.73 (1.04, 2.90)*
Anemia	No	306 (54.0)	-	1.0	1.0	1.0	1.0
	Yes	150 (63.0)	-	1.52 (1.09, 2.12)*	1.49 (1.07, 2.07)*	1.45 (1.04, 2.03)*	1.45 (1.04, 2.03)*
Individual parent factors							
Mother's education level	Never entered school	392 (58.5)	-	-	2.07 (1.26, 3.41)**	2.08 (1.25, 3.47)**	2.08 (1.25, 3.47)**
	Read and write only	47 (58.0)	-	-	1.97 (0.97, 4.02)	1.91 (0.92, 3.97)	1.91 (0.92, 3.97)
	Primary and above	38 (40.0)	-	-	1.0	1.0	1.0
Household factors							
Wealth	Poor	165 (57.9)	-	-	-	0.99 (0.69, 1.43)	0.99 (0.69, 1.43)
	Middle	165 (56.3)	-	-	-	1.08 (0.74, 1.58)	1.08 (0.74, 1.58)
	Rich	149 (54.8)	-	-	-	1.0	1.0
Water storage container	Closed container	440 (55.3)	-	-	-	1.0	1.0
	Open container	39 (72.2)	-	-	-	2.06 (1.07, 3.99)*	2.06 (1.07, 3.99)*
School factor							
Participates in school food program	No	250 (58.7)	-	-	-	-	1.0
	Yes	229 (54.0)	-	-	-	-	0.98 (0.66, 1.46)
Model fitness							
-2log likelihood			1160	1076	1062	1057	1056
AIC			1165	1104	1089	1091	1093

AIC: Akaike information criterion; CI: confidence interval; OR: odds ratio

**P < .01

*P < .05

https://doi.org/10.1371/journal.pntd.0008002.t003

For *A*. *lumbricoides* model, all significant variables in the bivariate, multilevel, mixed-effect model also were significant in the multivariate model. The odds of *A*. *lumbricoides* infection increased by 92% among anemic children (AOR: 1.92 [95% CI: 1.29, 2.88]). The odds were lower among children who received de-worming treatment in the past 6 months [AOR: 0.57 (95% CI: 0.33, 0.98)] and who used water from a protected source [AOR: 0.46 (95% CI: 0.28, 0.77)]. There were no statistically significant differences between *A*. *lumbricoides* infections and age, nail trimming, handwashing, wealth, source of drinking water, and participation in a school food program. The S9 and S12 Tables of supplementary data shows the results.

Zero-inflated negative binomial regression

Model fitness. The alpha dispersion parameter was significant for *T*. *trichiura* at 0.53 (95% CI: 0.45–0.61) and for *A*. *lumbricoides* infection at 0.47 (95% CI: 0.05, 0.37), indicating strong over-dispersion. For *T*. *trichiura* fecal egg count data; comparing the zero-inflated Poisson (ZIP) with a ZINB model, we observed a significant likelihood ratio test at (alpha = 0; Chi square = 38000; P < .001), indicating a ZINB model is best fitted for this data. Meanwhile, the Vuong test favors ZINB over a standard negative binomial (NB) for *T*. *trichiura* (Z = 17.5; P < .001) eggs count model, indicating the presence of excess zeroes to be accounted. The AIC and deviance results for *T*. *trichiura* show that the ZINB model offer a better fit compared to ZIP model (AIC = 4902 for ZINB and 43,186 for ZIP; deviance = 43,126 for ZIP and 4840 for ZINB) (S12 Table). For *A*. *lumbricoides* fecal egg count data; comparing the ZIP with a ZINB model, we observed a significant likelihood ratio test at (alpha = 0; Chi square = 21000; P < .001), indicating a ZINB model is best fitted. The Vuong test also favors ZINB over NB for *A*. *lumbricoides* (Z = 9.4; P < .001) eggs count model, indicating the presence of excess zeroes to be accounted. The AIC and deviance results for *A*. *lumbricoides* also show that the ZINB model offer a better fit compared to ZIP model (AIC = 2494 for ZINB and 23,845 for ZIP; deviance = 23,788 for ZIP and 2436 for ZINB) (S13 Table).

Negative binomial count model for *T*. *trichiura* and *A*. *lumbricoides* infections. Intensity of *T*. *trichiura* infection increased among girls (AOR: 1.23 [95% CI: 1.04, 1.45]), and in those using open container for water storage at home (AOR: 1.59 [95% CI: 1.14, 2.22]). The intensity of infection with *A*. *lumbricoides* (AOR: 1.08 [95% CI: 1.01, 1.16]) increased with increasing age. Unclean fingernails (AOR: 1.47 [95% CI: 1.07, 2.03]) were associated with increased intensity of *A*. *lumbricoides* infection. A habit of nail trimming (AOR: 0.56 [95% CI: 0.39, 0.79]) and handwashing with soap after using the latrine (AOR: 0.68 [95% CI: 0.48, 0.95]) lowered the intensity of *A*. *lumbricoides*. The intensity of *A*. *lumbricoides* was higher among children in school feeding programs (AOR: 1.97 [95% CI: 1.49, 2.61]) (Tables 4 and 5).

Logit model for predicting excess zeros for *T*. *trichiura* and *A*. *lumbricoides* infections. As shown in Tables 4 and 5, the odds of zero epg counts for *T*. *trichiura* (AOR: 1.13 [95% CI: 1.03, 1.25]) and *A*. *lumbricoides* (AOR: 1.20 [95% CI: 1.06, 1.36]) increased with increasing hemoglobin concentrations. The odds of zero epg counts for *T*. *trichiura* decreased for children who ate uncooked vegetables (AOR: 0.70 [95% CI: 0.50, 0.99]), children who reported loss of appetite in the past month (AOR: 0.52 [95% CI: 0.34, 0.81]), thin children (AOR: 0.59 [95% CI: 0.36, 0.94]), a mother or guardian with no formal education (AOR: 0.56 [95% CI: 0.34, 0.92]), and children in school feeding programs (AOR: 0.56 [95% CI: 0.41, 0.78]). Meanwhile, the odds of zero epg counts for *A*. *lumbricoides* eggs decreased with increasing age (AOR: 0.90 [95% CI: 0.81, 0.99]), whereas the odds increased among children who had received a de-worming drug in the past 6 months (AOR: 1.68 [95% CI: 1.01, 2.78]). However, no significant difference was observed between *T*. *trichiura* infections and age, nail trimming, or wealth. No statistically significant differences were observed between *A*. *lumbricoides* infections and sex, mother's educational, or wealth.

Discussion

Helminths infection were found to be a public health problem among schoolchildren aged 7 to 14 years in the Gedeo zone of Southern Ethiopia. Controlling for clustering effects at the school and class levels and accounting for excess zeros of fecal egg counts, we found an association between helminths infection and the following variables: age, thinness, anemia, loss of appetite in past month, unclean fingernails, lack of nail trimming, lack of hand washing with soap after using the latrine, de-worming treatment, mothers' education levels, water source, and using uncovered water storage container at home. Variations attributable to both class and school-level factors for helminth infections prevalence were less than 5%, indicating minor influence.

We used a large and representative sample of schoolchildren and applied a multilevel, mixed-effect model and a ZINB model to identify risk factors for prevalence and intensity of

Table 4. Zero-inflated negative binomial regression model for *T. trichiura* fecal egg count among schoolchildren in the Wonago district, Southern Ethiopia, 2017 (n = 850).

Variables	Zero-inflated negative binomial model		
	Negative binomial part	Zero-inflated part	
Individual child, parent, household and school factors	Infection intensity AOR (95% CI)	Infection probability AOR (95% CI)	
Sex	Boys	1.0	1.0
	Girls	1.23 (1.04, 1.45)*	1.06 (0.79, 1.43)
Age in years	Mean (SD)	1.01 (0.97, 1.05)	1.07 (0.98, 1.15)
Fingernails trimmed	Yes	0.82 (0.61, 1.09)	0.92 (0.57, 1.49)
	No	1.0	1.0
Habit of eating uncooked vegetable	Yes	1.05 (0.86, 1.27)	0.70 (0.50, 0.99)*
	No	1.0	1.0
Loss of appetite in past month	Yes	0.95 (0.75, 1.21)	0.52 (0.34, 0.81)**
	No	1.0	1.0
Hemoglobin concentration	Mean (SD)	0.96 (0.91, 1.01)	1.13 (1.03, 1.25)*
Thinness	No	1.0	1.0
	Yes	1.10 (0.86, 1.41)	0.59 (0.36, 0.94)*
Mother's education level	Never entered school	1.18 (0.86, 1.61)	0.56 (0.34, 0.92)*
	Read and write only	1.19 (0.80, 1.78)	0.64 (0.32, 1.26)
	Primary and above	1.0	1.0
Wealth status	Poor	0.99 (0.81, 1.22)	0.98 (0.68, 1.41)
	Middle-class	0.92 (0.74, 1.14)	0.95 (0.66, 1.38)
	Rich	1.0	1.0
Water storage	Closed container	1.0	1.0
	Open container	1.59 (1.14, 2.22)**	0.82 (0.44, 1.49)
Participates in school food program	No	1.0	1.0
	Yes	1.18 (0.98, 1.42)	0.56 (0.41, 0.78)**

AOR: adjusted odds ratio; CI: confidence interval

**P < .01

*P < .05

https://doi.org/10.1371/journal.pntd.0008002.t004

helminths infection. We examined nutritional status, and measured hemoglobin concentrations. To enhance the detection rate of helminth infections, we used two standard techniques, the Kato-Katz and FEC. Helminths detection and species identification require qualified laboratory expert, and thus we also reported the agreement level of the readers in either method. The dependence of clustered data within the school and class levels was measured and indicated using intra-cluster correlation coefficient. Unlike previous studies [8, 11–17], we reported the intensity of helminth infections and modelled the intensity of helminths egg using a ZINB count model. We determined the fit using deviance and AIC for each model.

Because of the cross-sectional nature of this study, causality between the outcome and the exposure variable cannot be determined with certainty. Multiple stool samples from each child could have enhanced the detection rate of helminths infection [51]. Unfortunately, we did not take multiple samples, due to logistics constraints, but we used two different techniques to analyze a single stool sample, which could have enhanced the detection rate. There is no a 'gold standard' test (with 100% accuracy) for diagnosing helminth infections, but it is recommended to use a combined test to improve the detection rate of helminth infections [52, 53]. The Kato-Katz and FEC techniques are recognized for soil-transmitted helminths detection [54]. Moreover, the Kato-Katz method is suitable for quantification of the helminths eggs. However, the

Table 5. Zero-inflated negative binomial regression model for *A. lumbricoides* fecal egg count among schoolchildren in the Wonago district, Southern Ethiopia, 2017 (n = 850).

Variables		Zero-inflated negative binomial model	
		Negative binomial part	Zero-inflated part
Individual child, parent, household and school factors		Infection intensity AOR (95% CI)	Infection probability AOR (95% CI)
Sex	Boys	1.03 (0.81, 1.32)	0.96 (0.66, 1.41)
	Girls	1.0	1.0
Age in years	Mean (SD)	1.08 (1.01, 1.16)*	0.90 (0.81, 0.99)*
Fingernails trimmed	Yes	0.56 (0.39, 0.79)**	0.66 (0.36, 1.20)
	No	1.0	1.0
Unclean fingernails	Yes	1.47 (1.07, 2.03)*	0.64 (0.37, 1.08)
	No	1.0	1.0
Handwashing with soap after latrine use	Always	0.94 (0.61, 1.44)	0.68 (0.35, 1.30)
	Sometimes	0.68 (0.48, 0.95)*	1.39 (0.85, 2.27)
	Never	1.0	1.0
De-worming drug in past 6 months	Yes	1.03 (0.76, 1.41)	1.68 (1.01, 2.78)*
	No	1.0	1.0
Hemoglobin concentration	Mean (SD)	0.99 (0.91, 1.07)	1.20 (1.06, 1.36)**
Mother's education level	Never entered school	1.10 (0.66, 1.85)	0.45 (0.21, 0.96)*
	Read and write only	0.89 (0.49, 1.64)	0.33 (0.13, 0.84)*
	Primary and above	1.0	1.0
Wealth status	Poor	1.17 (0.87, 1.58)	1.17 (0.74, 1.86)
	Middle-class	1.17 (0.87, 1.58)	1.22 (0.77, 1.95)
	Rich	1.0	1.0
Participates in school food program	No	1.0	1.0
	Yes	1.97 (1.49, 2.61)***	1.37 (0.87, 2.15)

AOR: adjusted odds ratio; CI: confidence interval

***P < .001

**P < .01

*P < .05

https://doi.org/10.1371/journal.pntd.0008002.t005

duration of the examination and the number of Kato-Katz smears are known to have impact on the sensitivity of Kato-Katz method for hookworm detection [52]. Thus, the low sensitivity of the Kato-Katz technique for hookworm detection, may have underestimated the prevalence of hookworm infection in this study. The performance of the Kato-Katz and FEC method for helminths detection varied in several studies. In this study, the performance of the Kato-Katz method slightly better than the FEC method, and in agreement with previous studies in Ethiopia [55, 56] and a review done by Nikolay et al. [57]. In contrast, Speich et al. and Glinz et al. [58, 59] showed similar or slightly higher sensitivity of the FEC method compared to the Kato-Katz method for helminth infections. The influence of the ether-based concentration techniques on helminth egg count require further studies [59]. Accurate counting of helminth eggs is challenging, it is not uncommon to detect discordant results in helminths diagnosis (e.g. helminth eggs can confuse with eggs from other helminths species or recording errors on the entry forms) [37, 52]. There was good agreement between the initial reading and re-reading from 10% of test result in either Kato-Katz or FEC method. In agreement with Speich et al. [37] the detected false positive results was higher for *T. trichiura* than for *A. lumbricoides* and the false negative results was higher for *A. lumbricoides* than for *T. trichiura* in the Kato-Katz method. A combined diagnostic methods, the Koga-agar-plate culture and Baermann are suggested methods for detection of *S. stercoralis* [51]. Neither Kato-Katz nor FEC methods are recommended for *S. stercoralis* diagnosis. Thus, we have probably underestimated the prevalence of *S. stercoralis*. Furthermore, recall bias could be introduced, while using a questionnaire to gather information on the past de-worming history. Moreover, due to homogeneity issues, we were unable to model most school-level risk factors in this study (e.g., sanitation and hygiene facilities were similar across all schools).

The prevalence of any helminths infection that we found was 56.4% align with the findings of 60% and 63% in Southern Ethiopia [17, 60]. However, it is higher than the 23% [24], and 27.7% [12] reported in another studies in Southern Ethiopia. Compared with the 24.6% prevalence found in Ethiopia [16], 26.3% in the Democratic Republic of Congo, 26.5% found in Kenya [61, 62], 10.7% found in Burkina Faso [63], and 10% of global report [64], we found a higher prevalence of 42.4% *T. trichiura* infection. The rate of *A. lumbricoides* infection 18.7% align with the global report of 20% [64]. However, the rates that we found are higher compared with rates of 10.6% to 13% in other areas of Southern Ethiopia [12, 65]. The rate of 4.4% for hookworm infection in this study aligned with the 7.4% rate found during national mapping [65]. However, it is lower than the 18% in Southern Ethiopia [24], 46.9% [66], and 56.8% [16] reported in other regions of Ethiopia, and 18% of global report [64]. All detected infections in this study were of light intensity [44], which is comparable with other studies in Ethiopia [24, 67, 68]. The rate of multiple helminth infections in this study was 16.7%, and higher than compared to what was reported in the Butajira town 2.6% [69] and in the Bahir Dar 6.3% [70]. Such variations in helminths prevalence could be due to different diagnostic techniques. For instance, among studies reporting low prevalence of any helminths infection in the same region of our study; some used only a single Kato-Katz method [24] and other used a wet mount (low sensitive) technique [12, 71]. In addition, the variations in helminths distribution might be due to difference in the studies' ecological settings such as altitude, soil type, rainfall, and land surface temperature [72].

We found a moderately high prevalence of 32% for stunting comparable with the values of 28% in the Southern Ethiopia [24], 30.7% in the Filtu Town [73], 32.9% in the Fogera district [30]. The rate of thinness that we found (9.9%) was also similar with the rates (11.6% to 14.0%) found by other studies in Southern Ethiopia [24, 60, 74] but are lower (19.6% to 27.6%) than studies documented in Northern Ethiopia [70, 75, 76]. Despite a well-documented link between soil-transmitted helminth infections and under-nutrition [64, 77], the evidence regarding this association varies. Some studies have reported the same risk of thinness and stunting among infected and non-infected children [11, 76, 78]. In agreement with other studies [70, 75], our study revealed higher rates of any helminth infections among thin children. These children often lose micronutrients, which can impair nutritional status and growth [77].

The rates of anemia was 29.6% among schoolchildren in this setting; higher than the 22% and 23% rates found in Southern Ethiopia [24, 60]. However, it is lower than the 43% rate found by studies of Southwest Ethiopia [16]. The observed association between helminth infections and anemia was expected, as helminth infections are risk factors for anemia [79–81]. Reduced food intake because of inflammatory reactions induced by lesions in the intestinal mucosa and impaired iron absorption due to worm infections could partly explain this association [69, 77]. Furthermore, we found high rates of helminth infections among children who reported a loss of appetite in the past month. Helminth infections increased among children whose mothers had no formal education, similar to previous studies in Ethiopia [8, 12] and rural Mexico [82]. This could be due to lack of knowledge about poor home sanitation and hygiene.

Using piped water has been shown to influence the prevalence of *A. lumbricoides* infection [9]. In this study, low rates of *A. lumbricoides* infection were observed among children living in households using a protected water source, indicating a possibility for contamination when water is not protected from soil-transmitted helminths eggs during transport and storage [83].

Our ZINB model indicated that eating uncooked vegetables lowered the probability of remaining free from *T. trichiura* infections. Ingesting contaminated raw vegetables could play an important role in transmitting helminths infection [84]. The zero-inflation model also indicated higher probability of children remaining free from *T. trichiura* and *A. lumbricoides* infections as their hemoglobin concentrations increase. The observed infection intensity in this study was light, and although light infection by *T. trichiura* and *A. lumbricoides* may not be enough to produce significant blood loss, it may aggravate the condition [85]. However, de Gier et al. found low hemoglobin concentrations among children with light *T. trichiura* infections [80]. This finding could be affected by unmeasured factors, such as low dietary iron intake and malaria. In the zero-inflation model, we also observed a high risk of helminths infection, particularly *T. trichiura* infection, among children in households using open containers for water storage. Similar findings have been observed in Kenya [61]. The high percentage of unimproved water sources and the practice of open defecation, particularly in rural Ethiopia, offer support for this finding [86]. We indeed observed a high percentage of unimproved toilet facilities in the study households.

Using the ZINB model, we observed increased intensity of *A. lumbricoides* infections and a decline in the probability of older children remaining free from this infection. Older children may participate in activities and environments that make them more prone to infection than younger children. In contrast, a previous study has reported a lower risk of helminths infection in the older age group [87]. This reduced risk could be due to immunological and behavioral factors related to hygiene [88].

Nail and hand hygiene are well known individual factors affecting helminths infection prevalence and intensity [89]. We found an increased intensity of *A. lumbricoides* infection among children with unclean finger nails, as has been reported by others [12, 15]. Nail trimming and handwashing with soap after using the latrine led to reduced intensity of *A. lumbricoides* infection, similar to findings in other studies [8, 9, 14, 90]. Eating uncooked vegetables has been reported as a risk factor for helminths infection [87]. Furthermore, receiving de-worming drugs in the past 6 months significantly increased the probability of children remaining free from *A. lumbricoides*, as has been observed in rural Bangladesh [91].

Children participating in school feeding programs had high rates of *T. trichiura* infection and increased intensity of *A. lumbricoides* infection. This finding suggests unsafe or unhygienic food preparation and poor sanitary facilities at schools in the study area. School sanitation and hygiene could affect this finding, though we were unable to show a link due to similarity of this potential exposure variable. Furthermore, some schools had no access to safe water, putting those children at higher risk. Schools with feeding programs thus may be area at high risk of food insecurity and vulnerability to infection.

Although Ethiopia launched a national school-based de-worming program in 2015, soil-transmitted helminth infection remain high among schoolchildren in the rural areas. Variations attributable to both class- and school-level factors for helminths infection prevalence were low. Most individual and few household factors were found to be important predictors for helminths infection prevalence and intensity, and high rates of *T. trichiura* infection and intensity of *A. lumbricoides* among children in school feeding programs also were observed. Interventions that improve hygiene among schoolchildren can reduce the burden of helminths infection in settings such as Gedeo. Access to safe water at school and at home is a crucial part of infection reduction strategies. Periodic de-worming programs in schools must be strengthened. To that end, school teachers should work with health workers to provide health education about personal hygiene. Integrated intervention activities focusing on the individual, household, and school will reduce the burden of helminths infections.

Supporting information

S1 Checklist. STROBE checklist.
(DOCX)

S1 Dataset. Dataset for continuous variables.
(XLSX)

S1 Table. Demographic and socio-economic status of schoolchildren and their parents in the Wonago district, Southern Ethiopia, 2017.
(DOCX)

S2 Table. Stunting, thinness, and anemia among schoolchildren in the Wonago district, Southern Ethiopia, 2017.
(DOCX)

S3 Table. Distribution of helminths co-infection among schoolchildren in the Wonago district, Southern Ethiopia, 2017.
(DOCX)

S4 Table. Distribution of helminths infection among schoolchildren in the Wonago district, Southern Ethiopia, 2017.
(DOCX)

S5 Table. The mean, median, SD, and IQR of *T. trichiuria* infection loads in egg per gram of stool among schoolchildren in the Wonago district, Southern Ethiopia, 2017.
(DOCX)

S6 Table. The mean, median, SD, and IQR of *A. lumbricoides* infection loads in egg per gram of stool among schoolchildren in the Wonago district, Southern Ethiopia, 2017.
(DOCX)

S7 Table. Inter-rater agreement for the readings of 85 Kato-Katz microscopic slides.
(DOCX)

S8 Table. Inter-rater agreement for the readings of 85 FEC microscopic slides.
(DOCX)

S9 Table. Bivariate, multilevel, mixed-effect, regression analysis of any helminths, *T. trichiuria*, and *A. lumbricoides* among schoolchildren in the Wonago district, Southern Ethiopia, 2017.
(DOCX)

S10 Table. Multivariate, multilevel, mixed-effect, regression analysis of any helminths infection among schoolchildren in the Wonago district, Southern Ethiopia, 2017.
(DOCX)

S11 Table. Multivariate, multilevel, mixed-effect, logistic regression analysis of *T. trichiuria* infection among schoolchildren in the Wonago district, Southern Ethiopia, 2017.
(DOCX)

S12 Table. Multivariate, multilevel, mixed-effect, logistic regression analysis of *A. lumbricoides* infection among schoolchildren in the Wonago district, Southern Ethiopia, 2017.
(DOCX)

S13 Table. Model validation for *T. trichiuria* and *A. lumbricoides* egg count model.
(DOCX)

Acknowledgments

We are grateful to the schoolchildren, parents, and guardians who participated in this study. We also thank the data collectors, supervisors, Gedeo Zone Health Department, Wonago District Education Office, school directors, and teachers. We are also grateful to the Ethiopian Public Health Institute for providing the Kato-Katz template. We would like to thank Dilla University Teaching and Referral Hospital for providing us with a laboratory examination room. We are deeply grateful to Hawassa University and the University of Bergen for their support.

Author Contributions

Conceptualization: Hiwot Hailu Amare, Bernt Lindtjørn.

Data curation: Hiwot Hailu Amare, Bernt Lindtjørn.

Formal analysis: Hiwot Hailu Amare, Bernt Lindtjørn.

Funding acquisition: Bernt Lindtjørn.

Investigation: Hiwot Hailu Amare, Bernt Lindtjørn.

Methodology: Hiwot Hailu Amare, Bernt Lindtjørn.

Project administration: Hiwot Hailu Amare, Bernt Lindtjørn.

Resources: Hiwot Hailu Amare, Bernt Lindtjørn.

Software: Hiwot Hailu Amare, Bernt Lindtjørn.

Supervision: Hiwot Hailu Amare, Bernt Lindtjørn.

Validation: Hiwot Hailu Amare, Bernt Lindtjørn.

Visualization: Hiwot Hailu Amare, Bernt Lindtjørn.

Writing – original draft: Hiwot Hailu Amare, Bernt Lindtjørn.

Writing – review & editing: Hiwot Hailu Amare, Bernt Lindtjørn.

References

1. WHO. Soil-transmitted helminth infections [Internet]. 2019. Available from: https://www.who.int/news-room/fact-sheets/detail/soil-transmitted-helminth-infections.
2. WHO Ethiopia. Ethiopian school-based deworming campaign targets 17 million children [Internet]. 2015. Available from: https://who.insomnation.com/news/ethiopian-school-based-deworming-campaign-targets-17-million-children.
3. Johnston EA, Teague J, Graham JP. Challenges and opportunities associated with neglected tropical disease and water, sanitation and hygiene intersectoral integration programs. BMC Public Health. 2015; 15: 547. https://doi.org/10.1186/s12889-015-1838-7 PMID: 26062691
4. Pullan R, Smith J, Jasrasaria R, Brooker S. Global numbers of infection and disease burden of soil transmitted helminth infections in 2010. Parasit Vectors. 2014; 7: 37. https://doi.org/10.1186/1756-3305-7-37 PMID: 24447578
5. World Health Organization. Soil-transmitted helminthiases: eliminating as public health problem soil-transmitted helminthiases in children: progress report 2001–2010 and strategic plan 2011–2020 [Internet]. World Health Organization. 2012. Available from: https://apps.who.int/iris/handle/10665/44804.
6. Tchuem Tchuenté L-A. Control of soil-transmitted helminths in sub-Saharan Africa: Diagnosis, drug efficacy concerns and challenges. Acta Trop. 2011; 120 Suppl 1: S4–S11. https://doi.org/10.1016/j.actatropica.2010.07.001 PMID: 20654570
7. Kassebaum NJ. The Global burden of anemia. Hematol Oncol Clin North Am. 2016; 30(2): 247–308. https://doi.org/10.1016/j.hoc.2015.11.002 PMID: 27040955

8. Asemahagn MA. Parasitic infection and associated factors among the primary schoolchildren in Motta Town, Western Amhara, Ethiopia. Am J Public Health Res. 2014; 2(6): 248–54.
9. Strunz EC, Addiss DG, Stocks ME, Ogden S, Utzinger J, Freeman MC. Water, sanitation, hygiene, and soil-transmitted helminth infection: a systematic review and meta-analysis. PLoS Med. 2014; 11(3): e1001620–e. https://doi.org/10.1371/journal.pmed.1001620 PMID: 24667810
10. hiwot Y G., Degarege A, Erko B. Prevalence of intestinal parasitic infections among children under five years of age with emphasis on Schistosoma mansoni in Wonji Shoa Sugar Estate, Ethiopia. PLoS One. 2014; 9(10): e109793. https://doi.org/10.1371/journal.pone.0109793 PMID: 25296337
11. Amare B, Ali J, Moges B, Yismaw G, Belyhun Y, Gebretsadik S, et al. Nutritional status, intestinal parasite infection and allergy among schoolchildren in northwest Ethiopia. BMC Pediatr. 2013; 13:7. https://doi.org/10.1186/1471-2431-13-7 PMID: 23311926
12. Haftu D, Deyessa N, Agedew E. Prevalence and determinant factors of intestinal parasites among schoolchildren in Arba Minch town, Southern Ethiopia. Am J Health Research. 2014; 2(5): 247–54.
13. Tulu B, Taye S, Amsalu E. Prevalence and its associated risk factors of intestinal parasitic infections among Yadot primary schoolchildren of South Eastern Ethiopia: a cross-sectional study. BMC Res Notes. 2014; 7: 848. https://doi.org/10.1186/1756-0500-7-848 PMID: 25425173
14. Gelaw A, Anagaw B, Nigussie B, Silesh B, Yirga A, Alem M, et al. Prevalence of intestinal parasitic infections and risk factors among schoolchildren at the University of Gondar Community School, Northwest Ethiopia: a cross-sectional study. BMC Public Health. 2013; 13: 304. https://doi.org/10.1186/1471-2458-13-304 PMID: 23560704
15. Mahmud MA, Spigt M, Mulugeta Bezabih A, Lopez Pavon I, Dinant GJ, Blanco Velasco R. Risk factors for intestinal parasitosis, anaemia, and malnutrition among schoolchildren in Ethiopia. Pathogens and global health. 2013; 107(2): 58–65. https://doi.org/10.1179/2047773213Y.0000000074 PMID: 23683331
16. Desalegn Wolide A, Mossie A, Gedefaw L. Nutritional iron deficiency anemia: magnitude and its predictors among school age children, southwest Ethiopia: a community based cross-sectional study. PLoS One. 2018; 13(8): e0202380. https://doi.org/10.1371/journal.pone.0202380 PMID: 30092032
17. Abossie A, Seid M. Assessment of the prevalence of intestinal parasitosis and associated risk factors among primary schoolchildren in Chencha town, Southern Ethiopia. BMC Public Health. 2014; 14: 166. https://doi.org/10.1186/1471-2458-14-166 PMID: 24528627
18. Ministry of Finance and Economic Development Federal Democratic Republic of Ethiopia. Assessing progress towards the Millenium Development Goals: Ethiopia MDGs Report Addis Ababa, Ethiopia 2012.
19. Government of the Federal Democratic Republic of Ethiopia. National Nutrition Programme. June 2013 –June 2015.
20. Ethiopia Ministry of Health. Health Sector Transformation Plan 2015/16–2019/20. 2015: 31–157.
21. Ethiopia Ministry Of Health. National Hygiene and Sanitation Strategic Action Plan for Rural, Per-Urban and Informal Settlements in Ethiopia. Addis Ababa, Ethiopia. 2011–2015.
22. Ministry of Education and UNICEF Ethiopia. Global Out of School Children Initiative. Study on Situation of Out of School Children (OOSC) in Ethiopia. 2012.
23. UNICEF'S Child-Friendly Schools: Ethiopia case study. Addis Ababa, Ethiopia. 2010.
24. Grimes JET, Tadesse G, Gardiner IA, Yard E, Wuletaw Y, Templeton MR, et al. Sanitation, hookworm, anemia, stunting, and wasting in primary schoolchildren in southern Ethiopia: Baseline results from a study in 30 schools. PLoS Negl Trop Dis. 2017; 11(10): e0005948. https://doi.org/10.1371/journal.pntd.0005948 PMID: 28991894
25. Alexander N. Review: analysis of parasite and other skewed counts. Trop Med Int Health. 2012; 17(6): 684–93. https://doi.org/10.1111/j.1365-3156.2012.02987.x PMID: 22943299
26. Standard Treatment Guideline for Health Centers. Drug administration and control authority of Ethiopia contents. Addis Ababa, Ethiopia: The Drug Administration and Control Authority (DACA) of Ethiopia; January 2010; 349.
27. Sullivan KM, Dean A, Soe MM. OpenEpi: a web-based epidemiologic and statistical calculator for public health. Public Health Rep. 2009; 124(3): 471–4. https://doi.org/10.1177/003335490912400320 PMID: 19445426
28. Daniel WW. Biostatistics: a foundation for analysis in the health sciences. New York: John Willey and Sons. 1999.
29. Mesfin F, Berhane Y, Worku A. Anemia among primary schoolchildren in Eastern Ethiopia. PLoS One. 2015; 10(4): e0123615. https://doi.org/10.1371/journal.pone.0123615 PMID: 25902055

30. Mekonnen H, Tadesse T, Kisi K. Malnutrition and its correlates among rural primary schoolchildren of Fogera District, Northwest Ethiopia. J Nutr Disord Ther. 2013: 2–7.
31. Ali J, Yifru S, Woldeamanuel Y. Prevalence of tinea capitis and the causative agent among schoolchildren in Gondar, North West Ethiopia. Ethiop Med J. 2009; 47(4): 261–9. PMID: 20067140
32. Komba EV, Mgonda YM. The spectrum of dermatological disorders among primary schoolchildren in Dares Salaam. BMC Public Health. 2010; 10: 765. https://doi.org/10.1186/1471-2458-10-765 PMID: 21162714
33. Montresor A, Crompton DWT, Hall A, Bundy DAP, Savioli L. Guidelines for the evaluation of soil-transmitted helminthiasis and schistosomiasis at community level: A guide for managers of control programmes. Geneva: World Health Organization; 1998.
34. WHO. Basic laboratory methods in medical parasitology. Geneva: World Health Organization; 1991.
35. Manser MM, Saez ACS, Chiodini PL. Faecal parasitology: Concentration methodology needs to be better standardised. PLoS Negl Trop Dis. 2016; 10(4): e0004579. https://doi.org/10.1371/journal.pntd.0004579 PMID: 27073836
36. WHO. Assessing the efficacy of anthelminthic drugs against schistosomiasis and soil-transmitted helminthiases. Geneva: World Health Organization; 2013.
37. Speich B, Ali SM, Ame SM, Albonico M, Utzinger J, Keiser J. Quality control in the diagnosis of Trichuris trichiura and Ascaris lumbricoides using the Kato-Katz technique: experience from three randomised controlled trials. Parasites and Vectors. 2015; 8(1): 82.
38. Vyas S, Kumaranayake L. Constructing socio-economic status indices: how to use principal components analysis. Health Policy Plan. 2006; 21(6): 459–68. https://doi.org/10.1093/heapol/czl029 PMID: 17030551
39. WHO AnthroPlus for personal computers manual. Software for assessing growth of the world's children and adolescents. Geneva: WHO; 2009. http://www.who.int/growthref/tools/en/.
40. de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. Bull World Health Organ. 2007; 85(9): 660–7. https://doi.org/10.2471/blt.07.043497 PMID: 18026621
41. WHO. Haemoglobin concentrations for the diagnosis of anaemia and assessment of severity. Vitamin and Mineral Nutrition Information System. Geneva, World Health Organization, 2011 (WHO/NMH/NHD/MNM/11.1).
42. Kirkwood BR, Sterne JAC. Essential Medical Statistics. 2 ed. Australia: Blackwell Publishing Ltd; 2003.
43. Leuenberger A, Nassoro T, Said K, Fenner L, Sikalengo G, Letang E, et al. Assessing stool quantities generated by three specific Kato-Katz thick smear templates employed in different settings. Infectious Diseases of Poverty. 2016; 5: 58. https://doi.org/10.1186/s40249-016-0150-9 PMID: 27364623
44. WHO. Prevention and control of schistosomiasis and soil-transmitted helminthiasis: Report of a WHO expert committee. Geneva; 2002. WHO Technical Report Series, 912.
45. Martin T, Wintle B, Rhodes J, Kuhnert P, Field S, Lowchoy S, et al. Zero tolerance ecology: Improving ecological inference by modelling the source of zero observations. Ecol Lett. 2005; 8: 1235–46. https://doi.org/10.1111/j.1461-0248.2005.00826.x PMID: 21352447
46. Xu L, Paterson AD, Turpin W, Xu W. Assessment and selection of competing models for zero-inflated microbiome data. PLoS One. 2015; 10(7): e0129606. https://doi.org/10.1371/journal.pone.0129606 PMID: 26148172
47. Forrer A, Vounatsou P, Sayasone S, Vonghachack Y, Bouakhasith D, Utzinger J, et al. Risk profiling of hookworm infection and intensity in Southern Lao People's Democratic Republic using bayesian models. PLoS Negl Trop Dis. 2015; 9(3): e0003486. https://doi.org/10.1371/journal.pntd.0003486 PMID: 25822794
48. Chipeta MG, Ngwira BM, Simoonga C, Kazembe LN. Zero adjusted models with applications to analysing helminths count data. BMC Res Notes. 2014; 7(1): 856. https://doi.org/10.1186/1756-0500-7-856 PMID: 25430726
49. Wang C, Torgerson PR, Höglund J, Furrer R. Zero-inflated hierarchical models for faecal egg counts to assess anthelmintic efficacy. Vet Parasitol. 2017; 235:20–8. https://doi.org/10.1016/j.vetpar.2016.12.007 PMID: 28215863
50. Twisk JWR. Applied multilevel analysis. A practical guides to biostatistics and epidemiology. Cambridge: Cambridge University Press; 2006.
51. Knopp S, Mgeni AF, Khamis IS, Steinmann P, Stothard JR, Rollinson D, et al. Diagnosis of soil-transmitted helminths in the era of preventive chemotherapy: effect of multiple stool sampling and use of different diagnostic techniques. PLoS Negl Trop Dis. 2008; 2. https://doi.org/10.1371/journal.pntd.0000331 PMID: 18982057

52. Tarafder MR, Carabin H, Joseph L, Balolong E Jr., Olveda R, McGarvey ST. Estimating the sensitivity and specificity of Kato-Katz stool examination technique for detection of hookworms, Ascaris lumbricoides and Trichuris trichiura infections in humans in the absence of a 'gold standard'. Int J Parasitol. 2010; 40(4): 399–404. https://doi.org/10.1016/j.ijpara.2009.09.003 PMID: 19772859

53. Knopp S, Salim N, Schindler T, Karagiannis Voules DA, Rothen J, Lweno O, et al. Diagnostic accuracy of Kato-Katz, FLOTAC, Baermann, and PCR methods for the detection of light-intensity hookworm and Strongyloides stercoralis infections in Tanzania. Am J Trop Med Hyg. 2014; 90(3): 535–45. https://doi.org/10.4269/ajtmh.13-0268 PMID: 24445211

54. Meurs L, Polderman AM, Vinkeles Melchers NVS, Brienen EAT, Verweij JJ, Groosjohan B, et al. Diagnosing polyparasitism in a high-prevalence setting in Beira, Mozambique: Detection of intestinal parasites in fecal samples by microscopy and Real-Time PCR. PLoS Negl Trop Dis. 2017; 11(1): e0005310–e. https://doi.org/10.1371/journal.pntd.0005310 PMID: 28114314

55. Endris M, Tekeste Z, Lemma W, Kassu A. Comparison of the Kato-Katz, Wet Mount, and Formol-Ether Concentration Diagnostic Techniques for Intestinal Helminth Infections in Ethiopia. ISRN Parasitology. 2013; 2013:180439. https://doi.org/10.5402/2013/180439 PMID: 27335845

56. Yimer M, Hailu T, Mulu W, Abera B. Evaluation performance of diagnostic methods of intestinal parasitosis in school age children in Ethiopia. BMC Res Notes. 2015; 8(1): 820. https://doi.org/10.1186/s13104-015-1822-4 PMID: 26708493

57. Nikolay B, Brooker SJ, Pullan RL. Sensitivity of diagnostic tests for human soil-transmitted helminth infections: a meta-analysis in the absence of a true gold standard. Int J Parasitol. 2014; 44(11):765–74. https://doi.org/10.1016/j.ijpara.2014.05.009 PMID: 24992655

58. Speich B, Utzinger J, Marti H, Ame SM, Ali SM, Albonico M, et al. Comparison of the Kato-Katz method and ether-concentration technique for the diagnosis of soil-transmitted helminth infections in the framework of a randomised controlled trial. Eur J Clin Microbiol Infect Dis. 2014; 33(5): 815–22. https://doi.org/10.1007/s10096-013-2019-1 PMID: 24272064

59. Glinz D, Silué KD, Knopp S, Lohourignon LK, Yao KP, Steinmann P, et al. Comparing Diagnostic Accuracy of Kato-Katz, Koga Agar Plate, Ether-Concentration, and FLOTAC for Schistosoma mansoni and Soil-Transmitted Helminths. PLoS Negl Trop Dis. 2010; 4(7): e754. https://doi.org/10.1371/journal.pntd.0000754 PMID: 20651931

60. Shaka MF, Wondimagegne YA. Anemia, a moderate public health concern among adolescents in South Ethiopia. PLoS One. 2018; 13(7): e0191467. https://doi.org/10.1371/journal.pone.0191467 PMID: 30016373

61. Worrell CM, Wiegand RE, Davis SM, Odero KO, Blackstock A, Cuéllar VM, et al. A cross-sectional study of water, sanitation, and hygiene-related risk factors for soil-transmitted helminth infection in urban school, and preschool-aged children in Kibera, Nairobi. PLoS One. 2016; 11(3): e0150744–e. https://doi.org/10.1371/journal.pone.0150744 PMID: 26950552

62. Matangila JR, Doua JY, Linsuke S, Madinga J, Inocêncio da Luz R, Van Geertruyden J-P, et al. Malaria, schistosomiasis and soil transmitted helminth burden and their correlation with anemia in children attending primary schools in Kinshasa, Democratic Republic of Congo. PLoS One. 2014; 9(11): e110789–e. https://doi.org/10.1371/journal.pone.0110789 PMID: 25372029

63. Erismann S, Diagbouga S, Odermatt P, Knoblauch AM, Gerold J, Shrestha A, et al. Prevalence of intestinal parasitic infections and associated risk factors among schoolchildren in the Plateau Central and Centre-Ouest regions of Burkina Faso. Parasit Vectors. 2016; 9(1): 554. https://doi.org/10.1186/s13071-016-1835-4 PMID: 27756339

64. Alum A, Rubino JR, Ijaz MK. The global war against intestinal parasites: should we use a holistic approach? Int J Infect Dis. 2010; 14(9): e732–8. https://doi.org/10.1016/j.ijid.2009.11.036 PMID: 20399129

65. Grimes JET, Tadesse G, Mekete K, Wuletaw Y, Gebretsadik A, French MD, et al. School water, sanitation, and hygiene, soil-transmitted helminths, and schistosomes: National mapping in Ethiopia. PLoS Negl Trop Dis. 2016; 10(3): e0004515. https://doi.org/10.1371/journal.pntd.0004515 PMID: 26954688

66. Yimam Y, Degarege A, Erko B. Effect of anthelminthic treatment on helminth infection and related anaemia among school-age children in northwestern Ethiopia. BMC Infect Dis. 2016; 16(1): 613. https://doi.org/10.1186/s12879-016-1956-6 PMID: 27793110

67. Gashaw F, Aemero M, Legesse M, Petros B, Teklehaimanot T, Medhin G, et al. Prevalence of intestinal helminth infection among schoolchildren in Maksegnit and Enfranz Towns, northwestern Ethiopia, with emphasis on Schistosoma mansoni infection. Parasit Vectors. 2015; 8(1): 567.

68. Habtamu K, Degarege A, Ye-Ebiyo Y, Erko B. Comparison of the Kato-Katz and FLOTAC techniques for the diagnosis of soil-transmitted helminth infections. Parasitol Int. 2011; 60(4): 398–402. https://doi.org/10.1016/j.parint.2011.06.020 PMID: 21726662

69. Stephenson LS, Holland CV, Cooper ES. The public health significance of Trichuris trichiura. Parasitol. 2000; 121 Suppl: S73–S95. https://doi.org/10.1017/s0031182000006867 PMID: 11386693

70. Hailegebriel T. Undernutrition, intestinal parasitic infection and associated risk factors among selected primary schoolchildren in Bahir Dar, Ethiopia. BMC Infect Dis. 2018; 18(1): 394. https://doi.org/10.1186/s12879-018-3306-3 PMID: 30103696

71. Yimer M, Hailu T, Mulu W, Abera B. Evaluation performance of diagnostic methods of intestinal parasitosis in school age children in Ethiopia. BMC Res Notes. 2015; 8:820–. https://doi.org/10.1186/s13104-015-1822-4 PMID: 26708493

72. Schüle SA, Clowes P, Kroidl I, Kowuor DO, Nsojo A, Mangu C, et al. Ascaris lumbricoides infection and its relation to environmental factors in the Mbeya region of Tanzania, a cross-sectional, population-based study. PLoS One. 2014; 9(3):e92032–e. https://doi.org/10.1371/journal.pone.0092032 PMID: 24643023

73. Gutema B, Adissu W, Asress Y, Gedefaw L. Anemia and associated factors among school-age children in Filtu Town, Somali region, Southeast Ethiopia. BMC hematology. 2014; 14(1): 13. https://doi.org/10.1186/2052-1839-14-13 PMID: 25170422

74. Getachew T, Argaw A. Intestinal helminth infections and dietary diversity score predict nutritional status of urban schoolchildren from southern Ethiopia. BMC Nutrition. 2017; 3(1): 9.

75. Nguyen NL, Gelaye B, Aboset N, Kumie A, Williams MA, Berhane Y. Intestinal parasitic infection and nutritional status among schoolchildren in Angolela, Ethiopia. J Prev Med Hyg. 2012; 53(3): 157–64. PMID: 23362622

76. Abdi M, Nibret E, Munshea A. Prevalence of intestinal helminthic infections and malnutrition among schoolchildren of the Zegie Peninsula, northwestern Ethiopia. J Infect Public Health. 2017; 10(1): 84–92. https://doi.org/10.1016/j.jiph.2016.02.009 PMID: 27026133

77. Katona P, Katona-Apte J. The interaction between nutrition and infection. Clin Infect Dis. 2008; 46(10): 1582–8. https://doi.org/10.1086/587658 PMID: 18419494

78. Degarege A, Hailemeskel E, Erko B. Age-related factors influencing the occurrence of undernutrition in northeastern Ethiopia. BMC Public Health. 2015; 15: 108. https://doi.org/10.1186/s12889-015-1490-2 PMID: 25885212

79. Degarege A, Animut A, Medhin G, Legesse M, Erko B. The association between multiple intestinal helminth infections and blood group, anaemia and nutritional status in human populations from Dore Bafeno, southern Ethiopia. J Helminthol. 2014; 88(2): 152–9. https://doi.org/10.1017/S0022149X12000855 PMID: 23286203

80. de Gier B, Nga TT, Winichagoon P, Dijkhuizen MA, Khan NC, van de Bor M, et al. Species-specific associations between soil-transmitted helminths and micronutrients in Vietnamese schoolchildren. Am J Trop Med Hyg. 2016; 95(1): 77–82. https://doi.org/10.4269/ajtmh.15-0533 PMID: 27246448

81. Suchdev PS, Davis SM, Bartoces M, Ruth LJ, Worrell CM, Kanyi H, et al. Soil-transmitted helminth infection and nutritional status among urban slum children in Kenya. Am J Trop Med Hyg. 2014; 90(2): 299–305. https://doi.org/10.4269/ajtmh.13-0560 PMID: 24343884

82. Quihui L, Valencia ME, Crompton DWT, Phillips S, Hagan P, Morales G, et al. Role of the employment status and education of mothers in the prevalence of intestinal parasitic infections in Mexican rural schoolchildren. BMC Public Health. 2006; 6: 225–. https://doi.org/10.1186/1471-2458-6-225 PMID: 16956417

83. Khairy AE, El Sebaie O, Abdel Gawad A, El Attar L. The sanitary condition of rural drinking water in a Nile Delta village. I. Parasitological assessment of 'zir' stored and direct tap water. J Hyg. 1982; 88(1): 57–61. https://doi.org/10.1017/s0022172400069898 PMID: 7057027

84. Mulambalah C, Ruto J. Prevalence and infection intensity of geohelminthiases among schoolchildren as an environmental health indicator to guide preventive activities in Nandi County, Kenya. Trop J Med Res. 2016; 19(2): 131–7.

85. Wani SA, Ahmad F, Zargar SA, Dar ZA, Dar PA, Tak H, et al. Soil-transmitted helminths in relation to hemoglobin status among schoolchildren of the Kashmir Valley. Parasitol. 2008; 94(3): 591–3.

86. WHO, UNICEF. Progress on sanitation and drinking water. 2015 update and MDG assessment. Geneva: World Health Organization. https://apps.who.int/iris/handle/10665/177752

87. Feleke BE. Nutritional status and intestinal parasite in school age children: A comparative cross-sectional study. Int J Pediatr. 2016; 1962128. https://doi.org/10.1155/2016/1962128 PMID: 27656219

88. O'Lorcain P, Holland CV. The public health importance of Ascaris lumbricoides. Parasitol. 2000; 121 Suppl: S51–S71. https://doi.org/10.1017/s0031182000006442 PMID: 11386692

89. Mahmud MA, Spigt M, Bezabih AM, Pavon IL, Dinant G-J, Velasco RB. Efficacy of handwashing with soap and nail clipping on intestinal parasitic infections in school-aged children: A factorial cluster randomized controlled trial. PLoS Med. 2015; 12(6): e1001837–e. https://doi.org/10.1371/journal.pmed.1001837 PMID: 26057703

90. Shumbej T, Belay T, Mekonnen Z, Tefera T, Zemene E. Soil-transmitted helminths and associated factors among pre-schoolchildren in Butajira Town, South-central Ethiopia: A community-based cross-sectional study. PLoS One. 2015; 10(8): e0136342. https://doi.org/10.1371/journal.pone.0136342 PMID: 26305361

91. Benjamin-Chung J, Nazneen A, Halder AK, Haque R, Siddique A, Kopor MSUK, et al. The interaction of deworming, improved sanitation, and household flooring with soil-transmitted helminth infection in rural Bangladesh. PLoS Negl Trop Dis. 2015; 9(12): e0004256. https://doi.org/10.1371/journal.pntd.0004256 PMID: 26624994

Helminth infections among rural schoolchildren in Southern Ethiopia: A cross-sectional multilevel and zero-inflated regression model

Hiwot Hailu Amare ✉, Bernt Lindtjørn

Published: December 22, 2020 • https://doi.org/10.1371/journal.pntd.0008002

Reader Comments

Post a new comment on this article

overdispersion

Posted by **SSubramaninan** on **29 Dec 2020 at 05:36 GMT**

I am refering to Section on "Zero-inflated negative binomial regression for modelling infection intensity".

The authors state that the mean was greater than the variance. Therefore Poisson can not be an appropriate model. But they menthioned that there is an overdispersion. This is contradicting with the criterion for overdispersion. For overdispersion the variance shoule be greater than the mean. May I request the authors to explain their justification for overdispersion?

Thanks and regards
S. Subramanian

RE: overdispersion

hhailu replied to **SSubramaninan** on **04 Jan 2021 at 20:42 GMT**

We are grateful to S. Subramanian for pointing to a writing error.

The sentences on page: 8: subheading: Zero-inflated negative binomial regression for modelling infection intensity: line: 4 reads: «the mean of A. lumbricoides and T. trichiura eggs was higher than the variance» was written incorrectly.

As shown in S5 and S6 Tables, as well as in the S1 Dataset, there was a typing error in the main text.

Therefore, the corrected text is: the variance of A. lumbricoides and T. trichiura eggs were higher than the mean.

Thank you

Best regards
Hiwot

No competing interests declared.

This is a correction for Table 4 in Paper II: The infection intensity AOR (95% CI) and infection probability AOR (95% CI) were misplaced during the publication process. Please find below the correct version of the Table 4.

Table 4: Zero-inflated negative binomial regression model for *T. trichiura* fecal egg count among schoolchildren in the Wonago district, Southern Ethiopia, 2017 (n=850).

Variables		**Zero-inflated negative binomial model**	
		Negative binomial part	**Zero-inflated part**
Individual child, parent, household and school factors		**Infection intensity AOR (95% CI)**	**Infection probability AOR (95% CI)**
Sex	Boys	1.0	1.0
	Girls	1.23 (1.04, 1.45)*	1.06 (0.79, 1.43)
Age in years	Mean (SD)	1.01 (0.97, 1.05)	1.07 (0.98, 1.15)
Fingernails trimmed	Yes	0.82 (0.61, 1.09)	0.92 (0.57, 1.49)
	No	1.0	1.0
Habit of eating uncooked vegetable	Yes	1.05 (0.86, 1.27)	0.70 (0.50, 0.99)*
	No	1.0	1.0
Loss of appetite in past month	Yes	0.95 (0.75, 1.21)	0.52 (0.34, 0.81)**
	No	1.0	1.0
Hemoglobin concentration	Mean (SD)	0.96 (0.91, 1.01)	1.13 (1.03, 1.25)*
Thinness	No	1.0	1.0
	Yes	1.10 (0.86, 1.41)	0.59 (0.36, 0.94)*
Mother's education level	Never entered school	1.18 (0.86, 1.61)	0.56 (0.34, 0.92)*
	Read and write only	1.19 (0.80, 1.78)	0.64 (0.32, 1.26)
	Primary and above	1.0	1.0
Wealth status	Poor	0.99 (0.81, 1.22)	0.98 (0.68, 1.41)
	Middle-class	0.92 (0.74, 1.14)	0.95 (0.66, 1.38)
	Rich	1.0	1.0
Water storage	Closed container	1.0	1.0
	Open container	1.59 (1.14, 2.22)**	0.82 (0.44, 1.49)
Participates in school food programme	No	1.0	1.0
	Yes	1.18 (0.98, 1.42)	0.56 (0.41, 0.78)**

AOR: adjusted odds ratio; CI: confidence interval; **P <.01;*P<.05

Paper-III

PLOS NEGLECTED TROPICAL DISEASES

RESEARCH ARTICLE

Risk factors for scabies, tungiasis, and tinea infections among schoolchildren in southern Ethiopia: A cross-sectional Bayesian multilevel model

Hiwot Hailu Amare[1,2,3]*, **Bernt Lindtjorn**[1,2]

1 School of Public Health, College of Medicine and Health Sciences, Hawassa University, Hawassa, Ethiopia, **2** Centre for International Health, University of Bergen, Bergen, Norway, **3** Department of Public Health, College of Health Sciences and Medicine, Dilla University, Dilla, Ethiopia

* hiwothailu14@yahoo.com

Check for updates

OPEN ACCESS

Citation: Amare HH, Lindtjorn B (2021) Risk factors for scabies, tungiasis, and tinea infections among schoolchildren in southern Ethiopia: A cross-sectional Bayesian multilevel model. PLoS Negl Trop Dis 15(10): e0009816. https://doi.org/10.1371/journal.pntd.0009816

Editor: Uwem Friday Ekpo, Federal University of Agriculture Abeokuta, NIGERIA

Received: July 14, 2021

Accepted: September 16, 2021

Published: October 6, 2021

Peer Review History: PLOS recognizes the benefits of transparency in the peer review process; therefore, we enable the publication of all of the content of peer review and author responses alongside final, published articles. The editorial history of this article is available here: https://doi.org/10.1371/journal.pntd.0009816

Data Availability Statement: All relevant data are within the manuscript and its Supporting Information files.

Abstract

Background

Skin problems cause significant sickness in communities with poor living conditions, but they have received less attention in national or global health studies because of their low mortality rates. In many developing regions, the prevalence of parasitic skin diseases among schoolchildren is not reported. Previous studies thus have attempted to identify risk factors for these conditions using the frequentist approach. This study aimed to assess the occurrence and risk factors of skin infections among rural schoolchildren in southern Ethiopia by combining a frequentist and a Bayesian approach.

Methodology/Principal findings

Using three-stage random sampling, we assessed 864 schoolchildren aged 7–14 years from the Wonago district in southern Ethiopia. We detected potential risk factors for scabies, tungiasis, and tinea infections and recorded their hygienic practices and socio-demographic information. The frequentist model revealed a clustering effect of 8.8% at the classroom level and an insignificant effect at the school level. The Bayesian model revealed a clustering effect of 16% at the classroom level and 5.3% at the school level. Almost three-fourths of the sample had at least one type of skin problem, and boys were at higher overall risk than girls (adjusted odds ratio [aOR] 1.55 [95% Bayesian credible interval [BCI] 1.01, 2.28). Risk factors included unclean fingernails (aOR 1.85 [95% BCI 1.08, 2.97]); not washing the body (aOR 1.90 [95% BCI 1.21, 2.85]) and hair (aOR 3.07 [95% BCI 1.98, 4.57]) with soap every week; sharing a bed (aOR 1.97 [95% BCI 1.27, 2.89]), clothes (aOR 5.65 [95% BCI 3.31, 9.21]), or combs (aOR 3.65 [95% BCI 2.28, 5.53]); and living in a poor household (aOR 1.76 [95% BCI 1.03, 2.83]). Washing legs and feet with soap daily was identified as a protective factor for each of the three skin diseases (aOR 0.23 [95% BCI 0.15, 0.33]).

Funding: Norwegian Programme for Capacity Development in Higher Education and Research for Development/ South Ethiopia Network of Universities in Public Health (NORHED/SENUPH) project provided funding in the form of a grant awarded to BL (ETH-13/0025). URL: https://www.uib.no/en. The sponsors or funders have no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Competing interests: The authors have declared that no competing interests exist.

Conclusions/Significance

We observed high variation in skin problems at the classroom level, indicating the presence of shared risk factors in these locations. The findings suggest the need to improve children's personal hygiene via health education by schoolteachers and health workers.

Author summary

Skin problems are common disorders in resource poor settings. Scabies and tungiasis are neglected tropical diseases causing significant sickness in communities with poor living conditions. Scabies is dermatosis caused by a burrowing mite, *Sarcoptes scabiei var. hominis*. Tungiasis is caused by a flea, *Tunga penetrans*, infesting the skin, usually on the feet or hands. Tinea infection is a fungal dermatophyte infection of the skin and the most common dermatological problem among schoolchildren in Ethiopia, especially tinea capitis. Application of a Bayesian approach to identify possible risk factors for these problems has seldom been used. We found that compared to the frequentist model, the Bayesian model better explained school- and classroom-level variations in skin problems among schoolchildren. Our findings also suggest that transmission of skin infections, especially fungal and scabies infections, frequently occurs in schools and classrooms. We identified several risk factors for these conditions, including low socioeconomic status; unclean fingernails; not washing with soap at least every week; and sharing beds, clothes, and combs. Thus, it is important to improve the personal hygiene of schoolchildren through education. Regular checkups by teachers also can improve skin health and related morbidity in rural schoolchildren in southern Ethiopia.

Introduction

Skin problems are major causes of disability worldwide. In 2013, the estimated disability-adjusted life years for skin problems was 1.79% of the total global burden of disease, including 0.15% for fungal skin diseases and 0.07% for scabies [1]. The prevalence of tungiasis (Jigger flea) infections is estimated to be up to 50% in some endemic areas [2]. Unfortunately, skin problems have received less attention in the national or global health studies because of their low mortality [3]. This study thus aimed to assess the occurrence and risk factors of three parasitic skin diseases (scabies, tungiasis, and tinea) and their risk factors among rural schoolchildren in southern Ethiopia using both a frequentist and Bayesian approach.

Neglected parasitic skin diseases are important medical challenges in resource-poor settings [4, 5]. Scabies, an intensely itchy ectoparasitic skin disease, results from infestations of the mite *Sarcoptes scabiei var. hominis* [5, 6]. Scabies lesions can occur in several body sites, but the topographic distribution of scabies lesions may vary with age [6–9]. Globally, it affects over 200 million people, with prevalence ranging from 0.2% to 71% [10]. Half of school-aged children in southern Ethiopia have scabies [11]. Tungiasis is a parasitic skin disease caused by the female sand flea *Tunga penetrans*, also known as the jigger flea [12]. It causes erythema, edema tenderness, itching, and pain in acute phase; and shining skin, desquamation, nail and toes deformity or loss of nails may occur in the chronic phase [13]. It have also socio-economic impact that includes difficulty walking or gripping, sleep disturbances, stigma, and all of which affects quality of life, school absenteeism, and dropout rates [13–16]. Bacterial superinfection is almost constant. Death may ensue when bacterial superinfection causes tetanus, gangrene, or septicaemia [13, 14, 17]. Ethiopia has a favorable environment for jigger fleas [18], and the prevalence of tungiasis ranges between 35% to 60% among school-aged children in southern Ethiopia [16, 19]. Tinea is a fungal infection caused by dermatophyte infestation, usually on the scalp, foot, hand, groin, nails, or face [20]. A recent study has indicated that one in five children in Africa has tinea capitis [21], and more than 96% (132.6 million) of cases occur in sub-Saharan Africa, mostly in Nigeria and Ethiopia [21]. The prevalence among schoolchildren in southern Ethiopia is about 25% [22]. Poor hygiene, large families, overcrowding, shared fomites, poverty, and environmental conditions are important underlying social determinants for these three diseases.

Schoolchildren in Ethiopia are vulnerable to various health problems [23]. High rates of nutritional disorders, intestinal parasitic infections, and skin problems have been reported [24]. Although some school health programs include programs to address scabies, tungiasis, and fungal infections, including mandatory periodic screenings, most of these programs are non-functional [23]. In 2012, Ethiopia established the National School Health and Nutrition Strategy aiming to improve schoolchildren's access to health interventions [25], such as nutrition [26], deworming [27], and water, sanitation, and hygiene [24]. These efforts are ongoing, but major gaps persist in the implementation of these school health services [23].

Most studies on skin problems among primary schoolchildren in Ethiopia did not assess them collectively [19, 22, 28, 29] or focus on scabies [11, 30–33]. To our knowledge, reports of scabies, tungiasis, and tinea prevalence among schoolchildren in southern Ethiopia have not been compiled independently. Moreover, previous studies on these diseases in Ethiopia have used a frequentist approach to identify risk factors. We examine whether a Bayesian model, which estimates credible intervals for unknown parameters from posterior distribution [34, 35], can provide important and additional information for assessing and managing these diseases.

Methods

Ethics statement

The institutional review board at the College of Medicine and Health Sciences of Hawassa University (IRB/005/09) and the Regional Ethical Committee of Western Norway (2016/1900/REK vest) provided ethical clearance. The Gedeo Zone Health Department and District Education Office provided a letter of permission. School directors and teachers were informed about the study objectives and procedures. We obtained informed written (signed) and verbal (thumb print) consent from all study participants' parents or guardians and written permission (assent) from children aged 12 years and older before the interviews. The participants' privacy and confidentiality were maintained. Children diagnosed with scabies and tinea infections were referred to the nearest health institution for treatment according to the standard national guidelines [36]. At the end of the study, we provided soap and Vaseline ointment to each child to encourage them to protect their legs and feet. Health education on personal hygiene also was provided to all children in each school.

Study location, design, participants, and sample size

We conducted this cross-sectional survey as part of a large project examining anemia, stunting, and intestinal helminth infections among schoolchildren in the Wonago district of the Gedeo zone in southern Ethiopia [37, 38]. The study period was from February 2017 to June 2017. The survey area, design, and sample size estimation are described in detail elsewhere [37, 38]. The study population included 864 randomly recruited schoolchildren aged 7–14 years and their parents or guardians. Using a three-stage cluster sampling method, we first randomly selected four schools and then 24 classrooms totaling 2,384 children. Children aged below 7 years and older than 14 years were excluded from this study. Finally, we included 864 children. Children were recruited at their schools, and their parents or guardians were contacted by visiting their homes. S1 Fig. illustrates the recruitment process.

Data collection tools and procedures

Using ten trained enumerators, we conducted interviews via a structured and pretested questionnaire, which was adapted and developed in English and then translated into the local Gedeo language. All personnel who participated in data collection, supervision, and data entry were trained accordingly. We conducted interviews with children at their schools and with the parents or guardians in their homes. We conducted a pre-test to validate the measurement tools; to reduce potential bias, the pre-test included 42 children from another primary school not included in this study. The completeness and consistency of data were regularly checked by supervisors.

Information related to the child's personal hygiene and household factors was collected via interviews and observation. Individual exposure variables included sex, age, personal hygiene (frequency of washing body, legs, feet, and hair with soap; frequency of nail trimming; presence of unclean fingernails; habit of walking barefoot; presence of footwear at time of examination; sharing of beds, combs, and clothes). The education level of the mother and father were included as parents' exposure variables. Household factors included family size and wealth status. Apart from access to health education on personal hygiene, school-level factors included information on availability of drinking water, handwashing facilities, latrines, and toilet paper.

Diagnosis and measurement of skin problems

Physical examinations from scalp to toes were performed in daylight in a private place by one of three nurses (a male nurse for boys and female nurse for girls) experienced in clinical diagnoses of dermatologic cases. Children's feet and hands were cleaned with water and soap before diagnosis of tungiasis. Any identified or suspected skin problems were recorded according to the involved site. To minimize bias in these assessments, 10% (86) of children were examined by two nurses to ensure reproducibility of results. In cases of disagreement, a third and experienced examiner joined the diagnostic process to reach a consensus.

The outcome variable for this study was the presence or absence of scabies, tungiasis, or tinea infection. Scabies was diagnosed via clinical findings of typical skin lesions on the hands, interdigital places, wrists, arms, elbows, armpits, abdomen, chest, mamillar or perimammillar areas, back, buttocks, genitalia, legs, or feet; as well as a history of itching that intensified at night [30, 39, 40]. Tinea infections were classified according to the involved body site [20, 41–44]: tinea capitis (scalp), tinea corporis (torso, arms, and legs), tinea pedis (feet), tinea cruris (groin), tinea unguium (nails), tinea faciei (face), and tinea manuum (hands). Tinea capitis involved one or more scaly patches of alopecia with hairs broken at the skin line (black dots) and crusting. Tinea corporis presented as a red or hyperpigmented lesions on skin other than the face, scalp, groin, hands, or feet. Tinea pedis involved red, scaly, fissures of the foot and maceration and itching between the toes extending to the sole borders, with occasional involvement of the dorsum. Tinea cruris was diagnosed in cases involving the groin and upper thigh but sparing the scrotum and penis. Yellow-brown to black discoloration of the distal portion of the nail, proximal nail bed, or undersurface of the nail plate was diagnosed as tinea unguium. Typical red or pink hyperpigmentation or lesions on the face was diagnosed as tinea faciei. Tinea manuum presented as a red and scaly lesions on the palmar or dorsum of the hands [20, 41–44]. Tungiasis was diagnosed with Fortaleza classification via clinical findings of penetrating sand fleas: a small, dark, itchy spot in the epidermis with visible posterior parts of the parasite, with or without local pain; a brownish or black dot surrounded by erythema; a circular yellow-white patch with a central black dot representing the posterior segments of the parasite; a circular brownish-black crust with or without surrounding necrosis of the epidermis. We also recorded a manipulated lesions: a characteristic crater-like sore or lesion and suppurating lesions caused by the use of non-sterile perforating instruments (i.e. needles) [45].

Statistical methods

Epi-data version 3.1 (EpiData Association; Odense Denmark, 2004) was used for double-data entry. Prior to analysis, data were cleaned, missing values addressed, and then data exported to SPSS version 20 (IBM Corp, 2011) and STATA 15 software (StataCorp LLC, College Station, TX, 2017) for analysis. Study variables were described using frequencies, percentages, means, ranges, and standard deviations (SD). We applied cross tabulation to calculate the percentage of categorical variables in relation to outcome variables for any scabies, tungiasis, and tinea infections. Using principal component analysis [46], we constructed a wealth index using 14 household asset variables described elsewhere in detail [37]. The socioeconomic indictors were categorized into poor, middle, and rich households based on the first component explaining 28.3% of the variance in the data. A frequentist model and a Bayesian, multilevel, mixed-effect, logistic, regression model were used to analyze binary outcome variables any skin problem (presence or absence of any one of three skin conditions such as scabies, tungiasis, and tinea) and presence or absence of scabies, tungiasis, and tinea.

Multilevel, mixed-effect, logistic regression (Frequentist approach)

We nested our data at three levels: individuals (level 1) within classrooms (level 2) within schools (level 3). Clustering effects at the school and classroom levels, including potential confounders and effect modifications, were assessed using multivariate, multilevel, mixed-effect, logistic regression and stratified analysis. Independent variables were checked for collinearity before the multivariate analysis. In both bivariate and multivariate analyses, we employed the model without random effects and with random school and class effects for all factors.

The null model contained no covariate variables and indicated whether to consider the random-effect model. Independent variables for which $P < 0.25$ in the bivariate, multilevel, mixed-effect, logistic regression model were included in all models, including the final model. To control for confounding, covariate variables for which $P > 0.25$ in the bivariate model were retained in the full multivariate model containing individual-, household- and school-level factors. These covariate variables included age in the model for any skin problem; body washing and household wealth in the scabies model; age, unclean fingernails, walking barefoot, family size, and access to health education on personal hygiene in the tungiasis model; and age, family size, and access to health education on personal hygiene in the tinea model.

The final model for any skin problem included sex; age; presence of unclean fingernails; presence of footwear; frequency of washing with soap; sharing beds, clothes, and combs; household wealth; and access to health education on personal hygiene. The scabies model included variables for sex; age; frequency of washing with soap; sharing beds, clothes, and combs; family size; household wealth; and access to health education on personal hygiene. The tungiasis model included variables for sex; age; nail trimming; walking barefoot; presence of footwear; frequency of washing with soap; sharing beds and clothes; family size; household wealth; and access to health education on personal hygiene. The tinea model included sex; age; presence of unclean fingernails; walking barefoot; presence of footwear; frequency of washing with soap; sharing beds and clothes; family size; household wealth; and access to health education on personal hygiene. Intra-cluster correlation coefficients (ICCs) for clustering effects at the school and classroom levels were reported for each model. We calculated the Akaike information criterion to evaluate model performance, with lower values indicating better fit [47].

Bayesian multilevel, mixed-effect, logistic regression

The Bayesian method provides probabilistic summaries for the parameters of interest, treating all model parameters as random quantities. Unlike the frequentist model, Bayesian analysis uses prior knowledge and provides interval estimates (credible intervals) in which the value of the unknown parameter lies [48]. We used a multilevel approach, assuming that the risks of skin problems across schools and classrooms were correlated. Independent variables where $P < 0.25$ in the bivariate, multilevel, mixed-effect, logistic regression model were used to estimate skin problems in the Bayesian model.

We estimated model parameters using Markov Chain Monte Carlo simulation. Primarily, we used uniform priors for slopes, normal prior for the intercept, and inverse-gamma prior for the variance parameter for all models. In addition, we formulated an informative prior using previous related studies, for scabies [11, 30–32, 49], tungiasis [16, 19], and tinea [16, 22]. We then considered informative priors for slopes, normal prior for the intercept, and inverse-gamma prior for the variance parameter for these three models. However, we didn't find compiled report of scabies, tungiasis, and tinea infection to formulate informative prior for any skin problem from previous studies. Thus, we used uniform priors for slopes, normal prior for the intercept, and inverse-gamma prior for the variance parameter. We ran 25,000 interations in the simulation, discarding the first 5,000, withdrawing 20,000 samples after values were thinned by 10, and storing values to compute the posterior probability. Before drawing samples, we tested parameters for Monte Carlo standard errors, and uncertainty due to simulation errors was confirmed to be below 5% of the standard deviation [35, 50].

An acceptance rate below 10% was used to identify a convergence problem in the Markov Chain Monte Carlo methods. For any skin problem, scabies, tungiasis, and tinea in the Bayesian models, the value of the acceptance rate according to the Metropolis-Hasting algorithm was 37% out of 20,000 proposed parameters. Efficiencies of at least 10% were considered good, and average efficiencies of 26% were achieved for any skin problem, 18% for scabies, 23% for tungiasis, and 24% for tinea. Convergence also was checked using diagnostic plots for all parameters. In the posterior estimate, the mean, SD, Monte Carlo standard error, median, credible intervals, and variance of the random effect were estimated for all parameters. ICCs measuring the clustering effects at the school and classroom levels were reported for each model. We did not find a postestimation command in STATA for the ICC calculation in the Bayesian approach. Therefore, we calculated the ICC using the following formulas:

$$\text{ICC at school}-\text{level} = \frac{\text{School level variance}}{\text{School} + \text{Class level variance} + \frac{\pi 2}{3}}, \text{ and}$$

$$\text{ICC at class}-\text{level} = \frac{\text{School} + \text{Class level variance}}{\text{School} + \text{Class level variance} + \pi 2/3},$$

where $\pi^2/3 = 3.29$ indicates variance at the individual level in the logistic distribution [51, 52]. We used the deviance information criterion to evaluate model performance, with lower values indicating better fit.

Results

The 861 schoolchildren (483 boys and 378 girls) in this study were aged 7 to 14 years, with a mean [SD] age of 11.4 [1.9] years. All recruited children's parents or guardians participated in the household survey. The family size ranged from 3 to 14 (mean 6.7) persons. Among parents, 88.4% (761/861) of mothers and 48.8% (420/861) of fathers had never attended school. More than half of the mothers (54%; 463/857) were housewives, and most fathers (77.4%; 619/800) were farmers. One third of the children (33.3%; 287/861) lived in a poor household (S1 Table).

Children's personal hygiene and school hygiene

At the time of the interview, most children 81.9% (705/861) had trimmed fingernails, 24.3% (209/861) had unclean fingernails, and 2.7% (23/861) habitually walked barefoot. More than half washed their body 57.1% (492/861) and hair 54.1% (466/861) with soap every week. About 47.3% (407/861) washed their legs and feet with soap once daily. Almost two thirds shared beds (65.6%; 565/861), clothes (40.2%; 346/861), and combs (72%; 620/861) with other family members (S2 Table). Among schools, none had access to drinking water or handwashing facilities. All schools in this study had pit latrines covered with cement, but latrine floors were unclean, and no toilet paper was available (S1 Data).

Prevalence of scabies, tungiasis, and tinea infections

As shown in Table 1, of 861 children examined for skin problems, 71.7% (617/861 [95% CI 68.6, 74.6]) had scabies, tungiasis, or tinea infections. Of those, 60% (370/617) were boys and 40% (247/617) girls. We found scabies in 5.3% (46/861 [95% CI 4.0, 7.1]) of children, all of whom had lesions in the interdigital places, hands, wrists, arms, and elbows, and 84.8% (39/46) of whom had lesions on the abdomen, chest, mamilla, or perimammillar area. The prevalence of tungiasis was 54.4% (468/861 [95% CI 51.0, 57.7]), 93.2% (436/468) of whom had infection on the feet and 6.8% (32/468) on both feet and hands. Of the 861 children, 39.1% (337/861 [95% CI 35.9, 42.5]) had tinea infections, most commonly tinea capitis (65%; 219/337). S3 Table presents the proportions of children with scabies, tungiasis, and tinea infections in relation to individual, household, and school factors.

Multilevel, mixed-effect, logistic regression (Frequentist and Bayesian approach)

S4, S5, S6, and S7 Tables show the frequentist approach for the full model. The clustering effect measured by ICC was 8.8% for prevalence of any of the three skin conditions, 2.8% for tungiasis, and 4.9% for tinea at the classroom level but low or insignificant at the school level, indicating that variability in prevalence was not attributable to school-level factors. The variability in scabies prevalence attributable to the classroom level was 28% and 8% at the school level. Low Akaike information criteria value were considered a better fit in the frequentist approach; for all outcomes, the full model containing individual-, household-, and school-level factors had low criteria values.

In the Bayesian model, the clustering effect measured by the ICC for any skin problem, scabies, tungiasis, or tinea was significant at both the school and classroom levels. The ICC values calculated in the Bayesian model were higher than those in the frequentist model. For instance, we observed 16% of classroom- and 5.3% of school-level variability for any skin problem (S8 Table); 49.3% of classroom- and 31.2% of school-level variability for scabies (S9 Table); 8.5% of classroom- and 3% of school-level variability for tungiasis (S10 Table); and 12.7% of classroom- and 5.7% of school-level variability for tinea (S11 Table). The full model containing

Table 1. Distribution of scabies, tungiasis, and tinea infections among schoolchildren in the Wonago district, southern Ethiopia, 2017.

Skin problem	N	n	Frequency	Percentage
Scabies	861		46	5.3
Hands, interdigital places, wrists, arms, elbows		46	46	100
Armpit		46	22	47.8
Abdomen, chest, mamilla, perimammillar area		46	39	84.8
Back area, buttock and genitals		46	35	76.1
Feet area		46	34	73.9
Tungiasis	861		468	54.4
Feet		468	436	93.2
Feet and hands		468	32	6.8
Tinea	861		337	39.1
Tinea capitis (scalp)		337	219	65.0
Tinea corporis (body)		337	104	30.9
Tinea pedis (foot)		337	90	26.7
Tinea unguium (toenails or fingernails)		337	83	24.6
Tinea cruris (groin)		337	22	6.5
Tinea manuum (hands)		337	12	3.6
Tinea faciei (face)		337	8	2.4

N: Total number of children examined; n: children with skin problems

https://doi.org/10.1371/journal.pntd.0009816.t001

individual- household-, and school-level factors showed a lower deviance information criterion value for any skin problems, scabies, tungiasis, and tinea models and thus was considered a better fit in the Bayesian approach.

Risk factors for any skin problem

Using the frequentist model, the bivariate and multivariate analysis of any skin problem model revealed that sex; unclean fingernails; frequency of washing body, hair, legs, and feet with soap; sharing beds, clothes, and combs; and household wealth were predictive factors (Tables 2 and S4).

As shown in Table 2, in the Bayesian multivariate analysis, boys had higher overall risk (aOR 1.55 [95% BCI 1.01, 2.28), as did children who had unclean fingernails (aOR 1.85 [95% BCI 1.08, 2.97]); who did not wash their body (aOR 1.90 [95% BCI 1.21, 2.85]) and hair (aOR 3.07 [95% BCI 1.98, 4.57]) with soap every week; who shared beds (aOR 1.97 [95% BCI 1.27, 2.89]), clothes (aOR 5.65 [95% BCI 3.31, 9.21]), or combs (aOR 3.65 [95% BCI 2.28, 5.53]); and who lived in poor households (aOR 1.76 [95% BCI 1.03, 2.83]). The odds were low among children who washed their legs and feet with soap every day (aOR 0.23 [95% BCI 0.15, 0.33]). S8 Table shows the results of the Bayesian model, including posterior mean, SD, Monte Carlo standard error, and median.

Risk factors for scabies

Using a frequentist model in both the bivariate and multivariate analyses, the odds of scabies increased among boys (aOR 2.07 [95% CI 1.02, 4.23]) and children who shared beds (aOR 2.97 (95% CI 1.22, 7.21]) or combs (aOR 3.68 [95% CI 1.31, 10.3), as shown in S5 Table. Similarly, in the Bayesian multivariate analysis, the odds of scabies increased among boys (aOR 2.62 [95% BCI 1.19, 5.19]) and children who shared beds (aOR 4.30 [95% BCI 1.55, 10.4]) or combs (aOR 5.77 [95% BCI 1.72, 16.1]), as shown in S9 Table.

Table 2. Frequentist and Bayesian multivariate, multilevel, mixed-effect, logistic regression analysis of skin problem among schoolchildren in the Wonago district, southern Ethiopia, 2017.

Variables		Any skin problem				
				Frequentist (Maximum Likelihood Estimation)		Bayesian estimation
				Multilevel, mixed-effect, logistic regression		Bayesian multilevel, mixed-effect, logistic regression
		Yes (n (%)	No (n (%)	Adjusted odds ratio (95% CI)	P-value	Adjusted 95% BCI odds ratio (95% BCI)
Individual child factors						
Sex	Boys	370 (76.6)	113 (23.4)	1.52 (1.02, 2.27)	0.04	1.55 (1.01, 2.28)*
	Girls	247 (65.3)	131 (34.7)	1.0		1.0
Age in years	Mean (SD)			1.02 (0.90, 1.16)	0.74	1.02 (0.89, 1.15)
Unclean fingernails	Yes	165 (78.9)	44 (21.1)	1.72 (1.05, 2.82)	0.031	1.85 (1.08, 2.97)*
	No	452 (69.3)	200 (30.7)	1.0		1.0
Presence of footwear during examination	Yes	603 (72.0)	235 (28.0)	2.53 (0.82, 7.78)	0.105	2.68 (0.74, 6.91)
	No	14 (60.9)	9 (39.1)	1.0		1.0
Frequency of washing body with soap	Once per week	326 (66.3)	166 (33.7)	1.0		1.0
	Every two weeks	291 (78.9)	78 (21.1)	1.81 (1.20, 2.75)	0.005	1.90 (1.21, 2.85)*
Frequency of washing hair with soap	Once per week	284 (60.9)	182 (39.1)	1.0		1.0
	Every two weeks	333 (84.3)	62 (15.7)	2.92 (1.95, 4.39)	0.000	3.07 (1.98, 4.57)*
Frequency of washing legs and feet with soap	Once per day	222 (54.6)	185 (45.5)	0.23 (0.15, 0.35)	0.000	0.23 (0.15, 0.33)*
	Sometimes	395 (87.0)	59 (13.0)	1.0		1.0
Sharing beds	No	165 (55.7)	131 (44.3)	1.0		1.0
	Yes	452 (80.0)	113 (20.0)	1.92 (1.28, 2.87)	0.001	1.97 (1.27, 2.89)*
Sharing clothes	No	302 (58.6)	213 (41.4)	1.0		1.0
	Yes	315 (91.0)	31 (9.0)	5.13 (3.09, 8.50)	0.000	5.65 (3.31, 9.21)*
Sharing combs	No	115 (47.7)	126 (52.3)	1.0		1.0
	Yes	502 (81.0)	118 (19.0)	3.45 (2.23, 5.34)	0.000	3.65 (2.28, 5.53)*
Household factors						
Wealth status	Poor	223 (77.7)	64 (22.3)	1.71 (1.04, 2.79)	0.035	1.76 (1.03, 2.83)*
	Middle	210 (70.7)	87 (29.3)	1.12 (0.69, 1.83)	0.643	1.13 (0.66, 1.79)
	Rich	184 (66.4)	93 (33.6)	1.0		1.0
School factors						

(*Continued*)

Table 2. (Continued)

Variables		Any skin problem				
				Frequentist (Maximum Likelihood Estimation)		Bayesian estimation
				Multilevel, mixed-effect, logistic regression		Bayesian multilevel, mixed-effect, logistic regression
		Yes (n (%)	No (n (%)	Adjusted odds ratio (95% CI)	P-value	Adjusted 95% BCI odds ratio (95% BCI)
Access to health education on personal hygiene	Yes	472 (70.0)	202 (30.0)	1.03 (0.54, 1.94)	0.932	1.26 (0.58, 2.44)
	No	145 (77.5)	42 (22.5)	1.0		1.0

BCI: Bayesian credible interval; CI: confidence interval; SD: standard deviation; *significant

https://doi.org/10.1371/journal.pntd.0009816.t002

Risk factors for tungiasis

As shown in S6 Table, using the frequentist model, the following variables were associated with tungiasis in both the bivariate and multivariate analyses: frequency of body, leg, and feet washing with soap; sharing beds or clothes; and household wealth status.

As shown in Table 3, the Bayesian multivariate analysis revealed that the odds of tungiasis increased among children who wore footwear at examination time (aOR 8.04 [95% BCI 2.46, 21.4]); who did not wash their body with soap every week (aOR 1.59 [95% BCI 1.13, 2.17]); who shared beds (aOR 2.00 [95% BCI 1.43, 2.71]) or clothes (aOR 2.85 [95% BCI 2.01, 3.97]); or who lived in poor households (aOR 1.93 [95% BCI 1.29, 2.79]). Rate were low among children who washed their legs and feet with soap every day (aOR 0.48 [95% BCI 0.35, 0.65]), compared with those who sometimes washed their legs and feet. S10 Table shows the results, including posterior mean, SD, Monte Carlo standard error, and median.

Risk factors for tinea infections

In both the bivariate and multivariate analyses (S7 Table), using the frequentist model, tinea was associated with sex; unclean fingernails; frequency of washing hair, legs, and feet with soap; sharing beds, clothes, or combs.

As indicated in Table 4, in the Bayesian multivariate analysis, the odds of tinea increased among boys (aOR 2.42 [95% BCI 1.72, 3.34]), children with unclean fingernails (aOR 2.96 [95% BCI 1.96, 4.31]), children who did not wash their hair with soap every week (aOR 1.94 [95% BCI 1.39, 2.66]), children who shared beds (aOR 1.78 [95% BCI 1.22, 2.51]), clothes (aOR 1.89 [95% BCI 1.30, 2.65]), or combs (aOR 2.93 [95% BCI 1.90, 4.37]). Rates were high among children who lived in households with more than or equal to five family size (aOR 2.25 [95% BCI 1.20, 3.92]); and children who lived in poor (aOR 1.99 [95% BCI 1.29, 2.94]) and middle-class (aOR 2.01 [95% BCI 1.30, 2.98]) households, compared to those who lived in rich households. S11 Table shows the results, including posterior mean, SD, Monte Carlo standard error, and median.

Discussion

In a randomly selected, representative sample of schoolchildren aged 7 to 14 years in the Gedeo zone of southern Ethiopia, almost three-fourths had at least one type of skin problem, most commonly tungiasis and tinea infections. Unlike previous studies in Ethiopia, we examined the skin from the scalp to the toes and assessed children for scabies, tungiasis, and tinea.

Table 3. Frequentist and Bayesian multivariate, multilevel, mixed-effect, logistic regression analysis of tungiasis among schoolchildren in the Wonago district, southern Ethiopia, 2017.

Variables		Tungiasis				
				Frequentist (Maximum Likelihood Estimation)		Bayesian estimation
				Multilevel, mixed-effect, logistic regression		Bayesian multilevel, mixed-effect, logistic regression
		Yes (n (%)	No (n (%)	Adjusted odds ratio (95% CI)	P-value	Adjusted 95% BCI odds ratio (95% BCI)
Individual child factors						
Sex	Boys	274 (56.7)	209 (43.3)	0.98 (0.72, 1.32)	0.890	1.08 (0.78, 1.46)
	Girls	194 (51.3)	184 (48.7)	1.0		1.0
Age in years	Mean (SD)			1.01 (0.92, 1.11)	0.790	1.01 (0.91, 1.11)
Fingernails trimmed	Yes	373 (52.9)	332 (47.1)	0.76 (0.51, 1.13)	0.178	0.93 (0.60, 1.38)
	No	95 (60.9)	61 (39.1)	1.0		1.0
Habit of walking barefoot	Always in barefoot	11 (50.0)	11 (50.0)	0.54 (0.21, 1.42)	0.211	2.41 (0.71,6.39)
	Sometimes in barefoot	225 (56.3)	175 (43.7)	1.13 (0.82, 1.56)	0.444	1.40 (0.99, 1.93)
	Never in barefoot	232 (52.8)	207 (47.2)	1.0		1.0
Presence of footwear during exam	Yes	459 (54.8)	379 (45.2)	2.07 (0.80, 5.37)	0.134	8.04 (2.46, 21.4)*
	No	9 (39.1)	14 (60.9)	1.0		1.0
Frequency of washing body with soap	Once per week	245 (49.8)	247 (50.2)	1.0		1.0
	Every two weeks	223 (60.4)	146 (39.6)	1.41 (1.03, 1.93)	0.031	1.59 (1.13, 2.17)*
Frequency of washing legs and feet with soap	Once per day	165 (40.5)	242 (59.5)	0.41 (0.30, 0.56)	0.000	0.48 (0.35, 0.65)*
	Sometimes	303 (66.7)	151 (33.3)	1.0		1.0
Sharing beds	No	121 (41.2)	174 (58.8)	1.0		1.0
	Yes	346 (61.2)	219 (38.8)	1.83 (1.34, 2.51)	0.000	2.00 (1.43, 2.71)*
Sharing clothes	No	230 (44.7)	285 (55.3)	1.0		1.0
	Yes	238 (68.8)	108 (31.2)	2.39 (1.72, 3.32)	0.000	2.85 (2.01, 3.97)*
Household factors						
Family size	1–4	45 (57.7)	33 (42.3)	1.0	1.0	
	≥5	423 (54.0)	360 (46.0)	0.80 (0.48, 1.35)	0.394	1.02 (0.58, 1.66)
Wealth status	Poor	174 (60.6)	113 (39.4)	1.51 (1.04, 2.20)	0.024	1.93 (1.29, 2.79)*
	Middle-class	158 (53.2)	139 (46.8)	1.08 (0.74, 1.58)	0.641	1.36 (0.89, 1.98)
	Rich	136 (49.1)	141 (50.9)	1.0		1.0
School factors						

(*Continued*)

Table 3. (Continued)

Variables		Tungiasis				
				Frequentist (Maximum Likelihood Estimation)		Bayesian estimation
				Multilevel, mixed-effect, logistic regression		Bayesian multilevel, mixed-effect, logistic regression
		Yes (n (%)	No (n (%)	Adjusted odds ratio (95% CI)	P-value	Adjusted 95% BCI odds ratio (95% BCI)
Access to health education on personal hygiene	Yes	364 (54.0)	310 (46.0)	1.03 (0.68, 1.58)	0.834	1.52 (0.087, 2.54)
	No	104 (55.6)	83 (44.4)	1.0		1.0

BCI: Bayesian credible interval; CI: confidence interval; SD: standard deviation; *significant

https://doi.org/10.1371/journal.pntd.0009816.t003

Using two approaches, the frequentist model and the Bayesian model, and adjusting for the effects of clustering at the school and classroom levels, we found associations between these skin problems and several variables (sex; fingernail condition; washing with soap; sharing beds, clothes, or combs; and household wealth). Unlike the frequentist model, a Bayesian model uses fixed data, and the estimated parameters are viewed as random. It also includes prior information and does not rely on sampling, instead using probability to indicate uncertainty in the model [34]. Interpreting credible intervals is easier in the Bayesian model than in the frequentist model because the range of values in the Bayesian approach has a direct probabilistic interpretation of the true estimate [34, 35]. In our model, we clustered individual data within the same classroom and classrooms within the same school. To account for clustering effects, we applied a multilevel analysis using both the frequentist and Bayesian approaches. Although both models yielded similar estimates, the Bayesian model had smaller standard errors compared with the frequentist model and thus demonstrated better performance [34]. The similarity in estimates of the two methods is probably due to the large sample size, particularly for the frequentist method. In the Bayesian Markov Chain Monte Carlo simulations, we applied a large number of iterations to achieve convergence. Moreover, compared with the frequentist approach, the Bayesian model demonstrated high clustering effects at the school and classroom levels, indicating the presence of shared risk factors for skin problems and underscoring the importance of the Bayesian approach for explaining the observed variations in skin problems.

The present study has some limitations. First, given its cross-sectional nature, causality between the outcome and exposure variables cannot be determined with certainty. Second, we diagnosed skin problems clinically but not via skin scrapings, as fungal cultures were not available in our setting [53]. Thus, the prevalence of tinea infections could be under or overestimated. However, our results align with those of other studies, including a recent study showing that almost 90% of clinically suspected tinea infections were confirmed by microscopy [54]. Some of the information related to personal hygiene may be prone to reporting biases, and observer bias may occur in recording the outcome variables. To address this issue, we had two examiners conduct exams on 10% of the children, which helped ensure reproducibility and agreement. The nonsignificant effect of habitually walking barefoot in the Bayesian model could be due to unmeasured confounding factors, such as type of footwear. Although we focused on scabies, tungiasis, and tinea infections and not other skin problems, we believe that our study provides relevant information regarding the epidemiology of skin conditions in general in the study area.

Table 4. Frequentist and Bayesian multivariate multilevel, mixed-effect, logistic regression analysis of tinea infections among schoolchildren in the Wonago district, southern Ethiopia, 2017.

Variables		Tinea infections				
				Frequentist (Maximum Likelihood Estimation)		Bayesian estimation
				Multilevel, mixed-effect, logistic regression		Bayesian multilevel, mixed-effect, logistic regression
		Yes (%)	No (%)	Adjusted odds ratio (95% CI)	P-value	Adjusted 95% BCI odds ratio (95% BCI)
Individual child factors						
Sex	Boys	226 (46.8)	257 (53.2)	1.92 (1.40, 2.63)	0.000	2.42 (1.72, 3.34)*
	Girls	111 (29.4)	267 (70.6)	1.0		1.0
Age in years	Mean (SD)			1.02 (0.92, 1.13)	0.697	1.05 (0.94, 1.16)
Unclean fingernails	Yes	106 (50.7)	103 (49.3)	2.02 (1.40, 2.92)	0.000	2.96 (1.96, 4.31)*
	No	231 (35.4)	421 (64.6)	1.0		1.0
Frequency of washing body with soap	Once per week	183 (37.2)	309 (62.8)	1.0		1.0
	Every two weeks	154 (41.7)	215 (58.3)	1.06 (0.76, 1.46)	0.741	1.36 (0.95, 1.88)
Frequency of washing hair with soap	Once per week	153 (32.8)	313 (67.2)	1.0		1.0
	Every two weeks	184 (46.6)	211 (53.4)	1.53 (1.13, 2.08)	0.006	1.94 (1.39, 2.66)*
Frequency of washing legs and feet with soap	Once per day	126 (31.0)	281 (69.0)	0.66 (0.48, 0.91)	0.011	0.89 (0.63, 1.23)
	Sometimes	211 (46.5)	243 (53.5)	1.0		1.0
Sharing beds	No	84 (28.4)	212 (71.6)	1.0		1.0
	Yes	253 (44.8)	312 (55.2)	1.48 (1.06, 2.08)	0.021	1.78 (1.22, 2.51)*
Sharing clothes	No	158 (30.7)	357 (69.3)	1.0		1.0
	Yes	179 (51.7)	167 (48.3)	1.63 (1.17, 2.27)	0.004	1.89 (1.30, 2.65)*
Sharing combs	No	62 (25.7)	179 (74.3)	1.0		1.0
	Yes	275 (44.4)	345 (55.6)	2.15 (1.46, 3.17)	0.000	2.93 (1.90, 4.37)*
Household factors						
Family size	1–4	27 (34.6)	51 (65.4)	1.0		1.0
	≥5	310 (39.6)	473 (60.4)	1.24 (0.73, 2.12)	0.428	2.25 (1.20, 3.92)*
Wealth status	Poor	119 (41.5)	168 (58.5)	1.19 (0.81, 1.75)	0.379	1.99 (1.29, 2.94)*
	Middle-class	120 (40.4)	177 (59.6)	1.23 (0.84, 1.81)	0.285	2.01 (1.30, 2.98)*
	Rich	98 (35.4)	179 (64.6)	1.0		1.0
School factors						

(*Continued*)

Table 4. (Continued)

Variables		Tinea infections				
				Frequentist (Maximum Likelihood Estimation)		Bayesian estimation
				Multilevel, mixed-effect, logistic regression		Bayesian multilevel, mixed-effect, logistic regression
		Yes (%)	No (%)	Adjusted odds ratio (95% CI)	P-value	Adjusted 95% BCI odds ratio (95% BCI)
Access to health education on personal hygiene	Yes	253 (37.5)	421 (62.5)	0.92 (0.58, 1.45)	0.706	1.11 (0.62, 1.88)
	No	84 (44.9)	103 (55.1)	1.0		1.0

BCI: Bayesian credible interval; CI: confidence interval; SD: standard deviation; *significant

https://doi.org/10.1371/journal.pntd.0009816.t004

Climate variation may play an important role in the occurrence of skin problems [55–57], but we did not assess it in our cross-sectional survey. Further studies should investigate the role of climate in skin problems. The health-seeking behavior of parents for children with skin problems also needs to be assessed at the community level. We conducted our study using a large representative sample of rural schoolchildren. We estimated the parameters using randomly generated Markov Chain Monte Carlo samples using a Bayesian approach. Therefore, the simulated data are large and close to the real population, making the findings generalizable to school-aged children in similar socio-economic and cultural settings.

ICC values for nested data are rarely reported in previous studies [58]. We calculated the ICC values using both the frequentist and Bayesian models. Compared to the frequentist model, the Bayesian model yielded higher clustering effects for skin problems at the school and classroom levels, suggesting that the Bayesian approach better explains variations in skin problems. In particular, the observed high variation in scabies prevalence at the school and classroom levels suggests increased risk of scabies due to close contact in these locations. The observed clustering of tungiasis prevalence at the classroom level indicates a commonality in the classroom (e.g., earthen or dusty or cracked floor) that could result in clustering.

Our finding of a 5% prevalence for scabies aligns with that of similar studies in southern Ethiopia [16] and with the 6% reported in the national survey among schoolchildren [49], though these findings are much lower than previous reports of 34% to 50% in the same region [11, 32]. These variations could be due to differences in personal hygiene, socioeconomic factors, study settings, climate variations, and disease outbreaks. Scabies varied with seasons [56, 57, 59]. Our study period was in dry season, this could also affect scabies prevalence because scabies is more common in cool and humid weather condition [57, 59]. In contrast, other evidence indicates that an increase in temperature, is associated with increased scabies prevalence [56]. It has previously been reported that the highest cases of scabies in community based study in drought affected area in Ethiopia [30]. Though we did not assess the seasonal variations in this study due to the nature of our study design, it might be linked with overcrowding and close contact in the cooler seasons. Other studies, however, did not find significant variations with seasons [7, 60, 61]. The prevalence of tungiasis was 54%, which aligns with other findings from rural southern Ethiopia [19] and Kenya [62] but exceeds the 35% found in other areas in southern Ethiopia [16]. The discrepancy may be explained by our rural study setting, where most children live in houses with earthen floors and attend classrooms with poor hygiene facilities. It also could be linked with seasonal variations because our study period was in dry season, where tungiasis is more common [2, 63, 64]. This may be explained with indirect link with access to water in the dry season for personal hygiene protection. The prevalence of tinea infections was 39%, which aligns with rates in other rural areas of southern Ethiopia [22] but exceeds those from urban areas of Ethiopia [16], from Cote d'Ivoire [65], and from Tanzania [66]. The variations could be associated with personal hygiene, poverty, and climate conditions [55], as well as immune factors [67–69]. Consistent with findings elsewhere in Ethiopia [22, 29, 70] and other African studies [65, 71–73], boys were more likely to be affected by tinea infection (particularly tinea capitis) than girls, perhaps due to the higher risk associated with frequent shaving or haircuts [55] or due to personal hygiene (e.g., frequency of hair washing).

Nail hygiene is a well-known factor preventing the spread of infection. Many pathogens can be shed from fingernails, resulting in transmission [74]. We found that children with unclean fingernails had higher risks of skin problems, particularly tinea. Infrequent body and hair washing with soap also is associated with increased skin problems [31, 62, 75, 76]. Our results similarly show that washing the feet daily with soap was a protective factor of both, tungiasis and tinea. Sharing beds, clothes, or combs also was associated with increased risk of scabies and tinea infections, as documented by other studies in Ethiopia [11, 32] and other African countries [75–78].

Similar to previous reports from Ethiopia [19] and Rwanda [15], we observed no differences in tungiasis rates among boys and girls. Our bivariate frequentist model identified boys as slightly more at risk ($p = 0.103$), perhaps due to behavioral factors related to hygiene. Findings by Elson et al. [62] and Wiese et al. [79] also show higher risk of tungiasis among boys. Other evidence suggests that the risk of acquiring tungiasis varies with age-specific behavioral patterns [62, 79] and increases among children younger than 15 years [62] and the elderly [79]. We could not confirm these findings as our study did not include adolescents older than 14 years or older age groups. Previous reports indicate that poor hygiene, including low frequency of washing with soap [79], is associated with increased tungiasis rates [15, 80]. We similarly found that children who did not wash with soap every week were more likely to be affected by tungiasis. Transmission also is more likely in places where shoes are not worn, such as sleeping rooms [81]. Our findings confirmed that sharing beds and clothes increased risk of tungiasis.

Poverty is an important risk factor for skin problems [82]. In our study, children living in poor households were more likely to be affected by skin problems, perhaps because these families cannot afford soap and other hygiene products. Housing construction material [83], contact with domestic animals [84, 85], and poor environmental hygiene [80, 81] also could be contributing factors. Studies from Kenya [62, 83] and Nigeria [86] show that floor type plays an important role in tungiasis transmission. Although we did not conduct a separate analysis for floor material in the multivariate model, we included it as part of our wealth index construction. We observed a high prevalence of tungiasis among children living in houses constructed with natural earth or dung floors. Dry, loose soil or sand is a favorable environment for tungiasis-transmitting fleas [62, 86]. Evidence suggests that large family size, is associated with the risk of acquiring skin problems [87]. We found that children who lived in households of large family size had higher risks of skin problems, particularly tinea infections, probably due to close contact as a result of overcrowding.

Foot hygiene and appropriate footwear provide important protection [88] against tinea [89, 90] and tungiasis [86, 91]. Walking barefoot is a known risk factor for tungiasis [15, 19]. In this study, walking barefoot was not associated with skin problems in either the Bayesian or frequentist model. The nonsignificant effect in the Bayesian model may be due to other unmeasured factors, such as type of footwear. However, the association between presence of foot wear during examination time and an increased risk of tungiasis was unexpected and should be interpreted with caution. A previous study has shown the association between wearing closed footwear and an increased risk of tungiasis [16].

Conclusion

Skin problems such as scabies, tungiasis, and tinea infections are major health concerns among schoolchildren in rural Ethiopia. National school health programs aim to detect active cases and apply preventive measures via periodic screenings, but most of these programs are non-functional due to lack of funding or resources [23]. We found significant associations between many individual hygiene-related factors and scabies, tungiasis and tinea. In particular, our findings highlight the link between skin problems and poverty.

Health education and regular checkups by schoolteachers can be vital to improving rates of infection. Education should emphasize the importance of regular washing of legs and feet with soap and appropriate footwear. The observed high clustering effects for skin problems at the school and classroom levels indicate that transmission occurs and may be more likely in these environments, probably via close contact. Important measures to prevent transmission include access to adequate water and soap in all schools, and reduced class sizes. Contagious and highly transmissible skin problems are important policy issues in Ethiopia. Addressing these issues will require efforts from the Ministry of Health and Education to reduce major gaps in school health services implementation and to improve children's health, particularly among rural schoolchildren in areas such as Gedeo.

Supporting information

S1 Checklist. STROBE checklist.
(DOCX)

S1 Fig. Flowchart of study inclusion.
(TIF)

S1 Data. Dataset.
(XLSX)

S1 Table. Demographic and socio-economic characteristics of schoolchildren and their parents in the Wonago district of southern Ethiopia, 2017.
(DOCX)

S2 Table. Personal hygiene of schoolchildren in the Wonago district, southern Ethiopia, 2017.
(DOCX)

S3 Table. The prevalence of skin problems in relation to individual, household and school factors among schoolchildren in the Wonago district, southern Ethiopia, 2017.
(DOCX)

S4 Table. Bivariate and multivariate, multilevel, mixed-effect, logistic regression analysis of skin problem among schoolchildren in the Wonago district, southern Ethiopia, 2017.
(DOCX)

S5 Table. Bivariate and multivariate, multilevel, mixed-effect, logistic regression analysis of scabies among schoolchildren in the Wonago district, southern Ethiopia, 2017.
(DOCX)

S6 Table. Bivariate and multivariate, multilevel, mixed-effect, logistic regression analysis of tungiasis among schoolchildren in the Wonago district, southern Ethiopia, 2017.
(DOCX)

S7 Table. Bivariate and multivariate multilevel, mixed-effect, logistic regression analysis of tinea infections among schoolchildren in the Wonago district, southern Ethiopia, 2017.
(DOCX)

S8 Table. Bayesian multivariate, multilevel, mixed-effect, logistic regression analysis of skin problem among schoolchildren in the Wonago district, southern Ethiopia, 2017.
(DOCX)

S9 Table. Bayesian multivariate, multilevel, mixed-effect, logistic regression analysis of scabies among schoolchildren in the Wonago district, southern Ethiopia, 2017.
(DOCX)

S10 Table. Bayesian multivariate, multilevel, mixed-effect, logistic regression analysis of tungiasis among schoolchildren in the Wonago district, southern Ethiopia, 2017.
(DOCX)

S11 Table. Bayesian multivariate, multilevel, mixed-effect, logistic regression analysis of tinea infections among schoolchildren in the Wonago district, southern Ethiopia, 2017.
(DOCX)

Acknowledgments

We are grateful to the schoolchildren, parents, and guardians who participated in this study. We also thank the data collectors, supervisors, Gedeo Zone Health Department, Wonago District Education Office, school directors, and teachers. We are deeply grateful to Hawassa University and the University of Bergen for their support.

Author Contributions

Conceptualization: Hiwot Hailu Amare, Bernt Lindtjorn.

Data curation: Hiwot Hailu Amare, Bernt Lindtjorn.

Formal analysis: Hiwot Hailu Amare, Bernt Lindtjorn.

Funding acquisition: Bernt Lindtjorn.

Investigation: Hiwot Hailu Amare, Bernt Lindtjorn.

Methodology: Hiwot Hailu Amare, Bernt Lindtjorn.

Project administration: Hiwot Hailu Amare, Bernt Lindtjorn.

Resources: Hiwot Hailu Amare, Bernt Lindtjorn.

Software: Hiwot Hailu Amare, Bernt Lindtjorn.

Supervision: Hiwot Hailu Amare, Bernt Lindtjorn.

Validation: Hiwot Hailu Amare, Bernt Lindtjorn.

Visualization: Hiwot Hailu Amare, Bernt Lindtjorn.

Writing – original draft: Hiwot Hailu Amare, Bernt Lindtjorn.

Writing – review & editing: Hiwot Hailu Amare, Bernt Lindtjorn.

References

1. Karimkhani C, Dellavalle RP, Coffeng LE, Flohr C, Hay RJ, Langan SM, et al. Global skin disease morbidity and mortality: An update from the global burden of disease study 2013. JAMA Dermatol. 2017; 153(5): 406–12. https://doi.org/10.1001/jamadermatol.2016.5538 PMID: 28249066
2. Karunamoorthi K. Tungiasis: A neglected epidermal parasitic skin disease of marginalized populations-a call for global science and policy. Parasitol Res. 2013; 112(10): 3635–43. https://doi.org/10.1007/s00436-013-3551-8 PMID: 23949241
3. Hay RJ, Johns NE, Williams HC, Bolliger IW, Dellavalle RP, Margolis DJ, et al. The global burden of skin disease in 2010: An analysis of the prevalence and impact of skin conditions. J Invest Dermatol. 2014; 134(6): 1527–34. https://doi.org/10.1038/jid.2013.446 PMID: 24166134
4. Heukelbach J, Feldmeier H. Scabies. The Lancet. 2006; 367(9524): 1767–74. https://doi.org/10.1016/S0140-6736(06)68772-2 PMID: 16731272
5. Heukelbach J, Walton SF, Feldmeier H. Ectoparasitic infestations. Curr Infect Dis Rep. 2005; 7(5): 373–80. https://doi.org/10.1007/s11908-005-0012-2 PMID: 16107235
6. Stamm LV, Strowd LC. Ignoring the "Itch": The global health problem of scabies. Am J Trop Med Hyg. 2017; 97(6): 1647–9. https://doi.org/10.4269/ajtmh.17-0242 PMID: 29016295
7. Jackson A, Heukelbach J, Filho AFDS, Campelo Júnior EDB, Feldmeier H. Clinical features and associated morbidity of scabies in a rural community in Alagoas, Brazil. Trop Med Int Health. 2007; 12(4): 493–502. https://doi.org/10.1111/j.1365-3156.2006.01809.x PMID: 17445140
8. McCarthy JS, Kemp DJ, Walton SF, Currie BJ. Scabies: More than just an irritation. Postgrad Med J. 2004; 80(945): 382. https://doi.org/10.1136/pgmj.2003.014563 PMID: 15254301
9. Johnston G, Sladden M. Scabies: diagnosis and treatment. BMJ. 2005; 331(7517): 619–22. https://doi.org/10.1136/bmj.331.7517.619 PMID: 16166133
10. World Health Organization. Neglected tropical diseases. Scabies [Internet]. Available from: https://www.who.int/neglected_diseases/diseases/scabies/en/.
11. Wochebo W, Haji Y, Asnake S. Scabies outbreak investigation and risk factors in Kechabira district, Southern Ethiopia: Unmatched case control study. BMC Res Notes. 2019; 12(1): 305. https://doi.org/10.1186/s13104-019-4317-x PMID: 31142358
12. Heukelbach J. Tungiasis. Rev Inst Med Trop Sao Paulo. 2005; 47(6): 307–13. https://doi.org/10.1590/s0036-46652005000600001 PMID: 16553319
13. Feldmeier H, Eisele M, Sabóia-Moura RC, Heukelbach J. Severe tungiasis in underprivileged communities: case series from Brazil. Emerg Infect Dis. 2003; 9(8): 949–55. https://doi.org/10.3201/eid0908.030041 PMID: 12967492
14. Feldmeier H, Sentongo E, Krantz I. Tungiasis (sand flea disease): A parasitic disease with particular challenges for public health. Eur J Clin Microbiol Infect Dis. 2013; 32(1): 19–26. https://doi.org/10.1007/s10096-012-1725-4 PMID: 22941398
15. Nsanzimana J, Karanja S, Kayongo M, Nyirimanzi N, Umuhoza H, Murangwa A, et al. Factors associated with tungiasis among primary schoolchildren: A cross-sectional study in a rural district in Rwanda. BMC Public Health. 2019; 19(1): 1192. https://doi.org/10.1186/s12889-019-7481-y PMID: 31464600
16. Walker SL, Lebas E, De Sario V, Deyasso Z, Doni SN, Marks M, et al. The prevalence and association with health-related quality of life of tungiasis and scabies in schoolchildren in southern Ethiopia. PLoS Negl Trop Dis. 2017; 11(8): e0005808. https://doi.org/10.1371/journal.pntd.0005808 PMID: 28771469
17. Feldmeier H, Heukelbach J, Eisele M, Sousa AQ, Barbosa LMM, Carvalho CBM. Bacterial superinfection in human tungiasis. Trop Med Int Health. 2002; 7(7): 559–64. https://doi.org/10.1046/j.1365-3156.2002.00904.x PMID: 12100437
18. Deka MA. Mapping the geographic distribution of tungiasis in Sub-Saharan Africa. Trop Med Infect Dis. 2020; 5(3): 122. https://doi.org/10.3390/tropicalmed5030122 PMID: 32722011
19. Girma M, Astatkie A, Asnake S. Prevalence and risk factors of tungiasis among children of Wensho district, southern Ethiopia. BMC Infect Dis. 2018; 18(1): 456. https://doi.org/10.1186/s12879-018-3373-5 PMID: 30200882
20. Ely JW, Rosenfeld S, Seabury Stone M. Diagnosis and management of tinea infections. Am Fam Physician. 2014; 90(10): 702–10. PMID: 25403034
21. Bongomin F, Olum R, Nsenga L, Namusobya M, Russell L, de Sousa E, et al. Estimation of the burden of tinea capitis among children in Africa. Mycoses. 2021; 64(4): 349–63. https://doi.org/10.1111/myc.13221 PMID: 33251631
22. Leiva-Salinas M, Marin-Cabanas I, Betlloch I, Tesfasmariam A, Reyes F, Belinchon I, et al. Tinea capitis in schoolchildren in a rural area in southern Ethiopia. Int J Dermatol. 2015; 54(7): 800–5. https://doi.org/10.1111/ijd.12691 PMID: 25557908

23. Federal Democratic Republic of Ethiopia Ministry of Health. School health programme framework. Addis Ababa, Ethiopia. 2017.
24. Federal Democratic Republic of Ethiopia Ministry of Education. National school water supply, sanitation and hygiene (SWASH) strategy and implementation action plan. 2017.
25. Ministry of Education. National school health and nutrition strategy. Addis Ababa, Ethiopia. 2012.
26. Federal Ministry of Education. Education Sector Development Programme V (ESDP V) 2015/16–2019/20: Programme action plan. Addis Ababa, Ethiopia. 2015.
27. Negussu N, Mengistu B, Kebede B, Deribe K, Ejigu E, Tadesse G, et al. Ethiopia schistosomiasis and soil-transmitted helminthes control programme: Progress and prospects. Ethiop Med J. 2017; 55(Suppl 1): 75–80. PMID: 28878432
28. Woldeamanuel Y, Leekassa R, Chryssanthou E, Menghistu Y, Petrini B. Prevalence of tinea capitis in Ethiopian schoolchildren. Mycoses. 2005; 48(2): 137–41. https://doi.org/10.1111/j.1439-0507.2004.01081.x PMID: 15743433
29. Pérez-Tanoira R, Marín I, Berbegal L, Prieto-Pérez L, Tisiano G, Cuadros J, et al. Mycological profile of tinea capitis in schoolchildren in rural southern Ethiopia. Med Mycol. 2016; 55(3):262–8.
30. Enbiale W, Ayalew A. Investigation of a scabies outbreak in drought affected areas in Ethiopia. Trop Med Infect Dis. 2018; 3(4): 114. https://doi.org/10.3390/tropicalmed3040114 PMID: 30380650
31. Dagne H, Dessie A, Destaw B, Yallew WW, Gizaw Z. Prevalence and associated factors of scabies among schoolchildren in Dabat district, northwest Ethiopia, 2018. Environ Health Prev Med. 2019; 24 (1): 67. https://doi.org/10.1186/s12199-019-0824-6 PMID: 31785612
32. Ejigu K, Haji Y, Toma A, Tadesse B. Factors associated with scabies outbreaks in primary schools in Ethiopia: Acase control study. Res Rep Trop Med. 2019; 10: 119–27. https://doi.org/10.2147/RRTM.S214724 PMID: 31695552
33. Azene AG, Aragaw AM, Wassie GT. Prevalence and associated factors of scabies in Ethiopia: Systematic review and meta-analysis. BMC Infect Dis. 2020; 20(1): 380. https://doi.org/10.1186/s12879-020-05106-3 PMID: 32460770
34. Hespanhol L, Vallio CS, Costa LM, Saragiotto BT. Understanding and interpreting confidence and credible intervals around effect estimates. Braz J Phys Ther. 2019; 23(4): 290–301. https://doi.org/10.1016/j.bjpt.2018.12.006 PMID: 30638956
35. Kruschke JK, Liddell TM. The Bayesian new statistics: Hypothesis testing, estimation, meta-analysis, and power analysis from a Bayesian perspective. Psychon Bull Rev. 2018; 25(1): 178–206. https://doi.org/10.3758/s13423-016-1221-4 PMID: 28176294
36. Drug Administration and Control Authority (DACA) of Ethiopia. Standard Treatment Guideline for Health Centers. Addis Ababa, Ethiopia: The Drug Administration and Control Authority (DACA) of Ethiopia; 2010.
37. Hailu Amare H, Lindtjørn B. Helminth infections among rural schoolchildren in Southern Ethiopia: A cross-sectional multilevel and zero-inflated regression model. PLoS Negl Trop Dis. 2020; 14(12): e0008002. https://doi.org/10.1371/journal.pntd.0008002 PMID: 33351816
38. Amare HH, Lindtjorn B. Concurrent anemia and stunting among schoolchildren in Wonago district in southern Ethiopia: A cross-sectional multilevel analysis. PeerJ. 2021; 9: e11158. https://doi.org/10.7717/peerj.11158 PMID: 33996276
39. Federal Democratic Republic of Ethiopia. Interim-guideline for multi-sectorial scabies outbreak emergency response. 2015.
40. Engelman D, Fuller LC, Steer AC. Consensus criteria for the diagnosis of scabies: A Delphi study of international experts. PLoS Negl Trop Dis. 2018; 12(5): e0006549. https://doi.org/10.1371/journal.pntd.0006549 PMID: 29795566
41. Gulgun M, Balci E, Karaoglu A, Kesik V, Babacan O, Fidanci M, et al. Prevalence and risk factors of onychomycosis in primary schoolchildren living in rural and urban areas in Central Anatolia of Turkey. Indian J Dermatol Venereol Leprol. 2013; 79(6): 777–82. https://doi.org/10.4103/0378-6323.120724 PMID: 24177609
42. Parker J. Management of common fungal infections in primary care. Nurs Stand. 2009; 23(43): 42–6. https://doi.org/10.7748/ns2009.07.23.43.42.c7060 PMID: 19634606
43. de Berker D. Clinical practice: Fungal nail disease. N Engl J Med. 2009; 360(20): 2108–16. https://doi.org/10.1056/NEJMcp0804878 PMID: 19439745
44. Noble SL, Forbes RC, Stamm PL. Diagnosis and management of common tinea infections. Am Fam Physician. 1998; 58(1): 163–74. PMID: 9672436
45. Eisele M, Heukelbach J, Van Marck E, Mehlhorn H, Meckes O, Franck S, et al. Investigations on the biology, epidemiology, pathology and control of Tunga penetrans in Brazil: I. Natural history of tungiasis

in man. Parasitol Res. 2003; 90(2): 87–99. https://doi.org/10.1007/s00436-002-0817-y PMID: 12756541

46. Vyas S, Kumaranayake L. Constructing socio-economic status indices: How to use principal components analysis. Health Policy Plan. 2006; 21(6): 459–68. https://doi.org/10.1093/heapol/czl029 PMID: 17030551
47. Twisk JWR. Applied multilevel analysis: A practical guides to biostatistics and epidemiology. Cambridge: Cambridge University Press; 2006.
48. Lunn DJ, Thomas A, Best N, Spiegelhalter D. WinBUGS—A Bayesian modelling framework: Concepts, structure, and extensibility. Statistics and Computing. 2000; 10(4): 325–37.
49. Hall A, Kassa T, Demissie T, Degefie T, Lee S. National survey of the health and nutrition of schoolchildren in Ethiopia. Trop Med Int Health. 2008; 13(12): 1518–26. https://doi.org/10.1111/j.1365-3156.2008.02168.x PMID: 18983269
50. Masuda MM, Stone RP. Bayesian logistic mixed-effects modelling of transect data: Relating red tree coral presence to habitat characteristics. ICES Journal of Marine Science. 2015; 72(9): 2674–83.
51. Merlo J, Wagner P, Ghith N, Leckie G. An original stepwise multilevel logistic regression analysis of discriminatory accuracy: the case of neighbourhoods and health. PLoS One. 2016; 11(4): e0153778. https://doi.org/10.1371/journal.pone.0153778 PMID: 27120054
52. Kidando E, Moses R, Sando T, Ozguven EE. An application of Bayesian multilevel model to evaluate variations in stochastic and dynamic transition of traffic conditions. J Mod Transport. 2019; 27(4): 235–49.
53. Yee G, Al Aboud AM. Tinea corporis. In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2020.
54. Alemayehu A, Minwuyelet G, Andualem G. Prevalence and etiologic agents of dermatophytosis among primary schoolchildren in Harari Regional State, Ethiopia. J Mycol. 2016; 2016: 1489387.
55. Coulibaly O, Kone AK, Niaré-Doumbo S, Goïta S, Gaudart J, Djimdé AA, et al. Dermatophytosis among schoolchildren in three eco-climatic Zones of Mali. PLoS Negl Trop Dis. 2016; 10(4): e0004675. https://doi.org/10.1371/journal.pntd.0004675 PMID: 27124571
56. Kim J-H, Cheong H-K. Epidemiologic trends and seasonality of scabies in South Korea, 2010–2017. Korean J Parasitol. 2019; 57(4): 399–404. https://doi.org/10.3347/kjp.2019.57.4.399 PMID: 31533406
57. Liu J-M, Wang H-W, Chang F-W, Liu Y-P, Chiu F-H, Lin Y-C, et al. The effects of climate factors on scabies. A 14 year population-based study in Taiwan. Parasite. 2016; 23: 54. https://doi.org/10.1051/parasite/2016065 PMID: 27905271
58. Romani L, Whitfeld MJ, Koroivueta J, Kama M, Wand H, Tikoduadua L, et al. The epidemiology of scabies and impetigo in relation to demographic and residential characteristics: Baseline findings from the skin health intervention Fiji Trial. Am J Trop Med Hyg. 2017; 97(3): 845–50. https://doi.org/10.4269/ajtmh.16-0753 PMID: 28722612
59. Mimouni D, Ankol OE, Davidovitch N, Gdalevich M, Zangvil E, Grotto I. Seasonality trends of scabies in a young adult population: a 20-year follow-up. Br J Dermatol. 2003; 149(1): 157–9. https://doi.org/10.1046/j.1365-2133.2003.05329.x PMID: 12890210
60. Feldmeier H, Jackson A, Ariza L, Lins Calheiros CM, de Lima Soares V, Oliveira FA, et al. The epidemiology of scabies in an impoverished community in rural Brazil: Presence and severity of disease are associated with poor living conditions and illiteracy. J Am Acad Dermatol. 2009; 60(3): 436–43. https://doi.org/10.1016/j.jaad.2008.11.005 PMID: 19064303
61. Armitage EP, Senghore E, Darboe S, Barry M, Camara J, Bah S, et al. High burden and seasonal variation of paediatric scabies and pyoderma prevalence in the Gambia: A cross-sectional study. PLoS Negl Trop Dis. 2019; 13(10): e0007801. https://doi.org/10.1371/journal.pntd.0007801 PMID: 31609963
62. Elson L, Wiese S, Feldmeier H, Fillinger U. Prevalence, intensity and risk factors of tungiasis in Kilifi County, Kenya II: Results from a school-based observational study. PLoS Negl Trop Dis. 2019; 13(5): e0007326. https://doi.org/10.1371/journal.pntd.0007326 PMID: 31095558
63. Heukelbach J, Wilcke T, Harms G, Feldmeier H. Seasonal variation of tungiasis in an endemic community. Am J Trop Med Hyg. 2005; 72(2): 145–9. PMID: 15741550
64. Pilger D, Schwalfenberg S, Heukelbach J, Witt L, Mencke N, Khakban A, et al. Controlling tungiasis in an impoverished community: An intervention study. PLoS Negl Trop Dis. 2008; 2(10): e324. https://doi.org/10.1371/journal.pntd.0000324 PMID: 18941513
65. Yotsu RR, Kouadio K, Vagamon B, N'guessan K, Akpa AJ, Yao A, et al. Skin disease prevalence study in schoolchildren in rural Côte d'Ivoire: Implications for integration of neglected skin diseases (skin NTDs). PLoS Negl Trop Dis. 2018; 12(5): e0006489. https://doi.org/10.1371/journal.pntd.0006489 PMID: 29771976

66. Komba EV, Mgonda YM. The spectrum of dermatological disorders among primary schoolchildren in Dares Salaam. BMC Public Health. 2010; 10: 765. https://doi.org/10.1186/1471-2458-10-765 PMID: 21162714
67. Blutfield MS, Lohre JM, Pawich DA, Vlahovic TC. The immunologic response to Trichophyton Rubrum in lower extremity fungal infections. J Fungi 2015; 1(2): 130–7. https://doi.org/10.3390/jof1020130 PMID: 29376904
68. García-Romero MT, Arenas R. New insights into genes, immunity, and the occurrence of dermatophytosis. J Invest Dermatol. 2015; 135(3): 655–7. https://doi.org/10.1038/jid.2014.498 PMID: 25666672
69. Hay RJ. Tinea capitis: Current status. Mycopathologia. 2017; 182(1–2): 87–93. https://doi.org/10.1007/s11046-016-0058-8 PMID: 27599708
70. Figueroa JI, Fuller LC, Abraha A, Hay RJ. Dermatology in southwestern Ethiopia: Rationale for a community approach. Int J Dermatol. 1998; 37(10): 752–8. https://doi.org/10.1046/j.1365-4362.1998.00425.x PMID: 9802685
71. Oke OO, Onayemi O, Olasode OA, Omisore AG, Oninla OA. The prevalence and pattern of superficial fungal infections among schoolchildren in Ile-Ife, South-Western Nigeria. Dermatol Res Pract. 2014; 2014: 842917. https://doi.org/10.1155/2014/842917 PMID: 25574161
72. Moto JN, Maingi JM, Nyamache AK. Prevalence of tinea capitis in school going children from Mathare, informal settlement in Nairobi, Kenya. BMC Res Notes. 2015; 8(1): 274. https://doi.org/10.1186/s13104-015-1240-7 PMID: 26116079
73. Kechia FA, Kouoto EA, Nkoa T, Nweze EI, Fokoua DCM, Fosso S, et al. Epidemiology of tinea capitis among school-age children in Meiganga, Cameroon. J Mycol Med. 2014; 24(2): 129–34. https://doi.org/10.1016/j.mycmed.2013.12.002 PMID: 24746727
74. Ford C, Park LJ. Hand hygiene and handwashing: Key to preventing the transfer of pathogens. Br J Nurs. 2018; 27(20): 1164–6. https://doi.org/10.12968/bjon.2018.27.20.1164 PMID: 30418841
75. Kouotou EA, Nansseu JRN, Kouawa MK, Zoung-Kanyi Bissek A-C. Prevalence and drivers of human scabies among children and adolescents living and studying in Cameroonian boarding schools. Parasit Vectors. 2016; 9(1): 400. https://doi.org/10.1186/s13071-016-1690-3 PMID: 27430556
76. Afolabi O, Oninla O, Funmito F. Tinea capitis: A tropical disease of hygienic concern among primary schoolchildren in an urban community in Nigeria. J Public Health Epidemiol. 2018; 10: 313–9.
77. Ugbomoiko US, Oyedeji SA, Babamale OA, Heukelbach J. Scabies in resource poor communities in Nasarawa State, Nigeria: Epidemiology, clinical features and factors associated with infestation. Trop Med Infect Dis. 2018; 3(2): 59.
78. Chikoi R, Nyawale HA, Mghanga FP. Magnitude and associated risk factors of superficial skin fungal infection among primary schoolchildren in Southern Tanzania. Cureus. 2018; 10(7): e2993. https://doi.org/10.7759/cureus.2993 PMID: 30245947
79. Wiese S, Elson L, Reichert F, Mambo B, Feldmeier H. Prevalence, intensity and risk factors of tungiasis in Kilifi County, Kenya: I. Results from a community-based study. PLoS Negl Trop Dis. 2017; 11(10): e0005925. https://doi.org/10.1371/journal.pntd.0005925 PMID: 28991909
80. Wafula ST, Ssemugabo C, Namuhani N, Musoke D, Ssempebwa J, Halage AA. Prevalence and risk factors associated with tungiasis in Mayuge district, Eastern Uganda. Pan Afr Med J. 2016; 24: 77. https://doi.org/10.11604/pamj.2016.24.77.8916 PMID: 27642416
81. Feldmeier H, Heukelbach J, Ugbomoiko US, Sentongo E, Mbabazi P, von Samson-Himmelstjerna G, et al. Tungiasis: A neglected disease with many challenges for global public health. PLoS Negl Trop Dis. 2014; 8(10): e3133. https://doi.org/10.1371/journal.pntd.0003133 PMID: 25356978
82. Feldmeier H, Heukelbach J. Epidermal parasitic skin diseases: A neglected category of poverty-associated plagues. Bull World Health Organ. 2009; 87(2): 152–9. https://doi.org/10.2471/blt.07.047308 PMID: 19274368
83. Mwangi JN, Ozwara HS, Gicheru MM. Epidemiology of tunga penetrans infestation in selected areas in Kiharu constituency, Murang'a County, Kenya. Trop Dis Travel Med Vaccines. 2015; 1: 13. https://doi.org/10.1186/s40794-015-0015-4 PMID: 28883944
84. Linardi PM, de Avelar DM. Neosomes of tungid fleas on wild and domestic animals. Parasitol Res. 2014; 113(10): 3517–33. https://doi.org/10.1007/s00436-014-4081-8 PMID: 25141814
85. Mutebi F, Krücken J, Feldmeier H, Waiswa C, Mencke N, Sentongo E, et al. Animal reservoirs of zoonotic tungiasis in endemic rural villages of Uganda. PLoS Negl Trop Dis. 2015; 9(10): e0004126. https://doi.org/10.1371/journal.pntd.0004126 PMID: 26473360
86. Ugbomoiko US, Ariza L, Ofoezie IE, Heukelbach J. Risk factors for tungiasis in Nigeria: Identification of targets for effective intervention. PLoS Negl Trop Dis. 2007; 1(3): e87. https://doi.org/10.1371/journal.pntd.0000087 PMID: 18160986

87. Gunathilaka N, Chandrasena N, Udayanga L. Prevalence of ectoparasitic infections and other dermatological infections and their associated factors among schoolchildren in Gampaha District, Sri Lanka. Can J Infect Dis Med Microbiol. 2019; 2019: 5827124. https://doi.org/10.1155/2019/5827124 PMID: 31019612

88. Emi W, Colleen MM, Abebayehu T, Desta AA, David F, Gail D. Use of footwear and foot condition among rural Ethiopian schoolchildren. J Epidemiol Glob Health. 2014; 4(4): 323–5. https://doi.org/10.1016/j.jegh.2014.06.001 PMID: 25455650

89. Hospenthal DR, Rinaldi MG. Diagnosis and treatment of fungal infections. 2nd ed. ed. Cham: Springer International Publishing: Imprint: Springer; 2015.

90. Russell JJ, Ryan EF Jr. Common dermatologic conditions in primary care. 1st ed. 2019. ed. Cham: Springer International Publishing: Imprint: Humana; 2019.

91. Tomczyk S, Deribe K, Brooker SJ, Clark H, Rafique K, Knopp S, et al. Association between footwear use and neglected tropical diseases: A systematic review and meta-analysis. PLoS Negl Trop Dis. 2014; 8(11): e3285. https://doi.org/10.1371/journal.pntd.0003285 PMID: 25393620

Supplementary file

Paper-I: Supplementary file

Table 1a. Demographic and socio-economic characteristics of schoolchildren and their parents in the Wonago district of southern Ethiopia, 2017 (n=861)

Variables		**Frequency**	**Percent**
Sex	Boys	483	56.1
	Girls	378	43.9
Child age group	7-9	158	18.4
	10-14	703	81.6
Child lives with whom	Father and mother	768	89.2
	Father	12	1.4
	Mother	48	5.6
	Relatives	27	3.1
	Guardian	6	0.7
Household head sex	Male	787	91.4
	Female	74	8.6
Family size	1-4	78	9.1
	≥5	783	90.9
Mother's education	No formal education	761	88.4
	Primary	83	9.6
	Secondary and above	13	1.5
	Mother or guardian not alive	4	0.5
Mother's occupation	Government employee	8	0.9
	Farmer	287	33.5
	Trader	61	7.1
	Daily laborer	32	3.7
	Housewife	463	54.0
	Student	6	0.7
Father's education	No formal education	420	48.8
	Primary	294	34.1
	Secondary and above	86	10
	Father or guardian not alive	61	7.1
Father's occupation	Government employee	44	5.5
	Farmer	619	77.4
	Trader	126	15.7
	Daily laborer	11	1.4
Wealth status	Poor	287	33.3
	Middle-class	297	34.5
	Rich	277	32.2

Table 2a. Food groups and beverages consumed by schoolchildren the day before the survey in the Wonago district of southern Ethiopia, 2017 (n=861)

Food group		**Frequency**	**Percent**
Group 1.	Cereals, roots, or tubers (Maize, wheat, teff, rice, white potato, kocho, or bulla*)	861	100
Group 2.	Vitamin A-rich plant foods (Carrot, sweet potato, papaya, mango)	85	9.9
Group 3.	Other fruits (avocado, orange)	160	18.6
Group 4.	Other vegetables (tomato, cabbage, onion)	195	22.6
Group 5.	Meat or fish	35	4.1
Group 6.	Eggs	147	17.1
Group 7.	Pulses or legumes (beans, peas, lentils)	404	46.9
Group 8.	Milk and milk products (milk, yogurt)	129	15.0
Group 9.	Food cooked in oils or fats	32	3.7
Coffee or tea		749	87.0

* Kocho or bulla: Flour made of the root and bark of *ensete or wasa.*

Table 3a. Affirmative responses to items on the Household Food Insecurity Access Scale (HFIAS) in the Wonago district of southern Ethiopia, 2017 (n=861)

HFIAS questions		**Frequency**	**Percent**
Q1.	Worry for food	437	50.8
Q2.	Unable to eat preferred foods	358	41.6
Q3.	Eat a limited variety of foods	291	33.8
Q4.	Eat foods that you did not want to eat	193	22.4
Q5.	Eat a smaller meal	121	14.1
Q6.	Eat fewer meals in a day	48	5.6
Q7.	No food to eat of any kind	29	3.4
Q8.	Go to sleep at night hungry	17	2.0
Q9.	Go day and night without eating anything	10	1.2
Prevalence of food insecurity	Food secure	424	49.2
	Mild food insecurity	252	29.3
	Moderate food insecurity	155	18.0
	Severe food insecurity	30	3.5

Table 4a. Prevalence of anemia, stunting, thinness, and underweight, among schoolchildren in the Wonago district, southern Ethiopia, 2017

Variables	Frequency	Percent
Non anemic	570	70.4
Anemic	240	29.6
Mild anemia	204	85
Moderate anemia	36	15
Not stunted	583	67.7
Stunted	278	32.3
Severely stunted	104	37.4
Not thin	776	90.1
Thin	85	9.9
Not underweight	247	81.3
Underweight	57	18.7
Severely underweight	3.3	10

Table 5a. The proportion of anemia, stunting, and CAS in relation to individual, household, and school factors among schoolchildren in the Wonago district of southern Ethiopia, 2017

Variables			**Anemia**			**Stunting**			**CAS**	
Individual child factors		**N**	**Yes (%)**	**No (%)**	**N**	**Yes (%)**	**No (%)**	**N**	**Yes (%)**	**No (%)**
Sex	Boys	456	134 (29.4)	322 (70.6)	483	167 (34.6)	316 (65.4)	456	44 (9.6)	412 (90.4)
	Girls	354	106 (29.9)	248 (70.1)	378	111 (29.4)	267 (70.6)	354	41 (11.6)	313 (88.4)
Age in years	7-9	151	61 (40.4)	90 (59.6)	158	25 (15.8)	133 (84.2	151	11 (7.3)	140 (92.7)
	10-14	659	179 (27.2)	480 (72.8)	703	253 (36.0)	450 (64.0)	659	74 (11.2)	585 (88.8)
Trim nails every week	Yes	623	191 (30.7)	432 (69.3)	665	200 (30.1)	465 (69.9)	623	65 (10.4)	558 (89.6)
	No	187	49 (26.2)	138 (73.8)	196	78 (39.8)	118 (60.2)	187	20 (10.7)	167 (89.3)
Handwashing with soap after latrine use	Always	97	21 (21.6)	76 (78.4)	103	22 (21.4)	81 (78.6)	97	6 (6.2)	91 (93.8)
	Sometimes or not always	467	111 (23.8)	356 (76.2)	487	167 (34.3)	320 (65.7)	467	45 (9.6)	422 (90.4)
	Never	246	108 (43.9)	138 (56.1)	271	89 (32.8)	182 (67.2)	246	34 (13.8)	212 (86.2)
Walking barefoot	Always	20	8 (40.0)	12 (60.0)	22	10 (45.4)	12 (54.6)	20	6 (30.0)	14 (70.0)
	Sometimes	381	112 (29.4)	269 (70.6)	400	139 (34.7)	261 (65.3)	381	40 (10.5)	341 (89.5)
	Never	409	120 (29.3)	289 (70.7)	439	129 (29.4)	310 (70.6)	409	39 (9.5)	370 (90.5)
Taking regular meals before attending school	Yes	752	219 (29.1)	533 (70.9)	798	261 (32.7)	537 (67.3)	752	80 (10.6)	672 (89.4)
	No	58	21 (36.2)	37 (63.8)	63	17 (27.0)	46 (73.0)	58	5 (8.6)	53 (91.4)
Reported illness in the past month	Yes	35	12 (34.3)	23 (65.7)	37	10 (27.0)	27 (73.0)	35	2 (5.7)	33 (94.3)
	No	775	228 (29.4)	547 (70.6)	824	268 (32.5)	556 (67.5)	775	228 (29.4)	692 (89.3)
Anemia	No	-	-	-	570	170 (29.8)	400 (70.2)	-	-	-
	Yes	-	-	-	240	85 (35.4)	155 (64.6)	-	-	-
Stunting	No	555	155 (27.9)	400 (72.1)	-	-	-	-	-	-
	Yes	255	85 (33.3)	170 (66.7)	-	-	-	-	-	-
A. lumbricoides	No	649	174 (26.8)	475 (73.2)	691	223 (32.3)	468 ()67.7	649	60 (9.2)	589 (90.8)
	Yes	156	64 (41.0)	92 (59.0)	159	49 (30.8)	110 (69.2)	156	23 (14.7)	133 (85.3)
T. trichiura	No	465	123 (26.5)	342 (73.5)	490	153 (31.2)	337 (68.8)	465	41 (8.8)	424 (91.2)
	Yes	340	115 (33.8)	225 (66.2)	360	119 (33.1)	241 (66.9)	340	42 (12.4)	298 (87.6)
Hookworm	No	268	221 (28.8)	547 (71.2)	813	260 (32.0)	553 (68.0)	768	78 (10.2)	690 (89.8)
	Yes	37	17 (45.9)	20 (54.1)	37	12 (32.4)	25 (67.6)	37	5 (13.5)	32 (86.5)

CAS; concurrent anemia and stunting; N: total number of children

Table 5a. The proportion of anemia, stunting, and CAS in relation to individual, household, and school factors among schoolchildren in the Wonago district of Southern Ethiopia, 2017 (**Continued**)

Variables		Anemia			Stunting			CAS		
		N	Yes (%)	No (%)	N	Yes (%)	No (%)	N	Yes (%)	No (%)
Received de-worming treatment in the past 6 months	Yes	174	66 (37.9)	108 (62.1)	191	59 (30.9)	132 (69.1)	174	21 (12.1)	153 (87.9)
	No	636	174 (27.4)	462 (72.6)	670	219 (32.7)	451 (67.3)	636	64 (10.1)	572 (89.9)
Head lice	Yes	315	101 (32.1)	214 (67.9)	342	123 (36.0)	219 (64.0)	315	42 (13.3)	273 (86.7)
	No	495	139 (28.1)	356 (71.9)	519	155 (29.9)	364 (70.1)	495	43 (8.7)	452 (91.3)
Individual parent factors										
Mother's education	No formal education	718	216 (30.1)	502 (69.9)	761	250 (32.8)	511 (67.2)	718	79 (11.0)	639 (89.0)
	Primary and above	88	24 (27.3)	64 (72.7)	96	27 (28.1)	69 (71.9)	88	6 (6.8)	82 (93.2)
Father's education	No formal education	391	122 (31.2)	269 (68.8)	420	140 (33.3)	280 (66.7)	391	46 (11.8)	345 (88.2)
	Primary and above	359	103 (28.7)	256 (71.3)	380	119 (31.3)	261 (68.7)	359	33 (9.2)	326 (90.8)
Household factors										
Wealth status	Poor	273	73 (26.7)	200 (73.3)	287	104 (36.2)	183 (63.8)	273	30 (11)	243 (89.0)
	Middle	275	92 (33.4)	183 (66.6)	297	88 (29.6)	209 (70.4)	275	28 (10.2)	247 (89.8)
	Rich	262	75 (28.6)	187 (71.4)	277	86 (31.1)	191 (68.9)	262	27 (10.3)	235 (89.7)
Family size	1-4	76	21 (27.6)	55 (72.4)	78	19 (24.4)	59 (75.6)	76	4 (5.3)	72 (94.7)
	≥5	734	219 (29.8)	515 (70.2)	783	259 (33.1)	524 (66.9)	734	81 (11.0)	653 (89.0)
Using treated drinking water at home	Yes	98	32 (32.6)	66 (67.4)	109	22 (20.2)	87 (79.8)	98	4 (4.1)	94 (95.9)
	No	712	208 (29.2)	504 (70.8)	752	256 (34.0)	496 (66.0)	712	81 (11.4)	631 (88.6)
Food insecurity	No	401	110 (27.4)	291 (72.6)	424	149 (35.1)	275 (64.9)	401	43 (10.7)	358 (89.3)
	Yes	409	130 (31.8)	279 (68.2)	437	129 (29.5)	308 (70.5)	409	42 (10.3)	367 (89.7)
Received food aid in the past 6 months	No	767	227 (29.6)	540 (70.4)	814	270 (33.2)	544 (66.8)	767	83 (10.8)	684 (89.2)
	Yes	43	13 (30.2)	30 (69.8)	47	8 (17.0)	39 (83.0)	43	2 (4.6)	41 (95.4)
School factors										
Participates in the school feeding programme	No	400	152 (38.0)	248 (62.0)	431	139 (32.3)	292 (67.7)	400	55 (13.7)	345 (86.3)
	Yes	410	88 (21.5)	322 (78.5)	430	139 (32.3)	291 (67.7)	410	30 (7.3)	380 (92.7)

CAS; concurrent anemia and stunting; N: total number of children

Table 6a. Bivariate, multilevel, mixed-effect, regression analysis of anemia, and stunting among schoolchildren in the Wonago district of southern Ethiopia, 2017

Variables		**Crude odds ratio (COR) (95% CI)**			
		Anemia	**P-value**	**Stunting**	**P-value**
Individual child factors					
Sex	Boys	1.01 (0.73, 1.39)	0.954	1.28 (0.96, 1.72)	0.094
	Girls	1.0		1.0	
Age in years	Mean (SD)	0.94 (0.84, 1.04)	0.212	1.41 (1.21, 1.65)	0.000
Nail trimming every week	Yes	0.79 (0.46, 1.37)	0.407	0.65 (0.47, 0.91)	0.011
	No	1.0		1.0	
Handwashing with soap after latrine use	Always	1.0		1.0	
	Sometimes or not always	1.40 (0.78, 2.53)	0.258	1.92 (1.16, 3.19)	0.012
	Never	2.17 (1.13, 4.20)	0.020	1.79 (1.05, 3.08)	0.032
Walking barefoot	Always	1.69 (0.62, 4.59)	0.303	2.01 (0.84, 4.79)	0.115
	Sometimes	0.99 (0.70, 1.41)	0.980	1.28 (0.95, 1.72)	0.099
	Never	1.0		1.0	
Taking regular meals before attending school	Yes	0.51 (0.28, 0.94)	0.030	1.31 (0.73, 2.33)	0.363
	No	1.0		1.0	
Reported illness in the past month	Yes	1.35 (0.64, 2.87)	0.432	0.77 (0.37, 1.61)	0.487
	No	1.0		1.0	
Anemia	No	-		1.0	
	Yes	-		1.32 (0.95, 1.84)	0.102
Stunting	No	1.0		-	
	Yes	1.36 (0.97, 1.93)	0.077	-	
Thinness	No	1.0		-	
	Yes	1.04 (0.61, 1.78)	0.870	-	
A. lumbricoides	No	1.0		1.0	
	Yes	1.81 (1.22, 2.68)	0.003	0.94 (0.64, 1.36)	0.724
T. trichiura	No	1.0		1.0	
	Yes	1.56 (1.13, 2.17)	0.008	1.09 (0.82, 1.47)	0.545
Hookworm	No	1.0		1.0	
	Yes	2.02 (0.98, 4.12)	0.055	1.02 (0.50, 2.07)	0.951
DDS		0.99 (0.87, 1.12)	0.889	0.97 (0.87, 1.07)	0.564
Received deworming treatment in the past 6 months	Yes	1.42 (0.87, 2.32)	0.160	0.93 (0.64, 1.34)	0.693
	No	1.0		1.0	
Head lice	Yes	1.22 (0.87, 1.70)	0.254	1.33 (0.99, 1.78)	0.058
	No	1.0		1.0	

CI: confidence interval; DDS: Dietary Diversity score; OR: odds ratio

Table 6a. Bivariate, multilevel, mixed-effect, regression analysis of anemia, and stunting among schoolchildren in the Wonago district of southern Ethiopia, 2017 (**Continued**)

Variables		**Crude odds ratio (COR) (95% CI)**			
Individual parent factors		**Anemia**	**P-value**	**Stunting**	**P-value**
Mother's education	No formal education	1.39 (0.81, 2.43)	0.234	1.35 (0.82, 2.22)	0.243
	Primary and above	1.0		1.0	
Father's education	No formal education	0.95 (0.66, 1.36)	0.768	1.12 (0.82, 1.52)	0.482
	Primary and above	1.0		1.0	
Household factors					
Wealth status	Poor	0.86 (0.57, 1.28)	0.450	1.27 (0.89, 1.81)	0.185
	Middle	1.03 (0.68, 1.55)	0.890	0.94 (0.66, 1.35)	0.746
	Rich	1.0		1.0	
Family size	1-4	1.0		1.0	
	≥5	1.09 (0.62, 1.91)	0.758	1.53 (0.89, 2.63)	0.121
Using treated drinking water at home	Yes	0.97 (0.59, 1.59)	0.920	0.49 (0.29, 0.79)	0.004
	No	1.0		1.0	
Food insecurity	No	1.0		1.0	
	Yes	1.25 (0.83, 1.88)	0.278	0.77 (0.58, 1.03)	0.078
Received food aid in the past 6 months	No	1.0		1.0	
	Yes	0.71 (0.34, 1.48)	0.362	0.42 (0.19, 0.90)	0.027
School factors					
Participates in the school feeding programme	No	1.0		1.0	
	Yes	0.44 (0.18, 1.12)	0.087	1.003 (0.74, 1.35)	0.984

CI: confidence interval; DDS: Dietary Diversity score; OR: odds ratio

Table 7a. Multivariate, multilevel, mixed-effect, regression analysis of anemia, and stunting among schoolchildren in the Wonago district of southern Ethiopia, 2017

Variables		**Adjusted OR (95% CI)**			
Individual child factors		**Anemia**	**P-value**	**Stunting**	**P-value**
Sex	Boys	0.92 (0.66, 1.28)	0.62	1.29 (0.93, 1.79)	0.13
	Girls	1.0		1.0	
Age		0.91 (0.81, 1.01)	0.09	1.47 (1.24, 1.74)	0.000
Handwashing with soap after latrine	Always	1.0		1.0	
	Sometimes or not always	1.52 (0.82, 2.84)	0.18	2.09 (1.17, 3.71)	0.01
	Never	2.09 (1.06, 4.14)	0.03	1.73 (0.88, 3.41)	0.11
Walking barefoot	Always	-		-	
	Sometimes	-		-	
	Never	-		-	
Head lice	Yes	-		1.41 (1.003, 1.97)	0.04
	No	-		1.0	
A. lumbricoides	No	1.0		-	
	Yes	1.73 (1.15, 2.62)	0.009	-	
T. trichiura	No	1.0		-	
	Yes	1.46 (1.04, 2.05)	0.02	-	
Household factors					
Using treated drinking water at home	Yes	-		0.52 (0.30, 0.90)	0.02
	No	-		1.0	
School factors					
Participates in the school feeding programme	No	1.0		1.0	
	Yes	0.58 (0.23, 1.43)	0.23	0.71 (0.40, 1.25)	0.23
Variation and model fitness					
Intra-cluster correlation	School	3.6%		NS	
	Class	8.9%		5.2	
-2 Log likelihood		880		926	
AIC		914		956	
AUC		0.75		0.72	

AIC: Akaike information criterion; AUC: area under the curve; CI: confidence interval; NS: Not significant; OR: odds ratio.

Paper-II: Supplementary file

Table 1b. Distribution of helminths co-infection among schoolchildren in the Wonago district, Southern Ethiopia, 2017 (n=850)

Co-infection	**Frequency**	**Percent**
No infection	371	43.6
Single infection	337	39.6
Double infections	101	11.9
Triple infections	37	4.4
Quadruple infections	4	0.5
T. trichiuria, and *A. lumbricoides*	90	10.6
T. trichiuria, and Hookworm	15	1.8
A. lumbricoides and Hookworm	13	1.5

Table 2b. Distribution of helminths infection among schoolchildren in the Wonago district, Southern Ethiopia, 2017 (n=850)

Variables		**Any helminths**	***T. trichiuria***	***A. lumbricoides***
Individual child factors		**Yes (n (%)**	**Yes (n (%)**	**Yes (n (%)**
Sex of child	Boys	276 (57.6)	206 (43.0)	96 (20.0)
	Girls	203 (54.7)	154 (41.5)	63 (17.0)
Child age in years	7-9	92 (58.6)	72 (46.0)	22 (14.0)
	10-14	387 (55.8)	288 (41.6)	137 (19.8)
Fingernails trimmed	Yes	386 (55.5)	296 (42.6)	128 (18.4)
	No	93 (60.0)	64 (41.3)	31 (20.0)
Unclean fingernails	Yes	121 (58.5)	89 (43.0)	48 (23.2)
	No	358 (55.7)	271 (42.2)	111 (17.3)
Handwashing with soap after latrine	Always	63 (61.8)	50 (49.0)	22 (21.6)
	Sometimes	264 (54.9)	200 (41.6)	78 (16.2)
	Never	152 (56.9)	110 (41.2)	59 (22.1)
Handwashing with soap before meals	Yes	466 (56.2)	349 (42.1)	155 (18.7)
	No	13 (61.9)	11 (52.4)	4 (19.1)
Eats uncooked vegetables	Yes	125 (60.0)	98 (47.1)	40 (19.2)
	No	354 (55.1)	262 (40.8)	119 (18.5)
Loss of appetite in the past month	Yes	82 (67.8)	60 (49.6)	34 (28.1)
	No	397 (54.5)	300 (41.2)	125 (17.2)
Stunting	No	326 (56.4)	241 (41.7)	110 (19.0)
	Yes	153 (56.3)	119 (43.7)	49 (18.0)
Thinness	No	422 (55.0)	314 (40.9)	141 (18.4)
	Yes	57 (68 .7)	46 (55.4)	18 (21.7)
Anemia	No	306 (54.0)	225 (39.7)	92 (16.2)
	Yes	150 (63.0)	115 (48.3)	64 (26.9)
Received deworming treatment in the past 6 months	Yes	109 (57.4)	82 (43.2)	28 (14.7)
	No	370 (56.0)	278 (42.1)	131 (19.8)
Individual parent factors				
Mother's education	Never entered school	392 (58.5)	297 (44.3)	130 (19.4)
	Read and write only	47 (58.0)	33 (40.7)	17 (21.0)
	Primary and above	38 (40.0)	28 (29.5)	12 (12.6)
Father's education	Never entered school	127 (60.2)	100 (47.4)	41 (19.4)
	Read and write only	112 (56)	78 (39.0)	39 (19.5)
	Primary and above	203 (53.7)	153 (40.5)	66 (17.5)
Household factor				
Wealth status	Poor	165 (57.9)	124 (43.5)	53 (18.6)
	Middle-class	165 (56.3)	121 (41.3)	53 (18.1)
	Rich	149 (54.8)	115 (42.3)	53 (19.5)
Source of drinking water	Unprotected	213 (58.8)	150 (41.4)	90 (24.9)
	Protected	266 (54.5)	210 (43.0)	69 (14.1)
Water storage container	Closed container	440 (55.3)	331 (41.6)	149 (18.7)
	Open container	39 (72.2)	29 (53.7)	10 (18.5)
Using treated water at the household level	Yes	60 (56)	42 (39.3)	19 (17.8)
	No	419 (56.4)	318 (42.8)	140 (18.8)
School factor				
Access to health education on personal hygiene	Yes	374 (56.4)	288 (43.4)	123 (18.6)
	No	105 (56.2)	72 (38.5)	36 (19.3)
Absent in the past one Month	Yes	217 (55.6)	155 (39.7)	76 (19.5)
	No	262 (57)	205 (44.6)	83 (18.0)
Participates in the school feeding programme	No	250 (58.7)	170 (39.9)	90 (21.1)
	Yes	229 (54)	190 (44.8)	69 (16.3)

Any helminths: *T. trichiura, A. lumbricoides, Taenia* species, hookworm species, *S. stercoralis, H. nana*

Table 3b. The mean, median, SD, and IQR of *T.trichiuria* infection loads in egg per gram of stool among schoolchildren in the Wonago district, Southern Ethiopia, 2017 (n=850)

Variables		***T.trichiuria* egg count**		
		Infection free (Epg=0)	**(Epg > 0)**	**(Epg > 0)**
Individual child factors		n (%)	Mean (SD)	Median (IQR)
Sex of child	Boys	273 (57.0)	138.6 (113.5)	120 (72-168)
	Girls	217 (58.5)	181.8 (406.2)	120 (72-168)
Child age in years	7-9	85 (54.0)	170.1 (140.6)	120 (72-192)
	10-14	405 (58.4)	153.1 (299.1)	120 (72-168)
Fingernails trimmed	Yes	399 (57.4))	145.6 (111.4)	120 (72-168)
	No	91 (58.7)	205.2 (603.2)	108 (72-144)
Unclean fingernails	Yes	118 (57.0)	185.1 (510.6)	120 (72-168)
	No	372 (57.8)	146.6 (114.2)	120 (72-168)
A habit of eating uncooked vegetable	Yes	110 (52.9)	146.3 (116.9)	120 (72-168)
	No	380 (59.2)	160.3 (315.8)	120 (72-168)
Loss of appetite in the past month	Yes	61 (50.4)	143.2 (109.5)	120 (72-168)
	No	429 (58.8)	159.1 (297.6)	120 (72-168)
Anemia	No	342 (60.3)	154.9 (122.0)	120 (72-168)
	Yes	123 (51.7)	166.6 (456.5)	120 (72-168)
Thinness	No	453 (59.1)	157.8 (292.2)	120 (72-168)
	Yes	37 (44.6)	147.3 (104.1)	120 (72-168)
Individual parent factor				
Mother's education	Never entered school	373 (55.7)	160.6 (301.2)	120 (72-168)
	Read and write only	48 (59.2)	146.2 (105.9)	120 (72-168)
	Primary and above	67 (70.5)	123.6 (70.0)	120 (72-168)
Household factor				
Wealth status	Poor	161 (56.5)	157.8 (130.7)	144 (72-192)
	Middle-class	172 (58.7)	134.0 (85.6)	120 (72-168)
	Rich	157 (57.7)	178.1 (460.2)	96 (72-168)
Water storage	Closed container	465 (58.4)	150.9 (281.7)	120 (72-168)
	Open container	25 (46.3)	226.6 (161.2)	168 (120-336)
School factor				
Participates in the school feeding programme	No	256 (60.1)	135.7 (100.7)	120 (72-168)
	Yes	234 (55.2)	173.9 (362.1)	120 (72-168)

EPG: Egg per gram of stool; IQR: Interquartile ranges; SD: Standard deviation

Table 4b. The mean, median, SD, and IQR of *A.lumbricoides* infection loads in egg per gram of stool among schoolchildren in the Wonago district, Southern Ethiopia, 2017 (n=850)

Variables		***A. lumbricoides* egg count**		
		Infection free (Epg=0)	**(Epg > 0)**	**(Epg > 0)**
Individual child factors		**n (%)**	**Mean (SD)**	**Median (IQR)**
Sex of child	Boys	383 (80.0)	321.6 (1213.2)	120 (96-216)
	Girls	308 (83.0)	232.4 (609.3)	120 (72-204)
Child age in years	7-9	135 (86.0)	124.6 (55.1)	120 (72-144)
	10-14	556 (80.2)	311.8 (1086.3)	120 (72-216)
Fingernails trimmed	Yes	567 (81.6)	157.8 (107.5)	120 (72-216)
	No	124 (80.0)	839.1 (2272.6)	120 (96-240)
Unclean fingernails	Yes	159 (76.8)	582.5 (1797.7)	156 (108-216)
	No	111 (17.3)	154.9 (112.1)	120 (72-192)
Handwashing with soap after latrine	Always	80 (78.4)	204 (142.0)	132 (72-360)
	Sometimes	403 (83.8)	347.8 (1366.2)	120 (72-192)
	Never	208 (77.9)	240.8 (628.2)	132 (72-216)
Received deworming treatment in the past 6 months	Yes	162 (85.3)	200 (144.5)	120 (120-264)
	No	529 (80.2)	304.1 (1113.4)	120 (72-192)
Anemia	No	475 (83.8)	195.1 (390.5)	120 (72-204)
	Yes	174 (73.1)	227.8 (610.3)	120 (96-216)
Individual parent factor				
Mother's education	Never entered school	540 (80.6)	226.3 (538.4)	120 (72-216)
	Read and write only	64 (79.0)	148.2 (78.8)	120 (96-216)
	Primary and above	83 (87.4)	1314.7 (3557.6)	120 (96-192)
Household factor				
Wealth status	Poor	232 (81.4)	226.2 (512.7)	120 (72-216)
	Middle-class	240 (81.9)	386 (1538.8)	120 (72-216)
	Rich	219 (80.5)	242.4 (665.4)	120 (72-192)
School factors				
Participates in the school feeding programme	No	336 (78.9)	145.1 (79.1)	120 (72-192)
	Yes	355 (83.7)	482.4 (1547.6)	120 (84-228)

EPG: Egg per gram of stool; IQR: Interquartile ranges; SD: Standard deviation

Table 5b. Inter-rater agreement for the readings of 85 Kato-Katz microscopic slides

		Second reader											
		A. lumbricoides			*T. trichiuria*			**Taenia** *spp.*			**Hookworm** *spp.*		
		+	-	T	+	-	T	+	-	T	+	-	T
First reader	+	34	1	35	41	5	46	27	3	30	22	2	24
	-	6	44	50	0	39	39	2	53	55	3	58	61
	T	40	45	85	41	44	85	29	56	85	25	60	85
Kappa (95% CI for Kappa)		**0.83 (0.72-0.95)**			**0.88 (0.78-0.98)**			**0.87 (0.76-0.98)**			**0.86 (0.74-0.98)**		

+: positive; -: Negative; T: Total

Kappa values were defined as follows: poor=0.01–0.2; fair=0.21–0.4; moderate=0.41–0.6; good=0.61–0.8; and perfect=0.81–1

Faecal egg counts of the false-positive Kato-Katz thick smears: For A. lumbricoides (10 eggs), for T. trichiuria (5, 5, 7, 10, 11 eggs), for Taenia species (5, 5, 11eggs), and for Hookworm (5, 6 eggs).

Faecal egg counts of the false-negative Kato-Katz thick smears: For A. lumbricoides (5, 5, 5 9, 9, 7 eggs), for Taenia species (6, 9 eggs), and for Hookworm (1, 3, 3 eggs).

Table 6b. Inter-rater agreement of 85 microscopic slides from FEC

		Second reader														
		A. lumbricoides			***T. trichiuria***			**Taenia spp.**			**Hookworm spp.**			***S. stercoralis***		
		+	-	T	+	-	T	+	-	T	+	-	T	+	-	T
First reader	+	37	2	39	24	3	27	19	2	21	7	1	8	10	2	12
	-	2	44	46	2	56	58	3	61	64	1	76	77	2	71	73
	T	39	46	85	26	59	85	22	63	85	8	77	85	12	73	85
Kappa (95% CI for Kappa)		**0.91 (0.82-0.99)**			**0.86 (0.75-0.98)**			**0.84 (0.71-0.97)**			**0.86 (0.67-1.00)**			**0.81 (0.62-0.99)**		

FEC: Formalin-ether concentration; +: positive; -: Negative; T: Total

Kappa values were defined as follows: poor=0.01–0.2; fair=0.21–0.4; moderate=0.41–0.6; good=0.61–0.8; and perfect=0.81–1

Table 7b. Model validation for *T.trichiuria* and *A.lumbricoides* egg count model.

Model fitness	***T. trichiuria* model**	
	ZIP	**ZINB**
-2 Log-likelihood (Deviance)	43126	4840
Likelihood ratio test	-	38000 (P < 0.001)
Vuong test	-	17.5 (P < 0.001)
Akaike information criterion (AIC)	43186	4902
	***A. lumbricoides* model**	
-2 Log-likelihood (Deviance)	23788	2436
Likelihood ratio test	-	21000 (P<.001)
Vuong test	-	9.4 (P<.001)
Akaike information criterion (AIC)	23845	2494

ZINB: Zero-inflated negative binomial regression; ZIP: Zero-inflated Poisson regression

Paper-III: Supplementary file

Table 1c. Bayesian multivariate, multilevel, mixed-effect, logistic regression analysis of scabies among schoolchildren in the Wonago district, southern Ethiopia, 2017

Variables		**Scabies**				
		Posterior mean	**SD**	**MCSE**	**Median**	**Adjusted 95% Bayesian credible intervals (BCI) OR (95% BCI)**
Individual child factors						
Sex	Boys	2.62	1.05	0.014	2.42	2.62 (1.19, 5.19)*
	Girls	-	-	-	-	1.0
Age in years (continuous)	Mean (SD)	0.82	0.09	0.005	0.81	0.82 (0.66, 1.04)
Frequency of washing body with soap	Every week	-	-	-	-	1.0
	Every two weeks	1.15	0.43	0.006	1.08	1.15 (0.52, 2.18)
Frequency of washing hair with soap	Every week	-	-	-	-	1.0
	Every two weeks	1.41	0.52	0.006	1.33	1.41 (0.68, 2.64)
Frequency of washing legs and feet with soap	Every day	0.88	0.33	0.005	0.83	0.88 (0.41, 1.65)
	Sometimes	-	-	-	-	1.0
Sharing beds	No	-	-	-	-	1.0
	Yes	4.30	2.36	0.05	3.74	4.30 (1.55, 10.4)*
Sharing clothes	No	-	-	-	-	1.0
	Yes	1.25	0.48	0.006	1.17	1.25 (0.56, 2.39)
Sharing combs	No	-	-	-	-	1.0
	Yes	5.77	3.93	0.08	4.75	5.77 (1.72, 16.1)*
Household factors						
Family size (continuous)	Mean (SD)	1.15	0.11	0.003	1.15	1.15 (0.94, 1.39)
Wealth status	Poor	1.68	0.85	0.011	1.50	1.68 (0.61, 3.79)
	Middle-class	1.92	0.96	0.014	1.72	1.96 (0.70, 4.32)
	Rich	-	-	-	-	1.0
School factors						
Access to health education on personal hygiene	Yes	0.77	0.46	0.008	0.66	0.77 (0.24, 1.95)
	No	-	-	-	-	1.0
Variation and model fitness						
Variation	School				2.29	
	Class				1.16	
Intra-cluster correlation coefficient	School				31.2%	
	Class				49.3%	
DIC					321	

BCI: Bayesian credible interval; OR: odds ratio; SD: standard deviations; MCSE: Monte Carlo standard errors; *significant

Table 2c. Bayesian multivariate, multilevel, mixed-effect, logistic regression analysis of tungiasis among schoolchildren in the Wonago district, southern Ethiopia, 2017

Variables		Tungiasis				
		Posterior mean	**SD**	**MCSE**	**Median**	**Adjusted 95% Bayesian credible intervals (BCI) OR (95% BCI)**
Individual child factors						
Sex	Boys	1.08	0.17	0.002	1.07	1.08 (0.78, 1.46)
	Girls	-	-	-	-	1.0
Age in years	Mean (SD)	1.01	0.05	0.002	1.01	1.01 (0.91, 1.11)
Fingernails trimmed	Yes	0.93	0.20	0.003	0.91	0.93 (0.60, 1.38)
	No	-	-	-	-	1.0
A habit of walking barefoot	Always in barefoot	2.41	1.53	0.027	2.03	2.41 (0.71, 6.39)
	Sometimes in barefoot	1.40	0.24	0.003	1.38	1.40 (0.99, 1.93)
	Never in barefoot	-	-	-	-	1.0
Presence of footwear during exam	Yes	8.04	4.98	0.29	6.76	8.04 (2.46, 21.4)*
	No	-	-	-	-	1.0
Frequency of washing body with soap	Every week	-	-	-	-	1.0
	Every two weeks	1.59	0.26	0.003	1.57	1.59 (1.13, 2.17)*
Frequency of washing legs and feet with soap	Every day	0.48	0.08	0.0009	0.48	0.48 (0.35, 0.65)*
	Sometimes	-	-	-	-	1.0
Sharing beds	No	-	-	-	-	1.0
	Yes	2.00	0.33	0.004	1.97	2.00 (1.43, 2.71)*
Sharing clothes	No	-	-	-	-	1.0
	Yes	2.85	0.50	0.006	2.80	2.85 (2.01, 3.97)*
Household factors						
Family size	1-4	-	-	-	-	1.0
	≥5	1.02	0.28	0.005	0.98	1.02 (0.58, 1.66)
Wealth status	Poor	1.93	0.39	0.005	1.89	1.93 (1.29, 2.79)*
	Middle-class	1.36	0.27	0.004	1.34	1.36 (0.89, 1.98)
	Rich	-	-	-	-	1.0
School factors						
Access to health education on personal hygiene	Yes	1.52	0.43	0.008	1.45	1.52 (0.87, 2.54)
	No	-	-	-	-	1.0
Variation and model fitness						
Variation	School				0.106	
	Class				0.198	
Intra-cluster correlation coefficient	School				3%	
	Class				8.5%	
DIC					1098	

BCI: Bayesian credible interval; OR: odds ratio; SD: standard deviations; MCSE: Monte Carlo standard errors; *significant

Table 3c. Bayesian multivariate, multilevel, mixed-effect, logistic regression analysis of tinea infections among schoolchildren in the Wonago district, southern Ethiopia, 2017

Variables		**Tinea infections**				
		Posterior mean	**SD**	**MCSE**	**Median**	**Adjusted 95% Bayesian credible intervals (BCI) OR (95% BCI)**
Individual child factors						
Sex	Boys	2.42	0.42	0.004	2.38	2.42 (1.72, 3.34)*
	Girls	-	-	-	-	1.0
Age in years (continous)	Mean (SD)	1.05	0.058	0.003	1.04	1.04 (0.94, 1.16)
Unclean fingernails	Yes	2.96	0.60	0.006	2.89	2.96 (1.96, 4.31)*
	No	-	-	-	-	-
Frequency of washing body with soap	Every week	-	-	-	-	1.0
	Every two weeks	1.36	0.24	0.003	1.34	1.36 (0.95, 1.89)
Frequency of washing hair with soap	Once per week	-	-	-	-	1.0
	Every two weeks	1.94	0.32	0.005	1.92	1.94 (1.39, 2.66)*
Frequency of washing legs and feet with soap	Every day	0.89	0.15	0.002	0.88	0.89 (0.63, 1.23)
	Sometimes	-	-	-	-	1.0
Sharing beds	No	-	-	-	-	1.0
	Yes	1.78	0.33	0.004	1.74	1.78 (1.22, 2.51)*
Sharing clothes	No	-	-	-	-	1.0
	Yes	1.89	0.35	0.004	1.86	1.89 (1.30, 2.65)*
Sharing combs	No	2.93	0.63	0.011	2.86	2.93 (1.90, 4.37)*
	Yes	-	-	-	-	-
Household factors						
Family size	1-4	-	-	-	-	1.0
	≥5	2.25	0.72	0.015	2.13	2.25 (1.20, 3.92)
Wealth status	Poor	1.99	0.42	0.006	1.94	1.99 (1.29, 2.94)*
	Middle-class	2.01	0.43	0.006	1.97	2.01 (1.30, 2.98)*
	Rich	-	-	-	-	1.0
School factors						
Access to health education on personal hygiene	Yes	1.11	0.32	0.006	1.06	1.11 (0.62, 1.88)
	No	-	-	-	-	1.0
Variation and model fitness						
Variance	School				0.217	
	Class				0.264	
Intra-cluster correlation coefficient	School				5.7%	
	Class				12.7%	
DIC					1071	

BCI: Bayesian credible interval; OR: odds ratio; SD: standard deviations; MCSE: Monte Carlo standard errors; *significant

Appendices

Appendix I: Consent form and Questionnaires for household information

Appendix Ia: Consent form

Information sheet and Consent form

Hello!

My name is --I am a data collector for a research project on the assessment of school health problems in the Gedeo zone, southern Ethiopia. The main aim of this study is to examine child health problems among school children living in Gedeo Zone, southern Ethiopia. This study will contribute to child health and school outcome. To find out the major health problems among school children we need to enroll students. However, your child is under 18 years of age; therefore, we would like to request your permission to conduct an interview, a laboratory investigation (i.e. anemia test, stool for parasites), measure weight and height, and also perform a physical examination to detect skin problems. To perform an anemia test, he/she will give a few drops of blood from a finger. The equipment used for taking the blood sample is never been used before and will be thrown away after each test. To examine the parasitic infection, we provide a clean, dry stool cup and pieces of applicator sticks to your child to bring a fresh stool. The results of the examination will be informed right away and kept strictly confidential. The examination is free, and if the examination shows any health problems, a referral linkage will be arranged to the nearest health facility for treatment. The project leader will cover the costs of transportation if needed.

Additionally, if you and your child agreed to participate in the study, we ask you to provide some important information related to a household asset, household conditions, and child health. Participation in this research project is not compulsory. The information you provide to us is very crucial to this study. Completing this questionnaire will take approximately 45 minutes. The information you provide us will remain confidential. If you are uncomfortable with the questions, you are free to withdraw at any time.

Finally, we want to assure you that your name and address will not be mentioned and handed over to others. However, the result will be organized and documented and might be submitted/given to the concerned Health Organizations or other bodies. Therefore, I need your honest and genuine response to questions prepared to attain the objective of the study.

Do you have any questions? Would you be willing to participate in the study?

Yes ☐ ⟶ If yes, proceed to the next page.

No ☐ ⟶ If no, please stop here.

In any case, you can contact the principal investigator by E-mail or mobile phone

Principal Investigator Address:
Hiwot Hailu Amare
E-mail: hiwothailu14@yahoo.com
Phone: 0913168483

Thank you!

Consent form

Having the above information, I invite you to agree on the child's participation and also your participation in the study.

"I, the undersigned, would like to confirm that, as I gave consent to participate in the study and also agreed for child participation with clear understanding and recognition of:

The objective of the study

My right to resign from the study at any stage of the study

I confirmed my agreement with my signature after the detailed objective of the study has been explained to me in the language I understand well."

Signature (participant's) ____________ Signature (data collectors) _______________

Date ______________________________ Date ___________________________

Place _____________________________

Supervisor Name________________________________ Date__________________________
Information sheet and consent form translated to local language
Information sheet and consent form in the Amharic language

መረጃ መስጫና የስምምነት ማረጋገጫ ቅፅ

ጤና ይስጥልን!

ስሜ______________________________ይባላል በደቡብ ኢትዮጲያ፣ በጌዲኦ ዞን፣ የሚገኙ የትምህርት ቤት ጤና ችግሮች ዙሪያ የተዘጋጀ ጥናት ላይ መረጃ ሰበሳቢ ነኝ። የዚህ ጥናት ዋና አላማም በደቡበ ኢትዮፕያ፣ በጌዲኦ ዞን የሚገኙ ተማሪዎች ልጆች የጤና ችግሮችን ለመለየትና ለማወቅ ነው። ሰለዚህ ይህ ጥናት በልጆች ጤና እና ተማሪዎች ውጤት ዙሪያ ላይ አስተዋፆ ይኖረዋል። በልጆች ተማሪዎች ላይ ዋና የሚባሉ ችግሮችን ለመለየት ተማሪዎችን መመዝገብ ይኖርብናል። ይሁን እንጂ በዚህ ጥናት ወስጥ እንዲሳተፍ/እንድትሳተፍ የምንፈልገው የእርሶ ልጅ እድሜ ከ18 ዓመት በታች ስለሆነ መጠይቁ ላይ እና የላብራቶሪ ምርመራ (የደም ማነስ እና የሰገራ ምርመራ)፣ የሰውነት ከብደት እና የቁመት ርዝመት ልኬት፣እንዲሁም በቆዳ ላይ ያሉትን ጭግሮች ለማየት የሰውነት ምረመራም ላይ እንዲሳተፍ/እነድትሳተፍ የእርሶን ፍቃደኝነት እንጠይቃለን። የደም ማነስ ምርመራ ለማድረግ ከልጁ/ልጅትዋ ትነሽ ጠብታ ደም ከጣት ላይ ይወሰዳል። የደም ናሙናውን ለመውሰድ የሚያገለግሉት መሣሪያዎች ከዚህ በፊት ጥቅም ላይ ውለው የማያውቁ እና ከእያንዳንዱ ምርመራ በኋላም የሚጣል ነው። የሆድ ትላትል ምርመራ ለማድረግ፣ ንጹሕና እና ደረቅ የሰገራ መቀበያ ኩባያ ለምርመራው የሚሆነ ሰገራ እንዲያመጡ ይሰጣቸዋል። የምርመራው ውጤትም ሚሥጥራዊነቱ ተጠብቆ ይነገራል። ምርመራው የሚደረገው በነፃ ሲሆን፣ የልጁ/ልጅቱዋ የምርመራ ውጤት ማንኛውንም የጤና ችግረ ካሳየ ወደ ቅርቡ ጤና ተቛም እንልካቸዋለን ከዚያም ልጁ/ልጅቱዋ ህክምናውን ይወስዳል/ ትወስዳለች። አስፈላጊ ሆኖ ከተገኘ የፕሮጀክቱ መሪ የትራንስፖርት ወጪውን ይሸፍናል።

በተጨማሪም የእርሶ ልጅ ጥናቱ ላይ አዲሳተፍ የሚስማሙ ከሆነ የቤተሰቡን ንብረት፣ የቤተሰብት ሁኔታና ከልጆች ጤንነት ጋር የተያያዙ ጠቃሚ መረጃዎችን እንድትሰጡን እንጠይቃችኋለን። በዚህ የምርምር

ፕሮጀክት መሳተፍ ግዴታ አይደለም። ለጥናት የሚሰጡን ትክክል የሆነ መረጃ በጣም ጠቃሚ ነው። ጥያቄውን ለማጠናቀቅ 45 ደቂቃ ሊወስድብን ይችላል። የሚሰጡን መረጃ ሁሉ ሚስጥራዊነቱ ተጠብቆ ለሚፍለገው ተግባረ ብቻ እንዲውል ይደረጋል። በማንኛውም ጊዜ መሳተፍ ካለፈለጉ ማቋረጥ ይችላሉ።

በመጨረሻም የእርሶ ስም እና አድራሻ አይጠቀስም ለሌላ ሰውም ተላልፎ አይሰጥም፣ ነገር ግን የጥናቱ ውጤት ተጠናቅሮ ተፅፎ ለሚመለከተው የጤና ድርጅት ሊሰጥ ይችላል። ስለዘህ የጥናቱን ዓላማ ለማሳካት ለጥያቄዎቹ ታዓማኝነትን የተሞላ እውነተኛ መረጃ እንዲሰጡን እንፍልጋለን።

ጥያቄዎች አሉት? በዚህ ጥናት ውስጥ መሳተፍ ይፍልጋሉ?

አዎ ☐ ⟶ ወደሚቀጥለው ገፅ በመሄድ ጥያቄዉን ይቀጥሉ

አይደለም ☐ ⟶ ጥያቄውን መጠየቅ አቁም

በ ኢሜል ና በሞባይል ስልክ በማንኛውም ጊዜ የጥናቱን ሰሪ ማግኘት ይችላሉ።

የጥናቱ ሰሪ አድራሻ- ህይወት ኃይሉ አማረ

ኢሜል-hiwothailu14@yahoo.com

ሞባይል ስልክ-0913168483

አመሰግናለው!

የስምምነት ማረጋገጫ ቅፅ

ከዚህ በላይ ያለውን መረጃ አውቀው፣ የእርሶ ልጅ ጥናቱ ላይ እንዲሳተፍ እንዲፈቅዱና እርሶም አዲሳተፉ እጠይቃለው። እኔ ፍርሚያዬን ከዚህ በታች ያስቀመጥቁት የጥናቱን አላማን አስመልክቶ ግለፅ የሆነ መረጃ ተሰቶኝ ፣ በማነኛውም ስዓት አቋረጬ መውጣት እደምችል ተገልፆልኝ በዚህ ጥናት ላይ ለመሳተፍና ልጄም እንዲሳተፍ በመፈቀድ መስማማቴን በፍርሚያዬ አረጋግጫለው።

የተሳታፊው ፍረሚያ...ቀን.. የመረጃ ሰብሳቢው ፍረሚያ….................................ቀን... ቦታ.. የተቆጣጣሪ ስም..ቀን..
Information sheet and consent form in Gedeo language

Kuta'ni Tarijuwwa uwwa bukki assatixxe forime.

Ashama!

Summi annik __________________________________hiyemaan. Bita'itaike topha'ni Gede'ixxe zoone'ni afemaake barachchoti minuwwa'ni lelitaxxa fayumatixxa ko'uwwa uudaxxe towwano'ni Tarija bukki assati oggeesan. Tenne towwanoki yaadi bita'ike Topha'ni Gede'ixxe zoone'ni afenidaaxe barattoolexxa fayunitetixxa rako foye ege'naten. Tennexxe tinni towachcho qo'ne baratooletixxe fayunite'ni nna gumma inisa'neexxa nossate'e la'o afe'en. Oose baratooletixxa lumolama rako ege'nate'e gargarti assati summa inisa'neka borreessa hasissaan. Kadomale'e tenne qo'ne giddo Oose ha'noxxi makemate'e 18 woggan butti'a kadeexxa kokkachchote laboratorete'ni (munide, fole'e) haurenna ejuma quleessa hasissamaxxe'e eeti uwwitinashsha laniqanen. Munidetikke shixxinixxe qo'ne'a shixxoxxa munide qubichoke naa'ni adhenidaan. Tenne qo'ne'a munide adhati miyuwwi ca'inni heqemeke. Konnechchi edo wele la''o'ni hosebaake nna mitte manijixxe qo'ne muuxenideeshshani hunemaken. Godobi giddixxa ko'o ege'nate'e ca'ichchia nna bagoke kubaaya fole'e iyedagate'e la'oofantaan. Labaratooretixxe qo'nuwwatixxe gumma maqo heqeeke jeejini ani annatini kulenidaan. Beltinna/belito maramarremexxe wuxxettetenn fayyuntetixxe raako lelishshaxxe kaadole shiqqo hedhekke fayyunitetike xaaban erginanonn. Okko'ni raako keeliteki belitokenna kaadi belti cillotika garqarissa alfaan. Yo'osh hassisexxe kaadoolle Projjectekki soorressi leemishattixxa maalleqa chufaan (uwaann).

Wele ga'mi'ni kinni Oose ha'noxxi tenne fayumatixxea qo'ne asexxashsha eeti hiyyati hadi afeexxa karra mini gidika jiroti jeejanna belitinika (belitotika wele fayuniteti jeeja ca'a asine kula lumoxxa la'o afeken. Qo'ne tenne'a hasissaaka qoritumuwwa Ooseti wellit muuxate'e 45 daqiqqi geyaan. Ha'no darenaa'ni bukki asinanoki hisichchuwwi weli mani afabaake jeejin maqo heqenidekenna hasedeexxe huje /qo'ne calla hossaan. Henne yanna'ni nna qo'ne tenne muuxxa gibinoole waale fula fedhi ha'noxxen.

Muuxake'ni ha'noki summi hexxinaabi tariji giddo abidemabaan. Wele kuta'anna uwemabaan. Tinni huje muuxenidexxi qo'ne tinni maxasenideechchi uduma uudaaxxe fayumatixxe origuwwa'a calla gelitaan. Tinni fayumatixxi qo'ne boggakenna ila boginixxe hegere'a affexxa la'o hedina'ni elloshsha muuxenido'a shiqake qoritumuwwi'a dhugatika hisichcho calla kulidino'a magane hinanen.

Qorituma afine'ek? Tenne qo'ne giddo fayunite Oose ha'noxxixxa ege'nate'e uudama hasine'e?

Eeti ☐ ⟶ Aanake qoola'ni sa'ati qorituma hiisse

Waawwoti ☐ ⟶ Qorituma qora waali

Tenne qo'ne hujaa'neka oggeesa bilibilikinna imeeleti eetinexxe yanna'ni afino'a danidetiknaan.

Oggeete/Oggeesi: Hiwoti Hailu Amare

Iimeele; hiwothailu14@yahoo.com

Bilibiliki laakkoossi 0913168483

Galatefatannon.

Weliaago quleesatixxa Forime

Konnechchi iima kulenide'eshsha Oose ha'noxxa tenne qo'neni horidofe asitashsha eeti uwwitinashshana ho'nonna qobo ha'nokixxa fulidinashsha laqanen.

Anni kaba butta beesissa anika ugeneki tenne go'nekea yaada uudaxxe dhuggaleessa Tarija ege'nati eyenexxe yanna waale fula danide'a noxxa kokkachisa'ni tenne qo'ne'ni horidofe assate'e nna bleliti / belito anixxi horidofe asinaashsha hobaasenexxa beesissiki ege'nishanen.

Horidofe aseeke ilaali beesissa ______________________Barra___________________

Tarija bubukki aseeke oggeesi beesissa________________Barra___________________

Bakka___________________________________

Hordofalli Summa_________________________Barra___________________________

Appendix Ib: Questionnaires for household information

A survey questionnaire was prepared to conduct a study on the assessment of school health problems in the Wonago district

Identification

Name of the child school________________________Child name___________________________

Child grade___________________________________Child code___________________________

Name of household head ______________________________Locality name_________________

House number___________________________Kebele_____________________________________

Interview vist

	First	**Second**	**Third**
Date			
Interviewer name			
Result			
Next visit date	__________________	____________________	__________________

Result code: 1. Completed 2. No household member at home or no competent respondent 3. Entire household absent for an extended period 4. Refused 5. Other (Specify)---
Section 1: Demographic and socio-economic characteristics of the household of the participating child
1.1 The head of household and household members (Start listing from respondents)

No.	**Questions**	**Categories**		**Skip**
Q001	Who is the head of the household?	1 . . . . Male 2. . . . . Female		
Q002	Name of a household member living in this household	Age	**Sex** 1……….... Male 2……..…Female	
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				

12				
13				
14				
Q002a	A total number of household members? **Record the number of family members by counting the name of the listed family members.**	[ ][ ]		
Q003	The child lives with whom?	1……………….……………Father and mother 2………………………………………Father 3………………………………………Mother 4………………………………………Relatives 5………………………………………Guardian		
Q004	What is the educational status of the father/guardian of the child (name)?	1…………… ....Never entered school (Illiterate) 2……….……...……...… Read and write only 3……………………………Primary (1-8) 4……………………………Secondary (9-10) 5……………………………Preparatory (11-12) 6…........…Technical/vocational training (TVET) 7……………………..........University/college 8…………………Father/guardian not alive →		Q006
Q005	What is the occupation of the father/guardian of the child (name)?	1……………….................Government employee 2…………………….................................Farmer 3……………………………….........Trader 4…………………….........................Daily laborer 5___________________________Others(specify)		
Q006	What is the educational status of the mother/guardian of the child (name)?	1…………….... Never entered school (Illiterate) 2………………….............. Read and write only 3……………….................................Primary (1-8) 4……………………………Secondary (9-10) 5……………………………Preparatory (11-12) 6……......Technical/vocational training (TVET) 7……..…………………...... University/college 8………......…..…Mother/guardian not alive →		Q008

Q007	What is the occupation of the mother/guardian of the child (name)?	1…..…………….............Government employee 2……..…..…………….......................... Farmer 3………..........….........……………......Trader 4……….......…...........................Daily laborer 5…….………………….....................Housewife 6………………….........…..........……...Student 7________________________Others (specify)	
Q008	What is the ethnicity of the mother/ father/ guardian of the child (name)? **Write respondent ethnicity.**	1…………………………..…….... ………..…Gedeo 2…………………………..……...……..... ..Oromo 3……………………………….………… .Amhara 4………………………………...…...... Sidamo 5________________________Others (specify)	
Q009	What is the religion of the mother/ father/ guardian of the child (name)? **Write respondant religion.**	1 ……………………...………………...Orthodox 2………………..…..………….. .... Protestant 3……………….…………................. Muslim 4_________________________Others(specify)	
Section 1.2: Demographic characteristics of study participant (child participating in the study)			
Q010	Sex of child (name)	Male . . . . . ….. . . . . …...1 Female 2	
Q011	Age of child (name)	Age in [ ][ ] completed years	
Section 1.3: Information about the household condition of the study participant's parent			
No.	**Question**	**Categories**	**Skip**
Q07	Is this home owned by a family member?	1. . . . ….. . .. . … ... . Yes 2.... . . . . …...……… No	
Q08	Does your household have: Electricity? A watch/clock? A radio A television? A mobile telephone?	Yes No 1 2 . .. . ……………. . … .. .. Electricity 1 2 .. . . Watch/clock 1 2 . . .. Radio 1 2 . . . . Television	

	A non-mobile telephone? A refrigerator? A table? A chair? ` A bed with cotton/sponge/spring mattress? An electric Mitad?	1 2 . . .. Mobile telephone 1 2 . . . . Non-mobile telephone 1 2 . . .. Refrigerator 1 2 . . .. Table 1 2 . . …. . . . . .Chair 1 2 ......A bed with cotton/sponge/Spring mattress 1 2 . . .. …..Electric Mitad	
Q09	What type of fuel does your household mainly use for cooking?	1. . .. . … . . . . …. .. .Electricity 2. . . . . ……….…... …. Biogas 3 . . . . …..…. …. Kerosene 4. . . . . …. . ... …...Charcoal 5. . . . . …..…………. ……Wood 6 . . . . ……….. . ………. Animal dung 7. . . . ..………No food cooked in household ⟶ 8------------------------------------ Other(specify	Q12
Q10	Where is the common cooking place?	1. . . . . …………..…...………...In the house 2. .. . . ……...…….…...In a separate building 3. . . . . …………………..………… Outdoors 4 ------------------------------------Other (specify)	
Q11	Do you have a separate room which is used as a kitchen?	1. . …. . . …….………… . …..…………… Yes 2….. ………. . . . . . . …………...……………No	
Q12	The main material of the floor **Record observation**	1……..……………………..…..….…Earth/ Dung 2....……………………………….Palm/bamboo 3……………...………………… ..Wood planks 4……..……………………………..……Cement 5..………………………..……... Ceramic tiles 6-------------------------------------Other (specify	
Q13	The main material of the roof. **Record observation**	1. . . ……..………...……...……Thatch/leaf/mud 2. . . . . ……………………..…….. .. . .Wood 3. . .. . …..Corrugated iron /metal 4. . . . . ………….…... Cement/concrete 5------------------------------------ Other (specify)	

Q14	The main material of the exterior walls. **Record observation**	1. . . . . ……………………. . ……… No wall 2 . . . . . …………. . . . …. ... ……. . …Wood 3. . . . . .. ………………………Wood with mud 4. . . . . ….. Wood with mud and cement 5. . . . . ……………. Stone with mud 6. . . . . . . ……. . . . . …Cement blocks 7-----------------------------------Other (specify)	
Q15	How many rooms in this household are used for sleeping?	Number of rooms ☐☐	
Q16	How many people sleep together in one bed in this household?	Number of people sleeping together in one bed ☐☐	
Q17	Does any member of this household own A bicycle? A motorcycle? An animal-drawn cart? A car or truck? **Record all responses**	Yes No 1 2 . . . . ……….…. . . . . Bicycle 1 2 . . . . …………..Motorcycle 1 2 . . . . . . …….Cart /Animal-drawn 1 2 ………………………..…. Car/truck	
Q18	Does any member of this household own any land that can be used for agriculture?	1. . . …... . . . . ……….. . . . . Yes 2. . . . .….No ⟶	Q20
Q19	How many (local units) of agricultural land do members of this household own?	Local units ☐☐ Specify the local unit------------------------------ 1………………………………..…. I don't know	
Q20	Does this household own any livestock, herds, other farm animals, or poultry and	1. . . . ……. . ... …. . ……….. . . . . Yes 2. . . . . No⟶	Q23

	beehives?		
Q21	How many of the following animals does this household own? Milk cows, oxen, or bulls? Horses, donkeys, or mules? Goats? Sheep? Chickens? Beehives? **Record all responses**	Yes No 1 2 ….….. . . . . Milk cows/bulls/oxen 1 2 ………… Horses/donkeys/mules 1 2 ……………………….……… Goats 1 2 …….………..……..…. …..Sheep 1 2 ...……………………… Chickens 1 2 ...………………………..Beehives	
Q22	If you have cattle, do they spend the night in the same house with you?	1. . . . . ……... . . . . Yes 2. . . . . No	
Q23	Does any member of this household have a bank or microfinance savings account?	1. . . . . Yes 2. . . . . No	
Q24	How long does it take you to walk to the nearest health center/health post?	Minutes [ ][ ] Hours [ ][ ]	
Q25	What is the main source of drinking water for members of your household?	Piped water 1. . . . . ………. . . ….…. Piped into dwelling 2. . .. . ….. …………....Piped into compound 3. .. . . ….. ……………..Public tap/standpipe Dung well 4.. . . . .………. Protected well 5. …... . . . . ………………... .. . Unprotected well Spring water 6. . . . . …. .. . . . ……... Protected spring 7.. . . . . ……….... . .. .Unprotected spring Surface water 8………………..... ...River/lake/pond/stream/dam	

		9------------------------------------ Other (specify)	
Q25a	What is the main source of water for cooking, and washing for members of your household?	Piped water 1. …..…………………….... Piped into dwelling 2. . . ……….. ……………...Piped into compound 3. . ……….. ………..……...Public tap/standpipe Dung well 4... .. . . ….. . . . .………. Protected well 5………. . . ……………..... .. . Unprotected well Spring water 6. . . . .…….. Protected spring 7.. . . . . ……... . .. .Unprotected spring Surface water 8…………… . …....River/lake/pond/stream/dam 9------------------------------------ Other (specify)	
Q26	How long does it take you to go there, get water, and come back?	Minutes [ ][ ] Hours [ ][ ]	
Q27	How is water stored in the household?	1. . ... Closed containers (jerican/ buckets) 2. .. . . Open containers (jerican/buckets) 3. . . . . Ensira (with constricted neck/end) 4------------------------------------ Other (specify)	
Q28	Do you make anything to make water safe to drink at the household level?/ Do you treat water at the household level?	1. . . . . Yes 2. . . . . ….. .. . .No ⟶	Q30
Q29	What type of treatment is frequently used in the household to make water safe for drinking? **Record all responses**	Yes No 1 2 . .. . ……….….. . . . . Boil 1 2 . .. ……….. .... Add bleach/chlorine 1 2 ...…………. .. Strain through a cloth 1 2 …...Use water filter (sand, ceramic, pot filter etc.)	

		1 2 ………... Store in a narrow-necked container --------------------------------------Other (specify)	
Q30	What washing detergents/ materials do you use in your household?	1……………………………...………Soap 2……………………...…………….…Shampoo 3………………...…………………….……. Ash 4……………………………… ..Plant extracts 5…………………………………....…..None	
Q31	What kind of toilet facility do most members of your household use? **(Observe latrine)**	1.. . . ……………………….. …... . . Flush toilet 2. . . . . ..….Ventilated improved pit latrine (VIP) 3 . . ..…………... . Pit latrine with slab 4. . . . .…...Pit latrine without slab 5. . . . . ………. ……. . . ….Open pit 6. . . . . . …...……........ No facility/bush/field⟶ 7-------------------------------------Other (specify)	Q35
Q32	The condition of the household toilet?	1. ..….... There is no defecation outside the hole 2.…..There is defecation outside the toilet hole	
Q33	Do you share this toilet facility with other households?	1.. . . . . Yes 2.. . . . . No	
Q34	Distance between latrine and water source (if underground or surface source)	1…. . . . . Below 30 meters 2……... . . . . 30 meters 3. . . . .……More than 30 meters	
Q35	Is there a hand washing facility in the household?	1 . . . . Yes 2. . . . . …. . No⟶	Q39
Q36	Please show me where members of your household most often wash their hands	1. …... . . . . . ………. . …. . . . .….Observed 2. . .. .….…. Not in dwelling/yard/plot 3. . . . .… ………. No permission to see 4--Other reason	Q39
Q37	**Observation only:** Observe the presence of water at the specific place for hand washing	1. . . .. …. . . . .… .. Water is available 2……. . . . . …. .Water is not available	

Q38	**Observation only:** Observe the presence of soap	1……....Soap or detergent (bar, liquid, powder, paste) 1………..…………...……..……Ash, mud, sand 3……………………………..……………..None	
Q39	Do you have a separate place for solid waste disposal?	1. . . . . …. . . . . Yes 2. . . . . No	
Section 2: Information regarding household food insecurity **Note: The respondents should answer on behalf of all members of the household**			
Q50	In the past four weeks, did you worry that your household would not have enough food?	1. . . . . Yes 2. . . . . No⟶	Q51
50a	How often did this happen in the past four weeks?	1……….. Rarely (Once or twice in the past four weeks) 2….Sometimes (Three to ten times in the past four weeks) 3…..... Often (More than ten times in the past four weeks)	
Q51	In the past four weeks, were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources?	1. . . . . Yes 2. . . . . No⟶	Q52
51a	How often did this happen in the past four weeks?	1……….. Rarely (Once or twice in the past four weeks) 2….Sometimes (Three to ten times in the past four weeks) 3…..... Often (More than ten times in the past four weeks)	
Q52	In the past four weeks, did you or any household member have to eat a limited	1. . . . . Yes 2. . . . .…. .No⟶	Q53

	variety of foods due to a lack of resources?		
Q52a	How often did this happen in the past four weeks?	1………….. Rarely (Once or twice in the past four weeks) 2.....Sometimes (Three to ten times in the past four weeks) 3…….. Often (More than ten times in the past four weeks)	
Q53	In the past four weeks, did you or any household member have to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of food?	1. . . . . Yes 2. . . . . …... . . No ⟶	Q54
Q53a	How often did this happen in the past four weeks?	1…..……… Rarely (Once or twice in the past four weeks) 2….Sometimes (Three to ten times in the past four weeks) 3….….. Often (More than ten times in the past four weeks)	
Q54	In the past four weeks, did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?	1. . . . . Yes 2. . . . .…. . No ⟶	Q55
Q54a	How often did this happen in the past four weeks?	1………….. Rarely (Once or twice in the past four weeks) 2….Sometimes (Three to ten times in the past four weeks) 3…….. Often (More than ten times in the past four weeks)	
Q55	In the past four weeks, did you or any other	1. . . . . Yes 2. . . . .…... No ⟶	Q56

	household member have to eat fewer meals in a day because there was not enough food?		
Q55a	How often did this happen in the past four weeks?	1………….. Rarely (Once or twice in the past four weeks) 2….Sometimes (Three to ten times in the past four weeks) 3…….. Often (More than ten times in the past four weeks)	
Q56	In the past four weeks, was there ever no food to eat of any kind in your household because of lack of resources to get food?	1. . . . . Yes 2. . . . . ……..No ⟶	Q57
Q56a	How often did this happen in the past four weeks?	1………….. Rarely (Once or twice in the past four weeks) 2….Sometimes (Three to ten times in the past four weeks) 3…….. Often (More than ten times in the past four weeks)	
Q57	In the past four weeks, did you or any household member go to sleep at night hungry because there was not enough food?	1. . . . . Yes 2. . . . . …... No ⟶	Q58
Q57a	How often did this happen in the past four weeks?	1………….. Rarely (Once or twice in the past four weeks) 2….Sometimes (Three to ten times in the past four weeks) 3…….. Often (More than ten times in the past four weeks)	
Q58	In the past four weeks, did you or any household member go a whole day and night without	1. . . . . Yes 2. . . . . ……….. No ⟶	Q60

	eating anything because there was not enough food?		
Q58a	How often did this happen in the past four weeks?	1………….. Rarely (Once or twice in the past four weeks) 2….Sometimes (Three to ten times in the past four weeks) 3…….. Often (More than ten times in the past four weeks)	
Section 3: Information regarding food aids to the household of the participating child			
Q60	Has the household received supplementary food through a food aid programme in the past six months?	1. . . . . ….…..... . . . . Yes 2. . . . . No 3 …. . ……... . . . . …….I don't know	
Section 4: Dietary habits of the child participating in the study (24-hour Dietary Diversity questions)			
Q61	From the time the child (name) woke up yesterday morning until this morning, did he or she eat any of the following separately or in combination with some other foods? **Record all responses**		
	Food groups	**Categories**	
Q611	Maize, rice, wheat, sorghum, millet, barley, sorghum, teff, or any other grains or foods made from these?	1. . . . . Yes 2. . . . . …… No Specify________________________________ ____________________________________ ____________________________________	
Q612	Pumpkin, carrots, sweet potatoes that are yellow or orange inside, or ripe mango or ripe papaya?	1. . . . . Yes 2. . . . . …… No Specify________________________________ ____________________________________ ____________________________________	
Q613	White potatoes, sweet potato, kocho/bulla made from flour of the root and bark of *ensete* (false banana), cassava, or other foods made from roots/tubers?	1. . . . . Yes 2. . . . . …… No Specify________________________________ ____________________________________ ____________________________________	

Q614	Dark green leafy vegetables like Kale	1. . . . . Yes 2. . . . . …… No Specify________________________________ ____ ____	
Q615	Other fruits (e.g. avocado, banana, or orange)	1. . . . . Yes 2. . . . . …… No Specify________________________________ ____ ____	
Q616	Other vegetables (e.g.tomato, cabbage, or onion)	1. . . . . Yes 2. . . . . …… No Specify________________________________ ____ ____	
Q617	Meat (e.g. beef, lamb, pork, goat, chicken)	1. . . . . Yes 2. . . . . …… No Specify________________________________ ____ ____	
Q618	Liver, kidney, heart, or other organ meat?	1. . . . . Yes 2. . . . . …… No Specify________________________________ ____ ____	
Q619	Fish?	1. . . . . Yes 2. . . . . …… No	
Q6110	Eggs?	1. . . . . Yes 2. . . . . …… No	
Q6111	Food made from pulses or legumes (e.g. beans, peas, lentils)?	1. . . . . Yes 2. . . . . …… No Specify________________________________ ____ ____	
Q6112	Milk, cheese, yogurt, or other milk product?	1. . . . . Yes 2. . . . . …… No Specify________________________________ ____ ____	

Q6113	Food cooked in oils or fats?	1. . . . . Yes 2. . . . . …… No Specify___________________________________ _____________________________________ _____________________________________	
Q6114	Sweet products (e.g. sugar, honey, or sugary foods)	1. . . . . Yes 2. . . . . …… No Specify___________________________________ _____________________________________ _____________________________________	
Q6115	Coffee or tea	1. . . . . Yes 2. . . . . …… No Specify___________________________________ _____________________________________	
Q6116	Any Alcohol drink?	1. . . . . Yes 2. . . . . …… No	
Q6117	Did the child (name) eat anything (meal or snack) outside the home yesterday? **Record child response.**	1. . . . . Yes 2. . . . . …… No Specify___________________________________ _____________________________________ _____________________________________	
Q6118	Any other food or drink?	1. . . . . Yes 2. . . . . …… No Specify___________________________________ _____________________________________ _____________________________________	
Section 5: Information regarding the health status of study participants and parent access to health information			
Q70	Has the child (name) ever been diagnosed by a physician with any illness in the past month?	1. . . . . ….…….. . ……. ……………..…....Yes 2 . . . . …………………... . . . . . . … ………..No	
Q71	In the past six months, was your child (name) given any deworming drug? (Show the drug)	1. . . . . …….. . . . . .Yes 2. . . . …. . . . . ….…. . . . . No 3. . . . . ……... . . ……….. .. . ..I don’t remember	(2, 3) Q73

Q72	How many times did he/she get the treatment?	1. . . . . ……………………..........One times 2 . . . . ……….....………Two times 3. . . . . ……….............More than two 4 . . . . ………….I don't remember	
Q73	Did you notice any appetite loss in the child (name) in the past month?	1. . . . . ………. . . . . ……. . . . . Yes 2. . . . . …..... . . . . No 3…. . . . . … . …. . ……. . . . . I don't know	
Section 6: Information regarding study participants' access to meals at school or home before school			
Q80	Does the child (name) get a meal at school?	1. . . . . …... . . . …….. . . . . ….Yes 2. . . . . ……. . . . . …... No	
Q81	Has the child (name) participated in any school feeding programme during the last six months?	1. . . . . …... . . . …….. . . . . ….Yes 2. . . . . ……. . . . . …... No	
Q82	Does the child (name) eat regularly before attending school? (e.g., breakfast if the child attended school in the morning, or lunch if the child attended school in the afternoon)?	1. . . . . …... . . . …….. . . . . ….Yes 2. . . . . ……. . . . . …... No	
Q83	If **no** for Q82, Reason for the child (name) not to eat before going to school?	1... . . . . Food in the household is not enough 2 .. . .…. . . Because he/she get food from school 3 .. . . ………. No time for preparing food 4__________________________________Other (specify)	

Appendix II: Assent form and Questionnaires for child interview

Appendix IIa: Assent form

Information sheet and assent (assent for those children 12 years and above)

Hello

My name is ---I am a data collector for a research project on the assessment of school health problems in the Gedeo zone, Southern Ethiopia. The main aim of this study is to assess child health problems among school children found in Gedeo Zone, Southern, Ethiopia. Therefore, this study will have a great contribution to assessing child health problems.

You are selected to participate in the study, and your parents have already consented to your participation. There will be an interview with you it will take 45 minutes to complete this questionnaire and the honest information you provide us is very essential for this study. As part of this survey you will be requested to participate in an anemia test, and stool examination for parasitic infection, your weight and height will be measured at the school level, and also clinical examination will be done to assess skin problems.

For the anemia test, you will give a few drops of blood from a finger and for the parasitic infection, you will bring a fresh stool. The result will be told right away and referral linkage will be arranged for the treatment depending on the result. Your result will be kept strictly confidential and will not be shared with anyone other than members of our survey team.

Do you have any questions?

Are you willing to participate in the anemia test, stool test, weight and height measurement, and clinical skin examination?

Yes ☐ → Proceed   No ☐ → Stop

Information sheet and assent form translated to local language

Information sheet and assent form in the Amharic language

መረጃ መስጫና ከልጁ/ልጅትዋ የሚወሰድ የስምምነት ማረጋገጫ (12 ዓመት ና ከዚያ በላይ ለሆኑ ልጆች)

ጤና ይስጥልን

ስሜ______________________________ይባላለ በደቡብ ኢትዮጵያ፣ በጌዲኦ ዞን፣ የሚገኙ የትምህርት ቤት ጤና ችግሮች ዙሪያ የተዘጋጀ ጥናት ላይ መረጃ ሰበሳቢ ነኝ። የዚህ ጥናት አላማም የልጆችን ጤና ችግር ለማወቅ ነው። ሰለዚህ ይህ ጥናት በልጆች ጤና ዙሪያ ላይ ትልቅ አስተዋፅ ይኖረዋል።

ያኝቺ /ያንተ ቤተሰብ በጥናቱ ላይ እንድትሳተፍ ፈቃደኝነታቸውን ስለገለጹ በዚህ ጥናት ላይ እንድትሳተፍ ተመርጠሃል/ተመርጠሻል. ለ45 ደቂቃ የሚቆይ መጠይቅ ይኖራል ስለዚህ የሚሰጡን ታማኝነትን የተሞላ መረጃ ለጠናቱ ጠቃሚ ነው። የዚህ ጥናት አካል የሆነው የደም ማነስ፣ የትላትል የሰገራ ምርመራም ይደረጋል፣ የክብደትና የርዝመት መለኪያም ይደረጋል፣ በቆዳ ላይ ያሉትን ጭግሮች ለማየት የሰውነት ምረመራም የደረጋል.

ለደም ማነስ ምርመራ ትንሽ ጠብታ ደም ከጣት ላይ ይወሰዳል፣ የሆድ ትላትል ምርመራ ለማድረግ ቲንሽ ሰገራ እንድታመጡ ይደረጋል። የምርመራው ውጤትም በምርመራ ወጤት መሰረት የነገራል። በውጤቱ መሰረትም ህክምና እነዲያገኝ /እንድታገኝ ይደረጋል።

የምርመራው ውጤትም ሚስጥራዊነቱ ይጠበቃል የጥናቱ ባለቤት ውጭ ለማንም አይሰጥም።

ጥያቄ አለ/አለሽ?

የደም ምርመራ ፣ ሰገራ ምርመራ፣ ከበደትና ርዝመት ለመለካት እንዲሀም የሰውነት ቆዳ ምርመራ ላይ ለመሳተፍ ፍቃደኛ ነክ/ነሽ?

አዎ ☐ → ቀጥል   አይደለም ☐ → አቁም

Information sheet and assent form in Gedeo language

Tarja bukkassate'e Beltokenna'ni / belttotenaa'ni Eetiti Yaada (Beltik/beltot 12 nna 12 iima)

Ashama

Summi annik--hiyemaan. Bita'ike topha'ni Gede'ixxe zoone'ni afemaake barachchoti minuwwa'ni lelitaxxa fayumatixxa ko'uwwa uudaxxe towa; no'ni tarja bukki assatixxe ogeten.Tenne towwanoki yaadi shixxarama Oosuwwaka fayumatixxa ko'o foye ege'naten.

Tennexxetinni towachcho/ qo'ne baratooletixxe fayunite'ni nna gumma insa'nexxa nossate'e la'o afe'en. Atikkinna iseki haddi qo'ne tenne'ni hordofe assate'e shenunteti hordofe assate'e filedinne'en. Tinni qo'ne 45 daqiqa tarja uwwate'e turte asitaxxenna qo'nete shenumati tarja uwwa elloxxen.Qo'netixxe hordofe giddo munidetixxi xe'ya gargarixxa bisigiddixxe raamoxxa, foole'ixxa towachcho, ha'urixxanna ejumatixxa mike assaan.

Mundetixxe xe'ya hennoxxi munide qubichchokenaa'ni bisi giddixxe raamo'a kinni heenoka foole'e axxine idaginaashsha asedinaan. Towachchotixxi gumma ifisaqicini aki uwwemashsha assendaan. Towanootixxi gumma ifisaxxa mayumma maqo heqa heqendaaxxenna towachcho kase'eki gadho weli ege'no'a hasedabaan.

Qortumma affe'ete?

Mundetixxa, foole'inixxa towachcho ha'urixxa, ejuma mikate'e nna manjumatika goga towachchisate?

Eet ☐ ⟶ Safi Waawwot ☐ ⟶ Uuris

Appendix IIb: Questionnaires for child interview

School name_______________________________ Grade level_____________Child code_______

Child name____________________________Sex______________Age_______________________

Name of data collectors____________________________ Supervisor signature________________

Result

Completed ☐ Refused ☐ Other (Specify)_________________________

Section 7: Information regarding the health condition of the study participant

No.	Question	Categories	Skip
Q100	Did you see any problems with your skin in the past two weeks?	1. . . . . Yes 2. . . . . No →	Q102
Q101	Do you itch your skin because of your current skin problem?	1. . . . . Yes 2. . . . . No	
Q102	If the participant child is of female sex above ten years of age? ask a question about whether she started menstruation or not?	1. . . . . Yes 2. . . . . No	

Section 8: Information regarding child hygiene behavior

Q111	Are the fingernails of the child trimmed? **Observation**	1. . . . . Yes 2. . . . . No	
Q112	Is dirt present on the child's fingernails **Observation**	1. . . . . Yes 2. . . . . No	
Q113	Do you trim your nails	1. . . . . Yes	

	every week?	2. . . . . . . ……... . . . . No	
Q114	Is the child's hair clean? **Observation**	1. … . . . . Yes 2. . . . . ……... . . . . No	
Q115	What is the habit of washing your hair with soap?	1..…………………..…………..…..………... Every day 2 ………….. ………………………..………... Every week 3…………………..…………………..... Every two weeks 4…………………………..………...Wash without soap	
Q116	Are the child's clothes clean **Observation**	1. . . . . Yes 2. . . . . …... . . . . No	
Q117	Do you have the habit of swimming or do you have activities in contact with water?	1. . . . . …... . . . . Yes 2. . . . . ……..... . . . . No	
Q118	Do you have the habit of sharing fomites within the family? **Probe and record all mentioned answers**	Yes No 1 2 . . . . Never shared any fomites 1 2 . . . . …. . . . . Bedding 1 2 . . . . Washing basin 1 2 . . . . Comb 1 2 . . . . …... . . . . .Razor blade 1 2 . . . . Clothing 1 2 ____________________________________ ____________________________________ _______________________Other (specify)	
Q119	What is your habit of body washing with soap?	1..…………………………………..……………... Every day 2.. ……………....………………..………... Every week 3...………………..…………………….Every two weeks 4 _________________________________Other (specify)	
Q120	Have you washed your hands with soap before	1. . . . . …. . . . . Yes 2. . . . . ……... . . . . No	

	a meal?		
Q121	What is your habit of handwashing after latrine use?	1. . . . . .Always 2. . . . . .Sometimes 3. . . . . Never⟶	Q123
Q122	Have you washed your hands with soap after latrine use?	1. . . . . .Always 2. . . . . .Sometimes 3. . . . . Never	
Q123	What is your habit of walking barefoot?	1. . . . . Always in barefoot 2. . . . . Sometimes in barefoot 3. . . . . Never in barefoot	
Q124	What is your habit of washing your legs and feet with soap?	1. . . . . Once per day 2 . . . . .Sometimes 3. . . . . .Every week 4_______________________________Other (Specify)	
Q125	Did you have habits of eating uncooked vegetables?	1. . . . . Yes 2. . . . . No	
Q126	Did you have habits of eating raw/ undercooked meat?	1. . . . . Yes 2. . . . . No	
Q127	Did you have a habit of contact with domestic animals?	1. . . . . Yes 2. . . . . No	
Q128	From where did you get drinking water while you are at school?	Piped water 1. Piped water inside the school 2. . . . . Piped water outside the school 3. . . . . .Public tap/standpipe Dung well 4.. . . . . Protected well 5. . . . . Unprotected well Spring water 6. . . . . Protected spring 7.. . . . . .Unprotected spring Surface water 8. . . . .River water	

		9. …………………..No drinking water access at school	
Section 9: Information regarding school children's access to health information and school absence			
Q130	Have you been taught in a school about personal hygiene protection?	1. . . . . Yes 2. . . . . No	
Q131	Have you ever been absent from school in the past month?	1. . . . .Yes 2. . . . . No →	Q137
Q132	The number of school days the child missed in the past month?	--days	
Q133	What was the main reason for absenteeism?	1. . . . .………. . . . Family illness 2. . . . . ……..……. . . . . Self-illness 3. . . . .Work within the household/ assist relatives 4. . . . . ……... . . . . Work (paid work) 5. . . . . ……...… . .. . School is far 6. . .. . ………. Lack of sanitation facilities 7. ... . ………. School is located in an insecure place 8________________________________Other (specify)	

Thank you for your participation!

Section 11: Checklist for school observation regarding toilet, handwashing facility, and school garden

School name______________________________			
Q150	Does the school have a toilet facility? **Observation**	1 . . . .Yes 2. . . . . .No →	Q155
Q151	Does the school have a separate functional toilet facility for girls and boys?	1 . . . .Yes 2. . . . .No	
Q152	Which type of toilet does the school have? **Observation**	1.. . ... Flush toilet 2. . . . .Ventilated improved pit latrine (VIP) 3 . . . . Pit latrine with slab 4. . . ..Pit latrine without slab 5. . . . .Open pit 6. . . ..No facility/bush/field 7--Other (specify)	
Q153	What is the condition of the school latrines/ How does the toilet look like **Observation**	1. . . .. There is no defecation outside the hole 2. ....There is defecation outside the toilet hole	
Q154	Is toilet paper available in the toilets? **Observation**	1 ....Yes 2.. ... . .No	
Q155	Does the school have a hand washing facility? **Observation**	1 . . . .Yes 2. . . . .No→	Q157
Q156	Does a hand washing facility have soap for cleansing? **Observation**	1 . . . .Yes 2. . . . .No	
Q157	Does the school have a school garden? **Observation**	1 . . . .Yes 2. . . . .No	

Section 12a: Laboratory result of blood sample for hemoglobin level

School name________________________________Grade level_______________________ Child code____________________ Child name____________________________________ Sex_______________Age__________________			
Blood sample result			
Q160	Record haemoglobin level here	[ ][ ] g/dL	

<table>
<tr><td colspan="4">Section 12b: Laboratory result of a stool sample for identification of parasitic infections</td></tr>
<tr><td colspan="4">School name_______________________ Grade level______________Child code_____________
Child name________________________________Sex_________Age________________________
Name of Lab. technicians___________________________________
Supervisor signature______________________________ Date_____________________________</td></tr>
<tr><td colspan="4">Result</td></tr>
<tr><td colspan="4">Kato-Katz ☐ FEC ☐</td></tr>
<tr><td>Q161</td><td>Did the child infected with parasite</td><td>Infected . . . . …... . . . ……. 1
Not infected. . . . . ….. . …... . . .. …. . . . .2</td><td></td></tr>
<tr><td>Q162</td><td>Specific parasite species</td><td>Yes No
Entamoeba Histolytica. 1 2
Giardia Lamblia. 1 2
Ascaris Lumbricoides. 1 2
Trichuris Trichiura. 1 2
S. stercoralis. 1 2
Enterobius Vermicularis. 1 2
Hookworm. 1 2
H. nana. 1 2
S. mansoni. 1 2
Taenia spp. 1 2
Other species
____
____
____</td><td></td></tr>
<tr><td>Q163</td><td colspan="2">Egg /cyst count for each specific parasite species
Egg count | Cyst count
Entamoeba Histolytica. …….. --------------- ---------------
Giardia Lamblia. . . . . . ……. --------------- ---------------
Ascaris Lumbricoides. . ……. --------------- ---------------
Trichuris Trichiura. . . . …….. --------------- ---------------
S. stercoralis. . . . . --------------- ---------------
Enterobius Vermicularis……. --------------- ---------------
Hookworm. . . . . ……... --------------- ---------------
H. nana. . . . . ……... --------------- ---------------
S. mansoni. . . . . ……... --------------- ---------------
Taenia spp. . . . . ……... --------------- ---------------
Other species......................... --------------- ---------------
Other species......................... --------------- ---------------
Other species......................... --------------- ---------------</td><td></td></tr>
</table>

Section 13: Clinical assessment result of skin problems (based on clinical findings)			
School name____________________________ Grade level______________Child code_________ Child name______________________________________Sex_______________Age___________ Name of examiner________________________________Supervisor signature________________			
No.	**Question**	**Categories**	**Skip**
Q170	Did the child have a skin lesion?	Yes. . . . . .1 No. 2	
Q171	Did the child's skin lesions stay> 2 weeks? Did the child face an itching problem? Did the itching intensify at night? **Record child response**	Yes No Did the child's skin lesions stay> 2 weeks?... 1 2 Did the child face an itching problem?................ 1 2 Did itching intensify at night?............... 1 2	
Q172	Is scabies present on a child's skin?	Yes . . . . .1 No . . . . .2 →	Q173
Q172a	Area infested by scabies?	Yes No Hands .... 1 2 Interdigital places................................ 1 2 Wrists, arms, elbows.............................. 1 2 Armpits.. 1 2 Abdomen, chest, mamilla,or perimammilar area.. 1 2 Back area.. 1 2 Buttock, genitals............ .... 1 2 Feet area... 1 2 Other (specify) _______________________________	
Q173	Is Jigger (T*unga penetrans*) present on child skin?	Yes . . . . .1 No...2 →	Q174
Q173a	Area infected by Jigger?	Yes No Feet. .... 1 2 Hands 1 2	

		Feet and hands……………………………. 1 2 Manupilated lesion on feet……………..… 1 2 Manupilated lesion on hands…...………… 1 2 Other (specify)________________________________	
Q174	Is the child infected with fungus	Yes . . . . ……………………. . .. . . ……. .1 No. . . .. ..…….. . …. . . . . . . ……….....……..……...2 ⟶	Q175
Q174a	Area infected with fungus	Yes No Tinea capitis (Scalp/ head). . . . . 1 2 Tinea faciei (Face) . . . . 1 2 Tinea manuum (Hands) . . . . 1 2 Tinea corporis (Body). . . . . 1 2 Tinea cruris (Groin) . . . . 1 2 Tinea unguium (Toe or finger nails). .. . . . 1 2 Tinea pedis (Foot). . . . . 1 2 Other (specify)________________________________	
Q175	Did the child wear shoes at the time of the examination? **Record observation**	1... ………. . . . . Yes 2. . . . . . . …….….. . . . . No	
Q200	Is the child's hair infested by head lice?	1. . . . . ………. . . . . Yes 2. . . . . . . …….….. . . . . No	

Thank you for your participation!

Form 1. Height and weight measurements form

School name____

Name of data collector_________________________Signature________________________

Supervisor signature______________________________Date_________________________

Child grade	Child ID	Child name	Age	Sex	Height (cm)	Weight (Kg)	Remark

Form 2. Blood sample collection form for heamoglobin test

School name____

Name of Lab. technicians________________________________Signature________________

Supervisor signature___________________________Date____________________________

Child grade	Child ID	Child name	Age	Sex	Hemoglobin g/dL	Remark

Appendix III: Ethical Approvals

REK
REGIONALE KOMITEER FOR MEDISINSK OG HELSEFAGLIG FORSKNINGSETIKK

Region:	Saksbehandler:	Telefon:	Vår dato:	Vår referanse:
REK vest	Øyvind Straume	55978497	14.12.2016	2016/1900/REK vest
			Deres dato:	Deres referanse:
			01.11.2016	

Vår referanse må oppgis ved alle henvendelser

Bernt Lindtjørn
Postboks 7804

2016/1900 Helseproblemer blant skolebarn i sør Etiopia

Institution responsible for the research: University i Bergen
Project manager: Bernt Lindtjørn

With reference to your application regarding the abovementioneded project. . The Regional Committee for Medical and Health Research Ethics (REC Western Norway) reviewed the application in the meeting 24.11.2016, pursuant to The Health Research Act § 10

Description of the project
This study will assess the prevalence of anaemia, malnutrition, intestinal parasites, and skin infections among rural school children aged 5-14 years in Wenago district in South Ethiopia. 845 children in the age group of 5 to 14 will be included in the study.

Ethical Review

Responsible conduct
The researchers will finger prick the children to see if the child is anaemic, and take stool samples to determine their parasitic loads. They expect to diagnose anaemia, intestinal parasites, malnutrition, and different skin diseases from many children. Each of the children will be referred to the nearest health centre where they will receive treatment according to the guidelines of the Ethiopian Ministry of health. The Committee set as a condition that the researchers where required will inform the participants about practical matters for follow up (including plan for referral, assistance and transportation).

The Research Ethics Committee (REC) assesses this as a justifiable study.

Research on children
§ 18 in the Health Research Act sets conditions for research including people who lack competence to give their consent. The project may only be done if the following conditions are met:
a) the potential risks or disadvantages for the person are insignificant,
b) the individual involved is not averse to it, and
c) there is reason to assume that the results of the research may be of use to the person concerned or other people with the same age specific disorder, disease, injury or condition.

For minors, it is also a requirement that similar research cannot be done on people who are not minors. The Committee finds that the conditions for research on minors are met in this study.

Insurance
According to the application Ethiopian authorities do not require separate insurance for observational studies. The Committee emphasize that it is the duty of the institution responsible for the research (University in Bergen) to ensure that research participants are covered by required insurance.

Storage and reusage of data
The project end date is 31.12.2017. All data will be stored in a secure place, which is at Hawassa University in Ethiopia. All storage of data must be in accordance to routines set by the institution responsible for the study (University of Bergen). The project ends at 31.12.2017, and all data must then by deleted or anonymized.

According to the application "some journals (for example PLoS ONE) now demand that we make most of the data from the research available for the public. In such cases, we will only present data where personal information such as codes, names and geo-referenced locations are deleted." REC Western Norway has no objections to this, but emphasizes that only anonymized data can be shared.

Conditions

- Practical information about follow up in the nearest health centre must be provided.
- Data must be deleted or anonymized at the project end date.
- Only anonymous data may be shared with journals or others.

Vedtak
REC Western Norway approves the project in accordance with the submitted application as long as the aforementioned conditions are met.

Further Information
The approval is valid until 31.12.2017. A final report must be sent no later than 30.06.2018. The approval is based on the grounds that the project is implemented as described in the application and the protocol, as well as the guidelines stated in the Health Research Act. If amendments need to be made to the study, the project manager is required to submit these amendments for approval by REC via the amendment form.

The decision of the committee may be appealed to the National Committee for Research Ethics in Norway. The appeal should be sent to the Regional Committee for Research Ethics in Norway, West. The deadline for appeals is three weeks from the date on which you receive this letter.

Sincerly

Marit Grønning
Prof. Dr.med
Chairman

Øyvind Straume
Committee Secretary

Copy:post@uib.no

ሀዋሳ ዩኒቨርሲቲ
ህክምናና ጤና ሳይንስ ኮሌጅ
የምርምር ስነ-ምግባር ገምጋሚ ቦርድ

HAWASSA UNIVERSITY
COLLEGE OF MEDICINE AND HEALTH SCIENCES
Institutional Review Board

Ref. No: IRB/005/09

Date: 28/09/2016

Name of Researcher(s): ***Hiwot Hailu, Bernt Lindtjorn, Teferi Abegaz***

Topic of Proposal: ***Assessment of school health problem in Gedeo zone, southern Ethiopia***

Dear researcher(s),

The Institutional Review Board (IRB) at the College of Medicine and Health Sciences of Hawassa University has reviewed the aforementioned research protocol with special emphasis on the following points:

1. Are all principles considered?
   - 1.1. Respect for persons: Yes ☑ No ☐
   - 1.2. Beneficence: Yes ☑ No ☐
   - 1.3. Justice: Yes ☑ No ☐
2. Are the objectives of the study ethically achievable? Yes ☑ No ☐
3. Are the proposed research methods ethically sound? Yes ☑ No ☐

Based on the aforementioned ethical assessment, the IRB has:

- A. Approved the proposal for implementation ☑
- B. Conditionally Approved ☐
- C. Not Approved ☐

Yours faithfully,

Hawassa University College of Medicine & Health Sciences Institutional Review Board

Ayalew Astatkie (PhD),

Institutional Review Board Chairperson.

☎ +046 820 92 90

Fax + 046 2208755
✉ 1560 Hawassa

Graphic design: Communication Division, UIB / Print: Skipnes Kommunikasjon AS

uib.no

ISBN: 9788230844410 (print)
9788230857564 (PDF)