Body weight and physical activity of adults in rural Uganda

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Thesis for the degree of philosophiae doctor (PhD)
at the University of Bergen

2017

Date of defence: 16.06.2017

To my husband,
Eric Ferdinand Tabusibwa and children,
Aniela Elizabeth Mwende and Amaris Asher Tabusibwa.

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Scientifc environment

This research is a result of the collaboration between Makerere University, Kampala, Uganda (www.mak.ac.ug) and the University of Bergen, Norway (www.uib.no). The thesis was funded by the University of Bergen, Norway. The PhD scholarship was provided by the Quota Scheme administered by the Norwegian State Educational Loan Fund (www.lanekassen.no).
This research was conducted in the Iganga-Mayuge Health and Demographic Surveillance Site (www.igangamayuge-hdss.mak.ac.ug).

Original papers

The thesis is based on the following papers:

I. Kirunda BE, Fadnes LT, Wamani H, Van den Broeck J, Tylleskar T. Population-based survey of overweight and obesity and the associated factors in peri-urban and rural Eastern Uganda. BMC Public Health. 2015; 15(1):1168. DOI 10.1186/s12889-015-2506-7.

II. Kirunda BE, Wamani H, Fadnes LT, Van den Broeck J, Tylleskar T. Objectively Assessed Physical Activity and Associated Factors among Adults in Peri-Urban and Rural Eastern Uganda: A Population-based Study. J Phys Act Health. 2016, 13, 1243 -1254 http://dx.doi.org/10.1123/jpah.2016-0025

III. Kirunda BE, Fadnes LT, Wamani H, Van den Broeck J, Tylleskar T. Physical activity in Ugandan adults: comparison of the Global Physical Activity Questionnaire (GPAQ) to pedometer assessment. *Manuscript*.

Abbreviations

AOR	Adjusted Odds Ratio
AUC	Area Under the Curve
BMI	Body Mass Index
CDC	Center for Disease Control and Prevention
CI	Confidence Interval
COR	Crude Odds Ratio
DALY	Disability Adjusted Life Year
DLW	Doubly Labelled Water
EE	Estimated Expenditure
EPAQ	EPIC Physical Activity Questionnaire
EPIC	European Prospective Investigation into Cancer and Nutrition Questionnaire
FPACQ	Flemish Physical Activity Computerised Questionnaire
GPAQ	Global Physical Activity Questionnaire
HDSS	Health and Demographic Surveillance Site
HIC	High Income Countries
HR	Heart Rate
IMHDSS	Iganga-Mayuge Demographic Surveillance Site
IPAQ	International Physical Activity Questionnaire
LMIC	Low and Middle Income Countries
MARCA	Multimedia Activity Recall for Children and Adults
MET	Metabolic Equivalent
MVPA	Moderate-to-vigorous physical activity
NCD	Non-Communicable Disease
PA	Physical Activity
PAQ	Physical Activity Questionnaire
REE	Resting Energy Expenditure
ROC	Receiver Operating Characteristic
RPAQ	Recent Physical Activity Questionnaire
SES	Socio-Economic Status
SQUASH	Short Questionnaire to Assess Health enhancing physical activity
SSA	Sub-Saharan Africa
SSAAQ	Sub-Saharan Africa Activity Questionnaire
TEE	Total Energy Expenditure
TCQ	Tecumseh Community Questionnaire
UBOS	Uganda Bureau of Statistics
UDHS	Uganda Demographic and Health Survey
WHO	World Health Organisation

Definitions

Metabolic equivalent (MET): Is a unit used to express physical activity (PA) intensity and defined as "the ratio of a person's working metabolic rate relative to the resting relative rate," [1]. One MET corresponds to the basal metabolic rate, or oxygen consumption that approximates to 3.5 ml/kg per minute, equivalent to about 1 kilocalorie (kcal)/kg body weight per hour [2].

Non-communicable disease: A disease that is not transmitted from one person to another directly [3].

Overweight: Is defined as having a body mass index (BMI) of at least 25 kg/m^2 [4-6].

Obesity: Is defined as having a BMI of at least 30 kg/m^2 [4-6].

Physical activity: Is defined as "bodily movement that is produced by the contraction of skeletal muscle and that increases energy expenditure above the basal level" [7]. It is also defined as "any bodily movement produced by skeletal muscles that results in caloric expenditure" [8].

Physically active: Attaining a physical activity threshold of at least an average of 7,500 steps per day for a seven-day period (Tudor-Locke, Bassett, 2004) or any combination of moderate- and vigorous-intensity activities amounting to an average of least 600 MET-minutes for the Global Physical Activity Questionnaire (GPAQ) over a seven-day period [9].

Physically inactive: Is defined as accumulating less than 7,500 steps per day on average over seven days (Tudor-Locke, Bassett, 2004) or any combination of activities amounting to less than 600 MET-minutes over seven days for GPAQ [9].

Physical activity energy expenditure: Is the energy required to sustain the demands of movement above that of resting states [10].

Resting energy expenditure: Is the energy required to maintain vital life functions during basal and sleeping states [10].

Sedentary behaviour: Is defined as a behaviour (e.g. sitting, driving, television watching etc) characterised by low energy expenditure and little physical movement [11, 12] or realising less than 5,000 steps per day [13].

Abstract

Background: Overweight, obesity and physical inactivity are on the increase across the world. However, the general lack of evidence on overweight, obesity and physical inactivity and their correlates in Africa, suggests a need for research in sub-Saharan Africa so as to inform the development of effective population-based interventions for the physical activity (PA) promotion, and prevention of overweight, obesity and non-communicable diseases (NCDs). The objectives of the thesis were to assess the prevalence of overweight and/or obesity, physical inactivity and sedentary behaviour and their associated factors and assess the validity of the Global Physical Activity Questionnaire (GPAQ) among peri-urban and rural Ugandan adults.

Methods: A population-based cross-sectional study of 1210 randomly selected adults was conducted in the Iganga-Mayuge Health and Demographic Surveillance Site, Uganda. Height, weight and socio-demographic variables were assessed. Physical activity was assessed by both a pedometer and the GPAQ for a seven-day period. Logistic regression was conducted to identify factors associated with overweight and/or obesity, physical inactivity and sedentary behaviour. Percent agreement scores and kappa statistics were computed and linear regression analysis was run.

Results: Of the participants, 17.8 % were overweight (12.4 % of men; 23.1 % of women, $p < 0.001$); and 7 % were obese (2.0 % of men; 12.7 % of women, $p < 0.001$). Prevalence of overweight was 15.8 % and 23.8 % among rural and peri-urban adults, respectively ($p < 0.001$). Prevalence of obesity was 3.9 % and 17.8 % among rural and peri-urban adults, respectively ($p < 0.001$). Factors associated with overweight and or/obesity were: being female, (adjusted odds ratio (AOR) 4.3; 95 % confidence interval (CI) 3.2–5.9); peri-urban residence (AOR 2.6; 95 % CI 1.9–3.6); being in age groups 35–44 (AOR 3.1; 95 % CI 1.8–5.3), 45–54 (AOR 4.1; 95 % CI 2.3–7.3), 55–64 (AOR 2.6; 95 % CI 1.4–5.0 and ≥ 65 years (AOR 3.1; 95 % CI 1.6–6.0); and having socio-economic status (SES) in the third (AOR 2.8; 95 % CI 1.7–4.6), fourth (AOR 2.5; 95 % CI 1.5–4.2 and fifth (AOR 2.7; 95 % CI 1.6–4.4) quintiles. Prevalence of sedentary behaviour was 18.8 % (10.6 % of men; 26.9 % of women, $p < 0.001$) while prevalence of physical inactivity was 37.6 % (28.5 % of men; 46.6 % of women, $p<0.001$). Factors associated with sedentary behaviour were being female, being older than 65 years, peri-urban residence, being a domestic worker, formal employment and lower primary education. Factors associated with physical inactivity were being female, being older than 54 years, peri-urban residence, overweight and obesity. Pedometer step counts correlated poorly with self-reported physical activity (GPAQ) (rho = 0.27, $p < 0.001$). Using pedometer counts as the reference, percent agreement with self-reported physical activity was 64.0 % (Kappa = 0.06) (72.8 %, Kappa = 0.09 for men and 55.2 %, kappa = 0.04 for women), respectively. Percent agreement between pedometers and self-reported physical activity among overweight and

obese persons was 51.3 % Kappa = 0.08) (50.0 %, kappa = 0.05 for peri-urban and 68.9 %, kappa = 0.04 for rural residents).

Conclusions: Overweight and/or obesity and physical inactivity were prevalent among adults. Overweight and/or obesity was associated with being female, being aged 35 years and older, residing in a peri-urban area and having a higher SES. Targeted PA promotion and overweight and/or obesity prevention interventions are needed. The GPAQ poorly correlates with pedometer step counts in PA assessments. The GPAQ alone is unlikely to adequately estimate the degree of activity among individuals in populations similar to our study population.

Acknowledgements

A number of individuals, institutions and entities have contributed significantly in numerous ways during my PhD journey and surely without them, I would not have attained successful completion. Words are not enough to express my sincere thanks. My deepest gratitude goes out to each one of you mentioned by name henceforth.

Above all, my deepest and utmost gratitude goes out to God my father. You are incredible. Marvelous are your works. Your name is above all names. Thank you so much for your unfailing and unwavering love for me. Thank you for moulding me into what you have made today. Thank you so much for beginning your great works of this PhD and bringing it to successful completion. Thank you for bringing along the right people of influence and peace from the conception stage and throughout this PhD journey. During the challenging times, thank you so much for being my refuge and very present help. For all persons who have played a significant role in this journey, may God grant you your heart desires and may your territories of influence expand beyond your expectations. To God be the Glory!

I would like to express my deepest and sincere thanks to my supervisors: The late Prof. Jan Van den Broeck, I am deeply grateful for his challenging technical insights, commitment, mentorship and continuous follow-up at the time when he was alive and during the difficult time when he was unwell. I would like to thank him for believing in my potential and accepting to be my main supervisor much as he did not know anything about me. I would like to thank Prof. Thorkild Tylleskär my main supervisor for his technical insights, commitment, patience, continuous support, mentorship and continuous follow-up during this academic journey. I would like to thank him for his willingness, time and technical input at the time we met to discuss the viability of the PhD concept. I would like to express my sincere gratitude for believing in my capabilities, introducing me to the late Prof. Jan Van den Broeck. I would like to specially thank him for the smooth transition and accepting to take over as the main supervisor following the death of Prof. Jan Van den Broeck. I am grateful to Dr. Henry Wamani for your technical input and continued support. I am also grateful for encouraging me to introduce myself to Prof. Thorkild Tylleskär. Without that bold step, this particular journey would not have started in the first place. Dr. Lars Thore Fadnes, thank you so much for your technical and detailed insights, commitment, continued support and time.

I would like to thank the leadership, faculty and administration at the Centre for International Health for providing an excellent training environment, particularly Prof. Bente Elisabeth Moen. Borgny Kvalnes Lavik, Solfrid Vikøren, Ingvild Hope, Gunhild Koldal and Linda Karin Forshaw are also duly acknowledged for their timely administrative, logistical and financial assistance whenever it was needed.

My sincere gratitude goes out to the management and staff of the IMHDSS for providing a supportive environment for my study. Specifically, I would like to acknowledge Mr. Edward Galiwango, Ms. Judith Kaija and Mr. John Karuhanga for their overwhelming support and commitment towards successful execution of the field component of my study. The excellent field data collection team namely: Judith Mirembe, Paul Waiswa, Salama Kagoya, Paul Wandera, Dan Ochomo, Michael Magemeso, Amina Namugosa, David Balidawa, Lydia Katushabe and Amina Namulondo, are duly acknowledged for their hard work and tireless commitment to successful completion of field data collection.

I am deeply grateful to the leadership and faculty of my employer institution, Makerere University School of Public Health (MakSPH) for their technical input, support and commitment. Assoc. Prof. William Bazeyo the Dean, is duly acknowledged for mentorship, continued support, follow-up and provision of an enabling environment for professional growth. I would like to thank him for the financial support that facilitated my initial travel to Norway. Prof. Chris Orach-Garimoi the Deputy Dean is also acknowledged for his continued insights, follow-up and words of encouragement. I would like to thank the current and previous Chairs namely Assoc. Prof. Nazarius Mbona Tumwesigye and Prof. Fred Makumbi, and faculty of the Department of Epidemiology and Biostatistics for supporting me every way while I undertook my PhD studies. I would like to acknowledge the senior faculty namely Prof. David Serwada, Assoc. Prof. David Guwatudde, Assoc. Prof. Noah Kiwanuka, Assoc. Prof. Freddie Sengooba and Assoc. Prof. Lynn Atuyambe for their technical insights, continued support and follow-up.

My fellow PhD forum members and predecessors, I am deeply touched and grateful for your contribution, words of encouragement and support. To mention a few, specifically, I thank Dr. Phyllis Awor for her excellent leadership of the forum, continued insights and encouragement especially during challenging times. Dr. Roy Mayega, Dr. Juliet N. Babirye and Dr. Christine Nalwadda together with the forum leadership, thank you so much for technical insights, words of encouragement and standing with me most especially during the difficult times of grief after my main supervisor had passed away. There are a quite a number of forum members and due to limitations on space, I am unable to mention all of you by name. In a special way, I thank you so much for your time and constructive feedback. To the PhD colleagues in Bergen, Norway, thank you so much for the support, insights and happy times. You made living in Bergen a worthwhile experience.

All study participants of IMHDSS are duly acknowledged for accepting to participate in the study, providing their invaluable time and information, without which this thesis would not have been possible.

My deepest and utmost gratitude goes out to my ever cheerful family. Words are not enough to express my sincere thanks. My parents, Dr. Daniel W. Kirunda and Mrs. Elizabeth A. Kirunda, words fail me. Thank you so much for your undying and unwavering love, support, follow-up and prayers during my PhD journey. Thank you so much for nurturing and providing wise counsel to me over the years, and providing a firm education that served as stepping stone for my PhD studies. Thank you so much for looking after my little angels – Aniela and Amaris while they were still very young. My siblings Jane, Ken, Daudi and Judith, thank you so much for assisting me in one way or another with my children and Eric. To my home assistants Susan Nakibirango and Maria Namutamba, thank you so much for the great work of looking after my home and family most especially while I was away. Your hard work is not in vain.

My dearest husband and best friend, Dr. Eric Ferdinand Tabusibwa, thank you so much for your unconditional love, selfless and overwhelming support, patience, commitment and encouragement during my PhD studies. I am deeply grateful to you for being an ever present father to our children. Your continued acts of love and support have been overwhelming and they continue to challenge me to become better. Thank you for continuing to love our children and I. My dearest children Aniela E. Mwende and Amaris A. Tabusibwa, words fail me. Thank you so much for being strong and patient with me while I was away for long times and when I was so pre-occupied with my laptop.

Introduction

Body weight in adults: normal weight, underweight and overweight

Body mass index (BMI), also known as the Quetelet's index is a measure of weight-for-height defined as an individual's weight in kilograms divided by the square of height in metres, kg/m^2 [14]. It is used to assess for underweight (BMI <18.5 kg/m^2), normal weight (BMI = 18.5–24.99 kg/m^2), overweight (BMI = 25.0–29.99 kg/m^2) and obesity (BMI ≥ 30 kg/m^2) in adults [4-6].

Body mass index depends on body height and weight measurements. Body height is measured using a stadiometer to the nearest 0.1 cm. Individuals wearing light clothing should stand upright with their arms freely hanging on the side and their weight distributed evenly on their feet while barefoot. The heels should be together with their feet slightly diverging. As the back of the head, buttocks and heels are in contact with the vertical board [4], move the head slightly until the Frankfort plane is horizontal. The movable head board is moved down to the top most of the head while applying adequate pressure to compress the hair [4] and at the same time applying counter pressure by the chin. The height reading is then taken. Body weight is measured using a weighing scale. Individuals wearing light clothing are required to stand still on the weighing scale with their weight evenly distributed on their feet. Weight is recorded to the nearest 0.1 kg [4].

Physical activity in adults

Physical activity (PA) is defined as 'any bodily movement produced by skeletal muscles that results in caloric expenditure' [8]. It is a complex behaviour and therefore it is challenging to assess. Measurement of PA is multidimensional and there is no single measure that can adequately assess the subcomponents and domains of activity. The methods for measuring free-living PA include self-report measures like questionnaires, diaries or logs and recalls and objective measures such as accelerometers, pedometers, heart rate monitoring, direct observation and doubly labelled water (DLW), Table 1 [15].

Subjective measures of PA

Subjective measures are used to indirectly assess PA and provide complementary information to objective measures [16]. They include direct observation, activity diaries, physical activity questionnaires (PAQs) and interviews [17]. These will be discussed in detail henceforth.

Physical activity questionnaires

Physical activity questionnaires are self-report measures used to assess the duration, intensity and domains of PA and sedentary behaviours. They are categorised in 3 groups: global, recall and quantitative history. First, global PAQs are short tools that provide brief information regarding PA level. Particularly, they are used to identify the active and inactive individuals [18]. Examples of common global questionnaires include the Exercise Vital Sign [19] and the European Prospective Investigation into Cancer and Nutrition (EPIC)

PAQ [20]. Second, recall PAQs are used to rapidly assess total volume of PA by dimension or domain [18]. Recalls are usually used to assess for change in PA behaviour in intervention studies [21] as well as establish the proportion of adults attaining national PA guidelines in surveillance and studies [22, 23]. Examples of short recalls include the International Physical Activity Questionnaire (IPAQ) [24] and the Global Physical Activity Questionnaire (GPAQ) [25]. Third, quantitative history PAQs are administered in surveys to obtain detailed information on the previous month or year or a lifetime. They are used in studies to understand the PA types and intensity relating with mortality, to examine types of morbidities and health-enhancing behaviours [26, 27]. An example of quantitative history questionnaires include the Bone Loading History Questionnaire [28].

Numerous PAQs have been developed and are briefly described henceforth. The IPAQ was developed by WHO and the Center for Disease Control and Prevention (CDC) in late 1990s to standardise PA assessment and assess its performance in a twelve-country study [24]. Following these developments, the IPAQ short and long forms were reviewed and due to their limitations, the GPAQ was developed in 2002 by World Health Organisation (WHO) for PA monitoring particularly in developing countries [29] and it was included into the WHO non-commuicable disease (NCD) risk factor surveillance systems. These efforts resulted in availability of data on PA patterns globally using the GPAQ and IPAQ [30]. Other PAQs that are commonly used include the Baecke PAQ, the Godin Shepard Leisure Time Questionnaire, Paffenbarger Physical Activity Questionnaire, the Bouchard's Activity Diary and the recall [31, 32], the Short Questionnaire to Assess Health enhancing physical activity (SQUASH) [33], the EPIC Physical Activity Questionnaire 2 (EPAQ2) [34], the Recent Physical Activity Questionnaire (RPAQ) that was developed from the EPAQ2 [35] and the Flemish Physical Activity Computerised Questionnaire (FPACQ) [36].

Much as PAQs are the most feasible measure used in large epidemiological studies, they have their limitations like biases resulting from recall, social desirability, misreporting and comprehension and errors during measurements [37, 38]. Systematic reviews of validity studies of PAQs have largely been conducted in HICs with accelerometry commonly used as the comparative PA measure. However, pedometers were least used as a criterion measure [39, 40] and yet they are simple affordable devices. A systematic review of validity of pedometers with accelerometers as the criterion measure found that they had high validity (r=0.86) [41]. A recent systematic review of PAQs indicated the median validity correlation coefficients to be poor for new PAQs (Spearman's r=0.27 and Pearson's r=0.28). The lowest validity correlations for total PA were noted for the Nord-Trøndelag health study (HUNT) 1 (r=0.03–0.07) [42] and the short EPAQ2 (r=0.04) whereas high validity correlations were reported for the Sub-Saharan Africa Activity Questionnaire (SSAAQ) in comparison to accelerometry (r=0.60–0.74) [43]. A prospective study of EPAQ2 among adults in 10 European countries reported a

moderate validity (r=0.33) in comparison to the combined heart rate and movement sensing [44]. With regard to the existing PAQs, the median validity correlations was moderate (Spearman's r=0.30; Pearson's r=0.46). With the exception of the validation studies of FPACQ in comparison to accelerometry across categories (r=0.39–0.85) [36], the Tecumseh Community Questionnaire (TCQ) for estimated energy expenditure (EE) against DLW determined total EE (r=0.63–0.64) [45], and the BAQ (r=0.68–0.69), the majority of PAQs had poor validity correlations [39]. Specifically, the GPAQ in comparison to accelerometry for total PA had low to moderate validity correlations (r=0.19–0.34) depending on the seasons [46]. Another study among Vietnamese adults on total PA by GPAQ reported low correlation with the IPAQ (r=0.32), a pedometer (r=0.39) and a PA log (r=0.31) for those with a stable work pattern and low correlations for those with unstable work patterns (r=−0.08 to 0.37) [47]. Similarly, low validity was found in a nine-country study of GPAQ version 1 for total PA against pedometer step counts (r=0.31), low criterion validity for total vigorous intensity PA against accelerometer average vigorous counts/day (r=0.23–0.26) and moderate convergent validity against the IPAQ (r =0.54) [25, 48].

Although most PAQs reported poor to moderate validity coefficients and acceptable validity findings based on the Pearson's and Spearman's correlation coefficients, evidence suggests that the bulk of the PAQs could be valid in ranking PA behaviour of individuals but with a limitation in absolute validity in PA quantification [39]. Therefore, self-report questionnaires that are accurate and precise are still scanty [49]. Available evidence therefore generates concerns about the generalisability of the validation findings of GPAQ to other populations or geographical regions, specifically to SSA.

Physical activity records or diaries

Physical activity records are commonly used to collect detailed data on PA and sedentary behaviours based either on activity or hour. These records can be used to capture the evaluation of pyschometric properties of PAQs and provide complementary information to objective PA measures [18]. Records can be either paper- [50] or cellphone-based, that can serve as a reminders to the users to input information on PA [51]. Information recorded in diaries may vary but largely includes start and end time of activity, intensity and activity type. Diaries can be included in ecological momentary assessments [52, 53] that involve recording features of a situation and examining the effect of the situation on PA behaviour in at a specific time and setting [54]. Examples of records include the Bouchard Physical Activity Record [55] and another log by Ainsworth et al [56].

Multimedia activity recall

The Multimedia activity recall for children and adults (MARCA) is computer-based measure that is used to elicit information from individuals about how they have spent their time in the previous 24 hours with meal times serving as key points [57]. The recall is based on blocks of 5 minutes or more by selecting

activities that have been categorised into different groups. A recent study comparing the adult version of MARCA with DLW reported a correlation for ρ=0.70 for total energy expenditure (TEE) [58]. Another study reported convergent validity of ρ=0.72 for MARCA PA level in comparison to accelerometer counts per minute. In the same study, the test-retest reliability scores for moderate-to-vigorous physical activity (MVPA), sleep and screen time and PA levels were between 0.990 – 0.997 [59].

Direct observation
This method involves observation or video recording of individuals while engaging in PA by well trained observer [60]. Contextual information such as type of PA, location in which the activity took place and individual characteristics can be examined [18]. It is more applicable among children than adults [61]. Use of short time intervals and codes for intensity and activity domain are common across the majority of observational approaches [18].

Objective assessment methods of physical activity
There are numerous objective methods for PA assessment in different populations [16]. Due to the complexity and multidimensional nature of PA, it is difficult to accurately assess it [62]. It is challenging to identify the most accurate and objective PA measure for assessment in large populations [63]. A number of factors influencing the selection of the method include age of respondent, sample size, duration of assessment, type of PA information, data management options, measurement errors as a result of the PA measure used [64, 65], cost and respondent burden [66]. Objective PA measures include accelerometers, pedometers, heart rate monitoring, direct observation and doubly labelled water (DLW) and are discussed in detail henceforth.

Doubly labelled water is considered as the 'gold standard' measure for assessing total energy expenditure (TEE) [67]. It involves oral administration of stable isotopes, deuterium (^{2}H) and oxygen-18 (^{18}O) through drinking water [68, 69], daily collection of urine samples for 7–14 days, isotope ratio mass spectrometry (IRMS) analysis [70]. The discrepancy between the elimination rates of ^{2}H and ^{18}O equates to the production rate of carbon dioxide, which is converted to average TEE [71]. The DLW can be used in different populations including infants, pregnant and lactating women. It is applicable in free-living settings, is non-invasive, accurate and precise, and has minimal respondent burden [16]. Total energy expenditure is usually measured for 7–14 days depending on the respondents' age and the analysis approach. The limitations of this technique include inability to provide specific information on daily PA [64], particularly it does not measure the intensity, duration and type of activity [66] and is expensive because of the laboratory equipment, costs of isotopes and analyses of biological samples like urine in large population-based studies [16]. This technique can be used as a criterion measure in PA validation studies of other measures for assessing energy expenditure (EE) in free-living subjects [72].

Accelerometry, an objective measure has become common in recent studies [73]. Accelerometers are small motion sensors that objectively measure acceleration, duration and intensity of movement [74] in at least three planes (vertical, horizontal, and perpendicular) [75]. Physical activity is expressed as activity counts per unit of time, commonly counts per minute [75]. Accelerometers are typically strapped on the thigh, hip, lower back, wrist and ankle [76]. Much as accelerometers are able to assess all types of PA, they have limitations such as: 1) inability to detect PA domains and all body movements like upper or lower motions by single accelerometers; 2) they are not designed for assessments that may take a long time and therefore repeated measurements are necessary so as to assess for variations in PA across seasons; 3) inadequate assessment of non-ambulatory activities like water-based activities (swimming), carrying heavy loads etcetera that may result into misclassification, and 4) expensive [76].

Heart rate monitoring is used to estimate EE and PA. This technique is convenient, cheap, widely used, non-invasive and useful [16] and detailed information on frequency, intensity and duration of free-living PA can be collected [77]. Estimation of EE by heart rate monitoring is hinged on a linear relationship between oxygen consumption (VO2) and heart rate (HR). There are intra- and inter-individual variations of this relationship [78]. Factors that influence this linear relationship include sex, age, weight, level of fitness [79], body posture, ambient temperature and emotional state (anxiety or stress) [15]. The establishment of the HR-EE relationship for an individual is based on a sub-maximal calibration method conducted soon after the resting energy expenditure (REE) assessment. A metabolic chart is used in measuring the heart rate and breath-by-breath VO2 and VCO2 [16] for a 5 minutes duration in the order of the following: sitting, standing, cycling at low resistance (55W) and blocks of increased cycling resistance being maintained at a cadence of 60 rpm [16]. Equations by Livesey and Elia (1988) are used to quantify the average EE from VO2 and VCO2 values for each activity and workload. The linear relationship estimates PAEE above the flex heart rate point, a threshold. If the heart rate is below the flex point, REE is assumed [15]. The strengths of this technique include the monitor can be calibrated at individual level, and it provides accurate and valid data based on individual regression equations because it caters for inter-individual differences in fitness and health. However, its drawbacks include due to differences in HR–VO2 between the upper and lower body movements, this technique inaccurately estimates EE for other activities as opposed to running or walking [78]. During exercise, HR and EE are closely related, but not during rest and low activity [64]. The individual calibration makes the method time-consuming and costly and excludes assessment of several population groups, for instance children and elderly.

Pedometers are motion sensors that detect the steps taken during running and walking. They are the most popular objective measure, inexpensive, easy to use, readily available and widely used. They serve as a motivational devices to

Table 1. Overview of PA assessment methods with reference to outcomes, validity, advantages and disadvantages

Method	Measurement	Primary (1◦) and secondary (2◦) outcomes	Validity for assessing primary outcomes and energy expenditure (EE)	Advantages	Disadvantages
Self-report measures (questionnaires, diaries, recalls and logs)	- Time spent in different activity types of with varying intensities - Time spent in different activity domains	1◦ – number of bouts and time spent in activities of varying intensities 2◦ – EE estimated by ascribing METs to reported activities for specified durations	1◦ – valid Not valid to estimate EE at individual level; varying validity for categorizing individuals into groups; and for ranking of individuals	- Suitable for all populations - Low respondent burden - Ease of data collection and analysis - Low cost - Captures quantitative and qualitative information - Can be used in large populations - Can be used to for assessment for PA dimensions and domains - Valid for assessment of structured PA Applicable for one-time assessment	- Proxy reporters required for children and possibly elderly - Reliability and validity problems associated with recall and social desirability - Need to be adapted to culture and population under study - Low validity lifestyle PA assessments - Specific to diaires – very high burden

Method	**Measurement**	**Primary (1◦) and secondary (2◦) outcomes**	**Validity for assessing primary outcomes and energy expenditure (EE)**	**Advantages**	**Disadvantages**
Doubly labelled water	CO_2 production	1◦ – total energy expenditure (TEE)	1◦ – valid	- Suitable for all populations - Moderate respondent burden - Good precision of measure	- Expensive - Does not provide information about intensity, frequency or duration of physical activity - Requires trained personnel and technical equipment - Resting energy expenditure (REE) and thermic effect of food should be measured so as to derive physical activity energy expenditure (PAEE) - Inability to assess PA dimensions and domains
Accelerometry	Acceleration of the body or body segments in one or more directions	1◦– acceleration 2◦– estimates of the intensity, frequency and duration of body movement	1◦– valid Validity for measuring PAEE varies between monitors and types of activities. - Valid at group level for free-living PAEE estimates	- Suitable for all populations - Low respondent burden - Objective indicator of body movement (acceleration) - Provides information about intensity, frequency and duration - Relatively easy data collection	- Inaccurate assessment of a large range of activities - Financial cost may prohibit assessment of large numbers of participants - Unable to assess non-ambulatory activities - Data reduction, transformation and analysis takes time

Method	Measurement	Primary (1◦) and secondary (2◦) outcomes	Validity for assessing primary outcomes and energy expenditure (EE)	Advantages	Disadvantages
Heart rate monitoring	Heart rate i.e. beats per minute	1◦– heart rate; intensity, frequency and duration of moderate-to-vigorous physical activity (MVPA)– vigorous physical activity (VPA) 2◦– PAEE estimated using regression equations derived from individual or group calibration	- 1◦– valid Valid at group level for estimating energy expenditure for higher intensity activities, improved by using individual calibration	- Suitable for all populations - Low respondent burden for short wearing times but may be problematic over longer periods - Provides information on intensity, frequency and duration - Good association with EE - Easy and quick for data collection and analysis - Relatively cheap	- Only useful for aerobic activities - Conditions unrelated to PA can cause an increase in heart rate without a corresponding increase in volume of oxygen - Can be affected by other stimuli like medications, caffeine, emotions - Subject to interference with signal
Combined heart rate and accelerometer devices	Acceleration of body and heart rate	1◦– acceleration and heart rate; PAEE, intensity, frequency and duration of PA	1◦– valid Valid for estimating PAEE at group level, evidence for validity in individuals emerging	- Suitable for all populations - Low respondent burden - Relative easy data collection - Accuracy is improved as opposed to a single assessment approach	- Data analysis is relatively complex - Monitors are relatively expensive - Increased burden of wearing different devices - Technical expertise is required depending on the devices used

Method	**Measurement**	**Primary (1◦) and secondary (2◦) outcomes**	**Validity for assessing primary outcomes and energy expenditure (EE)**	**Advantages**	**Disadvantages**
Pedometry	Step count	1◦– number of steps taken	1◦– valid Not valid to estimate EE during free living	- Suitable for all populations - Low respondent burden - Easy data collection and analysis - Cheap - Objective measure of common activity behaviour - Can be used as a motivational tool	- Suitable to measure steps taken during walking - Simple pedometers are unable to assess duration and intensity of PA - Unable to measure PA types - Some brands do not have adequate memory and participants have to document steps taken - Not accurate for assessing EE
Direct observation	Categorisation of activity	1◦– number of bouts and time spent in activities of varying intensity 2◦– estimates of energy expenditure by ascribing MET values	1◦– valid to estimate PAEE	- Mostly used in paediatric studies - No respondent burden - Provides excellent quantitative and qualitative information on PA undertaken for a specified timeframe - Recall is not necessary	- Expensive as labour intensive - Observer presence may artificially alter normal physical activity patterns - High burden on observers - Observers need to be trained

Source: Warren et al [15]; Strath et al [18].

promote PA among sedentary and physically inactive individuals. However, they have their limitations. They are not suitable for PA assessment among the older adults [80] because of inaccuracies at slow speeds of less than 60m/min [81] and pedometer data can vary with placement site on the body [81, 82], foot strike within and between individuals [83], stride length and walking speed [84]. They can overestimate the total step counts by shaking the device [16].

Burden of overweight and obesity among adults

Global burden of overweight and obesity

Due to the increasing prevalence of overweight and obesity in numerous countries worldwide [85-87], it is recognised as a global pandemic [88, 89] and public health challenge [86]. Adult prevalence of overweight and obesity has increased among men from 28.8 % in 1980 to 36.9 % in 2013 and among women from 29.8 % in 1980 to 38.0 % in 2013 globally [86], Figure 1. In 2014, the global prevalence of overweight and obesity among adults was estimated at 39 % (38 % of men and 40 % of women) and 13% (11 % of men and 15 % of women), respectively. Particularly, the global prevalence of obesity almost doubled between 1980 and 2014 [90]. It is projected that 2.16 billion adults will be overweight and 1.12 billion will be obese by 2030 worldwide [91]. Overweight and obesity are prevalent in LMICs [92].

Across the WHO regions, the Americas have the highest prevalence of overweight and obesity and obesity at 61 % and 27 %, respectively, with the lowest reported in the South-East Asia region (22 % overweight and 5 % obesity), Figure 2. More than 50 % of the women are overweight in the European, Eastern Mediterranean and American regions with, almost 50 % of the overweight women in the same regions being obese (European region at 25 %, Eastern Mediterranean region at 24 % and Americas region at 30 %). Specific to the African, Eastern Mediterranean and South-East Asian regions, the prevalence of obesity among the women has almost doubled that of men, [90]. Of the world's population, majority reside in countries where overweight and obesity accounts for most deaths than underweight [93].

Overweight and obesity are associated with increased risk especially for non-communicable diseases (NCDs) like cardiovascular diseases (coronary heart disease and stroke), certain cancers (colon, breast, endometrial, and gallbladder), type 2 diabetes, osteoarthritis and chronic kidney disease [94-97]. Most cardiovascular deaths are attributed to overweight and obesity [98]. Overweight and obesity are responsible for an estimated 3.4 million deaths annually, 3.9 % of years of life lost and 3.8 % of disability-adjusted life-years (DALYs) globally in 2010 [98].

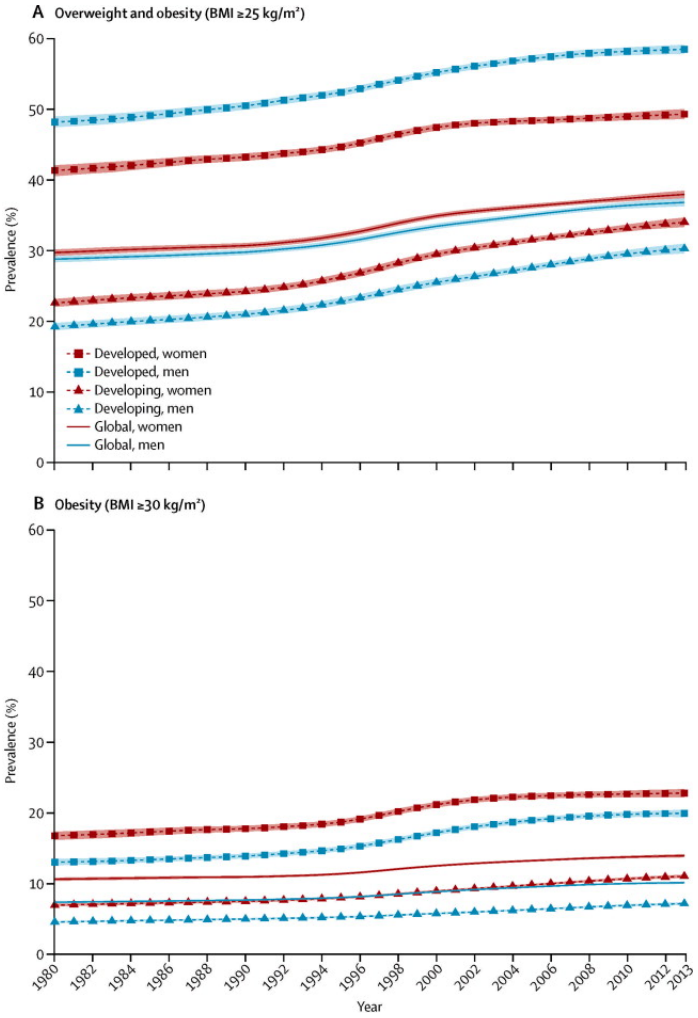


Figure 1. Age-standardised prevalence of overweight and obesity and obesity alone, ages ≥20 years, by sex, 1980–2013 based on BMI [86].

Burden of overweight and obesity in Africa

An estimated 20-50 % of urban populations are either overweight or obese in Africa [99, 100]. According to WHO, adult prevalence of obesity in Africa was about 6 % among men and 15 % among women in 2014 [90]. In eastern sub-Saharan Africa (SSA), the prevalence of overweight and obesity and obesity only among men was estimated at 14.9 % and 4.4 % in 2013, respectively. Among

women, the prevalence of overweight and obesity and obesity only was estimated at 23.7 % and 8.8 % in 2013, respectively [86].

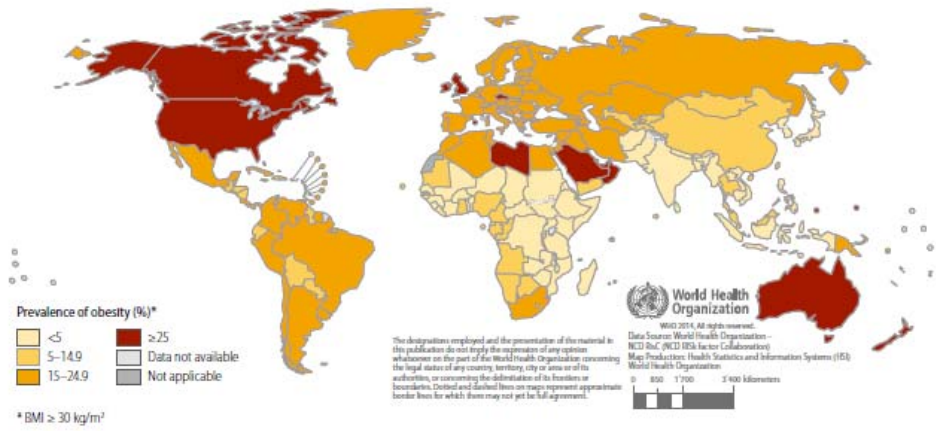
Burden of overweight and obesity in Uganda
Uganda's recent national NCD risk factor survey reported that the adult prevalence of overweight and obesity was 19.1 % (11.3 % of men and 27.1 % of women) and that of obesity was 4.6 % (1.8 % of men and 7.5 % of women) in 2014 [101]. The Uganda Demographic Health Surveys (UDHSs) indicate an increasing trend in the prevalence of overweight and obesity among women of reproductive age from 8 % in 1995 to 18.8 % in 2011 [102, 103].

There have been a few population-based studies on the prevalence of overweight and obesity in Uganda. A study in rural south-western Uganda among individuals aged 13 years and above reported that 3.6 % of males and 14.5 % of females were overweight and 0.5 % of males and 3.9 % of females were obese in south western Uganda [104]. Another study among 35–60 years old adults in rural eastern Uganda reported overweight prevalence of 12.3 % (7.5 % of men and 16.9 % of women) and obesity of 5.3 % (2.2 % of men and 8.2 % of women) [105]. A study in a large population cohort aged 13 years and above in south-western rural Uganda reported the prevalence of overweight at 11.8 % (5.2 % of men and 16.9 % of women [106]. According to a study among adults aged 25 years and more in Kasese district in rural Uganda, overweight was 15.6 % (14.7 % of men and 16.7 % of women) and obesity was 6.7 % (4.9 % of men and 9.0 % of women) [107].

Burden of sedentary behaviour and physical inactivity

Global burden of sedentary behaviour and physical inactivity
Physical inactivity, one of known four risk factors for NCDs [108], is on the increase in many countries globally [109]. The prevalence of self-reported physical inactivity prevalence among adults in 122 countries is 31.1 %, with wide regional variability like Southeast Asia (17.0 %), Africa (27.5 %), Western Pacific (33.7 %), Europe (34.8 %), Americas (43.3 %) and Eastern Mediterranean (43.2 %), Figure 3. The prevalence of self-reported physical inactivity is higher among women (33.9 %) than men (27.9 %). Across all the regions, the prevalence of physical inactivity increased with increasing age. Physical inactivity is more prevalent among the high-income countries (HICs) than the low- and middle-income countries (LMICs) [30]. Much as there is a limited data on levels of physical activity (PA) at population level [30], physical inactivity is increasingly becoming a major risk factor for NCDs in LMICs [3].

A.



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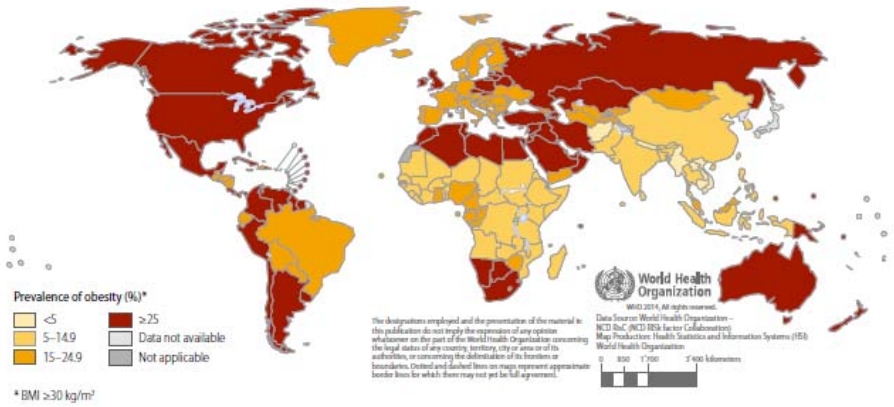

Figure 2. Age-standardised prevalence of obesity in men (A) and women (B) aged 18 years and above (BMI ≥ 30kg/m^2), 2014 [90].

Physical inactivity is responsible for more than 69 million disability adjusted life years and an annual average of 3.2 million global deaths [110], with most occurring in LMICs [109]. Furthermore, physical inactivity accounts for an estimated 21–25 % of breast and colon cancer burden, 27 % of diabetes and 30 % of ischaemic heart disease burden [111]. Similarly to obesity, eliminating physical inactivity would increase the life expectancy of the world's population by 0.68 years [109].

Sedentary behaviour has gained recognition as a public health challenge in the last decade. However, there is scanty evidence about the patterns of sedentary

behaviour in various countries [112]. The limited data from the WHO STEPwise approach to chronic disease risk factor surveillance (STEPS) surveys and the Eurobarometer in 66 high- and low income countries indicated that the adult prevalence of sedentary behaviour (defined by sitting for at least 4 hours per day) is 41.5 %. Wide variations across WHO regions were observed: 37.8 % in Africa, 55.2 % in the Americas, 41.4 % in Eastern Mediterranean, 64.1 % in Europe, 23.8 % in Southeast Asia and 39.8 % in the Western Pacific [30]. Another study in 20 countries reported a median of 300 min per day (IQR 180–480) of time spent sitting but with wide variability across countries and middle aged adults (40–65 years) spent more time sitting than in young adults (18–39 years) [112]. The limited evidence has been largely driven by self-report measures and therefore, there is little data of objectively-assessed sedentary behaviour and its risk factors in LMICs, particularly in Africa.

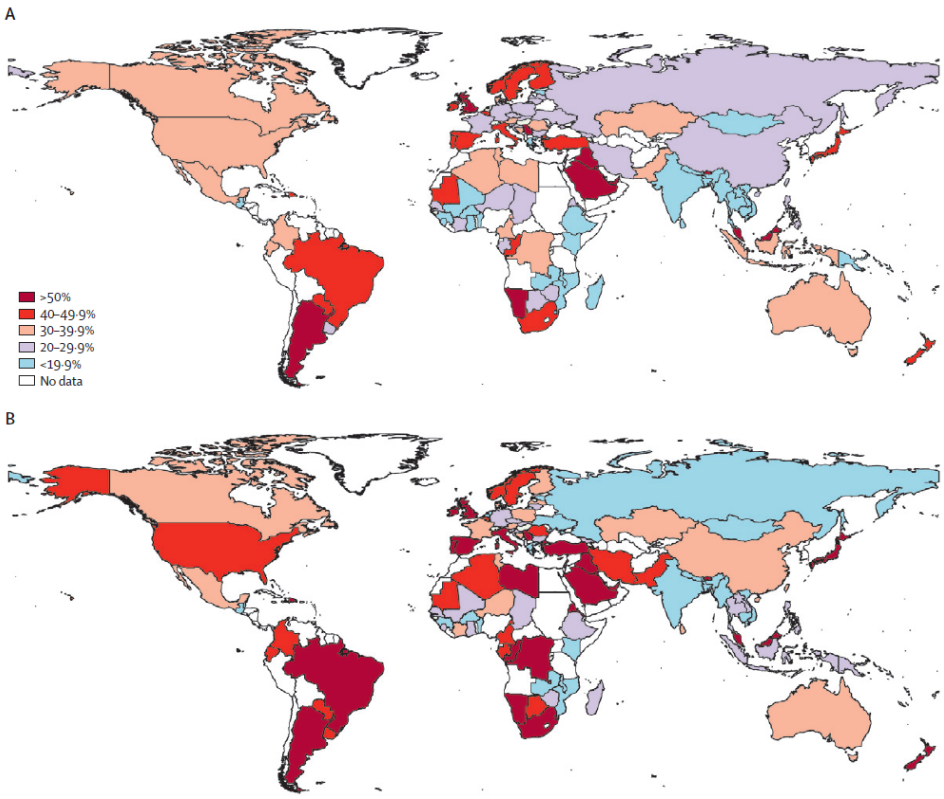

Figure 3. Age-standardised prevalence of insufficient physical activity among men (A) and women (B) aged 15 years and above, 2010 [30].

Burden of sedentary behaviour and physical inactivity in Africa

There is limited data at population level of physical activity in LMICs [30], including African countries. However, the limited evidence estimated self-reported physical inactivity among adults in 22 African countries at 20.9 % (16.2 % of men and 24.3 % of women) and 27.2 % (21.2 % of men and 31.6 % of women) according to WHO recommendations and GPAQ definitions, respectively [113]. Similar estimates of self-reported physical inactivity have been reported at 27.5 % [30].

The available literature on estimates of overweight, obesity and physical inactivity for the region are generated by WHO and based on limited data [114]. Additionally, the demographic and health surveys are conducted every 5 years, however, NCD related data has only been collected in some of them. The health and demographic surveillance sites (HDSSs) in 13 African countries in the INDEPTH network collect demographic data like births, deaths and migrations in addition to some NCD related data [115]. Much as these surveys and few epidemiologic studies have provided important evidence, they have varied in scope and representativeness. Continuous surveillance for NCD risk factors at national level is not being done in most African countries [30].

Burden of physical inactivity in Uganda

There are a few population-based studies on the prevalence of sedentary behaviour and physical inactivity in Uganda. Adult prevalence of self-reported physical inactivity in the Uganda's NCD risk factor survey was 5.7 % (4.5 % of men and 6.6 % of women) [116]. Self-reported physical inactivity among adults aged 35 – 60 years in rural eastern Uganda was estimated at 16 % [105]. A study in rural Uganda showed that the prevalence of self-reported physical inactivity was 29.8 % (20.8 % of men and 36.7 % of women) [106]. Additionally, physical inactivity was 51.0 % (48 % of men and 51 % of women) [107].

The limited evidence is based on the first ever a nationwide NCD risk factor survey that was conducted in 2014, data from the UDHSs that has primarily focussed on women of reproductive age and children and the few epidemiological studies that have been geographically localised, targeting different age groups, the prevalence estimates were limited to a few demographic characteristics and some studies had small sample sizes thus raising concerns of generalisability of the findings. Therefore, there is a dearth in population-based data on NCD risk factors like overweight, obesity and physical inactivity in SSA [117-119], of which Uganda is one of the countries amidst the rising burden of these NCD risk factors in Africa. The availability this data would inform development, implementation and evaluation of context specific interventions for prevention and management of NCDs and their risk factors.

Justification of the studies

Body weight and physical activity in adults in LMICs and in Africa are under-researched issues and there are substantial gaps in available data in these fields. In addition, we know that as part of the epidemiological and demographic transitions, dramatic changes in both body weight and physical activity are taking place at population level, yet these changes have not been adequately described. Furthermore, there is insufficient understanding of the link between individual, social and physical environment and overweight and/or obesity [120, 121]. The limited literature is focussed on urban and suburban populations [121] in HICs and therefore, there are limitations in inferring these findings to LMICs [122], particularly to rural settings. There is insufficient literature on the burden of NCDs and their risk factors in SSA [123-125] like obesity and physical inactivity by demographic variables [117] in addition to the influence of the environment on overweight and/or obesity in Africa [122]. There is a need for epidemiological for research in SSA [119] among peri-urban and rural populations to inform development of effective, culturally sensitive, context-specific and population-based interventions for the prevention of obesity and NCDs [122] (paper I, II).

Although there is inadequate literature on population-based PA patterns in SSA, the available evidence have been based mainly on self-reports [126] and numerous definitions of PA have been used [127] which renders comparisons difficult. Additionally, there is patchy evidence on the association between objectively-determined PA and obesity [128, 129]. Thus, there is a dearth of information about objectively-determined PA and its correlates in SSA. Appropriate PA assessment at population level in addition to identifying correlates of PA are critical in informing development, implementation and evaluation of public health policies and effective, context-specific interventions aimed at PA promotion for the prevention of obesity and NCDs (paper II).

Much as the GPAQ was developed for PA surveillance over time and for comparisons of PA patterns at national, regional and international levels primarily for use in developing countries with the aim of informing PA policies [29], the literature on the validity of GPAQ version 2 is still patchy in general and yet it is widely used in numerous countries [130]. A limited number of GPAQ version 1 validation studies have been conducted in a few countries. The only extensive nine-country validation study that included two African countries that is Ethiopia and South Africa examined the GPAQ version 1 [25, 48], and therefore data on the validity of GPAQ version 2 in Africa is still lacking and these findings cannot be extrapolated to the rest of Africa because of diversity in cultural norms, variations in perceptions, recall bias and differentials in understanding of psychometrics of the constructs. Given that there is no consensus on the gold standard measure of PA, there is a need to generate more information on the

validity of the constructs of GPAQ version 2 in order to better understand its usefulness as a tool for PA surveillance [130] (paper III).

Conceptual framework

This thesis is based on the Environmental Research framework for Weight Gain prevention (EnRG) originally developed by Kremers et al [131] and further adopted and adapted by Lakerveld et al [132]. The dual process framework and evidence were used to gain insights on factors associated with physical inactivity, sedentary behaviour, and overweight and/or obesity. The framework demonstrates the interplay of environmental factors, mediators and moderators which influence the obesogenic behaviours which in turn influence body composition determined by BMI, a measure of overweight and obesity. The environmental factors include physical, economical, political and socio-cultural factors that can either influence the obesogenic behaviours indirectly through mediators or directly include the perceived environment (traffic and crime safety, social support and norms, etc.), self-regulatory skills (goal setting, self-monitoring, action plans, etc.) and motivational factors (self-efficacy, goals, competence, etc.). A number of factors such as socio-demographic factors, habit strength, physiological factors, health literacy and awareness of risk factors may moderate the causal pathways directly – the environmental factor unconsciously automatically influences obesogenic behaviours or indirectly – the environment impacts on the obesogenic behaviours through mediators Figure 4.

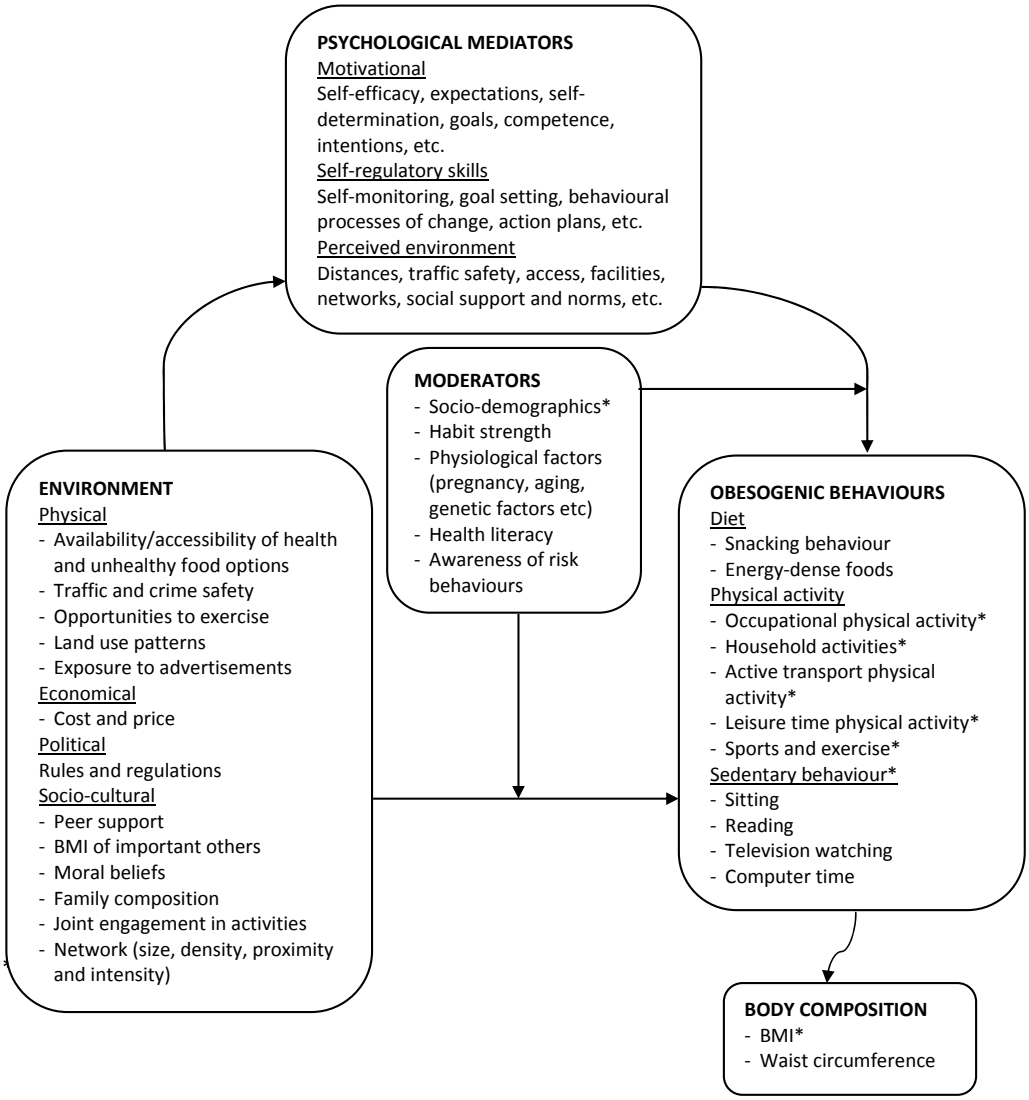

Figure 4. The Environmental Research for weight Gain prevention (EnRG) framework (Source. Kremers et al [131]; Lakerveld et al [132]).

Study objectives

Overall aim

To determine the prevalence of overweight and obesity and physical inactivity and associated risk factors among adults in Iganga-Mayuge Health Demographic Surveillance Site (IMHDSS) in Uganda

Specific objectives

- To determine the body weight distribution, the prevalence of overweight and obesity and their associated factors in a population-based sample of adults in peri-urban and rural eastern Uganda (paper I)
- To determine the prevalence of PA levels and the associated factors of sedentary behaviour and physical inactivity in a population-based sample of adults in peri-urban and rural eastern Uganda (paper II)
- To assess the level of agreement between the GPAQ and the pedometer in assessing PA levels among peri-urban and rural Ugandan adults (paper III)

Study subjects and methods

Study area

The study was conducted in the IMHDSS, which is situated astride two districts of Iganga and Mayuge in eastern Uganda, about 120 kilometres east of Kampala, the capital, Figure 5. The IMHDSS is a member of the International Network for continuous Demographic Evaluation of Populations and Their Health (INDEPTH) Network, [115].

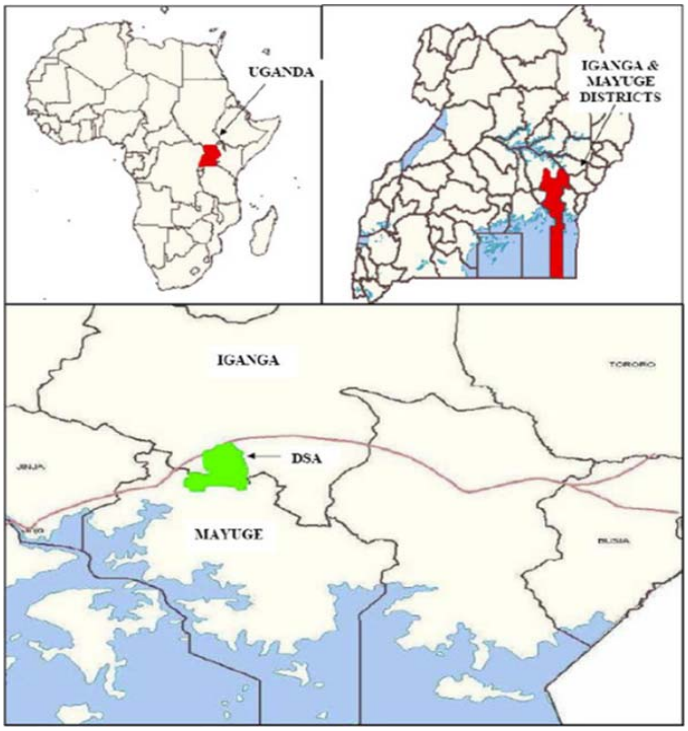

Figure 5. Map showing the IMHDSS within Iganga and Mayuge districts in Uganda
Source: Waiswa et al [133].

The estimated population size of the IMHDSS was 80,000 people in 2013, of whom 51.2 % were females. The population is young with more than 60 % aged below 15 years, characteristic of most Ugandan rural populations. The number of households is estimated at 13,000 on an area of about 155 square kilometres. The IMHDSS is composed of 65 villages with about 38 % of the population residing in peri-urban villages. Other demographic indicators include a crude birth rate of

31.6 per 1,000 population, crude death rate of 6.7 per 1,000 population, total fertility rate of 4.3, infant mortality of 41.4 per 1,000 live births, child mortality of 82.1 per 1,000 live births, neonatal mortality of 23.1 per 1,000 live births and post neonatal mortality of 18.3 per 1,000 live births.

There is continuous data collection on key demographic variables of births, deaths and their causes by verbal autopsy, in- and out-migration, education and socio-economic status using the standard INDEPTH Network recommended household registration database structure. Data on infant vaccination, malaria in under-five children, pregnancies and their outcomes, injuries and disabilities are also collected in addition to data for special studies [134].

Iganga district had an estimated population of 504,000, of whom 262,000 were females and 412,000 resided in rural areas in 2014. The estimated population of Mayuge district was 473,000, of whom 243,000 were females and majority of the population (440,000) resided in rural areas in 2014 [135]. The population in these districts are largely homogenous with the majority (80 %) from 'Basoga' ethnic group. However, other ethnic groups are also found in the districts. Small scale subsistence agriculture is the predominant economic activity with close to 90 % involved growing food crops like beans, ground nuts, maize, rice, sweet potatoes and cassava. Small scale trade is commonly done in the peri-urban areas and fishing along the shores of Lake Victoria.

Methods

This thesis is based on a mix of subjective and objective quantitative methods of data collection and analyses employed to generate complementary information on which the three papers are based. Subjective methods of data collection included interviews by semi-structured questionnaires while the objective methods involved physical measurements by stadiometers, digital weighing scales and pedometers at households. The methodological approach for the three papers is summarised in Table 2.

Study design and sample size

All three papers in this thesis are based on one population-based, cross-sectional survey among adults aged 18–92 years that was nested in the active study cohort of 1 January 2005 to 30 September 2013 in the IMHDSS.

The sample size of the studies was based on the formula for cluster surveys, ($C=[z^2pq]d / \delta^2b$) [136]: z_α, the standard normal deviate at 95 % confidence (or a significance level of 0.05), is 1.96; p, the prevalence of malnutrition (underweight, overweight and obesity) in a population-based study in south-western rural Uganda (P) was 34.4 % or 0.344 [104]; q = 1-P = 0.656; d, represents a design effect of 2 because sampling was done at rural/peri-urban village/cluster level

and at household level; δ, represents a sampling error of 4 % and b, the average number of individuals sampled per cluster was 30. Substituting into this formula, the minimum number of clusters needed for the survey was 36, implying a minimum sample size of 1,084 adults. After adjustment for 10 % potential non-response, the sample size was 1,205 adults, selected from 40 clusters and maximum one adult per household.

Study population and sampling

Study participants comprised of men and non-pregnant women aged 18 years and above in the IMHDSS. Participants were required to have been residents for at least 4 months, to have an individual identification IMHDSS number and to be part of a household with an IMHDSS identification number. Adults were excluded from participating in the study on the basis of inability to communicate with the research team, reported illness and for whom any form of physical activity was contradicted.

Respondents were drawn from the active IMHDSS study cohort using a two-stage sampling [136]. A total of 40 villages were randomly selected using probability proportionate to size sampling and within each village, 30 households/participants were selected by simple random sampling using Stata data analysis and statistical software. Within each village, an equal number of women and men were selected. A household was defined as a group of people who were living and eating their meals together for at least 6 of the 12 months preceding the study. In the event that a study participant was not found at their place of residence, this person was replaced by an individual of the same sex from a neighbouring household using the IMHDSS village lists.

A sample of 1,280 adults was first drawn from the IMHDSS database to participate in the household survey that involved two steps. In step 1, all participants were interviewed using a semi-structured questionnaire to elicit information on socio-demographics, self-reported PA behaviour and physical measurements of height and weight were done. In step 2, participants wore a pedometer to collect objective data on the number of steps accumulated for seven consecutive days. Of the 1,280 participants, 72 (5.6 %) did not have pedometer data for at least 4 days and therefore were excluded from the sample.

Measurements

Independent variables

The independent variables that were assessed using a semi-structured questionnaire include age, marital status, education level, religion, residence, occupational activities, income, and ownership of household assets that were used to generate a socio-economic status (SES) index. The questions on independent

variables were validated and are used in the IMHDSS surveillance data collection tools and the UDHSs [103]. These variables were used in all papers I, II and III.

Table 2. **An overview of data collection methods, variables and analyses by papers**

Paper	Data collection methods	Variables	Analyses
I	- Interviewer administered questionnaire - Physical measurements	- Socio-demographics - Height, weight and BMI	- Means and their standard deviation - Medians and interquartile ranges - Sensitivity analysis on household assets - Principal component analysis for SES index - Prevalence of underweight, overweight and obesity - Logistic regression analysis for factors associated with overweight or obesity
II	- Same as paper I - PA assessment by pedometers for a week	- Same as paper I - Number of step accumulated in a week	- Means and their standard deviations - Medians and their interquartile ranges - Prevalence of sedentary behaviour, low active, somewhat active, active and highly active - Sex- and age-specific PA levels - Logistic regression analysis for factors associated with physical inactivity and sedentary behaviour
III	- Same as paper II - PA assessment by GPAQ for a week	- Same as paper II - Number of days in a week spent in vigorous- and moderate-intense PA - Duration in hours and minutes spent in vigorous- and moderate-intense PA	- Prevalence of inactivity and activity by GPAQ and pedometer - Sensitivity, specificity, positive- and negative predictive values, % agreement and kappa statistics by sample, sex, BMI groups and residence. - Spearman's correlation coefficient analysis to assess the relationship between average number of steps/day and GPAQ average PA in MET-minutes/day - Receiver operating characteristic analysis to determine the performance of GPAQ

Age in complete years was recorded as a continuous variable. In the event that a respondent was unable to recall their age appropriately, significant past political or social local events were used as a proxy to estimate their age. Age in years was further transformed in a categorical variable by classifying into six groups, namely 18–24, 25–34, 35–44, 45–54, 55–64 and ≥ 65 years. Marital status was classified into 3 groups namely single, widowed/separated/divorced and cohabiting/married. Religion was classified as catholic, protestant, other christian, moslem and traditionalist. The IMHDSS peri-urban/rural classification was used for residence. This classification is based on population size, distance to Iganga town, access to amenities like piped water and mobility of the population.

The highest level of education attained was assessed in the following categories: none, lower primary, upper primary and secondary and above. The main occupational activities in the previous month were measured in seven domains

namely: subsistence agriculture, commercial agriculture, casual labour, domestic work, student, trade and formal salaried employment. Income was assessed in Ugandan shillings (UGX) using a question on average monthly earnings and this was classified as none, less than 60,000 (US $ 23), 60,000 – 100,000 (US $ 23 – 38) and more than 100,000 (US$ 38 (exchange rate September 2014: 1 US $ = UGX 2,620).

Socio-economic status was assessed based on ownership of 14 out of 27 household items that were first checked for internal consistency using the Cronbach's alpha measure (Cronbach's alpha = 0.732). The fourteen items included: 1) radio, 2) mobile phone, 3) bicycle, 4) motorcycle, 5) table, 6) machete, 7) axe, 8) hoe, 9) cattle, 10) goats, 11) poultry, 12) land ownership, 13) kerosene lantern, and 14) charcoal iron. Using principal component analysis, the factor scores of the first principal component were used to create 5 SES quintiles: first (poorest), second, third, fourth and fifth (least poor) [137].

Outcome variables

Paper I

Body mass index was the main outcome variable for paper I. Using standard protocols, body height and weight were measured with the study participants standing upright and wearing lightweight clothing and no shoes. Body height was assessed in centimetres (cm) using Seca™ 213 portable stadiometers (Seca GmbH & Co. Kg., Hamburg, Germany, [138]). Body weight was assessed in kilograms (kg) with calibrated Seca™ 876 digital weighing scales (Seca GmbH & Co. Kg., Hamburg, Germany, [138]). For each participant, two measurements for height and weight were taken so as to compute averages. The height and weight measurements within participants had intraclass correlation coefficients (ICCs) of 0.982 and 0.960, respectively, suggestive of well above acceptable intra-rater reliability [139].

Height and weight measurements were used to compute body mass index as an indicator of underweight (BMI <18.5 kg/m^2), normal weight (BMI = 18.5–24.99 kg/m^2), overweight (BMI = 25.0–29.99 kg/m^2) and obesity (BMI ≥ 30 kg/m^2) [4-6]. Furthermore, overweight and obesity was defined as BMI ≥ 25 kg/m^2 including obesity (BMI ≥ 30 kg/m^2).

Paper II and III

Physical activity was the main outcome variable for papers II and III. Physical activity was assessed for seven consecutive days subjectively using the GPAQ and objectively using the Isport W181 wrist 3 Axis Sensor Accelerometer Silicon Pedometer Watch (Million Concept Electronic (Shenzhen) Co., limited (LTD), Guangdong, China, [140]).

GPAQ-assessed PA
The GPAQ was used to assess PA in a usual week across three domains of work, transport and recreation. The GPAQ was developed by WHO as part of the WHO STEPwise approach to chronic disease risk-factor surveillance (STEPS) tool, as a self-report measure that assesses PA patterns at the population level so as to allow comparisons across studies and countries, particularly in the context of developing countries [29].

Participants were asked questions on the number of days and duration of time in hours and minutes spent usually in activities of different intensities for each of the PA domains for at least 10 minutes and while sedentary during the week and weekend. For each PA domain, the time in minutes in a week in different intensities was multiplied by metabolic equivalent (MET) score weights namely: 4.0 METs for walking, cycling and moderate activity and 8.0 METs for vigorous activity to get MET-minutes/week.

For each participant, the total PA in MET-minutes/week was computed by summation of total MET-minutes/week scores for each domain of work, transport and recreation. Total PA MET-minutes/week scores were dichotomised into 'physically inactive' for a combination of moderate- and vigorous-intensity PA amounting to less than 600 METs-minutes/week and 'physically active' for a combination of moderate- and vigorous-intensity PA totalling to at least 600 METs-minutes/week [1, 141].

Pedometer assessed PA
Multi-functional 3D wrist accelerometer pedometers (figure 6) with the TriAxis sensor technology were used to allow PA assessment while either wearing the pedometers on the wrist or carrying in the pocket so as to ensure high accuracy in measurement of steps [140]. For each day of observation, the number of steps accumulated was recorded by the pedometer. The pedometers have not been validated in population-based studies, however, internal manufacturer audit reports indicate an accuracy of 95 %. Participants were asked to wear pedometers only during their wake hours and remove them when going to sleep, bath or shower. Additionally, participants removed their pedometers and placed them on either other body parts or in a pocket away from heat or water when involved in heat- or water-related activities.

The pedometer data had 8,456 days of observation with 255 (3.0 %) days of missing data. For each participant with days of missing step data, a daily average number of steps was imputed based on the available step data for the days of observation. For each participant, the total number of steps accumulated in a week was calculated by adding the daily number of steps for seven consecutive days. The daily average number of steps was calculated by dividing the total step counts in a week by the seven days of observation for each individual. Of the 156

participants whose missing pedometer data had to be imputed, 86 had 1 day, 41 had 2 days and 29 had 3 days of missing data.

Figure 6. A study participant wearing the pedometer watch

For paper II, the daily average number of steps was categorised using the adult graduated step index to create PA levels of sedentary behaviour (< 5,000 steps/day), low active (5,000–7,499 steps/day), somewhat active (7,500–9,999/day), active (10,000–12,499 steps/day) and highly active (≥ 12,500 steps/day) [13]. Furthermore, the daily average number of steps data was dichotomised into 'physically inactive' for < 7,500 steps/day and 'physically active' for ≥ 7,500 steps/day. The daily average number of steps data was also dichotomised into 'sedentary behaviour' for < 5,000 steps/day and 'not sedentary behaviour' for ≥ 5,000 steps/day [142].

For paper III, the cut-offs of the daily adult graduated step index [13] were used to classify total steps taken over seven days into sedentary behaviour (< an average 5,000 steps/day), low active (average of 5,000–7,499 steps/day), somewhat active (average of 7,500–9,999/day), active (average of 10,000–12,499 steps/day) and highly active (≥ an average of 12,500 steps/day). Furthermore, the total steps counts were dichotomised into 'physically inactive' for an average < 7,500 steps/day over seven days and 'physically active' for an average ≥ 7,500 steps/day over seven days.

Data management and analysis

EpiData version 3.1 software [143] was used for double data entry and consistency check. The clean dataset was then exported to IBM SPSS statistics 19 [144] for analysis.

Paper I

Descriptive statistics of mean, standard deviation, median, interquartile range and percentages were computed where appropriate and expressed by independent variables and BMI. Prevalence estimates of underweight, normal weight, overweight and obesity were expressed as percentages of the overall sample size. Bi-variable analysis was first conducted to identify possible factors associated with overweight and obesity ($p < 0.10$) using crude odds ratios (COR) and their 95 % CI. The significant factors namely age, sex, residence, SES, marital status, and occupational activities were included in the logistic regression model for further analysis. Logistic regression analysis was used to identify associated factors of overweight and obesity using adjusted odds ratio (AOR) and their 95 % CI. Variables were retained in the logistic regression model using an alpha level of 0.10.

Paper II

Descriptive statistics of mean, standard deviation, median, interquartile range in addition to percentages were calculated. The daily average step counts by sex was computed by dividing the total daily average number of steps for each sex by sex-specific populations. The overall daily average number of steps was calculated by dividing the total daily average number of steps for the entire sample by the total sample. The weekly average number of steps for each sex was calculated by dividing the total weekly step counts for each sex by sex-specific population. The weekly average step counts for the sample was estimated by dividing the total weekly steps for the entire sample by the overall sample. Prevalence estimates of PA levels were calculated as percentages of the total sample size. Sex-specific, age-specific and overall prevalence of PA levels were also calculated using sex-specific, age-specific and overall populations as the denominators, where appropriate. Prior to running the logistic regression model, all factors associated with being sedentary and physical inactivity ($p<0.05$) at bi-variable analysis were included in the model. Logistic regression analysis was conducted to establish factors associated with sedentary behaviour and physical inactivity using AOR and their 95% CI.

Paper III

Descriptive statistics of percentages were computed where appropriate. Sensitivity, specificity, positive- and negative predictive values of GPAQ were calculated with pedometer step data as the reference. Percent agreement and kappa statistic scores were used to compare the level of agreement between the

GPAQ and pedometer in assessing PA. Kappa classification used was less than chance agreement (< 0.00), slight agreement (0.01–0.20), fair agreement (0.21–0.40), moderate agreement (0.41–0.60), substantial agreement (0.61–0.80) and almost perfect agreement (0.81–0.99) [145]. Furthermore, the Spearman's correlation coefficient (rho) was used to evaluate the relationship between total PA in MET minutes per week and the total step counts per week i.e. criterion validity. Receiver operating characteristic (ROC) analysis evaluated the performance of GPAQ. Based on the ROC analysis, the area under the curve (AUC) classified perfect prediction (AUC = 1.0), highly predictive (0.90–0.99), moderately predictive (0.70–0.89), less predictive (0.50–0.69) and non-predictive (AUC = 0.5) [146, 147].

Ethical considerations

This study was approved by Makerere University School of Public Health Higher Degrees Research and Ethics Committee (IRB00011353) and the Uganda National Council for Science and Technology (HS1322). The IMHDSS steering committee granted permission to conduct the study in the IMHDSS. Each participant consented to participating in the study by signing a written informed consent form.

Results

This section provides a summary of key findings highlighting the burden of overweight, obesity, sedentary behaviour and physical inactivity, the associated risk factors and the performance of the GPAQ as a tool in PA assessment among adults aged 18–92 years in a predominantly rural setting in SSA.

Characteristics of the participants

Of the 1,210 participants, 50 % were women, 25 % were aged 35 – 44 years, 73 % were either cohabiting or married, 55 % were moslems, 34 % attained upper primary education and 60 % were subsistence farmers, Table 3.

Prevalence of overweight, obesity and associated factors (paper I)

Prevalence of overweight and obesity

The overall prevalence of overweight was 17.8 % (12.4 % of men and 23.1 % of women, $p < 0.001$). Obesity prevalence was 7.4 % with significant differences across sex (2.0 % of men and 12.7 % of women, $p < 0.001$). Overweight and obesity was observed among 25.2 % of participants, with significant differences by sex (12.4 % of men and 35.8 % of women). Obesity prevalence was highest among participants aged 45–54 years. The prevalence of overweight alone (23.8 % of peri-urban and 15.8 % of rural) and obesity alone (17.8 % of peri-urban and 3.9 % of rural) was higher among peri-urban areas compared to the rural areas, Table 3 in paper I.

Factors associated with overweight and obesity

Factors associated with overweight and obesity were female sex, age 35 years and older, peri-urban residence and higher SES. Women were 4 times more likely to be overweight and obese than men (AOR 4.3; 95% CI: 3.2–5.9). Participants in the age groups 35–44 years (AOR 3.1; 95% CI: 1.8–5.3), 45–54 years (AOR 4.1; 95% CI: 2.3–7.3), 55–64 years (AOR 2.6; 95% CI: 1.4–5.0) and ≥ 65 years (AOR 3.1; 95% CI: 1.6–6.0) were more likely to be overweight and obese than those in the age group 18-24 years. Participants who resided in peri-urban villages were 3 times more likely to be overweight and obese (AOR 2.6; 95% CI: 1.9–3.6) than those who resided in rural villages. Participants of the third (AOR 2.8; 95% CI: 1.7–4.6), fourth (AOR 2.5; 95% CI: 1.5–4.2) and fifth SES quintiles (AOR 2.7; 95% CI: 1.6–4.4) were more likely to be overweight and obese than those of the first SES quintile, Table 4 in paper I.

Table 3. Socio-demographic characteristics of study participants, N=1210

Characteristics	Number n	Percent (%)
Sex		
Male	604	49.9
Female	606	50.1
Age groups		
18–24	167	13.8
25–34	247	20.4
35–44	297	24.5
45–54	222	18.3
55–64	137	11.3
≥ 65	140	11.6
Marital status		
Single	130	10.3
Widowed/separated/divorced	193	16.0
Cohabiting/Married	887	73.3
Religion		
Catholic	105	8.7
Protestant	364	30.1
Other christian	74	6.1
Moslem	665	55.0
Traditionalist	2	0.2
Residence		
Peri-urban	298	24.6
Rural	912	75.4
Education level		
None	143	11.8
Lower primary	250	20.7
Upper primary	415	34.3
Secondary and above	402	33.2
Main occupation in the previous month		
Casual labour	85	7.0
Domestic work	73	6.0
Student	23	1.9
Subsistence agriculture	720	59.5
Trade	189	15.6
Commercial agriculture	69	5.7
Formal employment	51	4.2
Average monthly earnings (UGX)		
None	113	9.3
< 60,000	458	37.9
60,000-100,000	344	28.4
> 100,000	295	24.4
Socioeconomic quintiles		
First (poorest)	242	20.0
Second	244	20.2
Third	234	19.3
Fourth	263	21.7
Fifth (least poor)	227	18.8

Sedentary behaviour, physical inactivity and associated factors (paper II)

Prevalence of sedentary behaviour and physical inactivity
Overall, participants accumulated a mean of 9,855 steps/day (95% CI: 9,550–10,159). Men accumulated more steps/day than women (11,192 95% CI: 10,736–11,643 vs. 8,522, 95% CI: 8,146–8,897). The prevalence of sedentary behaviour was 18.8 %, with significant sex differences (10.6 % of men; 26.9 % of women, $p < 0.001$). Nineteen percent of the participants were low active, with significant sex disparities (17.9 % of men; 19.7 % of women, $p < 0.001$). High activity was at 27.6 %, with significant differences by sex (35.3 % of men; 19.8 % of women, $p < 0.001$), Table 2 in paper II.

Factors associated with sedentary behaviour and physical inactivity
Women were 3 times more likely to sedentary than men (AOR 3.4; 95% CI: 2.4–4.9). Participants who were aged ≥ 65 years 5 times more likely to be sedentary than the younger age group of 18 – 24 years (AOR 4.9; 95% CI: 2.5–9.7). Participants who resided in peri-urban areas were 3 times more likely to be sedentary than those who resided in rural areas (AOR 2.9; 95% CI: 1.9–4.6). Engaging in domestic work (AOR 2.1; 95% CI: 1.2–3.7) and formal employment (AOR 5.5; 95% CI: 2.5–12.0), and having attained lower primary education (AOR 2.4; 95% CI: 1.4–4.1) were associated with sedentary behaviour.

Women were 2 times more likely to be physically inactive compared to the men (AOR 2.1; 95% CI: 1.6–2.8). Participants residing in peri-urban areas were 3 times more likely to physically inactive than those from rural areas (AOR 2.5; 95% CI: 1.9–3.2). Participants aged 55–64 years (AOR 2.1; 95% CI: 1.3–3.5) and ≥ 65 years (AOR 4.2; 95% CI: 2.6–7.0) were more likely to be physically inactive than those of the younger age 18–24 years. Participants who were overweight (AOR 1.6; 95% CI: 1.2–2.2) and obese (AOR 2.5; 95% CI: 1.5–4.1) were more likely to be physically inactive than those of normal weight, Table 3 in paper II.

Validity of the GPAQ in comparison to the pedometer (paper III)

Prevalence of physical inactivity by GPAQ and pedometer
Both PA measures showed that men were more physically active than women. According to GPAQ, participants aged 25–34 years and 35–44 years were most active while participants aged 18–24 years were most active as reported by the pedometer. Both PA measures indicated that participants who were overweight, obese and residents in peri-urban areas were least active, Table 2 in paper III. There were marked disparities in the prevalence of physical inactivity and activity as estimated by the GPAQ compared to the Pedometer (inactivity: GPAQ 3.1 % vs. pedometer 37.3; activity: GPAQ 96.9 % vs. pedometer 62.7 %).

Validity measures of GPAQ
The GPAQ had a generally low sensitivity in indentifying physical inactivity. Data show that it is able to correctly identify only 6.0 % of the study sample, 8.2 % of men, 4.6 % of women, 9.9 % of overweight/obese participants, 9.9 % of peri-urban residents and 3.8 % of rural residents as being physically inactive. On the otherhand, the GPAQ had high specificity in identifying physically active individuals among the different sub-populations. Among physically active participants based on the pedometer, the GPAQ classified 98.5 % as being physically active. Among men reported as physically active by the pedometer, the GPAQ classified 98.2 % as active. Among active overweight and obese participants according to the pedometer, GPAQ classified 98.6 % as being physically active, Table 3 in paper III.

Slight agreement scores were observed between the GPAQ and pedometer in classifying PA among the sample (64.0 %, kappa=0.06, $p < 0.001$), men (72.8 %, kappa=0.09, $p < 0.001$), women (55.2 %, kappa=0.04, $p=0.01$) and rural residents (68.9 %, kappa=0.04, $p < 0.001$), Table 3 in paper III.

The scatter plot indicated a weak but significant correlation between pedometer average number of steps/day and the GPAQ average PA in MET minutes/day ($rho=0.27$, $p < 0.001$), Figure 1 in paper III.

Furthermore, the ROC curve analyses indicated less predictive ability (performance) of GPAQ in differentiating physically inactive individuals from the active among the study sample (AUC=0.64, 95% CI 0.61–0.68) and overweight and obese individuals (AUC=0.67, 95% CI 0.61–0.73), Figure 2 in paper III.

Discussion

We have conducted a cross-sectional survey of body weight and physical activity in a population-based sample of 1,210 adults in rural and peri-urban Uganda within the IMHDSS. This study can be used as a baseline for any future studies of body weight and physical activity. In this section, we will first discuss our findings, then the methodological considerations before we make conclusions.

Discussion of the main findings

Prevalence of overweight and obesity and associated factors

Our study shows that the prevalence of overweight and obesity among adults aged 18–92 years in peri-urban and rural eastern Uganda was substantial (25.2 %) implying that 1 in every four adult was either overweight or obese. This finding is comparable to findings in previous studies in Uganda specifically, the national NCD risk factor survey found an adult prevalence of overweight and obesity of 19.1 % [101]. Similarly, the prevalence of overweight and obesity of 22.3 % was found among adults aged 25 years and above in Kasese district in rural Uganda [107]. A study among 35–60 year old adults in rural eastern Uganda reported a prevalence of overweight and obesity at 17.6 % [105]. However, our prevalence estimate was higher than 11.3 % [104] and 11.8 % [106] among individuals aged 13 years and above in rural south-western Uganda, possibly due to differences in the year of study and the age composition of the populations under study.

Our findings are in consonance with findings elsewhere in Africa. For instance, the prevalence of overweight and obesity in Malawi was found to be 21.9 % [148], 29.2 % in Nigeria [149], 20.1 % and 22.2 % among normotensive and hypertensive Nigerian adults, respectively [150] and 27.1 % in rural Ghana [151]. In comparison to other African studies, our prevalence estimate of overweight and obesity was lower than 37.1 % in Ghana [151] and 31.6 % in Nigeria [152], probably due to differences in the definition and assessment of the rural-urban divide.

The socio-demographic factors found to be associated with overweight and obesity included female sex, increasing age, peri-urban residence and higher SES quintiles. The association between female sex and overweight and obesity has been showed in studies in Uganda [105], Zambia [153], Malawi [148] and Mozambique [154]. Additionally, a higher prevalence of overweight and obesity and obesity alone among women compared to men has been shown in Uganda [101, 106, 107] and other African studies [99, 148, 151-161]. However, our finding was not consistent with findings in Nigeria [149] and specifically in HICs, men have a higher prevalence of overweight and obesity than women [162-164]. These difference could be due to primarily dietary and physical activity behaviours

[165]. Additionally, a number of African studies have indicated a social desirability for overweight and obesity particularly in women and its perceived association with affluence [166-169]. The link between increasing age and overweight and obesity has been documented in previous African studies [105, 148, 154, 159]. Additionally, the highest prevalence of overweight and obesity among adults aged 45–54 years has been shown in Africa [105, 148, 154].

Peri-urban residence was associated with overweight and obesity. This finding is consistent with findings in Africa [105, 159], but differed with findings in urban Zambia [153]. The high prevalence of overweight and obesity among peri-urban residents is comparable with previous findings in Africa [105]. Additionally, the high prevalence of overweight only and obesity only among peri-urban residents are comparable with findings in SSA [148, 151-154], but less than findings in South Africa [170, 171]. The high prevalence among peri-urban residents could be attributed to changes in dietary and physical activity behaviours as a result of changes in the physical environment. In SSA, the changes in lifestyle in peri-urban populations may be similar to but not to the extent of urban populations. Most studies in SSA reported a high prevalence of overweight and obesity among in urban areas compared to rural areas [99, 148, 151, 153, 154, 156, 157, 159, 161, 165, 170-176] due to changes in diet and physical activity levels [9, 177]. The urban populations have increased access to unhealthy high energy and fat foods and reduced physical activity resulting from engaging in occupation activities that encourage sedentary behaviour. Studies in SSA have shown that exposure to urban environment increases the risk of obesity [175, 178, 179]. Potentially these arguments may be applicable to peri-urban populations. However, most of the studies have limited their findings to urban-rural dichotomy and therefore, data from on overweight and obesity among peri-urban populations in Africa remains scarce.

We found that higher SES quintiles was being associated with overweight and obesity. This has also been reported elsewhere in Africa [105, 180] and other LMICs [181]. These findings may be a result of increased access to affordable high energy dense foods [182] and decline in physical activity due to urban sprawl [180]. It is interesting to note that in HICs an inverse relationship has been found: an increased likelihood of overweight and obesity among populations of low SES. This inversion of relationship remains largely unexplained, but there are two other factors with a similar inversion of relationships between LMICs and HICs: smoking and breastfeeding. Differences in the physical enviroment and measurement of SES may partly explain the discrepancy.

Sedentary behaviour, physical inactivity and associated factors

This predominantly rural population accumulated almost a mean of 10,000 steps/day but with a wide spread. This mean is demonstrative of an active lifestyle according to the daily adult graduated step index [13]. This finding is similar to

findings in Belgium [183] and a meta-analysis involving studies from America, Australia, Japan, England, Canada, Finland and Switzerland [184]. The high activity levels could partly explain the high proportion of individuals with a normal weight in our study. In comparison to findings from studies among adults in USA [185, 186], China [187] and a multi-country study involving America, Canada, France and Sweden [188], our study population were found to be more active. The differences in occupational and transportation PA, the physical environment and the duration of step data collection across studies could explain the variability in the findings. Additionally, men were more physically active than women according to the pedometer and this pattern was consistent with the GPAQ. These findings have been replicated in South Africa [189], Belgium [183] and the USA [185].

Importantly, the prevalence of objectively assessed sedentary behaviour and physical inactivity were substantial among the predominantly rural adult population. These findings imply that parts of this population may have an increased risk to developing NCDs. Our findings on high prevalence of physical inactivity are consistent with findings from a previous study among Nigerian adults [190]. However, our findings differed with previous studies in SSA [189, 191]. The marked contrast in findings could be due to differences in PA definition used, the measures, response rate, age composition of the study population and the physical environment.

Factors associated with sedentary behaviour included female sex, being aged 65 years and above, peri-urban residence, having attained lower primary education and occupational activities of domestic work/student/formal employment. Physical inactivity was associated with female sex, age of 55 years and above, peri-urban residence, overweight and obesity. A higher prevalence of sedentary behaviour and physically inactivity among women than men has been affirmed in previous studies [127, 192, 193] and may explain the increased likelihood of women being overweight and obese than men. The average age of the study population was 42.8 years and one possible explanation to the difference in PA across sex may be a shift of labour to the younger generation in the household. Additionally, women often are involved in activities characteristic of light-to-moderate intensity while men tend to be involved in moderate-to-vigorous intense activities and spend a shorter time in sedentary activities [191].

The relationship between older age and sedentary behaviour and physical inactivity has previously been described in studies in Africa [127, 193] and elsewhere in both women and men [194], much as different PA measures were used. Barriers to an active lifestyle in older populations such as lack of social support, health problems and fear of falling may explain this finding. However, our findings contrast with findings in New Zealand, China and Hong Kong, where older adults had increased PA probably due to increased access to supportive

recreational PA facilities in New Zealand and the walking culture in China and Hong Kong [22].

The association between peri-urban residence and sedentary behaviour and physical inactivity may be as a result of peri-urban populations just like to the urban populations may engage in occupations and use motorised means of transport that are sedentary in nature as opposed to the rural populations who are involved in active transport and labour intensive occupations like agriculture [191].

The inverse relationship between PA and increasing level of education has been reported in studies in Cameroon [191] and Vietnam [195] and may be explained that persons who have attained low education status could be involved in occupations that are labour intensive as well as use active transport in so doing, they are attain high PA levels.

Potential implications of our findings

Our findings on the BMI in the study population imply that the transition from low BMI to high BMI has already started in this population specifically in the sub-groups of females, peri-urban residents, adults who are middle age and above and of higher SES quintiles. Uganda, like many of the countries in SSA, is still faced with the high burden of the communicable diseases, persistently high rates of undernutrition and now the growing the burden of NCDs and their risk factors. In light of this, a multi-sectoral approach with a focus on environmental supports for lifestyle behaviours may have larger chance of success. In this approach, lifestyle and nutrition education on the role of healthy diets, regular PA, active living and reduction of sedentary behaviours in prevention of overweight, obesity and NCDs in addition to self-monitoring of weight and PA at population level may be necessary. At national level, structures like the National Physical Planning Board may need to formulate and implement planning policies, standards and regulations for urban planning and transport that influence development of physical plans at different levels so as to influence PA environments. Physical planning committees at the district level may need to develop and implement urban physical development plans that influence the environment to promote PA. Stakeholders like the Ugandan ministries of Health, Agriculture, Animal Industry and Fisheries, and Trade, Industry and Cooperatives, food industries, food advertising industry and NGOs may need to be involved in formulating and implementing food policies that promote healthy and safe food choices like food and nutrition labelling and restriction of food marketing and advertisement of unhealthy beverages and foods.

Much as the health systems in most LMICs are severely challenged with the double burden of communicable and NCDs, are still largely configured towards addressing communicable diseases only and have weaknesses across health

systems building blocks, it may not be practical to massively screen at population level. Therefore, the most appropriate approach may be to employ early detection of overweight and obesity and their comorbidities by health workers at the health facilities particularly among the high risk groups as indicated by our data for targeted lifestyle modification interventions.

Our findings on physical activity show that a high proportion of the population is active. However, our data also shows that a significant proportion of the population are sedentary, taking less than a mean of 5,000 steps per day and are physically inactive, taking less than a mean of 7,500 steps per day. These findings suggest that there is a reduction in levels of PA in sub-groups of the population, which may result in an increased risk of developing NCDs and a reduction in the life expectancy. Therefore, a targeted approach is required for promotion of PA, prevention and control of overweight and/or obesity and NCDs among the high risk populations.

Much as overweight, obesity, physical inactivity and sedentary behaviour are public health priorities, there has been limited surveillance of NCD risk factors at population level in Uganda. The UDHSs provide limited NCD-related surveillance data on body weight specific to women and young children. Of recent, the first ever national WHO NCD risk factor survey provided data on overweight and/or obesity, physical activity and sedentary behaviour in addition to other relevant data. However, data on PA and sedentary behaviour are based on self-reports that have their known weaknesses. Few population-based studies on NCDs and their risk factors have been conducted in some of the geographical regions of Uganda. Much as there are efforts to generate NCD data in some geographical areas and at national level, it is not known if there is a plan for continued surveillance on NCD risk factors. Therefore, there is a need for surveillance on BMI, physical inactivity, sedentary behaviour and the associated factors in the adult population so as to generate evidence on temporal trends at population level for public health action.

Validity of the GPAQ in comparison to the pedometer

We found a weak correlation for PA between GPAQ and pedometer (rho=0.27), which is comparable with findings from previous studies. For instance, in a nine-country study, the validity of the GPAQ version 1 among 2,657 adults was weak (rho=0.31) for total PA score in comparison with pedometer step counts, paper III Table 5. The criterion validity evidence of GPAQ against the pedometer for total PA by country indicated weak correlation for countries namely: Province of Taiwan, China (rho=0.35), Ethiopia (rho=0.31), India (rho=0.35), Indonesia (rho=0.30) and Japan (rho=0.23) with the exception of Bangladesh that had a very weak correlation (rho=0.06) [25]. A study among 251 Vietnamese adults indicated that GPAQ total PA weakly correlated with the pedometer for those who had stable work patterns (r=0.39) [47]. A validation study of GPAQ among 262 individuals aged 15–65 years in urban and rural India found weak validity

evidence of GPAQ total PA in minutes/week (rho=0.35) and total PA in MET minutes/week (rho=0.36) in comparison with the pedometer [196]. Conversely, our findings differed from findings showing no correlation (rho=0.08, p=0.15) in a study among office workers in Bangkok, Thailand probably as a result of differences in the study population, cut-offs used for categorisation of step data, sample size and sampling method used [197]. These findings raise concerns on the usefulness of GPAQ alone for PA assessment. With the availability of affordable and reliable pedometers on the market, increasingly it is paramount to objectively assess PA in addition to questionnaires in future studies.

Our findings of slight agreement scores (kappa=0.03–0.09) among the study sample, men, women, overweight and obese individuals, peri-urban and rural residents for total PA between the GPAQ and pedometer suggest that the validity of GPAQ in different sub-populations is poor. Our findings were inconsistent with findings from a previous validation study in urban and rural India that found the level of agreement between the GPAQ and pedometer was moderate for sample (kappa=0.58), males (kappa=0.52), females (kappa=0.51), rural areas (kappa=0.55) and urban areas (kappa=0.53) [196]. This could be due to differences in the sample size, sampling method used, brand and specifications of the pedometer and targeted age group. Importantly, poor validity measures of GPAQ suggest that there could be considerable misclassification of GPAQ-assessed PA which has implications on the prevalence estimates of inactivity and activity. In turn, this would influence the ability of the study to detect associations between PA and its correlates [198] that have a bearing on the developing, implementing and evaluating PA promotion interventions.

Regarding the usefulness of the GPAQ in assessing PA in predominantly rural settings, the questionnaire is one of the most commonly used, practical and economically feasible method that is applicable in various settings. It focuses on activity domains of work, transport and recreation [25]. However, the GPAQ appears to invalidly assess the duration of PA because its overestimation has been linked higher PA levels [199]. The GPAQ relies on recall which could potentially introduce bias. Additionally, the perceived concepts of ‘a duration of at least 10 minutes’ and varying intensities of activities leading to errors in interpretation and responses in reference to the International Physical Activity Questionnaire long form (IPAQ-LF) [200] are also applicable to the GPAQ.

On the other hand, this study demonstrates the usefulness of pedometers in objectively assessing PA in a large population-based study. Importantly, pedometers provide comprehensive, accurate and reliable estimates [82] of overall volume of habitual PA which therefore eliminates recall and interviewer biases. Additionally, they are simple to use and relatively affordable in comparison to other objective PA assessment methods like accelerometers [183]. However, they have their limitations like variability in the mechanisms of

detecting steps across brands [201], insensitivity to non-ambulatory activities [202, 203] and do not provide information on the type of activity performed. In light of these arguments and findings from our study, the utility of GPAQ may not be optimal for assessing PA at an individual level [204].

In summary, our data suggests that there may be a need to improve the current version of GPAQ and complement it with a new standardised method for PA assessment based on objective assessment methods given that PA is a complex construct with various dimensions like types, duration, intensity, location and domains of activity and each PA assessment methods differ in the aspects that are being measured. Forms of the modified GPAQ could be considered for inclusion into routine primary care screening targeting particularly people aged 55 years and above.

Methodological considerations

Design
Our survey was cross-sectional in nature and therefore it is difficult to draw inferences on causality. However, the objectives of the studies were to describe the distribution of BMI, to determine the prevalence of sedentary behaviour and physical inactivity and to determine factors associated with overweight and/or obesity, sedentary behaviour and physical inactivity. Another objective of the studies was to compare the GPAQ to pedometer measure to assess if the GPAQ may be an appropriate tool for PA surveillance in low-income settings. Additionally, the survey included a large population-based representative sample of adults aged 18–92 years and therefore the sample size was sufficient for relevant analyses for comparisons between sub-groups. The studies have generated useful information from resource constrained settings particularly, paper II and III are among the first few that have been conducted among adults in peri-urban and rural Africa.

Study context
The study was conducted in the IMHDSS where there is continuous data collection on key demographic and health characteristics in addition to special studies which may result into respondent fatigue and a reduction in participation rate. These limitations were anticipated and mitigated by using the IMHDSS field coordination team to gain entry into the field. Additionally, the village based scouts and local leaders were sensitised about the study prior to data collection so that they could inform the community members about the study. The field research team composed of individuals who were known to the communities, experienced in research and have continuously been involved in studies undertaken in the IMHDSS.

Given that the IMHDSS population is continuously under observation, there is a possibility that the population may have better health indicators compared to other populations in similar settings because regular assessments may serve as a passive intervention. Additionally, there is a possibility that this population may be exposed to studies on NCD interventions that could influence our study findings. However, at the time of the survey there were no ongoing studies targeting NCD risk factors of overweight, obesity and PA that could potentially influence the findings of our studies.

Measurement of socio-behavioural and physical characteristics

The methods used for obtaining information from respondents have a bearing on the validity of the findings. A combination of objective and subjective methods of data collection were used to provide comprehensive information regarding socio-demographics, PA and anthropometric measurements of body height and weight in rural Uganda. The objective methods included the use of pedometers, portable stadiometers and digital weighing scales while the subjective measure included a questionnaire. However, self-report questionnaires can have biases due to recall, social desirability, misreporting and comprehension and errors during measurements [37, 38] which may influence the validity of the findings. Recall bias may have occurred when the respondents were asked about the activities they usually engage in across the different intensities of PA over a week's period. Differential recall of activities of different intensities may have occurred. Individuals may be less likely to recall activities of moderate intensities as opposed to those of vigorous intensities because most activities are largely of moderate-intensity and may be integrated in our day-to-day routines. In light of the limitations of self-report measures, validated questionnaires and pedometers were used for PA assessment. For instance questions on PA were obtained from the GPAQ that was developed by WHO for PA surveillance in developing countries [29] and it is part of the WHO NCD risk factor surveillance systems. Questions on socio-demographic characteristics were obtained from validated tools used in IMHDSS and UDHSs [103]. The household items used to create the SES index used in this study were first subjected to reliability analysis and fourteen household items of high internal consistency (Cronbach's Alpha = 0.732) were used to create the index.

Pedometers provide objective accurate and reliable information [82] which takes care of biases as a result of recall and assessors as opposed to physical activity questionnaires that provide subjective data. The pedometer brand used in the study was not validated in population-based studies. However, the pedometer brand used in the study has TriAxis sensor technology that allows the placement of the device on either the wrist or in pocket thus ensuring a high accuracy of 95 % in step detection. Other limitations include variations in the detection of steps across different brands of pedometers [205] and inadequate assessment of non-ambulatory activities such as cycling and weightlifting [202]. Additionally, they

do not record the type of activity or the domain of activity (work, active transport and recreation), and the potential mis-classification of non-ambulatory activities. We used the GPAQ to provide complementary PA data across the domains of work, active transport and recreation. The combination of two PA assessment methods departs from many other studies that use questionnaires and provides an opportunity to compare these methods in a population that is predominantly naïve about wearable technologies for PA assessment.

The adult graduated PA index was used to determine the prevalence of sedentary behaviour, physical inactivity, low activity, somewhat activity, activity, high activity [13]. This index was originally created based on pedometer data from 22 studies of small sample sizes among adults aged 19–82 years [206] and therefore the index has its limitations. Step counting devices vary across brands in the mechanism of step detection and counting [205, 207] and sensitivity [208]. There are various brands of step-counting devices that are available that can be worn on the wrist, arm and ankle, in the pocket, at the waist, as an earpiece and as apps on smart phones [142]. However, they have limitations like the mechanisms of step-counting and detection change are different and patent protected, they become outdated with new versions of the instrument introduced to the market and step-based outputs do not certainly imply that they assess the same behaviour [209]. Another concern is optimal duration of wear time of the device. Devices with time-stamping technology provide additional information that can be used to assess for duration of wear time. However, data indicates that the influence of duration of wear time on steps per day data is minimal [210, 211].

Body mass index is based on height and weight measurements and therefore is an indirect measure of body fat. As an indirect measure of body fat, BMI has inherent drawbacks which can result into misclassification of weight status of individuals, which in turn introduces bias in findings [212]. First, its inability to reflect the actual body fatness [213-215] and its distribution as a result of disparities in sex, age, ethnicity and types of obesity [216]. Second, BMI is limited in assessing for risk of obesity-related diseases among individuals with low muscle mass and high body fat [217] and those with high percentage of body fat and normal BMI [216]. Third, BMI can either under- or over-estimate body fat. For instance, some chubby elderly people with low muscle mass can have normal or even low BMI or lean individuals with high muscle mass can have a high BMI. Fourth, the nonlinear relationship between BMI and percentage of fat suggests that some individuals may have similar body fat percentages and yet different BMI scores [212]. All these drawbacks are true on an individual level, however, at a population level they are unlikely to produce large errors because these issues would even out [218]. Second, BMI was used as a proxy indicator for risk of NCDs since it is not obvious that body fat is a better proxy than BMI. Third, BMI is the most frequently used measure for overweight and obesity. Fourth, the field team was rigorously trained in conducting height and weight measurements

following the standard protocols. Intra-rater reliability was assessed for both height and weight measurements within participants and the ICCs for height and weight measurements were 0.982 and 0.960 respectively, indicative of well above acceptable levels [139].

Confounding
Logistic regression analysis was used to control for confounders in paper I and II. All variables that were found to be associated with the outcome variables ($p < 0.10$) at bivariate analysis were included in the logistic regression model using backward selection procedure.

Generalisability/external validity
The IMHDSS is geographically localised in rural eastern Uganda and has been curved out of two districts namely Iganga and Mayuge. It could therefore be argued that this area is not representative of the entire eastern region and therefore there could be limitations of making inferences from the data to other regions or nationally. However, comparison of the IMHDSS and DHS data for instance on the prevalence of underweight and overweight among the adult population demonstrates congruence between both approaches (in paper I; [102]). This has also been observed in Ethiopia where the overall mortality patterns were comparable between both methods [219].

The basic demographic information of the IMHDSS population is continuously updated thus providing an appropriate sampling frame from which a probability sample can be drawn for the studies. Probability samples are highly representative and generate findings with less biases which can definitely be generalised to the adult population in the IMHDSS.

Therefore, we are of the view that the findings of this population relating to prevalence of overweight and/or obesity, sedentary behaviour and physical inactivity and their associated factors are also generalisable to similar adult populations in East Africa and perhaps also beyond. Populations with markedly different lifestyles such as the Karamajong pastoralists may require their own studies. The wide age range in our study including young-, middle- and older aged adult populations increases its generalisability. Similarly, validity findings of the GPAQ in comparison to the pedometer measure as the criterion can also be extrapolated to similar settings.

Conclusions and recommendations

Conclusions

The prevalence of overweight and/or obesity among people aged 18 years and above in this predominantly rural setting are substantial, especially among the women, middle aged adults, adults of higher socioeconomic status and adults residing in peri-urban areas.

There is a substantial prevalence of sedentary behaviour and physical inactivity among the predominantly rural adult population aged 18 years and above, indicating the need for PA promotion interventions.

The concordance between the GPAQ and pedometer in assessing PA in different sub-populations in peri-urban and rural Uganda was poor, implying that GPAQ alone may not adequately assess PA at an individual level.

Recommendations

Recommendations for policy and practice
Based on our findings and the assumption that they are generalisable to most of the Ugandan population, the following conclusions have been drawn.

- Uganda has a substantial prevalence of overweight and/or obesity, physical inactivity and sedentary behaviour. It is imperative that appropriate population-based public health policies and interventions aimed at prevention and control of overweight and/or obesity and promoting PA are developed, tested and implemented.
- Population-based lifestyle and nutrition education on the importance of healthy eating and regular PA in prevention of obesity and NCDs in addition to self-monitoring of weight and PA may be necessary to avert escalation of risk.
- A high risk approach involving screening of body weight and PA of patients with a certain profile who are seeking outpatient services may be necessary for the different sub-populations. Additionally, motivational counselling for goal setting either individually or in groups may need to be done by health workers with patients who have presented at the outpatient clinic.

Recommendations for future research

Our study findings have highlighted the need for further research on the following:

- Understanding the perceptions about body weight, PA and diet in the general population
- Examining the relationship between the rural physical environment and socio-cultural environment.
- Population-based data on objectively-assessed NCD risk factors like diet, physical inactivity and sedentary behaviour and their correlates like social and physical environment in Africa.
- Physical activity assessment studies in the future require objective PA assessment measures like pedometers and accelerometers because questionnaire data alone are insufficient among populations in Africa.
- Future similar surveys in the IMHDSS have the potential of monitoring changes in BMI and PA over time.

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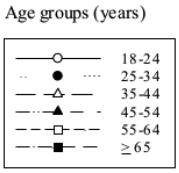
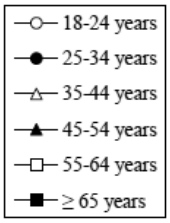
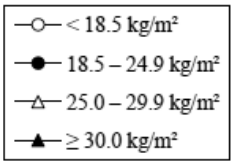
Errata list

Errata	**Was**	**Now reads**
Page 15, second para Acknowledgements	Dr. Lynn Atuyambe	Assoc. Prof. Lynn Atuyambe
Page 26, third para	Across the WHO regions, the Americas has	Across the WHO regions, the Americas have .....
Paper I, figures 1, 2 and 3	Missing legends	
Paper II, figure 2 on page 1248 of the article.	Missing legend	
Paper II, figure 3 on page 1249 of the article.	Missing legend	

Paper I

Kirunda et al. BMC Public Health (2015) 15:1168
DOI 10.1186/s12889-015-2506-7

BMC Public Health

RESEARCH ARTICLE Open Access

Population-based survey of overweight and obesity and the associated factors in peri-urban and rural Eastern Uganda

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Abstract

Background: In sub-Saharan Africa (SSA), the rising prevalence of overweight, obesity and non-communicable diseases co-exists with the high burden of under-nutrition. The paucity of data on adulthood overweight and obesity, disaggregated by socio-demographic characteristics and in rural settings in SSA calls for research. We determined the prevalence of underweight, overweight/obesity and associated factors among adults in peri-urban and rural Uganda.

Methods: A cross-sectional study of 1210 randomly selected adults aged ≥ 18 years was conducted in Iganga-Mayuge Health and Demographic Surveillance Site in eastern Uganda in 2013. Height, weight and socio-demographic variables were assessed. Overweight was defined as BMI = 25.0-29.99 kg/m^2, obesity ≥ 30 kg/m^2 and overweight/obesity ≥ 25 kg/m^2. Logistic regression was used to identify factors associated with overweight/obesity.

Results: Of the participants, 7 % were underweight (8.1 % of men; 5.9 % of women, $p = 0.99$); 17.8 % were overweight (12.4 % of men; 23.1 % of women, $p < 0.001$); and 7 % were obese (2.0 % of men; 12.7 % of women, $p < 0.001$). Overweight prevalence was 15.8 % and 23.8 % among rural and peri-urban adults, respectively ($p < 0.001$). Obesity prevalence was 3.9 % and 17.8 % among rural and peri-urban adults, respectively ($p < 0.001$). Factors associated with overweight/obesity were: being female, adjusted odds ratio (AOR) 4.3 (95 % confidence interval (PloS one 8:e75640, 20013) 3.2–5.9); peri-urban residence AOR 2.6 (1.9–3.6); being in age group 35–44, AOR 3.1 (1.8–5.3); 45–54 AOR 4.1 (2.3–7.3); 55–64 AOR 2.6 (1.4–5.0); ≥ 65 years AOR 3.1 (1.6–6.0); and having socio-economic status (SES) in the third AOR 2.8 (1.7–4.6), fourth 2.5 (1.5–4.2) and fifth 2.7 (1.6–4.4) quintile.

Conclusions: Overweight/obesity was prevalent among adults. Overweight/obese was associated with being female, being aged 35 years and older, residing in a peri-urban area and having a higher SES. The time has come to develop interventions to prevent and control overweight/obesity.

Keywords: Overweight, Obesity, Associated factors, Peri-urban and rural Uganda

Background

Worldwide, the prevalence of overweight and obesity are on the rise [1, 2] while the prevalence of under-nutrition has not significantly changed over the last decade [3]. While underweight prevalence is still high [4], overweight and obesity are now prevalent in low- and middle-income countries [4, 5], including those in Africa [1, 6], at a prevalence of 20–50 % [7–12] in urban areas and 7–30 % in rural areas [9–15].

In SSA, the rising prevalence of overweight and obesity co-exists with the under-nutrition epidemic [16, 17] and the increasing prevalence of non-communicable diseases (NCD) with an anticipated largest increase in NCD deaths of 27 % in Africa over the next decade [18]. Underweight, overweight and obesity are known risk factors for NCDs [19, 20]. Similarly, the Uganda Demographic and Health Surveys (UDHS) from 1995 to 2011 reported an increasing prevalence of overweight and

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obesity from 8 to 18.8 % while underweight prevalence stagnated at 10 – 12 % [21, 22].

However, evidence examining the influence of the individual, social and built environment on overweight/obesity is still patchy [23, 24] and limited to urban and suburban populations [24] in high-income countries which cannot be generalized to low- and middle-income countries [25] and this is even more true in rural settings.

The paucity of research on obesity and physical inactivity disaggregated by age, sex and residence [26] and the influence of the environment on overweight/obesity in Africa [25] calls for research in SSA [27] among peri-urban and rural populations in order to develop effective, culturally sensitive, context-specific and population-based interventions for the prevention of obesity and NCDs [25]. The objective of this study was to determine the prevalence of underweight, overweight and obesity and associated factors in a population-based sample of adults in peri-urban and rural Uganda.

Methods

Study design and setting

An observational cross-sectional study was conducted in 2013 among adults drawn from an active study cohort of 1 January 2005 to 30 September 2013 in the Iganga-Mayuge Health and Demographic Surveillance Site (IMHDSS) located in Iganga and Mayuge Districts in eastern Uganda, 120 km east of Kampala, the capital. The IMHDSS had an estimated population size of 80,000 people in 2013 of whom 51.2 % are females. The estimated number of households is 13,000 across an area of about 155 km^2. The IMHDSS is composed of 65 villages with about 38 % of the population residing in peri-urban villages. Routine data collection is regularly carried out for births, deaths and their causes, marriages, in- and out-migration, education and socio-economic status. In addition to these routine surveillance activities, data are also collected for special studies.

Study population and sampling

The study population comprised of men and non-pregnant women aged 18 years and above residing in the IMHDSS for at least 4 months, who had an individual identification IMHDSS number and were part of a household with an IMHDSS identification number. Adults who were ill, for whom physical activity was constrained or who were unable to communicate with the research team were excluded from participating in the study. Cluster sampling [28] was used to select participants from the active HDSS study cohort, with villages being the clusters. Probability proportionate to size sampling was used to select 40 villages, from which 30 households/participants were selected by simple random sampling using Stata data analysis and statistical software. From each village, an equal number of female and male respondents were randomly selected. In this study, a household was defined as a group of people who had been living and eating their meals together for at least 6 of the 12 months preceding the study. Study participants who were not found at their place of residence were replaced by individuals in neighbouring households who were matched by sex using the IMHDSS village lists.

Data collection strategy

A field team of ten research assistants and one supervisor underwent a three-day standardized training on the study objectives, administration of the questionnaire and physical measurements of body weight and height. A semi-structured questionnaire was used to collect quantitative data on physical measurements of body weight and height and socio-demographic variables including sex, age, residence, marital status, religion, education level, occupation in the previous month, average monthly earnings and ownership of assets for purposes of assessing socio-economic status. Validated questions on socio-demographic variables were adopted from the IMHDSS [29] surveillance data collection tools and the Uganda Demographic and Health Survey [22]. The questionnaire was translated into the local language and pretested in the neighbouring district to check on the ease of comprehension of questions and anomalies were corrected. The field assistants worked in pairs composed of a nutrition assessor and an interviewer so as to optimize the quality of anthropometric measurements. The questionnaires from the field were checked daily for errors and missing data by the quality assurance officer.

Outcome measure

For each study participant, anthropometric measurements of body height and weight were assessed using standard protocols, with subjects standing upright, not wearing shoes and wearing light weight clothes. Body height in centimetres (cm) was measured twice to the nearest 0.1 cm using Seca™ 213 portable stadiometers (Seca GmbH & Co. Kg., Hamburg, Germany). Body weight in kilograms (kg) was measured twice to the nearest 0.1 kg using calibrated Seca™ 876 digital weighing scale (Seca GmbH & Co. Kg., Hamburg, Germany). Final height and weight values were obtained as averages of the two measurements. The intraclass correlation coefficients (ICCs) for height and weight measurements within participants were 0.982 and 0.960 respectively, suggesting that intra-rater reliability was well above acceptable levels [30]. The outcome variable, body mass index was calculated and used as indicator of underweight (BMI <18.5 kg/m^2), normal weight (BMI = 18.5 – 24.99 kg/m^2), overweight (BMI = 25.0–29.99 kg/m^2)

and obesity (BMI ≥ 30 kg/m^2) using the international classification of BMI [31–33]. For further analysis, overweight/obesity was defined as BMI ≥ 25 kg/m^2 inclusive of the obese (BMI ≥ 30 kg/m^2).

Independent variables: socio-demographic factors

Age was recorded in complete years and significant past political or social local events were used as a proxy to estimate the ages of some respondents who did not know. Age in years was classified into 6 groups, namely 18 – 24, 25 – 34, 35 – 44, 45 – 54, 55 – 64 and ≥ 65 years. Marital status was classified as single, widowed/separated/divorced and cohabiting/married. Religion was classified as Catholic, Protestant, Other Christian, Moslem and Traditionalist. Residence was assessed using the HDSS peri-urban/rural classification which is based on population size, distance to Iganga town, access to amenities like piped water and mobility of the population. Education level was classified as none, lower primary, upper primary and secondary and above. Occupational activities in the previous month were classified as subsistence agriculture, commercial agriculture, casual labour, domestic work, student, trade and formal salaried employment. Average monthly earnings were assessed in Ugandan shillings (UGX) and classified as none, less than 60,000 (US$ 23), 60,000 – 100,000 (US$ 23 – 38) and more than 100,000 (US$ 38 (exchange rate September 2014: 1 US$ = UGX 2,620). Prior to creating the SES index, 27 items were checked for internal consistency using the Cronbach's alpha measure. Fourteen items namely: 1) radio, 2) mobile phone, 3) bicycle, 4) motorcycle, 5) table, 6) machete, 7) axe, 8) hoe, 9) cattle, 10) goats, 11) poultry, 12) land ownership, 13) kerosene lantern, and 14) charcoal iron were identified (Cronbach's alpha = 0.732) and used to create the SES index using principal component analysis. The factor scores of the first principal component were used to create 5 SES quintiles namely: first (poorest), second, third, fourth and fifth (least poor) [34].

Statistical methods

Double data entry was done using EpiData version 3.1 software, cleaned and exported to IBM SPSS statistics 19 for analysis. Descriptive statistics were computed and expressed by socio-demographic characteristics and BMI. The prevalence estimates for underweight, normal weight, overweight and obesity were computed as percentages with the total sample size as the denominator. Crude odds ratios (COR) and their 95 % CI were computed to check for associations between categorical variables. All factors significantly associated with overweight/obesity ($p < 0.10$) in the bi-variable analysis such as sex, age, residence, marital status, occupational activities and socio-economic status, were included in the logistic regression model. In addition, an alpha level of 0.10 was used as a criterion for retaining a variable in the final logistic regression model. Logistic regression was used to identify factors associated with being overweight and obese using AOR at 95 % CI.

Ethical considerations

Ethical approval for the study was obtained from Makerere University School of Public Health Higher Degrees Research and Ethics Committee (IRB00011353) and the Uganda National Council for Science and Technology (HS1322). Permission to conduct the study in the HDSS was also sought from the Iganga-Mayuge HDSS steering committee and written informed consent was obtained from each participant.

We report following the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: Guidelines for reporting observational studies [35].

Results

Characteristics of participants

Of the 1210 participants, 50.1 % were women, 73 % were married/cohabiting, 55 % were Moslems, 12 % had no formal education and 60 % were involved in subsistence agriculture as the main source of livelihood, Table 1. The mean and median age of women in years were 42.5 ± 15.3 and 40.0 (Interquartile range (IQR) = 31.0–52.0). The mean and median age of men in years were 43.2 ± 16.6 and 42.0 (IQR = 30.0–54.0).

Prevalence of underweight, normal weight, overweight and obesity

The mean and median height, weight and BMI for women were 1.58 ± 0.07 m, 1.59 m (IQR = 1.54–1.63), 61.1 ± 13.1 kg, 58.8 kg (IQR = 51.6–67.8) and 24.4 ± 5.1 kg/m^2, 22.1 kg/m^2 (IQR = 20.9–26.4). The mean and median height, weight and BMI of men were 1.68 ± 0.06 m, 1.68 m (IQR = 1.64–1.72), 62.0 ± 9.8 kg, 60.3 kg (IQR = 55.9–67.2) and 21.9 ± 3.1 kg/m^2, 21.3 kg/m^2 (IQR = 19.9–23.0). The mean and median age and BMI were 42.8 ± 16.0 years, 41.0 (IQR = 30.0–53.0) and 23.2 ± 4.4 kg/m^2, 22.1 kg/m^2 (IQR = 20.3–25.0) kg/m^2, Table 2.

Overall, 7 % of the participants were underweight, with no significant difference by sex (8.1 % of men vs. 5.9 % of women, $p = 0.99$). The prevalence of underweight was higher in rural areas at 8.1 % versus 4.0 % in the peri-urban areas, $p = 0.26$, Table 3. Among women of 55–64 years and ≥ 65 years, the prevalence of underweight was 14.1 % and 15.4 %, respectively; and among men, the prevalence of underweight was highest (17.3 %) in the oldest age group, 65 years and above, Additional file 1.

Eighteen percent of participants were overweight, with significant disparity by sex (12.4 % of men vs. 23.1 % of women, $p < 0.001$). Obesity was observed in 7 % of the respondents, with significant disparity by sex (2.0 % of

Table 1 Socio-demographic characteristics of study participants, $N = 1210$

Characteristics	Number *n*	Percent (%)
Sex		
Male	604	49.9
Female	606	50.1
Age groups		
18–24	167	13.8
25–34	247	20.4
35–44	297	24.5
45–54	222	18.3
55–64	137	11.3
≥65	140	11.6
Marital status		
Single	130	10.3
Widowed/separated/divorced	193	16.0
Cohabiting/Married	887	73.3
Religion		
Catholic	105	8.7
Protestant	364	30.1
Other Christian	74	6.1
Moslem	665	55.0
Traditionalist	2	0.2
Residence		
Peri-urban	298	24.6
Rural	912	75.4
Education level		
None	143	11.8
Lower primary	250	20.7
Upper primary	415	34.3
Secondary and above	402	33.2
Main occupation in the previous month		
Casual labour	85	7.0
Domestic work	73	6.0
Student	23	1.9
Subsistence agriculture	720	59.5
Trade	189	15.6
Commercial agriculture	69	5.7
Formal employment	51	4.2
Average monthly earnings (UGX[a])		
None	113	9.3
<60000	458	37.9
60000-100000	344	28.4
>100000	295	24.4
SES[b] quintiles		
First (poorest)	242	20.0
Second	244	20.2
Third	234	19.3
Fourth	263	21.7
Fifth (least poor)	227	18.8

[a] UGX, Ugandan shillings, [b]SES, socioeconomic status

men vs. 12.7 % of women, $p < 0.001$). The prevalence of overweight/obesity was 25.2 %. Overweight was more common in the peri-urban areas (23.8 %) compared to rural areas (15.8 %), $p < 0.001$, Table 3.

The prevalence of overweight was high in middle-aged adults, in age groups 35–44 years (29.1 % of women vs. 17.2 % of men) and 45–54 years (28.8 % of women vs. 17.1 % of men). In the younger age group, 25–34 years, the prevalence of overweight was high among women (21.8 %) compared to men (4.2 %). The prevalence of obesity was high (22.5 %) among women in the age group 45–54 years while the prevalence of obesity among men was highest (5.4 %) in the age group 55–64 years, Additional file 1.

Both men and women in the two oldest age groups (above 55 years) were shorter in height than those in the age groups below 55 years, Fig. 1. Among women, the age groups below 55 years were on average heavier than the age group ≥ 55 years while, for men, the middle age groups were heavier than other age groups, Fig. 2.

Table 2 Age, height, weight and body mass index (BMI) by sex

	Age (years)	Height (m)	Weight (kg)	BMI, (kg/m^2)
Women				
Mean	42.5	1.58	61.1	24.4
Median	40.0	1.59	58.8	22.1
SD[a]	15.3	0.07	13.1	5.1
IQR[b]	31.0–52.0	1.54–1.63	51.6–67.8	20.9–26.4
Men				
Mean	43.2	1.68	62.0	21.9
Median	42.0	1.68	60.3	21.3
SD[a]	16.6	0.06	9.8	3.1
IQR[b]	30.0–54.0	1.64–1.72	55.9–67.2	19.9–23.0
F test, *p*-value	4.93, 0.03	2.69, 0.10	36.44, 0.00	84.16, 0.00
Sexes combined				
Mean	42.8	1.63	61.6	23.2
Median	41.0	1.64	59.7	22.1
SD[a]	16.0	0.08	11.5	4.4
IQR[b]	30.0–53.0	1.57–1.69	54.2–67.4	20.3–25.0

[a] SD, standard deviation, [b] IQR, interquartile range

Table 3 Distribution of body mass index by sex, age and residence

Characteristics	Underweight %	Normal weight %	Overweight %	Obesity %	Chi-square value, *p*-value
Sex					
Male	8.1	77.5	12.4	2.0	85.3, < 0.001
Female	5.9	58.3	23.1	12.7	
p-value	0.99	Reference	<0.001	<0.001	
Age groups					
18–24	3.6	83.8	9.6	3.0	82.3, < 0.001
25–34	5.7	76.9	13.4	4.0	
35–44	5.1	62.6	23.6	8.8	
45–54	5.0	58.6	23.0	13.5	
55–64	11.7	65.0	15.3	8.0	
≥65	16.4	61.4	17.1	5.0	
Residence					
Peri-urban	4.0	54.4	23.8	17.8	82.0, < 0.001
Rural	8.1	72.3	15.8	3.9	
p-value	0.26	Reference	<0.001	<0.001	
Overall	7.0	67.9	17.8	7.4	

Among the middle age groups (35–44 and 45–54), women had a much higher BMI compared to men, Fig. 3.

Factors associated with overweight/obesity

Factors found to be associated with being overweight/obese were being female, age ≥ 35 years, peri-urban residence and higher SES. Females were 4 times more likely to be overweight/obese than males (AOR 4.3; 95 % CI 3.2–5.9). Participants who were aged 35–44 (AOR 3.1; 95 % CI 1.8–5.3), 45–54 (AOR 4.1; 95 % CI 2.3–7.3), 55–64 (AOR 2.6; 95 % CI 1.4–5.0) and ≥ 65 years (AOR 3.1; 95 % CI 1.6–6.0) were more likely to be overweight/obese than those aged 18–24 years. Peri-urban residents were 3 times more likely to be overweight/obese (AOR 2.6; 95 % CI 1.9–3.6) than rural residents. Participants who were in the third (AOR 2.8; 95 % CI 1.7–4.6), fourth (AOR 2.5; 95 % CI 1.5–4.2) and fifth SES quintiles (AOR 2.7: 95 % CI 1.6–4.4) were more likely to be overweight/obese than those in the first SES quintile, Table 4.

Discussion

In this study of randomly selected adults in rural and peri-urban eastern Uganda, we found a relatively low burden of underweight and a high prevalence of overweight and obesity, particularly among middle aged women.

Our findings of a low prevalence of underweight was lower than findings in rural Uganda [14, 15], Kenya [9] and Congo-Brazzaville [36] probably as a result of variations in the age groups studied, definition and measurement of rural–urban divide. However, our findings were similar to those of African studies in Malawi [11], Cameroon [7], Ghana [37] and Nigeria [13, 38]. The higher prevalence of underweight among men (8.1 %) than women (5.9 %) is in consonance with findings elsewhere in Africa [7, 9, 10, 14, 15, 37, 39–41]; however, some studies in Africa have reported an insignificant inverse relationship [11, 13, 38].

This peri-urban and rural adult population already has a high burden of overweight (17.8 %) or obesity (7.4 %), the two combined affect 25.2 % of the population, comparable to contemporary findings in rural eastern Uganda (17.6 %) [15] but contrasting with rural southwestern Uganda (11.3 %) [14], probably due to differences in the age composition of study populations. Our findings are consistent with findings in Africa of an overall overweight/obesity prevalence of 21.9 % in Malawi [11], 29.2 % in Nigeria [13], 20.1 % of the normotensive and 22.2 % of the hypertensive adult populations in Nigeria [42], and 27.1 % of rural residents in Ghana [37]. The overall prevalence estimate of overweight/obesity is less than the estimates in a few studies in Africa, such as 37.1 % in Ghana [37], and 31.6 % in Nigeria [38], probably as a result of differences in the definition and measurement of the rural–urban divide.

Being female was the most significant factor associated with being overweight/obese. This is in consonance with findings in Uganda [15], Mozambique [10], Malawi [11] and Zambia [43]. A higher prevalence of overweight, obesity and overweight/obesity among women than men are consistent with findings in Uganda [14, 15]. These findings are consistent with findings reported elsewhere in Africa for instance in Nigeria [38, 44], Kenya [9],

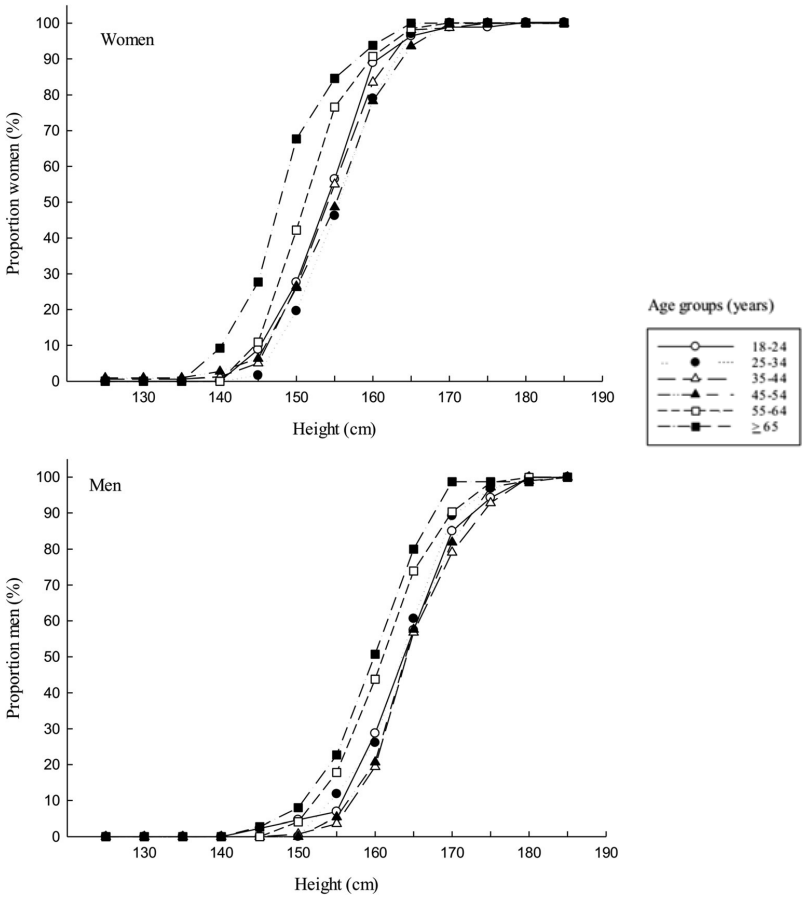

Fig. 1 Distribution of body height (cm) by age group, *top*) women, *bottom*) men

Mozambique [10], Malawi [11], Botswana [40], Ghana [37], Zambia [43], Tanzania [45], Algeria [39], South Africa [41, 46] and Cameroon [7]. However, they differ from the findings of one study in Nigeria [13] and studies in high income countries where men have a higher prevalence of overweight/obesity than women [47–49]. These differences can probably be explained by behavioural factors given that both men and women are exposed to the genetic, physical and social environment [12, 50]. In addition, studies in Africa have reported a social norm of acceptability, or even preference for overweight and obesity particularly among women and it is perceived to be associated with affluence [51–54].

Age was another factor found to be associated with overweight/obesity and has been found in other studies in Africa [10, 11, 15, 40]. It has also been observed that the prevalence of overweight/obesity was highest in the age group 45–54 years and this has been confirmed elsewhere in Africa [10, 11, 15]. Similarly mean BMI was highest in the middle age group, more evidently among the urban than rural residents in Kenya [9] and in Mozambique [10].

Our study affirms that peri-urban residence was another significant factor, similar to findings in Africa [15, 40] but contrasting with findings in urban Zambia [43]. It was also observed that the prevalence of overweight/obesity of 41.6 % among peri-urban residents is comparable to 35.7 % reported in peri-urban eastern Uganda [15]. Our study estimates of overweight and obesity of 23.8 % and 17.8 % among peri-urban residents, respectively, are comparable to 18.5 % and 13.1 % of overweight and obesity respectively in Nigeria [38] and also comparable to findings

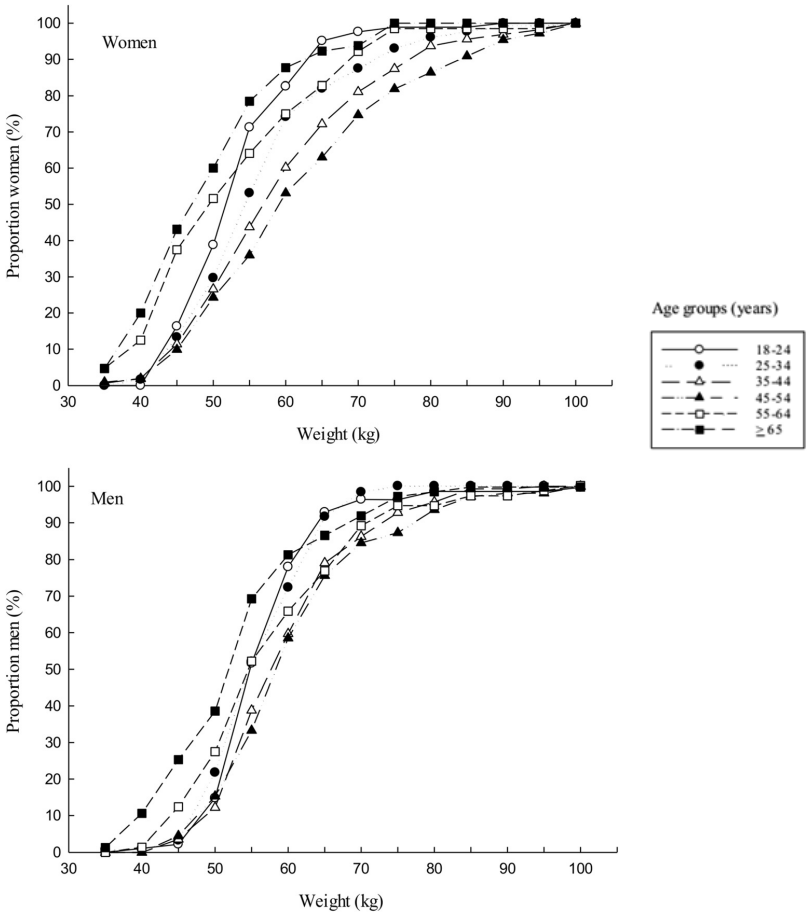

Fig. 2 Distribution of body weight (kg) by age group, *top*) women, *bottom*) men

in Zambia [43], Malawi [11], Ghana [37], Mozambique [10], Tanzania and Namibia [55]. Our prevalence estimate is lower than findings in South Africa [56, 57]. The prevalence of obesity among rural residents in our study is comparable to findings in rural Nigeria [44], Malawi [11] and Kenya [9]. A higher prevalence of overweight and obesity among peri-urban residents compared to rural residents could be attributed to rural residents being more actively involved in labour intensive subsistence farming [12] than peri-urban residents whose occupations may encourage sedentariness which is more common in urban areas. However, most studies in Africa have reported a higher prevalence of overweight and obesity in urban areas than to rural areas [9–12, 37, 39, 40, 58–61]. The data is often limited to an urban–rural dichotomy instead of presenting the whole spectrum and therefore, there is paucity on data on overweight and obesity among peri-urban populations in Africa.

An increase in the prevalence and likelihood of being overweight/obese was observed with increasing SES in our study, indicating that this population could be vulnerable to co-morbidities associated with being overweight or obese. These findings could be explained by the availability of affordable, high energy-dense foods due to urban sprawl, and reduced physical activity resulting into a sedentary lifestyle as observed in a study in Kenya where women who were most sedentary were in the highest income group [62] with the ability to purchase energy-dense foods [63]. These findings have been confirmed in studies in rural Uganda [15], elsewhere in

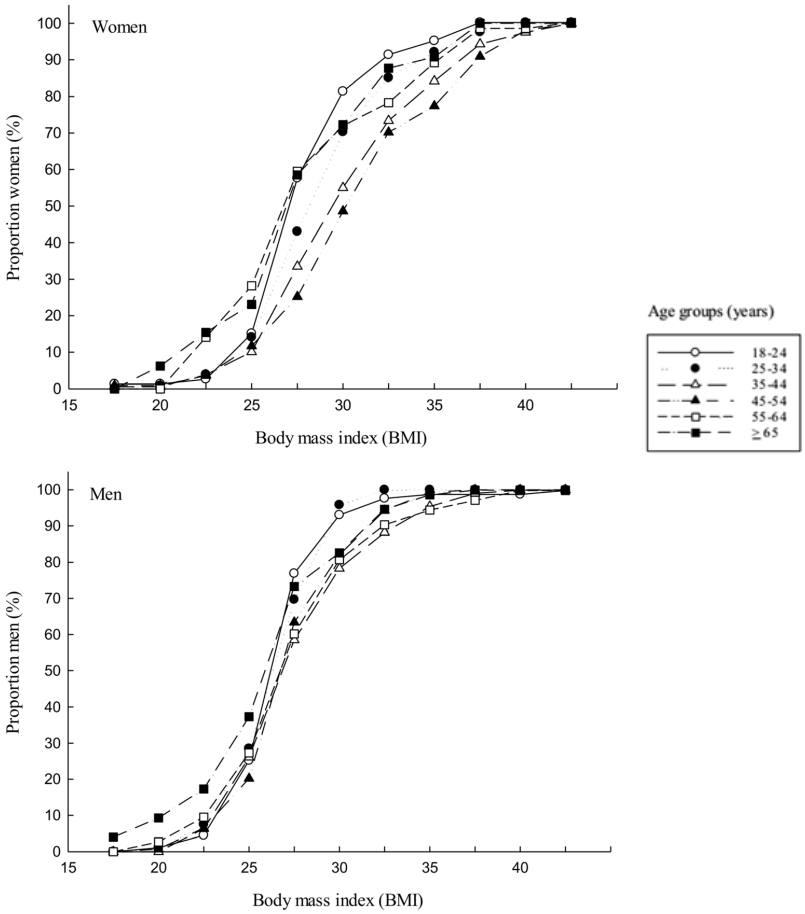

Fig. 3 Distribution of BMI by age groups, *top*) women, *bottom*) men

Africa [45, 62] and other low- and middle income countries [64], but are in contrast to findings in the high income countries, where the low-income earners are most likely to be overweight/obese. Due to differences in methods of measurement, analysis and categorisation of SES, cross-study comparisons were difficult and limited.

Strengths and limitations

The main strengths of our study include a large population based, representative study sample which allows comparisons, and a wide age group of 18–92 years, which included younger and older adults, who are often left out of surveys. A small number of trained measurers conducting repeated anthropometric measurements provided fairly accurate and consistent estimates. The SES index was based on relevant specific household items after checking the reliability of each of the items using item analysis. The international classification of BMI recommended by the WHO was used for categorisation.

The study had some methodological limitations. It was cross-sectional in nature and therefore we cannot infer causality. However, the motivation was to describe the distribution of BMI and provide cues to potential associations that can be further explored using robust study designs. Despite the inherent limitations of BMI as a measure of weight status, it remains the most widely used measure for assessing weight status in populations. We acknowledge the relevance of assessing proximate factors for overweight/obesity such as physical activity and dietary intake; however, this was beyond the scope

Table 4 Factors associated with being overweight or obese (body mass index, BMI ≥ 25 kg/m^2), $N = 1210$

Characteristics	n	Overweight or obese %	Crude OR[a] [95 % CI[b]]	Adj OR[a] [95 % CI[b]]
Sex				
Male	604	14.4	1.0	1.0
Female	606	35.8	3.3 [2.5–4.4]	4.3 [3.2–5.9]
Age groups				
18–24	167	12.6	1.0	1.0
25–34	247	17.4	1.5 [0.8–2.6]	1.4 [0.8–2.5]
35–44	297	32.3	3.3 [2.0–5.6]	3.1 [1.8–5.3]
45–54	222	36.5	4.0 [2.3–6.8]	4.1 [2.3–7.3]
55–64	137	23.4	2.1 [1.2–3.9]	2.6 [1.4–5.0]
≥65	140	22.1	2.0 [1.2–3.6]	3.1 [1.6–6.0]
Residence				
Rural	912	19.7	1.0	1.0
Peri-urban	298	41.6	2.9 [2.2–3.8]	2.6 [1.9–3.6]
Marital status				
Single	130	10.8	1.0	
Widowed/separated/divorced	125	27.5	3.1 [1.7–5.9]	
Married/cohabiting	887	26.7	3.0 [1.7–5.4]	
Religion				
Christian/traditionalist	545	23.5	1.0	
Moslem	665	26.5	1.2 [0.9–1.5]	
Education level				
None	143	30.8	1.0	
Lower primary	250	24.8	0.7 [0.5–1.2]	
Upper primary	415	21.9	0.6 [0.4–1.0]	
Secondary and above	402	26.6	0.8 [0.5–1.2]	
Occupation in the previous month				
Casual labour	85	16.5	1.0	
Domestic work/student	96	32.3	2.4 [1.2–5.0]	
Subsistence agriculture	720	20.8	1.3 [0.7–2.4]	
Trade	189	40.7	3.5 [1.8–6.6]	
Commercial agriculture	69	20.3	2.8 [1.3–5.7]	
Formal employment	51	35.3	2.8 [1.2–6.2]	
Average monthly earnings (UGX[c])				
None	113	22.1	1.0	
<60000	458	25.3	1.2 [0.7–2.0]	
60000-100000	344	25.3	1.2 [0.7–2.0]	
>100000	295	25.8	1.2 [0.7–2.0]	
SES[d] quintiles				
First (poorest)	242	15.7	1.0	1.0
Second	244	18.9	1.3 [0.8–2.0]	1.5 [0.9–2.4]
Third	234	29.9	2.3 [1.5–3.6]	2.8 [1.7–4.6]
Fourth	263	28.1	2.1 [1.4–3.3]	2.5 [1.5–4.2]
Fifth (least poor)	227	33.5	2.7 [1.7–4.2]	2.7 [1.6–4.4]

[a] OR odds ratio, [b] CI confidence interval, [c] UGX Ugandan shillings, [d] SES socioeconomic status

of this study. Given that the study was undertaken in the IMHDSS, where there is continuous data collection of demographic characteristics and special studies, during the time of the study, there were no interventional studies on NCDs. Data on human immunodeficiency virus (HIV) was not collected and yet it could have confounded the anthropometric measurements given that wasting and lipodystrophy are characteristic presentations [65]. However, HIV prevalence in the East Central Region where the IMHDSS is located is relatively low at 5.8 % [66], which would not confound the overall picture. Data on the physical and social environment were not collected and yet there are indications that the environment influences lifestyle behaviours such as physical activity and diet, which have an impact on the prevalence of overweight and obesity.

Conclusions

In the predominantly rural adult population, the prevalence of overweight and overweight/obesity are already high, particularly among women, middle aged adults, peri-urban residents and adults in the higher quintiles of SES. Overweight/obesity appears to occur in significant proportions among young adults, particularly the women. The time has come to try to prevent and control overweight/obesity. Further inquiry is required to understand the perceptions of weight, diet and physical activity in the general population, and describe dietary diversity and physical activity, as well as the influence of the rural physical and social environment on diet, physical activity and BMI so as to guide the design and implementation of appropriate strategies for the prevention and control of overweight and obesity in similar populations.

Additional file

Additional file 1: Distribution of body mass index by age, sex and sexes combined. Description of data: The table provides details on the distribution of different groups of body mass index stratified by sex and age groups. (XLSX 11 kb)

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

BEK, LTF, HW, JVB and TT formulated the research questions and designed the study. BEK, JVB and TT elaborated the data gathering methods and database architecture. BEK implemented the study. BEK, LTF, HW, JVB and TT performed the data management and statistical analysis. All authors were active in the interpretation of the results. The article was prepared by BEK, LTF, HW, JVB and TT. All authors have approved the final article.

Acknowledgements

We thank all the men and women who participated in this study. We also thank the field data collection team for their dedicated and tireless effort to ensure that data collection was successfully completed. This work was supported by the University of Bergen and the Quota Scheme administered by the Norwegian State Educational Loan Fund. These institutions had no role in the design, analysis or writing of this article.

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Received: 28 April 2015 Accepted: 17 November 2015
Published online: 24 November 2015

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Appendices

Appendix I: Informed consent form

Introduction: Okweyandula: Good morning/afternoon/evening Sir/Madam..... My name is ..... and my colleagues are..... .....(mention your names). We are a team from Makerere University School of Public Health, Uganda. We are conducting a study titled "*Effect of built, natural and social environment on diet, physical activity and body mass index in adult rural population in Uganda*". *Mwasuze mutya musubyemutya mwena. Amanya gange nze ..... era nebanange beba ..... (yogera amanya gamwe). Tuli jubinja nga tuva Makerere University School of Public Health, Uganda. Tulikukola okunonenkereza okugema kungeri endya, okulabirira omubiri nokuzimba omubiri yebikosebwamu embera eyabulida mubitundubyaife mubantu abakulu abomubyalo mu Uganda.*

Purpose of the study: The objectives of the study are to assess communities' perceptions of rurality and its influence on diet, physical activity and body mass index, the prevalence of underweight, overweight and obesity and investigate the influence of the environment on diet, physical activity and body mass index of an adult rural population aged 18 years and above in Iganga-Mayuge demographic surveillance site in Uganda. *Ebigendererwa byokunonenkereza kuno tilikwenda kufuna ndowoza edengeri eyokuba mukyalo nangeriki yekiyinza okukosamu ebyendya, emirimu gyabulido nokukosa omubiri, embera eyokukoiga oba okugeda eino, okugeda eino, era nokunonenkereza kubuzibu obuva kubitwetoloire nga bikosa ebyokulya, ebikolebwa nokuzimba omubiri mubantu abakulu mubyalo abaweza emyaka eikumi nomunaana nokusingawo mu DSS mu Uganda.*

Research procedure: Emitendera egyokunonenkereza: We have selected a sample of adults of which you are one of the selected to participate in this study. The study procedures involve asking you questions using a questionnaire; taking your weight and height measurements using a digital weighing scale and a height measure respectively; wearing an accelerometer watch which is a small device which will measure physical activity continuously during the day and night for 7 days and only remove when you are going to bath or shower and filling out two record sheets to record the duration and time of physical activities you have been doing for 7 days. I request you to participate in this study and provide us with honest answers to our questions. There are no "right" or "wrong" answers as we want information based on your experiences, observations and feelings. Please feel free to ask for clarifications where needed. You do not have to reveal any personal information if you do not want to. The questionnaire usually takes _____ minutes to complete. *Twida kwetaga okunumya mukibinja nimwe kitusobozese okufuna amawulire agagema kuntegera yaimwe kumbera yekyalo nokunmana endowoza yaimwe kungeriki embera eyekyalo yekosamu emirimo jabulido, endya, nendabirira yomubiri. Omuku iffe aidha kutubisa mulupapula olwebibuzo nimunange aidha kuwandiika asobole okubona nti bulikimu kyemutukobeire akiwandiise wansi nga bwekyogeirwa. Okwongera kwekyo, akaradiyo akagema amalobozi kona kaidha kukozesebwa okusobola okugema amalobozi gaiffe kitusobozese obutasubwa kintu kyona kyona kyemutukobye. Wazira kintu kitufu oba kifu kubanga tulikwenda amawulire kunsinziira nga buli muntu bwategera ekintu, bwakibona era bwalowooza. Oliwaidembe okubuza wekenenie wa wotategeire. Tikikwetagisa kwogera byama bikugemaku bwoba tiwetaze kubyogera. Ebibuzo bitela kutwala dakika _____ okumaliriza*

Benefits and risks: Emiganulo n'obulabe: There are no direct benefits of participating in this study. However, the findings of this study will generate information

that will provide a better understanding of why rural populations are vulnerable to malnutrition and malnutrition-related morbidities than urban populations and also to determine the extent to which the rural environment explains this vulnerability. There are no known foreseeable risks to you for participating in this study. *Ezira miganulo jabuliwo gija kukuwebwa olwokwetaba mukunonenkereza kuno. Nolwekyo, ebinava mukunonenkerezakuno bida kutuwa amawulire aganatuyamba okutegera lwaki abomubyalo bafuna obuzibu obwokukonziba oba okufa okuva kukukonziba olwebyokulya okusinga abomubibuga era nekindi okugezaku okupima embera yekyalo yeyinza okwinonolamu okukosebwa kuno. Wazira bulabe bulambike bwoja kufuna olwokwetaba mukunonereza kuno.*

Confidentiality: Enkuma eyebyama: Whatever information you provide will be kept strictly confidential and will not be shown to other persons. All the information you will provide us with will be completely confidential and only used for purposes of this study. Apart from conducting this interview in privacy, data will be securely kept under the custody of the principal investigator. *Amawulire gona gona gemunatuwa gaida kukumibwa nga gakyama ino era digaida kulagibwa kumuntu wundi yena yena. Amawulire gona gona gemunatuwa gaida kukumibwa nga gakyama era gaida kukozesebwa kukunonenkereza kuno kwonka. Nga otoireku okukola olukungana luno mungeri yakyama, byemunatukobera bida kukumibwa butiribiri oya akulira okunonenkereza kuno.*

Voluntary participation: Okwetabamu kwakyeyendere: Participation in this survey is voluntary and you can choose not to answer any individual question or all of the questions. However, we hope that you will participate in this survey since your views are important. *Okwetaba mukunonenkereza kuno kwakyeyendere era oyinza okusalawo obutailamu kintu ekimu ku bibuzo oba byona byona. Nolwekyo, tusubira nti oida kwetaba mukunonereza kuno engeri ebirowozo byo yebiri byamugaso.*

At this time, do you want to ask me anything about the survey? *Kukiserakino wetaga okumbuza ekintu kyona kyona ekigema kukunonenkereza kuno?*
Now, given the information I have given you do you accept to participate in the study? *Buti oluvainuma olwokuwebwa obubaka obwo bwenkuwaire, oikiriza okwetaba mukunonenkereza kuno?*
Thank you for accepting to take part in this survey. *Webale okwikiriza okwetaba mukutesa kuno.*

RESPONDENT AGREES TO BE INTERVIEWED AND TO WEAR THE ACCELEROMETER *ABUZIBWA AIKIRIZA OKUBUZIBWA*

_____
Signature and Date *Omukono nenaku edomwezi*

RESPONDENT DOES NOT AGREE TO BE INTERVIEWED AND TO WEAR THE ACCELEROMETER *ABUZIBWA ALOBYE OKWIKIRIA OKUBUZIBWA*

_____(terminate interview) *Komawo okubuza*
Signature and Date *Omukono nenaku edomwezi*

Signature of witness and date:
_____

Omukono gwoyo abairewa nenaku edomwezi
Signature of interviewer and date:

_____

Omukono gwabuza nenaku edomwezi

Contact information:
For more information regarding this study, please contact the Principal investigator – **Mrs. Barbara Kirunda Tabusibwa, Makerere University School of Public Health, P. O Box 7072, Kampala. Mobile no: +256712882994 or email: bkirunda@musph.ac.ug**
Ebisingawo ebigema kukunonereza kuno, mbasaba mutukirire akulira okunonenkereza kuno Mukyala ***Barbara Kirunda Tabusibwa, Makerere University School of Public Health, P. O Box 7072, Kampala. Mobile no: +256712882994 or email: bkirunda@musph.ac.ug***

In case of any ethical issues related to the study, contact **Dr. John Ssempebwa, the Chairperson of Makerere University School of Public Health, Higher Degrees Research and Ethics Committee, P.O Box 7072, Kampala. Mobile no: +256772963074**

Bwemuba mukoseibwa mungeri yona yona nga kivire kukunonereza kuno, mutukirire ***Dr. John Ssempebwa, the Chairperson of Makerere University School of Public Health, Higher Degrees Research and Ethics Committee, P.O Box 7072, Kampala. Mobile no: +256772963074***

Appendix II: Household survey questionnaire

00.Identification

001	Identification Number			
002	Household ID. Number:			
003	Date of interview:	DD	MM	YYYY
004	Start date for wearing accelerometer:	DD	MM	YYYY
005	End date for wearing accelerometer:	DD	MM	YYYY
006	District: Disitulikiti	*Record:*		
007	Sub-county: Eigombolola	*Record:*		
008	Parish: Omuluka	*Record:*		
009	Village: Ekyalo	*Record:*		

100. Socio-demographic characteristics

I am going to ask you questions regarding your socio-demographic characteristics that will help us to describe our study population. The information is confidential and will be used for study purposes only.
Njakukubuza ebibizo ebikugemaku kisobole okutuyamba okwinonola obunene bw'okunonenkereza kwaife. Amawulire gaidha kukumibwa nga gakyama era gaidha kukozesebwa kukunonenkereza kuno kwonka.

No	Item	Option	Code	Skip to
101	Sex of the respondent *(Record Sex)* *Ekikula kyabuzibwa*	Male Female	1 2	
102	What is your relationship to the Head of this household? Olina lugandaki kwakulira amakagano?	Actual Head of household Wife to Head of household Other relative of Head Other, not a relative	1 2 3 4	
103	What is your date of birth? Wazaallibwa kunakuki edh'omwezi?	_____ _____ _____ DD MM YYYY		
104	How old are you? Oweza emyaka emeka egyobukulu?	Age in completed Years:_____		
105	What is your tribe? Oliwaigwangaki?	Musoga Mugere Muganda Other, specify_____	1 2 3 4	
106	What is your religion? Oliwaidiniki?	Catholic Protestant Pentecostal Other Christian Moslem Traditional/Other None	1 2 3 4 5 6 7	
107	What is the highest level of education that you have attained? Wakoma ku idalaki ely'obwegerese?	None/never attended school Lower Primary (P1-P4) Upper Primary (P5-P7)	1 2 3	

		Secondary – O' level (S1-4) Secondary – A' level (S5-6) College/University completed Post graduate degree	4 5 6 7	
108	What is your current marital status? Oli mufumbo? Bwoba olimufumbo bufumbo bwakikaki?	Married Cohabiting Single and Never Married Widowed Separated Divorced	1 2 3 4 5 6	
109	How many people older than 18 years including yourself, live in this household? Bantu bameka abali waigulu wemyaka eikumi nomunana nga otaireku niwe ababa mumaka gano	Indicate Number _____		
110	How many children aged less than 18 years live in this household? Baana bameka abaliwansi awemyaka eikumi nomunaana ababa mumaka gano?	Indicate Number_____		
111	What occupation activities have you been involved in the previous month? (*Ask, classify and tick accordingly)* *Multiple response question* Mirimuki gyobaire wetabamu mumwezi ogubise? (buza otegeke era olage nga bwekyetagisa) *Osobola okutwala ekisoba mukirala*	Subsistence agriculture Commercial agriculture Small scale trade Medium or large trade Domestic work Formal salaried employment Casual labour and barter Mason or Artisan Other, specify _____	1 2 3 4 5 6 7 8 9	
112	What occupation activities were you involved in the previous year? (*Ask, classify and tick accordingly)* *Multiple response question* Mirimuki gyobaire wetabamu mumwaka ogubise? (buza otegeke era olage nga bwekyetagisa) *Osobola okutwala ekisoba mukirala*	Subsistence agriculture Commercial agriculture Small scale trade Medium or large trade Domestic work Formal salaried employment Casual labour and barter Mason or Artisan Other, specify _____	1 2 3 4 5 6 7 8 9	
113	What was/were your sources of income in the previous month? *Multiple response question* *Kiki/biki byobaire otolamu sente mumwezi ogubise?* *Osobola okutwala ekisoba mukirala*	Trade Sale of agricultural produce Formal employment Labourer (wage earner) Remittance Fishing Others, specify _____	1 2 3 4 5 6 7	
114	What was/were your sources of income in the previous year? *Multiple response question* *Kiki/biki byobaire otolamu sente*	Trade Sale of agricultural produce Formal employment Labourer (wage earner) Remittance	1 2 3 4 5	

	mumwaka ogubise? *Osobola okutwala ekisoba mukirala*	Fishing	6	
		Others, specify _____	7	
115	What is the total estimated amount of money that you earn per month from all your income sources? In what range is it (in shillings) Okugeragerania oingiza muwendo gwa sente imeka buli mwezi okuva mumagira gonagona gofunamu sente? Bwogeragerania diri mu sente nga imeka.	None	1	
		Less than 60,000 Ug.shs	2	
		Between 60,000 to 100,000	3	
		Between 100,000 to 200,000	4	
		Between 200,000 to 1,000,000	5	
		Over 1,000,000	6	
116	What is the main source of water for general household use? Musinga kutolawa amadhi agakozesebwa mumaka gano?	**Buy water**		
		From the taps	1	
		From the water tanks	2	
		From hawkers	3	
		Piped water		
		Into the residence/plot	4	
		Public tap	5	
		Well water		
		Well on the residence/plot	6	
		Public well/shadoof	7	
		Spring water		
		Protected spring	8	
		Unprotected spring	9	
		Borehole	10	
		Surface water		
		River/stream/swamp	11	
		Pond/lake	12	
		Rain water	13	
		Other, specify _____	14	
117	What is the main source of drinking water for household members? Musinga kutolawa amadhi agokunwa agakozesebwa abomumaka gano?	**Buy water**		
		From the taps	1	
		From the water tanks	2	
		From hawkers	3	
		Piped water		
		Into the residence/plot	4	
		Public tap	5	
		Well water		
		Well on the residence/plot	6	
		Public well/shadoof	7	
		Spring water		
		Protected spring	8	
		Unprotected spring	9	
		Borehole	10	
		Surface water		
		River/stream/swamp	11	
		Pond/lake	12	
		Rain water	13	
		Other, specify _____	14	
118	Observe and record the type of dwelling Wetegereze era owandike ekika	Independent house	1	
		Independent one room	2	
		One room/Muzigo	3	

	ky'amaka.	Independent flat	4	
		Shared house/flat	5	
		Servant's quarters	6	
		Hut	7	
		Garage	8	
		Uniport	9	
		Commercial shop	10	
		Others, specify _____	11	
119	What is the total number of rooms in the house? Muwendoki ogwebisenge ebiri munumba?			
120	What is the total number of rooms in the house used for sleeping? Muwendoki ogwebisenge ebiri munumba ebisulwamu?			
121	What is the main material of the floor? *Observe and record* Kiki ekikulu kyebakozesa okuzimba wansi? *Wetegereze owandike*	Sand/gravel	1	
		Earth	2	
		Earth and cowdung	3	
		Wooden planks	4	
		Cement	5	
		Others, specify _____	6	
122	What is the main material of the wall? *Observe and record* Kiki ekikulu kyebakozesa okuzimba ekisenge? *Wetegereze owandike*	Mud and poles	1	
		Wood/timber	2	
		Iron/metal sheets	3	
		Burnt bricks	4	
		Unburnt bricks	5	
		Concrete blocks	6	
		Others, specify _____	7	
123	What is the main material of the roof? *Observe and record* Kiki ekikulu kyebakozesa okusereka akasulya? *Wetegereze owandike*	Grass thatched	1	
		Plastic sheets	2	
		Wood/timber	3	
		Iron/metal sheets	4	
		Asbestos sheets	5	
		Clay/concrete tiles	6	
		Others, specify _____	7	
124	What type of toilet/sanitary facility does your household use? Kyoloni kikaki ekikozesebwa mumaka gano?	Own flush toilet	1	
		Shared flush toilet	2	
		Own pit latrine	3	
		Shared pit latrine	4	
		Own VIP latrine	5	
		Shared pit latrine	6	
		No facility/bush	7	
		Other, specify _____	8	
125	What is the main source of cooking fuel used in the household? Kiki kyebasinga kukozesa okufumbisa mumaka gano?	Paraffin/kerosene	1	
		Gas	2	
		Biogas	3	
		Electricity	4	
		Charcoal	5	

		Solar	6	
		Firewood	7	
		Crop residue/saw dust	8	
		Pellets made from animal waste	9	
		Others, specify _____	10	
126	What is the main source of lighting in this household? Kiki kyebasinga kukozesa okwakisa mumaka gano?	Paraffin lantern/tadooba	1	
		Candle (wax)	2	
		Electricity	3	
		Solar	4	
		Others, specify _____	5	
127	Does your household own any of the following animals? Amakago gali nebimu kubisolo bino wansi?	Yes No	1 2	
	Cattle Ente			
	Sheep Entama			
	Goats Embuzi			
	Chicken Enkoko			
	Pigs Embidi			
	Others, specify _____ Ebindi inonola_____			
	Do you personally own the following items? *Inform the respondents that the information is confidential and will only be used for study purposes* Iwe mwene olinebintu bino wansi? *Kobera bolikubuza nti ebintu bino bikumibwa mungeri yamutindo era bidha kukozesebwa kukunonenkereza kuno kwonka.*	Yes No	1 2	
128	Bicycle Egali			
129	Motorcycle Piki piki			
130	Car Emotoka			
131	Television Tivi			
132	Radio Ladiyo			
133	Stereo/CD player Kaseti			
134	Mobile phone Eisimu elyomungalo			
135	Fixed telephone Eisimu elyokumeza			
136	Table Emeza			
137	Chairs Entebe			
138	Mosquito net Akatimba akensiri			
139	Electric iron Amasanalaze			
140	Charcoal iron Pasi eyamanda			
141	Wheel burrow Akasolo			
142	Plough Embago eyente			
143	Hoes Embago eyemikono			
144	Panga Ekipanga			

145	Axe Empasa			
146	Sewing machine Ekyalani			
147	Refrigerator Efirigi			
148	Gas/electronic cooker Kuka eya gasi			
149	Camera Kamera			
150	Kerosene stove Sitovu eyamafuta			
151	Kerosene lantern Eitala eryakowero			
152	Truck/bus/tractor Lole/ebasi/etulakita			

200. First physical measurements

I am going to measure your full height using a height measure and your weight using a digital weighing scale twice. In order to take accurate measurements, I would like to request you that all items that will interfere with measurements like keys, bungles, mobile phones, jackets, shoes, scuffs, sweaters etc should be removed.
Ndija kukupima buwanvubwo nga nkozesa ekipima obuwanvu ndija kupima n'obuzito nga nkozesa eminzani. Mungeri eyokutwala ebipimo ebitufu ndakusaba wetoleku ebintu ebiyinza okutawania ebipimo nga ebisumuluzo, ebikomo, amasimu, ebikoti, engaito, akakaya, esweta nebindi.

No	Item	Option	Code	Skip to
	Height and weight			
201	Measure the weight in kgs to the nearest 0.1kgs Pima obuzito mukilo obuli okumpi ni 0.1 kilo *The person should be wearing light clothes without socks and shoes* *Omuntu atekwa kubanga avaire engoye editazitowa nga tavaire sitokisi nangaito*	_____kgs		
202	Measure the standing height in cms to the nearest 0.1cm Pima obuwanvu mu cm obuli okumpi ni 0.1 cm *The person should be wearing light clothes without socks and shoes* *Omuntu atekwa kubanga avaire engoye editazitowa nga tavaire sitokisi nangaito*	_____cms		

*300. **Physical activity***

Next, I am going to ask you about the time you spend doing different types of physical activity in a typical week. Please answer these questions even if you do not consider yourself to be a physically active person. Think first about the time you spend doing work. Think of work as the things that you have to do such as paid or unpaid work, study/training, household chores and maintenance, care of family, harvesting foods/crops, fishing, hunting for food, seeking employment etc.

Ekiraku, ndija kubuza kubisera byomala nga okola ebintu ebyendawulo mu wiki enamba. Nsaba oiremu ebintu biino waire nga wetwala nti tobikola. Soka olowoze kubisera byomala nga okola emirimo lowoza kukukola nga ebintu byokola nga byakusasulira obanga tibyakukusasula, okusoma/okutendekebwa, okukola ejomunumba, okukungula emere/ebirime, okuvuba, okuyiiga ebyokulya, okunonia emirimo nebindi.

	Activity at work			
301	Does your work involve vigorous-intensity activity that causes large increases in breathing or heart rate like carrying or lifting heavy loads, digging or construction work for at least 10 minutes continuously? Emirimugyo gyamani nga gikuletera okwia eino oba okukuba omutima nga okwetwika oba okusitula ebizitowa, okulima oba okuzimba okumala eibanga ery'edakika eikumi ediraganwaku.	Yes	1	
		No	2	Go to 504
302	In a typical week, on how many days do you do vigorous-intensity activities as part of your work? Mu wiki enamba, naku imeka dokola emirimo egy'amani nga negimu kumirimugyo?	Number of days _____		
303	How much time do you spend doing vigorous-intensity activities at work on a typical day? Sawa imeka domala nga okola emirimo egy'amani kumulimo mulunaku olulamba?	Hours_____ Minutes _____		
304	Does your work involve moderate-intensity activity that causes small increases in breathing or heart rate such as brisk walking or carrying light loads for at least 10 minutes continuously? Emirimugyo gitwaliramu emirimu egitali gyamani nga tigikuletera kwisa ino oba okukuba omutima okugeza nga okutambula oba okusitula ebintu ebitazitowa okumala dakika ediwera eikumi ediraganwa?	Yes	1	
		No	2	Go to 507
305	In a typical week, on how many days do you do moderate-intensity activities as part of your work?	Number of days _____		

	Muwiki enamba, nnaku imeka dokola emirimo emisamusamu nga gimu kumirimogyo?			
306	How much time do you spend doing moderate-intensity activities at work on a typical day? Kikutwalira ibbangaki nga okola emirimo emisamusamu kumulimogwo mulunaku olulamba?	Hours_____ Minutes _____		
Travel to and from places/Transportation physical activity *Includes to work, market, shopping, places of worship etc and excludes physical activities at work that have been already mentioned* Kitwaliramu okuja kumulimo, mukatale, okugula ebintu, okuja mumasinzizo nebindi nga otoireku emirimu jetwogeireku waigulu				
307	Do you travel in a vehicle like a bus/taxi/car/motorbike (bodaboda) for at least 10 minutes continuously to get to and from places? Otambulira mumotoka nga basi/takisi/ mayika/epiki piki (boda boda) okumala nga dakika 10 edomudiringanwa okuja oba okuva mubifo	Yes No	1 2	 Go to 510
308	In a typical week, on how many days do you travel in a vehicle for at least 10 minutes continuously to get to and from places? Muwiki enamba, naku imeka otambulira mumotoka okumala dakika ediwera eikumi edomudiringanwa okuja oba okuva mubifo?	Number of days_____		
309	How much time do you spend travelling in a bus/taxi/car/motorbike (bodaboda)? Kikutwalira kisera kyagawa okutambulira mu basi/takisi/mayika/piki piki (boda boda)?	Hours_____ Minutes_____		
310	Do you walk for at least 10 minutes continuously to get to and from places? *Otambula okumala dakika ediwera eikumi edomudiringanwa okutuka oba okuva mubifo?*	Yes No	1 2	 Go to 513
311	In a typical week, on how many days do you walk for at least 10 minutes continuously to get to and from places? Muwiki enamba, naku imeka dotambula omala dakika ediwera eikumi edomudiringanwa okuja oba okuva mubifo?	Number of days _____		
312	How much time do you spend walking for travel on a typical day?	Hours _____		

	Kiseraki kyotwala okutambula olugendo mulunaku olulamba	Minutes _____		
313	Do you use a bicycle for at least 10 minutes continuously to get to and from places? *okozesa egali okumala dakika ediwera eikumi edomudiringanwa okutuka oba okuva mubifo?*	Yes	1	
		No	2	Go to 516
314	In a typical week, on how many days do you ride a bicycle for at least 10 minutes continuously to get to and from places? *Muwiki enamba, naku imeka dovuga egali okumala dakika ediwera eikumi edomudiringanwa okuja oba okuva mubifo?*	Number of days _____		
315	How much time do you spend riding a bicycle for travel on a typical day? *Kikutwalira kiseraki okuvuga egali okutambula olugendo mulunaku olulamba*	Hours _____ Minutes _____		
Recreational activities *includes sports, fitness and leisure recreational activities*				
325	Do you do any vigorous-intensity sports, fitness or recreational activities that cause large increases in breathing or heart rate like running, football, aerobics, fast swimming and fast bicycling for at least 10 minutes continuously? Okola ebyemizano byona byona ebyamaani ebikuletera okuweera eino oba okukuba omutima nga okulumuka, okusamba omupiira, okukola bizimba omubiri, okuwuga kusupiidi, okusoita gali kusupiidi okumala dakika nga ikumi edomudiringanwa?	Yes	1	
		No	2	Go to 528
326	In a typical week, on how many days do you do vigorous-intensity sports, fitness or recreational activities? Mu ibanga lya wiki enamba, nnaku imeka dokola ebyemizaano nebizimba omubiri ebyamaani?	Number of days _____		
327	How much time do you spend doing vigorous-intensity sports, fitness or recreational activities on a typical day? Bisera byagawa byomala nga okola ebyemizano oba okuzimba omubiri mulunaku olulamba?	Hours_____ Minutes _____		
328	Do you do any moderate-intensity sports, fitness or recreational activities that cause causes small	Yes	1	

	increases in breathing or heart rate like brisk walking, cycling at a regular pace, swimming at a regular pace, volleyball for at least 10 minutes continuously? Okola ebyemizano byona byona ebisamu samu ebikuletera okuweera okutono tono oba okukuba omutima okutono tono nga okutambula, okuvuga egali empolampola okuwuga, empolampola okuzana akapiira akengalo okumala dakika nga ikumi edomudiringanwa?	No	2	Go to 531
329	In a typical week, on how many days do you do moderate-intensity sports, fitness or recreational activities? Mu ibanga lya wiki enamba, nnaku imeka dokola ebyemizaano nebizimba omubiri ebisamu samu?	Number of days _____		
330	How much time do you spend doing moderate-intensity sports, fitness or recreational activities on a typical day? Bisera byagawa byomala nga okola ebyemizano oba okuzimba omubiri ebisamu samu mulunaku olulamba?	Hours_____ Minutes _____		
Sedentary behaviour *Includes sitting or reclining at work, at home, getting to and from places or with friends including time spent sitting at a desk, sitting with friends, travelling in vehicle, reading, playing cards, ludo or watching television etc but does not include time spent sleeping* Kitwaliramu okutyama, okugalamira kumulimo, awaka, okuva nokuja mubitundu oba nemikwano nga otaireku ebisera byomala nga otyaime ku fomu, okutyama nimikwanojo, okutambulira mumotoka, okusoma, okuzana kyanisi, ludo oba okubona tivi nebindi aye togaitaku sawa domaze nga otendwike.				
531	How much time do you usually spend sitting or reclining on a typical day? Otera kumala ibangaki nga otyaime oba okugalamiramu mulunaku olulamba?	Hours_____ Minutes _____		

400.Second physical measurements

I am going to measure your full height using a height measure and your weight using a digital weighing scale the second time. In order to take accurate measurements, I would like to request you that all items that will interfere with measurements like keys, bungles, mobile phones, jackets, shoes, scuffs, sweaters etc should be removed.

Ndija kupima buwanvu nobuzito nga nkozesa minzani. Emirundi ebiri. Mungeri eyokutwala ebipimo ebitufu ndakusaba wetoleku ebintu ebiyinza okutawania ebipimo nga ebisumuluzo, ebikomo, amasimu, ebikoti, engaito, akakaya, esweta nebindi.

No	Item	Option	Code	Skip to
	Height and weight			
401	Measure the weight in kgs to the nearest 0.1kgs Pima obuzito mukilo obuli okumpi ni 0.1 kilo *The person should be wearing light clothes without socks and shoes* *Omuntu atekwa kubanga avaire engoye editazitowa nga tavaire sitokisi nangaito*	_____kgs		
402	Measure the standing height in cms to the nearest 0.1cm Pima obuwanvu mu cm obuli okumpi ni 0.1 cm *The person should be wearing light clothes without socks and shoes* *Omuntu atekwa kubanga avaire engoye editazitowa nga tavaire sitokisi nangaito*	_____cms		

Appendix III: Pedometer Data Abstraction Form

00.Identification

001	Identification Number/Bar code				
002	Household ID. Number: Enamba y'amaka				
003	Date: Enaku edomwezi		DD	MM	YYYY
004	Start date for wearing accelerometer:		DD	MM	YYYY
005	End date for wearing accelerometer:		DD	MM	YYYY
004	District: Disitulikiti	*Record:*			
005	Sub-county: Eigombolola	*Record:*			
006	Parish: Omuluka	*Record:*			
007	Village: Ekyalo	*Record:*			
008	Watch ID Enamba erondoola				
009	Download date				
010	File name Elina lya failo				

01. Physical activity data

Day	Number of Steps	Distance (Kms)	Energy (Kcal)	Duration (minutes)

Appendix IV: Ethical clearance letter

MAKERERE UNIVERSITY
P.O. Box 7072 Kampala Uganda
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Tel: 256 414 532207/543872/543437
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COLLEGE OF HEALTH SCIENCES
SCHOOL OF PUBLIC HEALTH
HIGHER DEGREES, RESEARCH AND ETHICS COMMITTEE

15th January 2013

Ms. Barbra Kirunda
Principal Investigator, Protocol (200) – MakSPH
University of Bergen (PhD study)

Re: (IRB00011353) Approval of Proposal titled: Effect of the built, natural and social environment on dietary diversity, physical activity and malnutrition in an adult peri –urban and rural population in Uganda

This is to inform you that at its meeting held on 16/10/2012, the Higher Degrees, Research and Ethics Committee (HDREC) approved your study documents for the above referenced study:

	Document Name	Version Date	Approval Date
1	Research Protocol	November, 2012	15/01/2013
2	Informed Consent	November, 2012	15/01/2013
3	Data collection tools	November, 2012	15/01/2013

Also note that the initial approval date for your proposal by HDREC is 15/01/2013, and therefore approval expires at every annual anniversary of this approval date. The current approval is therefore valid until: 14/01/2014.

Continued approval is conditional upon your compliance with the following requirements:

1) No other consent form(s), questionnaire and/or advertisement documents should be used. The consent form(s) must be signed by each subject prior to initiation of any protocol procedures. In addition, each subject must be given a copy of the signed consent form.

HIGHER DEGREES, RESEARCH AND ETHICS COMMITTEE APPROVED ON 15 JAN 2013 P. O. BOX 7072, KAMPALA MAKERERE UNIVERSITY SCHOOL OF PUBLIC HEALTH

2) All protocol amendments and changes to other approved documents must be submitted to HDREC and not be implemented until approved by HDREC except where necessary to eliminate apparent immediate hazards to the study subjects.
3) Significant changes to the study site and significant deviations from the research protocol and all unanticipated problems that may involve risks or affect the safety or welfare of subjects or others, or that may affect the integrity of the research must be promptly reported to HDREC.
4) All deaths, life threatening problems or serious or unexpected adverse events, *whether related to the study or not,* must be reported to HDREC in a timely manner as specified in the National Guidelines for Research Involving Humans as Research Participants.

- Please complete and submit reports to HDREC as follows:

a) For renewal of the study approval – complete and return the continuing Review Report – Renewal Request (Form 404A) at least 60 days prior to the expiration of the approval period. The study cannot continue until re-approved by HDREC.

b) Completion, termination, or if not renewing the project – send a final report within 90 days upon completion of the study.

- Finally, the legal requirement in Uganda is that all research activities must be registered with the National Council of Science and Technology. The forms for this registration can be obtained from their website www.uncst.go.ug. Please contact Mr. Tusiime Wilson, Administrative Assistant of the Higher Degrees, Research and Ethics Committee at wtusiime@musph.ac.ug or telephone number (256)-41-543872 or +256772496136 if you encounter any problems.

Yours sincerely

HIGHER DEGREES, RESEARCH AND ETHICS COMMITTEE APPROVED ON 15 JAN 2013 P. O. BOX 7072, KAMPALA MAKERERE UNIVERSITY SCHOOL OF PUBLIC HEALTH

Dr. John Ssempebwa
Chairman, Higher Degrees, Research and Ethics Committee

Enclosures:

a) A stamped, approved study documents (informed consent documents):