

Social relationships, stress and infection risk in mother and child

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Scientific environment

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The project originates from Samliv og Helse (Couple Relationships and Health), a research programme led by Professor Frode Thuen. This programme is concerned with the factors that influence marital stability and quality and with the influence of marital status and couple relationship quality on mental and somatic health.

The supervisors of this project have been:

Frode Thuen, psychologist, professor at the Centre for Evidence-Based Practice, Bergen University College

Torbjørn Torsheim, psychologist, professor in the Department of Psychosocial Science, Faculty of Psychology, University of Bergen

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Abstract

This thesis draws on theoretical orientations and conceptual models of how social networks, the quality of social relationships and stressful conditions, are linked to physiological responses which can influence health and behaviour.

The original contribution of this work was to add to the existing literature on the links between social relationships and health, by showing the degree to which couples' relationship dissatisfaction during pregnancy is associated with the risk of infectious diseases in both mother and children. Additionally, the project provided empirical data to a relatively new theoretical contribution to this field of research, by investigating a hypothesis derived from social baseline theory.

The project includes three research articles published in peer-reviewed journals. All three articles are based on data from the Norwegian Mother and Child Cohort Study, a prospective population-based pregnancy cohort study conducted by the Norwegian Institute of Public Health.

The first paper tested a hypothesis derived from social baseline theory. This theory gives a basis for understanding the impacts of social relationships on the regulation of metabolic resources. A hypothesis derived from social baseline theory is that relative social isolation leads to increased sugar intake. The present results supported this hypothesis by showing that perceived loneliness was associated with elevated intake of sugar-containing beverages. In contrast, high relationship satisfaction levels, marriage, supportive friends and a sense of togetherness at work were negatively associated with the intake of sugar-sweetened beverages. These associations remained statistically significant after controlling for scores for body mass index, weight-related self-image, depression, physical activity, educational level, age and income. Moreover, this pattern of associations was not found when sugary beverages were replaced with artificially sweetened beverages as outcome-variables, suggesting that sugar was the key component responsible for the associations between social factors and sugar-containing beverages.

The second paper explored the association between levels of relationship satisfaction and risk of infectious diseases among pregnant women. In addition, it examined whether relationship satisfaction interacted with the association between stressful life events and risk of infectious diseases during pregnancy. The results showed that, after controlling for socioeconomic factors and stressful life events, higher levels of relationship satisfaction at gestational week 15 were associated with a lower risk for 8 of 9 categories of infectious diseases during gestational weeks 17–30. Additionally, the results showed a positive association between the level of stressful life events and infectious diseases. However, no interaction effect was found between relationship satisfaction and stressful life events on the risk of infections.

The third paper investigated the degree to which relationship dissatisfaction and stressful life events during pregnancy predicted risk for 8 categories of infectious diseases in children during their first year of life. The results showed that maternal relationship dissatisfaction was associated with increased risk for all tested infectious diseases among infants less than 6 months old and increased risk for 7 categories of diseases among 6–12-month-old children. The associations remained statistically significant after adjusting for scores for socioeconomic factors, prenatal stressful life events, smoking, maternal depression, breastfeeding, child's sex and use of childcare. It was also found that maternal stressful life events were associated with 7 of 8 groups of diseases in both age groups of children. Finally, the results showed that pregnant women who experienced higher degrees of relationship dissatisfaction and higher numbers of stressful life events reported a higher frequency and greater variety of infectious diseases in their children.

Overall, this work supports that couples' relationship dissatisfaction during pregnancy is associated with the risk of infectious diseases in both mother and children.

Additionally, it provides support for social baseline theory by demonstrating that loneliness, relationship quality, and other social factors were associated with the level of consumption of sugary beverages. Thus, the project provided empirical data to a relatively new theoretical contribution to the field of research concerned with how social relationships are linked to physiological responses which in turn have the potential of influencing health and behaviour.

List of publications

Henriksen RE, Torsheim T, Thuen F (2014) Loneliness, social integration and consumption of sugar-containing beverages: testing the social baseline theory. PLoS One 9: e104421.

Henriksen RE, Torsheim T, Thuen F (2015) Relationship satisfaction reduces the risk of maternal infectious diseases in pregnancy: the Norwegian Mother and Child Cohort Study. PLoS One 10: e0116796.

Henriksen RE, Thuen F (2015) Marital quality and stress in pregnancy predict the risk of infectious disease in the offspring: the Norwegian Mother and Child Cohort Study. PLoS One 10: e0137304.

Contents

SCIENTIFIC ENVIRONMENT	2
ACKNOWLEDGEMENTS	3
ABSTRACT	5
LIST OF PUBLICATIONS	7
1. INTRODUCTION	11
2. BACKGROUND	13
2.1 SOCIAL RELATIONSHIPS AS HEALTH DETERMINANTS	13
2.2 RELATIONSHIP QUALITY AND PHYSICAL HEALTH	14
2.3 PRENATAL STRESS, RELATIONSHIP QUALITY AND INFANT INFECTIONS	15
3. THEORETICAL FRAMEWORK	17
3.1 THEORETICAL PRECONCEPTIONS AND DEVELOPMENT OF A THEORETICAL FRAMEWORK	17
3.2 COGNITIVE ACTIVATION THEORY OF STRESS	18
3.3 SELFISH BRAIN THEORY	19
3.4 SOCIAL BASELINE THEORY	20
3.5 COMBINATION OF ELEMENTS FROM THE COGNITIVE ACTIVATION THEORY OF STRESS, SELFISH BRAIN THEORY AND SOCIAL BASELINE THEORY	22
4. OBJECTIVES	24
5. METHODS	25
5.1 DESIGN AND RECRUITMENT	25
5.2 SAMPLE	25
5.2.1 Attrition and missing data	26
5.2.2 Paper I.....	27
5.2.3 Paper II.....	27
5.2.4 Paper III.....	27

5.3	MEASUREMENTS	28
5.3.1	<i>Relationship satisfaction</i>	30
5.3.2	<i>Stressful life events</i>	30
5.3.3	<i>Support from friends and family</i>	31
5.3.4	<i>Marital status</i>	31
5.3.5	<i>Loneliness</i>	32
5.3.6	<i>Cohesiveness at work</i>	32
5.3.7	<i>Maternal infectious diseases</i>	32
5.3.8	<i>Infectious diseases in offspring</i>	32
5.3.9	<i>Consumption of sugar-sweetened and artificially sweetened beverages</i>	33
5.3.10	<i>Confounding variables</i>	33
5.4	STATISTICAL ANALYSIS	37
5.4.1	<i>Paper I</i>	37
5.4.2	<i>Paper II</i>	37
5.4.3	<i>Paper III</i>	38
5.5	ETHICAL CONSIDERATIONS.....	39
6.	SUMMARY OF RESULTS	40
6.1	PAPER I.....	40
6.2	PAPER II	41
6.3	PAPER III.....	41
7.	DISCUSSION.....	43
7.1	SOCIAL INTEGRATION AND SUGAR INTAKE	43
7.2	RELATIONSHIP QUALITY, STRESS AND INFECTIOUS DISEASES	45
7.3	POSSIBLE MECHANISMS RELATED TO THE FINDINGS OF PAPERS II AND III	47

7.4	STRENGTHS AND LIMITATIONS	48
7.5	FUTURE PERSPECTIVES	50
7.5.1	<i>Clinical implications</i>	50
7.5.2	<i>Implications for future research</i>	51
7.6	CONCLUSIONS	52
	REFERENCES	53
	Paper I	
	Paper II	
	Paper III	

1. Introduction

This thesis centres on three published scientific papers. The first paper investigated the association of social relationships with levels of intake of sugary beverages during pregnancy. Papers II and III examined the degree to which stressful life events and dissatisfaction with a partner during pregnancy were associated with the risk of infectious disease in the mother before giving birth and in the child during its first year of life. It should be noted that the purpose of Paper I was to test a hypothesis derived from a certain theory, so the paper had a more theoretical aim. It is important to stress that the study was not intended to investigate the magnitude of sugar intake predicted by social isolation. The aim simply was to examine whether an association between social relationships and sugar intake existed in a real-life setting. The study is relevant as it contributed empirical data that may improve understanding of the physiological mechanisms underlying the link between social relationships and somatic health. This point is explained in more depth in section 3 on the theoretical framework. Papers II and III have clinical relevance because infections during pregnancy have been associated with an increased risk of preeclampsia and adverse birth outcomes [1, 2]. Prenatal infectious disease and infectious disease in infants have also been linked to adverse long-term effects in later life [3, 4], and early life infections have been associated with an increased risk of hospitalisation and even death [5-7]. In addition, few studies have investigated the association between prenatal relationship satisfaction and infectious diseases in pregnant women and their children.

All three studies share the same theoretical framework and were based on empirical data from the Norwegian Mother and Child Cohort Study (MoBa).

Thematically and methodologically, the present work falls within the broad tradition of social epidemiology, defined as ‘the branch of epidemiology that studies social distribution and social determinants of states of health’ [8]. An important fundamental element of modern social epidemiology is work on stress and physiological responses to stressful experiences. A substantial body of research supports that stressful conditions may lead to adverse health outcomes and that the underpinning biological

mechanisms related to stress can be directly or indirectly influenced by social factors, such as social integration and supportive social relationships [9-11].

Throughout the present work, 'health' or 'health outcomes' mainly refer to somatic diseases, mortality or biological processes linked to somatic diseases (e.g. high blood pressure, suppressed immune function). Thus, in the present context, 'health' refers to a relatively narrow concept [12].

In addition to being presenting these three papers, this thesis builds on previous empirical findings and theoretical models concerning the relationships among stress, social phenomena and health outcomes, as presented in the following sections.

2. Background

2.1 Social relationships as health determinants

More than 100 years of systematic research on the influence of social relationships on health, including Durkheim's pioneering work on the link between social ties and suicide rates, offer strong support that social relationships play a significant role in health and well-being [13]. In a meta-analysis of 148 studies, Holt-Lunstad, Smith and Layton [14] found that stronger social relationships were associated with a 50% increased likelihood of survival. They concluded that social relationships have an influence on mortality comparable to that of well-established risk factors, such as smoking, obesity, excessive alcohol consumption and a lack of physical activity [14].

The literature on social relationships and health is broad and includes various measures and conceptualisations. Berkman and Krishna [15] argue that social relationships directly or indirectly influence health-related behaviours and physiological processes through five primary pathways. The first is the provision of different types of social support, such as instrumental, financial, informational, appraisal and emotional support. The second is social influences, which includes the impact of norms, social comparison processes and peer pressure on health behaviour. The third is social engagement, which ranges from participation in sport activities and volunteer community work to bonding, attachment and intimate romantic or sexual contact. The fourth pathway is access to resources and material goods as a function of social ties and integration in a social network. Finally, the fifth pathway emerges from the downside of social relationships. It includes the costs of maintaining social relationships and direct negative interpersonal interactions, such as interpersonal conflict, perceived isolation and abuse.

Although the present work is concerned with several aspects of these pathways, the main concern is couples' relationship satisfaction as the romantic relationship is often regarded as the most important source of support in an adult's life [16] and might be of

particular importance during pregnancy [17]. Moreover, studies on relationship satisfaction as a predictor of physical health in reproductive health are limited.

2.2 Relationship quality and physical health

There is evidence that intimate relationships influence a range of illness processes and health outcomes [18]. Importantly, the literature shows both that supportive relationships are associated with positive health outcomes and that relationship conflicts are associated with adverse outcomes [19-21]. Different mechanisms have been proposed to explain the protective elements of high-quality romantic relationships [21, 22]. One, a romantic partner may facilitate successful coping by providing various types of social support. For example, in a study of 176 pregnant woman, satisfaction with a partner was found to be correlated positively with provided task, informational and emotional support [17]. Another pathway is that a caring, supportive partner is likely to foster healthy behaviours, such as a healthy diet and exercise; encourage medical care and discourage unhealthy habits, such as the use of cigarettes and alcohol [20, 23-25]. Research on health behaviour indicates that individuals who report high levels of relationship satisfaction also have the most positive attitude towards partners' attempts to regulate behaviour [23]. Moreover, partners' attempts to control health behaviour in low-quality relationships may even be perceived as provocative, resulting thus not only in a less positive influence on health behaviour but also in higher levels of marital distress [23].

Another set of mechanisms linking couple relationship quality and physical illness involves the neuropsychological pathways associated with physiological responses to stress. Appropriate physical responses to stress might be crucial in demanding situations. However, as research has repeatedly demonstrated, prolonged stress responses also suppress the immune system and make individuals more susceptible to a variety of diseases [9, 26]. A substantial body of research has assessed the link between marital quality and physiological stress responses. For instance, it has been demonstrated that relationship conflict increases stress-related activities in the hypothalamic-pituitary-adrenocortical system (HPA-axis) and the sympatho-

adrenomedullary system (SAM) [18, 27]. These two interacting systems control the release of cortisol, epinephrine and norepinephrine. These molecules affect a wide range of processes throughout the body, including heart rate, respiratory rate, blood pressure, blood glucose levels and changes in the immune domain [28-30]. If sustained, such stress responses make individuals more vulnerable to a range of diseases, including infections [9, 31, 32].

It has been demonstrated that support from a romantic partner can dampen these stress responses [33]. Research also suggests that the magnitude of these effects is a function of relationship quality [33, 34]. A comprehensive review by Kiecolt-Glaser and Newton [18] found evidence from 64 articles indicating that low marital quality and negative partner interactions have direct impacts on a number of physiological mechanisms, including the immune domain. This finding suggests a link between couple relationship quality and manifested infectious diseases. However, I have not found any previous studies that have investigated these links in pregnant woman.

2.3 Prenatal stress, relationship quality and infant infections

Animal models and human studies have provided ample evidence that maternal stress in pregnancy leads to suppressed immune function in offspring [35-38]. There seems to be consensus that maternal HPA-axis and cortisol production play key roles in this relationship. Recent research also suggests a role for the 11 β -hydroxysteroid dehydrogenase enzyme, increased catecholamines and intestinal microbiota as mediating mechanisms [39]. Given that couple relationship quality has impacts on somatic health through physiological stress responses, the existing evidence supporting a link between prenatal stress and alterations in children's immune domain suggests that prenatal maternal relationship quality also influences children's immune function. Although few studies have demonstrated such a relationship, some have found associations of prenatal psychosocial stress, emotional stress and stressful life events with infections in infants, toddlers and older children. In a study of pregnant woman (n = 3000), stress was measured using the Psychosocial Hassles Scale [40]. It is noteworthy that half of the items in this scale are related to social relationships,

including problems related to family, fights with one's partner, fights with other family members, problems with friends and neighbourhood crime or safety. The results showed that high levels of psychosocial stress during pregnancy were associated with reports of cough, cold and diarrhoea in children during the first year after birth. However, other illnesses, such as ear infections and fever, were not associated with prenatal stress [40]. In a large Danish cohort study, associations were found between women's experience of stressful life events before or during pregnancy and different types of severe or less severe infections in their children (0–14 years old) [41]. Yet another Danish study investigated the effects of stressful life events and emotional stress during pregnancy and found associations between both factors and increased risk of infectious disease in children (0–3 years old) [42].

In sum, few previous studies have focused on the association between couples' prenatal relationship quality and infectious diseases in children. However, the literature on stress and reproductive health suggests that such a relationship exists.

3. Theoretical framework

3.1 Theoretical preconceptions and development of a theoretical framework

The present work was based on already collected data from the MoBa. To the process of choosing what hypotheses to construct and which variables to include in my PhD project, I brought a prior understanding based on influential interactional theories of stress. As pointed out in section 2.2, the associations between social relationships and health are often explained, at least partly, by the influence of social factors on how individuals cope with stress stimuli. On a theoretical level, several transactional or interactional theories of stress explain this relationship. Examples include the Lazarus and Folkman theory of stress and coping [43], Antonovsky's theory of salutogenesis [44] and Ursin and Eriksen's cognitive activation theory of stress (CATS) [32]. A common idea in these theories is that stress involves interaction between a person and the environment. For example, a threat is not simply an attribute of the environment or the person. Rather, a threat consists of attributes of the environment and the reaction of the person who perceives these attributes as threatening. As a part of this process, the person-in-context evaluates the situation based on previous experiences and available resources, including social resources. This idea explains how individuals can evaluate or appraise external stimuli differently, ultimately leading to individual differences in stress responses and health outcomes.

When I first studied the variables available in the MoBa dataset, I planned to analyse the relationship between close social relationships and somatic health. It should be mentioned that, during the early stage of this process, my prior understanding of what variables would be meaningful to include in an analytical model was largely guided by the Lazarus and Folkman theory of stress and coping [43, 45]. However, as the work progressed, it became clear that CATS [32] provided more direct explanations for the topics at hand due to its emphasis on physiological stress responses. For this reason, CATS is the only interactional theory described in more detail.

Moreover, the elements of CATS seemed compatible with two other frameworks that guided the present work in general and Paper I in particular: social baseline theory [46] and selfish brain theory [47]. Coan's social baseline theory presents a new way of understanding the purpose of social interaction, and at an early stage, I planned to investigate a hypothesis derived from this theory through the use of a large, real-life sample. The theory states that:

'Indeed, in relative isolation, one might expect an increased need for sleep, increased food intake, decreased physical activity, and perhaps even decreased immune activity, all as a function of increased perceived energy demands'. [46]

From that statement, I isolated one hypothesis to test: that relative (social) isolation increases food intake. For theoretical and methodological reasons (see sections 3.3–3.4 and 5.3.9), the respective analytical models did not include food intake in general but, more specifically, sugar intake through sugary beverages.

As I worked simultaneously on Papers I and II, it appeared that social baseline theory might also be valuable in explaining how social relationships influence the immune functions through the social regulation of brain glucose metabolism. However, a more comprehensive model, such as selfish brain theory [47], was needed to explain in detail how mechanisms that increase food intake can also suppress immune function.

The following sections briefly describe these theories and illustrate how elements from them support the main hypotheses of all three papers.

3.2 Cognitive activation theory of stress

CATS [32] builds on the pioneering research of Selye [48]. In his early work, Selye experimented on animals, exposing them to a wide range of physical strains [48]. He concluded that exposure to such stimuli led to typical physiological changes independent of the nature of the damaging agent and that the brain and body displayed general responses to such damage. Accordingly, CATS proposes that the stress response is a general, unspecific response. Sustained stress responses typically occur

when individuals lack the ability to cope with stress, for example, when the situation is experienced as so uncontrollable that attempts to cope with it will not change it (helplessness) and could even lead to negative outcomes (hopelessness) [32]. This theory may explain why major negative life events, such as a serious accident, fire, robbery or death of a close friend or relative, seem to affect most people.

CATS proposes that the stress response is an alarm in a homeostatic system which produces general activation of the HPA-axis and the SAM system, leading to an increased level of arousal in the face of threats or novel or unexpected situations. The theory proposes that homeostatic imbalance or threats to homeostasis in a biophysical system might also activate stress responses [32]. This means that a discrepancy between a set value and an actual value, as in the case of hypoglycaemia, activates the alarm. According to CATS, the alarm functions as a safety system that prompts coping behaviours. In the example of hypoglycaemia, intake of food is the appropriate solution.

In accordance with contemporary stress research, CATS posits that stress stimuli are filtered through previous experience and available resources, which affects salience, perceptions of what could be done about the stress stimuli and expected outcomes after responding to it [32]. When an individual expects positive outcomes, there is no health risk. If, however, an individual fails to eliminate the discrepancy between a set and real value, stress responses may be sustained and eventually lead to illness and disease [32].

3.3 Selfish brain theory

Selfish brain theory, described by Peters and colleagues [47], seeks to explain the function or purpose of increased cortisol levels and nutrient intake in times of stress. The theory argues that both factors play crucial roles in safeguarding the brain and providing it with sufficient amounts of energy.

Based on empirical findings, the theory holds that the energy supply to the brain has priority over other organs in the body. The brain requires large amounts of energy in

the form of glucose. Even during rest, the brain accounts for about 20% of the body's total energy consumption [49]. During cognitive tasks and stress, the glucose metabolism of the brain increases [50, 51]. Selfish brain theory explains how the energy supply to the brain is regulated through the stress system and, as under CATS, adjusted around setpoints, at which the stress system is in a state of rest [47]. The theory builds on empirical data showing that the brain has two principal mechanisms for regulating energy supply. One is the regulation of appetite and eating behaviour. The second is brain-pull mechanism that allocates energy from the body's periphery to the brain. A key feature of this mechanism is that stress responses in the brain suppress insulin secretion, reducing the uptake of glucose to muscle and adipose tissue via the insulin-dependent glucose transporter GLUT4. This process leaves higher levels of blood glucose available for the brain via GLUT1, an insulin-independent glucose transporter [51].

A recent study designed to test the central hypotheses of selfish brain theory demonstrated that social stress, induced by the Trier Social Stress Test, increased carbohydrate intake and cortisol production [51]. The study also detected stress-related insulin resistance, suggesting that energy from the body outside the skull is allocated to the brain. These findings support the notion that the brain safeguards its own supply of glucose, even at the expense of other organs [47, 51].

3.4 Social baseline theory

Social baseline theory, developed by Coan and colleagues [46, 52], proposes that the human brain is designed to expect access to social relationships characterised by interdependence, shared goals and joint attention [53]. The theory proposes that violations of this expectation increase cognitive and physiological activation as the human brain is phylogenetically designed to treat supportive social relationships as 'bioenergetic resources, much like oxygen or glucose' [53].

In social baseline theory, social relationships are considered helpful not only in coping with stress but also in minimising the use of metabolic resources in a range of activities. For example, belonging to a social group means that an individual may

benefit as the group has more eyes and ears, and the task to pay attention to possible dangers in the environment is distributed across the group. This phenomenon is called risk distribution and is the opposite of how potential dangers are handled by socially isolated individuals. According to social baseline theory, solitary strategies require more neural resources to monitor for potential threats and achieve a satisfactory safety level [46].

In relationships characterised by familiarity and interdependence, load sharing is an additional benefit of social integration. Family members and close friends tend to engage in behaviours that facilitate each other's well-being, for example, sharing resources, pursuing the same goals and helping each other in problem solving [54]. According to selfish brain theory, such outsourcing of brain-work is especially beneficial in the regulation of emotional responses as self-regulating processes supported by the prefrontal cortex are believed to be more metabolically costly than many other cognitive processes. Thus, socially mediated forms of emotion regulation may have significant energy-conservation advantages [46, 52].

The argument that relative social isolation requires more neural metabolic recourses was based on data showing that the neural systems that support self-regulatory efforts were less active when a romantic partner provided support [33, 34, 55]. A more recent study found that people who tend to avoid social ties, such as individuals with high scores on attachment avoidance, consumed more sugar-rich food than more socially oriented people [56]. Interestingly, in line with selfish brain theory, it has also been found that avoidant people maintained higher basal concentrations of blood glucose, which is the most easily accessible metabolic fuel for the human brain [56, 57].

In agreement with CATS, social baseline theory proposes that access to supportive, reliable social relationships is a basic assumption (set value) for the brain. Moreover, a difference between this set value and the lack of social support (real value) can lead to higher levels of arousal in vigilance against threats, solitary coping strategies or metabolically expensive emotion regulation. It is worth noting that, according to this line of thinking, relationship conflicts and the lack of satisfying social relationships are

both sources of physiological responses to stress, while satisfying relationships can reduce stress.

3.5 Combination of elements from the cognitive activation theory of stress, selfish brain theory and social baseline theory

Figure 1 illustrates how elements from the three theories discussed were organised and combined into one theoretical model that applies all the main hypotheses of the present work. Put simply, the model shows that what increases infection risk might also increase sugar intake.

Figure 1.

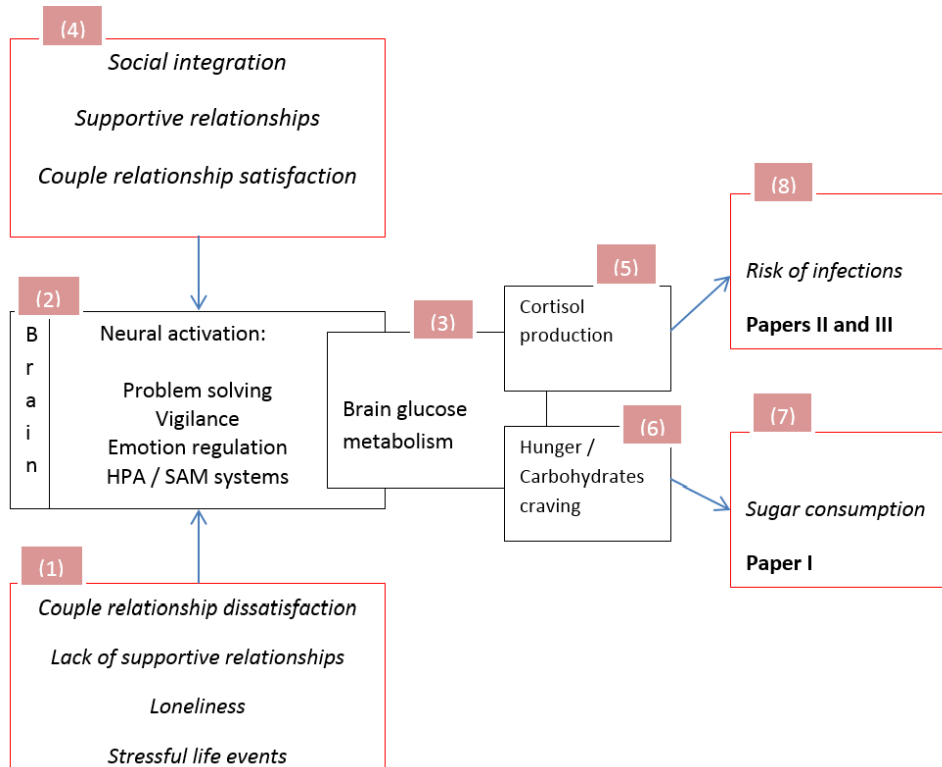


Figure legend: CATS proposes that stress (1) motivates cognitive processes related to evaluation and coping and may lead to increased alertness and general activation of physiological stress responses (2). Social baseline theory and selfish brain theory agree with this view and add notions about the metabolic costs of stress-related neural activation (3). In addition, social baseline theory contributes the notion that a lack of social resources (1) leads to increased neural activation (2) due to higher vigilance and to solitary strategies for problem solving and emotion regulation. In contrast, reliable, supportive relationships (4) may decrease neural activation (2) as a result of risk distribution, load sharing and social emotion regulation. Selfish brain theory suggests that sustained activation of physiological stress responses leads to changes to cortisol production (5) and increased hunger, especially for carbohydrates (6), to supply the brain with sufficient glucose. The latter is also proposed by social baseline theory. Given that stress-related changes in cortisol production predict immune dysfunction and that hunger for carbohydrates predicts increased sugar intake, it is reasonable to expect elevated intake of sugary beverages (7) and increased risk of infectious diseases (8) as outcomes of stressful life events, relationship conflicts and a lack of social relationships (1). In contrast, positive relationships (4) may be associated with lower infection risk and sugar intake.

4. Objectives

The objectives of this thesis were twofold. The first was to contribute empirically based findings to a field of research examining the role of social relationships in the regulation of metabolic resources. The second was to add knowledge to research investigating the clinical consequences of unsatisfying romantic relationships and stressful life events.

Paper I

The aim of this study was to test a hypothesis derived from social baseline theory: relative social isolation leads to increased levels of sugar intake. Specifically, the study was aimed at examining whether marital status and levels of relationship satisfaction, loneliness, cohesion at work and social support from family and friends were associated with the level of intake of sugary beverages.

Paper II

The main purpose of this study was to explore the association between relationship satisfaction levels and infectious disease risk during pregnancy. A second aim was to examine whether relationship satisfaction moderates the association between stressful life events and infectious disease risk during pregnancy.

Paper III

The main purpose of the third study was to examine the degree to which relationship dissatisfaction during pregnancy predicts infectious disease risk in children during the first year of life. A second aim was to examine the association between stressful life events reported by women during pregnancy and their children's infectious disease risk.

5. Methods

5.1 Design and recruitment

All 3 papers were based on data from MoBa, an ongoing prospective population-based pregnancy cohort study conducted by the Norwegian Institute of Public Health. From 1999 to 2008, all but 2 hospitals in Norway with more than 100 births per year invited pregnant women who could read Norwegian to participate in the study [58]. Potential participants received a postal invitation 3 weeks before the ultrasound examination routinely offered to all pregnant women in Norway. Blood samples were obtained from both parents during pregnancy and from mothers and children (umbilical cord) at birth. Follow-up was conducted through questionnaires administered at regular intervals and through linking to national health registries. Several sub-studies were conducted to collect additional data and biological materials. The present papers were all based on Version 7 of the quality-assured data files released for research on 17 October 2012. The present work did not include data on biological materials or data derived from any of the MoBa sub-studies.

5.2 Sample

Of the invited women, 40.6% consented to participate, resulting in a cohort of 114,500 children, 95,200 mothers and 75,200 fathers. The full MoBa sample has been compared with 2000–2006 data from the population-based Medical Birth Registry of Norway ($n = 398,849$) [59]. Underrepresentation of the youngest women (< 25 years old) and those living alone was found in the MoBa database. Women who took supplements of multivitamin and folic acid supplements were overrepresented in the MoBa. There were also statistically significant relative differences between MoBa participants and the total population in prevalence estimates for several outcome variables. However, there were no statistically relative differences in estimates of exposure–outcome associations between the MoBa sample and the total population. This finding suggests that self-selection in MoBa may not reduce validity in studies of exposure–outcome associations [59].

5.2.1 Attrition and missing data

The sample size differed for each analysis depending on the data included. One reason for the variation was that some participants dropped out of the study throughout the succeeding waves of measurement. Moreover, there was a possibility that participants could choose to not complete a questionnaire but remain in the study and complete the next one. Based on Version 7 of the MoBa data files, the total number of participating pregnancies at gestational week 15 (T1¹) was 101,769. By gestational week 30 (T2), the number of participating pregnancies decreased by 7.4%. At 6 months after giving birth (T3) and 18 months after giving birth (T4), the number of participating pregnancies was 11.8% and 24.9%, respectively, less than at T1.

Another reason for the varying sample sizes was different inclusion criteria applied. For example, Paper I used data from only first participating pregnancies (a total of 15,277 mothers participated in MoBa during more than 1 pregnancy). The exclusion criteria applied for each paper are described later.

A third reason was missing data. During the 10 years of continuous recruitment of participants, different versions of questionnaires were used, and some items applied in the present work were not included in all versions. As well, some data were missing as participants did not answer all questions, or technical difficulties in reading and inputting data arose.

Based on preliminary descriptive analyses, missing data was assumed missing at random. The preliminary descriptive analyses showed that the different samples used in the papers were very similar, based on mean scores and standard deviations for age, education and income. However, these values were slightly different from the corresponding values for the full T1 sample, indicating that the likelihood of completing all questions of interest for the present project partly depended on participants' education and income levels. To avoid nonresponse bias, socioeconomic

¹ Please note that according to the MoBa protocol (<http://www.fhi.no/dokumenter/c2b3af8eb1.pdf>), most participating women received the first questionnaire 3 weeks prior to the routinely ultrasound examination performed during gestational weeks 17-19. Unfortunately, this led to a certain inconsistency in the sense that I have referred to T1 as gestational week 17 in Paper I and gestational week 15 in Paper II.

variables (i.e. age, education level, income) were included as control variables in all regression analyses.

5.2.2 Paper I

In the first study, women who participated in the MoBa study for the first time were included in the analysis. For women who participated multiple times, only data from their first participating pregnancy was used to avoid comparing participants with themselves. Participants who reported that they were diagnosed with type 1 diabetes were also excluded. In all, 90,084 women were eligible to be included in the analysis. Participants did not necessarily answer all questions concerning beverage consumption, so the regression models were based on sample sizes ranging from 24,223 to 50,055.

5.2.3 Paper II

The second study included only women who were married or cohabiting as we were primarily interested in relationship quality. Single and widowed women were excluded. To avoid comparing participants with themselves, only the first pregnancy of women who participated multiple times was considered. A total of 75,730 pregnant women met the inclusion criteria. Of these, 67,244 answered all questions of concern for the present study. Thus, 8,486 participants were excluded from the multivariable analysis due to missing values for 1 or more of the included variables.

5.2.4 Paper III

The third study also included only married and cohabiting women ($n = 90,912$) and their participating children ($n = 100,027$). Women with multiple pregnancies and all their participating children were included. Some participants were excluded from the analyses due to missing values for 1 or more variables. Data were obtained from an average of 58,530 children for each category of infectious disease. It should be noted that one item (throat infection) for 6–12-month-old children, was only included in the early versions of the MoBa questionnaire. The dataset contained relatively few responses to that particular question ($n = 8,788$).

5.3 Measurements

Fifty-two variables were included in the three papers. Most variables were based on items from lists (e.g. lists of events or diseases) or single questions. The exception was the use of the relationship satisfaction scale [60], which has been validated. Some variables were used as exposure variables in some analyses and as confounding variables in others. Specifications and timing of measurements are explained in more detail later. Table 1 provides an overview of how the different variables were used.

Table 1. Overview of the exposure, confounder and outcome variables in Papers I–III.

	Exposures	Confounders	Outcomes
Paper I	<ul style="list-style-type: none"> ▪ Loneliness ▪ Relationship Satisfaction ▪ Marital status ▪ Cohesion at work ▪ Support from other than partner 	<ul style="list-style-type: none"> ▪ Body mass index ▪ Weight-related self-image ▪ Depression ▪ Physical activity ▪ Educational level ▪ Age ▪ Income 	<ul style="list-style-type: none"> ▪ Sugar-containing cola ▪ Other sugar-containing sodas ▪ Sugar-containing juices ▪ Artificially sweetened cola ▪ Other artificially sweetened sodas ▪ Artificially sweetened juices
Paper II	<ul style="list-style-type: none"> ▪ Relationship satisfaction ▪ Stressful life events* 	<ul style="list-style-type: none"> ▪ Educational level ▪ Age ▪ Income ▪ Marital status ▪ Stressful life events* 	<p>Nine categories of maternal infectious diseases:</p> <ul style="list-style-type: none"> ▪ Influenza ▪ Pneumonia/bronchitis ▪ Diarrhoea/gastric flu ▪ Common cold ▪ Throat infection ▪ Sinusitis/ear infection ▪ Vaginal thrush ▪ Vaginal catarrh ▪ Bladder infection
Paper III	<ul style="list-style-type: none"> ▪ Relationship satisfaction** ▪ Stressful life events* 	<ul style="list-style-type: none"> ▪ Maternal age ▪ Level of education ▪ Income ▪ Marital status ▪ Support from other than partner ▪ Frequency of contact with friends/family ▪ Breastfeeding ▪ Smoking during pregnancy ▪ Maternal depression ▪ The sex of the offspring ▪ Use of childcare ▪ Stressful life events* ▪ Relationship satisfaction** 	<p>Eight categories of infectious diseases in the children:</p> <ul style="list-style-type: none"> ▪ The common cold ▪ Throat infection ▪ Bronchitis/RS virus/pneumonia ▪ Pseudocroup ▪ Gastric flu ▪ Ear infection ▪ Conjunctivitis ▪ Urinary tract infection

*Stressful life events was included as a confounder in the models where relationship satisfaction was the exposure variable

**Relationship satisfaction was included as a confounder in the models where stressful life events was the exposure variable

5.3.1 Relationship satisfaction

Relationship satisfaction (RS) was measured at T1 for papers I and II and at T2 for Paper III. In all three papers, relationship satisfaction was measured using the full 10-item version of the relationship satisfaction scale. This scale was developed for the purposes of the MoBa study and builds on core items used in previously developed measures of marital satisfaction and relationship quality [61-63]. The scale has shown high internal and test-retest reliability and high structural, convergent and discriminant validity [60]. The scale has a 6-step scoring scale from 1 = totally agree to 6 = don't agree at all. The items included the following statements: 'My husband/partner and I have a close relationship', 'My partner and I have problems in our relationship', 'I am very happy in my relationship', 'My partner is usually understanding', 'I often think about ending our relationship', 'I am satisfied with my relationship with my partner', 'We often disagree about important decisions', 'I have been lucky in my choice of a partner', 'We agree about how children should be raised' and 'I think my partner is satisfied with our relationship'. The scoring of 3 questions were reversed so that all scores reflected the same direction (high RS = 1, low RS = 6). The mean scores of the 10 questions were then calculated and used in the analyses. In Paper II the scale was indexed to achieve a minimum score of 0 (high RS) and a maximum score of 1 (low RS).

5.3.2 Stressful life events

Stressful life events were measured at T2 for use in papers II and III. The measure consisted of 11 questions concerning different types of demanding experiences. Participants were asked to report whether they had experienced any of the listed situations during the preceding 12 months. The items included: 'Have you had problems at work or where you study?', 'Have you had any financial problems?', 'Have you been divorced or separated or ended your relationship with your partner?', 'Have you had problems or conflict with your family, friends or neighbours?', 'Have you been seriously ill or injured?', 'Has anyone close to you been seriously ill or injured?', 'Have you been involved in a serious accident, fire, or robbery?', 'Have you

lost someone close to you’? and ‘Other’. The scoring format for each question was no (0) or yes (1). In both papers, a scale was used based on sum scores for the number of reported stressful life events, ranging from 0 to 8. In Paper II, the sum scores were reduced to 4 categories: 0 (score = 0), 1 (score = 1), 2 (score = 2) and 3 or more (score = 3).

5.3.3 Support from friends and family

Perceived availability of support from persons other than a partner was included as a main study variable in Paper I (measured at T1) and as a control variable in Paper III (measured at T2). This factor was measured with 1 question: ‘Do you have anyone other than your husband/partner from whom you can ask for advice in a difficult situation’? There were 3 response options: no (score = 1); yes, 1–2 people (score = 2) and yes, more than 2 people (score = 3). In Paper III, frequency of contact with family and close friends was also measured based on the following questions: How often do you meet or talk on the telephone with relatives (other than those with whom you live) or close friends? There were 3 response options: once a month or less (score = 1), 2–8 times a month (score = 2) and more than twice a week (score = 3). For both questions, a 3-point scale was used.

5.3.4 Marital status

In Paper I, marital status was one of the main study variables. It was measured at T1 by asking participants to select one of the following categories: ‘married’, ‘co-habiting’, ‘single’ and ‘separated/divorced’. To group the participants not in a relationship, single and separated/divorced were collapsed into one category. In Papers II and III, marital status was included as a control variable (measured at T2). Women not in a relationship were excluded from these studies, so only two categories were used: married and co-habiting.

5.3.5 Loneliness

Loneliness was measured at T1 by 1 item: ‘Do you often feel lonesome?’ A 5-point scale ranging from almost never (score = 1) to almost always (score = 5) was used to measure this variable. Loneliness was a main variable in Paper I.

5.3.6 Cohesiveness at work

Perceived group cohesiveness at work was measured at T1 by 1 item: ‘There is great cohesion at work’. A 4-point scale with 4 response categories ranging from agree (score = 1) to do not agree at all (score = 4) was used to measure this variable. For the purpose of the present analysis, the scoring scale was reversed, so the highest score represented the highest level of perceived cohesiveness. This was a main variable in Paper I.

5.3.7 Maternal infectious diseases

Self-reported maternal infectious diseases were measured at T2 and were the outcome variable in Paper II. This measure builds on a checklist that included 9 categories of infectious diseases: influenza, pneumonia/bronchitis, diarrhoea/gastric flu, common cold, throat infection, sinusitis/ear infection, vaginal thrush, vaginal catarrh and bladder infection. The respondents were asked to indicate whether they had experienced these diseases during weeks 17–30 of the current pregnancy. To examine the associations between relationship satisfaction and stressful life events with the total number of self-reported infections, a scale based on the sum scores of the reported diseases was used.

5.3.8 Infectious diseases in offspring

Maternal-reported incidents of infectious diseases in children were recorded at 6 months after birth for the period when the child was less than 6 months old and at 18 months after birth for the period when the child was 6–12 months old. Only data from the first year of life were used. The recording was based on a checklist with 8 categories of infectious diseases: the common cold, throat infection, pneumonia/RS

virus/bronchitis, diarrhoea/gastric flu, ear infection, pseudocroup, urinary tract infection and conjunctivitis. Mothers were asked to indicate whether their child had experienced these diseases when the child was younger than 6 months old and when 6–12 months old. To measure the variety of diseases experienced by each subject, a scale was used based on the number of reported categories of infectious diseases. To measure the frequency of disease for each subject, a scale based on the sum scores of the occurrence of each disease during a given period of time was used. These measures were the outcome variables in Paper III.

5.3.9 Consumption of sugar-sweetened and artificially sweetened beverages

Paper I was aimed at examining whether associations between certain social factors and sugar intake exist. For this purpose, sugar intake was measured as intake of sugary beverages. This measurement enabled comparing the results with associations between social factors and artificially sweetened beverages.

The consumption of sugar-sweetened sodas and juices was measured at T1 by 3 questions. Participants were asked to report how many cups of 1) sugar-containing cola, 2) other sugar-containing soda products and 3) sugar-containing juices they had drunk daily during the past 17 weeks. The same question format was used to record how many cups of 1) artificially sweetened cola, 2) other artificially sweetened sodas and 3) artificially sweetened juices participants had drunk daily during the given period of time. A table showing the conversion for bottles and large glasses into the standardised study unit (1 cup < 2 cl) was presented in brackets next to the question (1 mug = 2 cups; 1 small plastic bottle (0.5 litres) = 4 cups; 1 large plastic bottle (1.5 litres) = 12 cups). For each of the 6 groups of beverages, a 7-point scale based on the sum scores of reported units (reduced into 7 categories ranging from 0 units daily to 6 or more units daily) was used.

5.3.10 Confounding variables

Numerous studies have shown that socioeconomic factors are associated with physical health outcomes [64]. Therefore, age, education level and income were included as

control variables in all three studies. These variables were also included to avoid nonresponse bias (see section 5.2.1, Attrition and missing data). These three variables, along with marital status and stressful life events, were the only confounding variables in Paper II.

In Paper I, several factors that might be associated with both social integration and intake of sugary drinks were also included as confounding variables: body mass index (BMI), weight-related self-image, depression, participation in sports and physical strain at work. In Paper III, the following confounding variables were included: age, education, household income, prenatal stressful life events, marital status, support from other than partner, frequency of contact with friends/family, smoking, breastfeeding, maternal depression, child's sex and use of childcare. More details on each variable follow.

Age

Information on age of the mother was originally collected from the Medical Birth Register and was then provided in the MoBa dataset.

Level of education

Level of education was measured at T1 by asking the participating women to indicate which of the following levels of education they had completed: 9-year secondary school, 1–2-year high school, technical high school, 3-year high-school general studies, junior college, regional technical college, 4-year university degree (bachelor's degree, nurse, teacher, engineer) or university, technical college, more than 4 years (master's degree, medical doctor, PhD). The responses were scored from 1 (lowest education level) to 6 (highest education level).

Income

Income was measured at T1 by asking the participating women: 'What is your and the baby's father's yearly gross income'? Participants were asked to indicate the income of themselves and their partners in the following categories: no income, less than 150,000 NOK, 150,000–199,999 NOK, 200,000–299,999 NOK, 300,000–399,999 NOK, 400,000–499,999 NOK, and more than 500,000 NOK. The responses were

scored from 1 (lowest income) to 7 (highest income). In Papers I–II, maternal income was analysed. In Paper III, the sum of maternal income and partner income was treated as 1 variable (household income).

Participation in sports

Physical activity can reduce stress [65, 66] and, in many cases, is a social activity. Physical activity naturally increases thirst and energy use, so it might also influence the level of soda or juice consumption. Measures for engagement in sports and other physical activities and for physical strain at work, therefore, were included as potential confounders in Paper I. Sport activities was measured at T1 by 14 items covering such activities as running, biking, horse riding, dancing, walking and exercising at a fitness studio. Participating women were asked to report how often they had exercised during the first 17 weeks of the current pregnancy. There were 5 response categories: never (score = 1), 1–3 times per month (score = 2), once per week (score = 3), twice per week (score = 4) and 3 times or more per week (score = 5). A scale based on the mean scores from all 14 items was made.

Physical strain at work

Physical strain at work was measured at T1 with a single item: ‘My work is physically hard’. A 4-point scale was based on the 4 response options: agree (score = 1), agree mostly (score = 2), disagree mostly (score = 3) and disagree completely (score = 4).

Body mass index

Maternal BMI was included as a potential confounder in Paper I as performance of a demanding cognitive task has been shown to increase energy intake more in overweight persons than normal-weight persons [67]. Maternal weight and height were measured at T1 and BMI scores were calculated ($\text{weight}/\text{height}^2$) based on self-reported height and weight at the beginning of pregnancy.

Weight-related self-image

Perceived social pressure to be thin (the thin ideal) is related to negative emotions and dieting [68]. Self-image related to bodyweight, therefore, was included as a confounding variable in Paper I. It was measured at T1 by a single item: ‘Is it

important for your self-image that you keep a certain weight'? A 3-point scoring scale was based on the 3 response options: yes, very important (score = 1); yes, somewhat important (score = 2) and no, not particularly important (score = 3).

Maternal depression

Depression is associated with low marital quality [69], higher stress-related cortisol levels [70] and increased desire for sweet foods [71, 72]. Maternal depression, therefore, was included as a confounder in Paper I (measured at T1) and Paper III (measured at T2). It was measured by a single item from a checklist covering various diseases and illnesses. Respondents were asked to indicate whether they had ongoing depression or had had depression during the first 17 weeks of the current pregnancy. A dichotomised variable was based on an affirmative response to the item (i.e. depression) versus no affirmative response (i.e. no depression).

Smoking

Smoking during pregnancy may be a risk factor for infant respiratory infections [73] and was included as a control variable in Paper III. It was measured at T1, T2, T3 and T4 by 1 item: 'Do you smoke at present'? A dichotomised variable was based on sum scores of the 3 response options: no (i.e. not smoking) and sometimes or daily (i.e. smoking).

Breastfeeding

Breastfeeding has been shown to reduce the risk of infectious diseases in infants [74]. This variable, therefore, was included as a control variable in Paper III. To measure breastfeeding, a variable based on the sum scores for the number of months of breastfeeding was used.

Sex of offspring

Prenatal stress might have sex-specific effects on foetal development [75] and, therefore, was included as a control variable in Paper III. The child's sex was reported by the mothers 6 months after giving birth.

Use of childcare

For many children, everyday exposure to viruses and bacteria naturally increases when they start in childcare. This factor was controlled for in Paper III. Whether the children stayed at home or used childcare facilities was reported by the mothers 18 months after giving birth.

5.4 Statistical analysis

IBM SPSS Version 21 or 22 was used to conduct statistical analyses for Papers I and II and Paper III, respectively.

5.4.1 Paper I

First, the bivariate associations between the main exposure variables (loneliness, relationship satisfaction, marital status, cohesion at work and available support from friends and family) and the outcome variables (sugary beverages and artificially sweetened beverages) were determined by calculating Pearson product-moment correlations. Then, the associations between the main exposure variables and consumption of cola, soda and juice (sugary and artificially sweetened) were tested through the performance of six separate linear multiple regression analyses, one for each type of beverage as an outcome variable. The analyses were performed with the simultaneous entry of all exposure variables, and the following confounding variables: age, education level, income, BMI, weight-related self-image, depression, participation in sports and physical strain at work.

5.4.2 Paper II

Associations between relationship satisfaction and infectious diseases were tested by the performance of separate bivariate logistic regression analyses, one for each of nine infectious diseases. Nine multivariable logistic regression analyses were then performed, including the following independent confounding variables: age, marital status, education, income and stressful life events. In addition, one logistic regression analysis was conducted in which all nine categories of infectious diseases were

computed into one dichotomised variable (no infections versus one or more infections). To assess the possible interaction of relationship satisfaction with stressful life events on the number of self-reported infectious diseases, hierarchical multiple regression analysis was performed. First, the main predictor variables (relationship satisfaction and stressful life events) and the control variables were entered in the model. The second step was to enter an interaction term based on the scores on the self-reported levels of relationship satisfaction and stressful life events. To avoid collinearity between the main effects and the interaction term, the scores for relationship satisfaction and stressful life events were both centred on their means and then multiplied together.

5.4.3 Paper III

Associations between the levels of prenatal maternal relationship satisfaction and infectious diseases in the children were tested by performing separate bivariate logistic regression analyses for each of the eight categories of infectious diseases in infants less than 6 months old and 6–12-month-old infants. The age groups were separated as research indicates that infants less than 6 months old may be protected by maternal antibodies (IgG) [76]. Two corresponding sets of multivariable logistic regression analyses were performed using the following independent control variables: stressful life events, maternal age, education level, income, marital status, available support from friends/family, breastfeeding, maternal depression, child's sex and smoking during pregnancy. In addition, the use of childcare was included as a control variable in the analyses of the group of the oldest infants. A similar procedure was used to test the associations between prenatal stressful life events and infectious diseases in children. The difference was that stressful life events were replaced with maternal relationship satisfaction as a control variable in the multivariable analyses.

Multivariable linear regression analyses were conducted to examine the associations of prenatal maternal relationship satisfaction and stressful life events with the variety of infectious diseases in children. The same type of analysis was also performed to explore the associations of prenatal maternal relationship satisfaction and stressful life

events with the frequency of reported episodes of infectious diseases. The analyses were performed separately for the two age groups of infants.

5.5 Ethical considerations

All three studies were based on data collected for MoBa. The study was approved by the Norwegian Data Inspectorate and the Regional Committee for Medical Research Ethics.

Increased knowledge about the underlying factors and mechanisms of disease processes is a major advantage of the study. However, some disadvantages may also have arisen. Some participants might have experienced as intrusive certain questions, such as those on relationship satisfaction, mental health and death of a child. Others might have found the scope of the questionnaire broader and the questions more detailed than expected. In addition, although the present thesis used only data from the MoBa questionnaires, participants also agreed to donate biological material for the main study. They might have experienced this as invasive or felt some concern about the storage of their DNA in a biobank.

To minimise these disadvantages, MoBa was based on voluntary participation and written informed consent. Participants could withdraw from the study at any time. Children were included after consent from their mother and will be informed personally about the study when they are 15 years old. Once a child reaches 18 years old, MoBa will need informed consent from the child for further storage of the data.

Funding can contribute to biased interpretation of results, so it should be noted that MoBa is supported by the Norwegian ministries of Health and of Education and Research (NIH/NIEHS contract no. NO1-ES-75558, NIH/NINDS grant no.1 UO1 NS 047537-01 and grant no. 2 UO1 NS 047537-06A1) and the Norwegian Research Council/FUGE (grant no. 151918/S10).

6. Summary of results

6.1 Paper I

The main purpose of this study was to investigate the associations between social factors and the intake of sugar-sweetened beverages.

Results from regression analyses showed that high levels of relationship satisfaction were negatively associated with the intake of sugar-sweetened soda, cola and juice. Being married, having supportive friends and experiencing group cohesiveness at work were associated with lower intake of 2 of 3 types of sugary beverages. In contrast, perceived loneliness was associated with elevated intake of all 3 types of sugar-containing beverages. These associations remained statistically significant after controlling for scores on BMI, weight-related self-image, depression, physical activity, educational level, age and income.

To investigate whether the sugar or another component in the beverages accounted for the observed associations, associations between social factors and the intake of artificially sweetened beverages were also investigated. Results from regression analyses showed that no social factors were associated with consumption of artificially sweetened soda (other than cola) or juices. A negative association was found between consumption of artificially sweetened cola and relationship satisfaction but no other social factor.

All associations were weak, and the multiple regression models explained a small portion of the variance in consumption of the three types of sugar-sweetened beverages (1.9%, 7.5%, 9.1% for sugar-sweetened juice, soda other than cola, and cola, respectively). For the 3 types of artificially sweetened beverages, the models explained 3.1%, 4.1% and 7.8% (for artificially sweetened juice, soda other than cola, and cola, respectively) of the variance in consumption.

6.2 Paper II

The aims of this study were to investigate the degree to which couple relationship satisfaction predicted infectious disease risk among married and cohabiting women in pregnancy and to examine whether relationship satisfaction interacted with the association between stressful life events and infection risk. Results from multivariable logistic regression analyses showed that, after controlling for socioeconomic factors and stressful life events, lower levels of relationship satisfaction at gestational week 15 were associated with a higher risk for 8 of 9 categories of infectious diseases at gestational weeks 17–30, with the odds ratios ranging from 1.4 to 3.4. Among the infectious diseases assessed in this study, only urinary bladder infections were not associated with relationship satisfaction.

The results from the hierarchical multiple regression analysis showed a positive association between stressful life events and infectious diseases (unstandardised $B = .125$; standardised $\beta = .087$; $p < .001$) and a negative association between relationship satisfaction and infectious diseases (unstandardised $B = -.174$; standardised $\beta = -.069$; $p < .001$). No interaction effect was found between relationship satisfaction and stressful life events on infection risk.

6.3 Paper III

This study examined the degree to which prenatal maternal relationship dissatisfaction and stressful prenatal life events were associated with the risk of infectious disease in children in their first year of life. Associations with eight categories of infectious diseases were assessed: the common cold, throat infection, bronchitis/RS virus/pneumonia, pseudocroup, gastric flu, ear infection, conjunctivitis and urinary tract infection.

The results from the logistic regression analyses showed that maternal relationship dissatisfaction was associated with increased risk of all 8 categories of infectious diseases among infants less than 6 months old and increased risk of 7 diseases among 6–12-month-old children. The exception in the oldest group was urinary tract

infection. The associations were statistically significant for both age groups after adjusting for scores on age, education, household income, available support from friends/family, prenatal stressful life events, smoking, maternal depression, breastfeeding, child's sex and use of childcare.

The results from the logistic regression analyses also showed that maternal stressful life events were associated with 7 of 8 diseases in both age groups. This association remained valid after adjusting for scores on socioeconomic factors, prenatal relationship dissatisfaction, available support from friends/family, smoking, breastfeeding, maternal depression, child's sex and use of childcare. The exceptions were bronchitis/RS virus/pneumonia among infants less than 6 months old and urinary tract infection among 6–12-month-old infants.

Finally, the results from multivariable linear regression analyses showed that women who reported higher relationship dissatisfaction or more stressful life events during pregnancy also reported a higher frequency and greater variety of infectious diseases in their children.

7. Discussion

The present project was aimed at investigating the degree to which couples' relationship dissatisfaction and stressful life events were associated with the risk of infectious diseases in women during pregnancy and in their children during their first year of life. The project was also designed to investigate a hypothesis derived from social baseline theory proposing that there is an association between social integration and sugar intake.

The empirical findings of the present project are first discussed in light of previous research on related topics, followed by an exploration of the possible mechanisms underlying the findings. Finally, the limitations and implications of the study are considered.

7.1 Social integration and sugar intake

In an attempt to increase understanding of how social relationships regulate the need for metabolic resources, Paper I was aimed at investigating whether there is an association between social integration and sugar intake, as proposed by social baseline theory. The theory suggests that individuals who perceive themselves as socially isolated expend more neural resources and need more energy due to the higher metabolic costs of vigilance, solitary coping strategies and emotion regulation [53]. Empirical support for this theory was originally based on small, fMRI-based experiments which demonstrated correlations between social support and neural activation [33, 46] but did not include measurements for energy intake. Paper I tested the associations between five social factors and the level of sugar intake from soda, cola and juice in a larger sample. Overall, the hypothesis was confirmed by the results. Perceived loneliness was associated with higher intake of sugary beverages, while being married, having supportive friends, scoring high on relationship satisfaction and experiencing group cohesiveness at work were associated with lower intake of sugary beverages. Moreover, this pattern was not found between the exposure variables and

artificially sweetened beverages, suggesting that sugar was the key component responsible for the associations between social factors and sugary beverages.

The findings of Paper I are in line with studies linking various social factors with food consumption. For example, it has been found that social rejection caused participants to eat more sweet food than non-rejected participants [77] and that low levels of emotional support and the absence of a relationship predicted higher consumption of high-carbohydrate foods [78]. Additional support for social baseline theory was recently provided by Ein-Dor and colleagues [56]. They found that individuals with high avoidant-attachment scores consumed more sugar-rich food than more securely attached individuals [56]. As well, after facing a stressful task in the presence of others, avoidant participants ate larger amounts of sugar-rich food than their more socially oriented counterparts. In another recent study, Booth and Williams [79] investigated the relationship between type D personality and food intake. Type D represents a tendency towards negative affectivity and social inhibition [80]. Among the 187 participants, individuals with type D personalities consumed higher amounts of sugar than non-type D individuals [79]. Interestingly, the researchers found that the relationship between type D and food choice was partially mediated by dysfunctional coping styles, as measured by the Brief COPE scale [79].

These findings clearly support the notion that social relationships can influence the level of sugar intake. Keeping this in mind, a study by Hitze and colleagues [51] is especially interesting as it suggests that this association is related to the level of glucose metabolism in the brain. The study was designed to test a number of hypotheses derived from selfish brain theory by investigating how the brain controls demand for extra energy during acute mental stress [51]. Stress was induced by the Trier Social Stress Test, which is a standard procedure for induction of psychosocial stress [81]. Participants (N = 40) were assigned to 4 experimental groups based on the form of energy or food they were provided during and after the stress intervention (intravenous lactate infusion, dextrose infusion, meagre salad or rich buffet) [51]. Measurements included the assessment of mood, plasma glucose, serum insulin, serum cortisol, plasma epinephrine and norepinephrine and symptoms of glucose shortage in

the brain (neuroglycopenia). The study had a cross-over design, so each subject participated in 1 stress and 1 non-stress intervention. The results showed that stressed subjects, on average, ate 34 g more carbohydrates from the buffet than non-stressed participants. Both before and after the buffet, higher blood glucose levels were found in the stressed group than the non-stressed group. However, the rise in blood glucose after stress did not lead to higher insulin secretion in the stressed group. Based on these findings and the examination of the physiological stress responses of the participants, the results provided a strong indication that cortisol production and carbohydrate consumption perform the function of ensuring the supply of glucose to the brain [51].

The results of Paper I seem to be in line with previous research on the links between social factors and nutritional intake. Moreover, given that social relationships influence the level of stress, the associations between social factors and sugar intake found in the present study could be explained by the impact of social relationships on homeostatic factors related to brain glucose metabolism [46, 51].

7.2 Relationship quality, stress and infectious diseases

Paper II of this thesis examined the associations between levels of relationship satisfaction and self-reported infectious diseases among married and cohabiting women during pregnancy. Mostly in line with the hypothesis, the results showed that low levels of relationship satisfaction measured in week 15 of pregnancy were associated with 8 of 9 categories of infectious diseases experienced later in pregnancy.

Few studies have assessed the potential direct association between relationship satisfaction and manifested infectious diseases during pregnancy. A recent meta-analysis also indicates that few, if any, studies have investigated this association in the general population [82]. However, the findings of the present study do agree with previous research that has linked marital quality to biomarkers of stress associated with vulnerability to infections [83, 84].

Although Paper II did not focus on the direct effects of stressful life events, analyses testing whether relationship satisfaction interacts with the adverse effects of stressful life events revealed a positive association between the level of stressful life events and the number of self-reported infectious diseases. This finding was expected and in line with previous research in the general population [28, 85].

Contrary to expectations, the results did not support the hypothesis that high levels of relationship satisfaction moderate the association between stressful life events and infectious diseases. This hypothesis was based on studies suggesting that partner support may downregulate the stress-related activation of the HPA axis and decrease the levels of biomarkers associated with stress and suppressed immune function, such as pro-inflammatory cytokines [20, 33, 86]. However, the present findings indicate that there is no major interaction effect between marital satisfaction and stressful life events on the level of self-reported infectious diseases during pregnancy.

Paper III investigated the degree to which prenatal maternal relationship dissatisfaction and stressful life events predict the risk of infectious disease in children during their first year of life. Overall, the results supported the hypotheses. Specifically, it was found that maternal relationship dissatisfaction was associated with 8 groups of infectious diseases among infants less than 6 months old and with 7 of 8 groups of infectious diseases among 6–12-month-old infants. Similar patterns between stressful life events and infectious diseases emerged.

I did not find any previous studies focused on couples' relationship quality during pregnancy and its impact on the occurrence of infectious disease in children. However, previous research has shown that stressful prenatal life events predict infectious disease in infants and older children [41, 42, 87]. Animal and human studies also suggest that prenatal stress affects the development of foetus's immune domain [37, 88]. In sum, the empirical findings of Papers II and III are in line with research that links different measures of stress during pregnancy to reduced immune function or increased infection risk in mothers and children.

7.3 Possible mechanisms related to the findings of Papers II and III

The present project was not aimed at investigating possible underlying mechanisms that might link social relationships and stress with infection risk. Nevertheless, the project was guided by research on humans and animals demonstrating that stress activates the HPA-axis and SAM system and that these responses affect a wide range of bodily processes, including cortisol production, metabolism and alterations in the immune domain [28-30]. Importantly, activation of the HPA-axis and SAM system may be downregulated by supportive social relationships [18, 27, 33]. Research has demonstrated that sustained stress responses suppress the immune system [28, 30] and that marital quality and social interaction can regulate stress responses [33, 34]; therefore, it is likely that the main findings of Paper II were, at least partly, mediated by physiological responses to stress. In animal models, prenatal maternal stress has been linked to suppressed immune function in developing foetuses and to increased infectious disease risk after birth [37, 75, 89]. Therefore, it is also reasonable to assume that the findings from Paper III were mediated by physiological responses to stress.

Supportive partners tend to encourage healthy behaviours, such as exercising, eating healthy food and seeking medical advice, and discourage risky health behaviours [11, 18, 21]. Hence, the influence of social interaction on health-related behaviours is another possible explanation of the results in Paper II.

The two explanations might well both be true: a low-quality relationship might lack the beneficial effects of partners' attempts to regulate health behaviours and, at the same time, lead to higher levels of marital distress and physiological stress responses in pregnant woman [18].

Stressful events and marital dissatisfaction may also influence behaviour in a way that explains the increased risk of infectious diseases in children. For example, maternal relationship distress that persists after delivery could lead to suboptimal parent-child interaction and contribute to a stressful environment for the child [90]. Consequently,

the child might feel insecure and respond to the environment with higher levels of physiological stress responses which, in turn, suppress the immune system. This influence might be in addition to suppressed immune functions due to prenatal exposure to maternal stress [39, 89].

7.4 Strengths and limitations

The nature of the main hypotheses made it reasonable to expect relatively small effect sizes. Therefore, a strength of the present project was a large sample size, which permitted assessing the associations of interest within a narrow confidence interval. Another advantage of using the MoBa dataset was the inclusion of a high number of variables, which allowed for controlling for a wide range of confounding variables in the analyses. However, including a high number of variables in a questionnaire often limits space and makes it necessary to use measurements based on single items or short versions of instruments. One example of this limitation from the present work is the variable of loneliness. This is a complex construct, often measured by larger scales, such as the UCLA Loneliness Scale [91]. Hence, some measurements used in the present work might lack precision.

Another specific concern is the measurement of sugar intake. Participants were asked to retrospectively report their consumption of a wide range of beverages, so the scores for sugary beverages could have suffered from recall bias and inaccurate reports. It should be noted that a clinical perspective of the relationship between social integration and sugar intake should take into account a wide range of nutritious sources. For example, some persons simply do not have a habit of drinking sugary soda but might eat chocolate or fruit when craving carbohydrates. Therefore, an investigation of the magnitude of sugar intake predicted by, for example, social isolation should include relevant outcome variables in addition to sugary beverages. However, this investigation was not the aim of the present work. As stated, Paper I had a theoretical orientation and was aimed at examining whether associations between certain social factors and sugar intake exist. The decision to measure sugar intake through sugary beverages can be regarded as a strength of the study, though, as it

made it possible to compare the results with the associations between social factors and artificially sweetened beverages. Additionally, this study contributed data from a real-life setting, complementing the existing laboratory-based experimental literature.

A general concern of self-report questionnaires is that participants might provide inaccurate answers. For example, reports of the frequency and types of infectious diseases might have been subject to inaccurate memories or unqualified interpretations of symptoms. It is also possible that some participants either underestimated or overestimated the occurrence of diseases. For instance, people who score high on neuroticism tend to report somatic symptoms more frequently than those who score low on neuroticism [92]. The symptom perception hypothesis holds that this difference arises not because of actual physical differences between people who are high and low in neuroticism; rather, neurotic individuals are more likely to perceive and react to minor somatic symptoms [93]. Moreover, neuroticism has been shown to be associated with marital quality, and people high in neuroticism report lower marital quality [94]. These findings suggest that, in some cases, the association between relationship dissatisfaction and infectious diseases might have been amplified by neuroticism. Thus, a limitation of Paper II is that neuroticism was not included as a confounding variable.

A related concern for the interpretation of the results of Paper III is that previous research has shown a positive relationship between maternal emotional distress and maternal reports of children's somatic symptoms [95]. This finding suggests that maternal relationship dissatisfaction and maternal emotional status may be associated with reporting bias for children's symptoms. Potential problems with maternal reporting bias could have been avoided by using data based on diagnostic criteria derived from medical records. However, data from medical records could also suffer from reporting bias as mothers' views of how severe or serious symptoms should be before seeking medical advice might differ. In addition, less severe infections, such as the common cold, are naturally less likely to be treated by medical doctors. Hence, both medical records and self-reports of diseases have strengths and limitations.

Another limitation of the present work was the lack of data on biomarkers related to stress and disease, such as measurements of cortisol levels, cytokine levels and blood pressure. Unlike some of the experiments that guided the hypotheses of the present study, there was no possibility to rule out which biological mechanisms accounted for the associations among stress, social relationships and infections.

Finally, none of the studies was designed to draw conclusions about causality. An experimental design would have been necessary to assess the causal effects of the exposure variables. However, an experimental design might not be regarded as a preferable alternative to the present project. Clearly, an experimental study designed to manipulate harmful exposures for randomly selected pregnant woman is not ethically acceptable. A strength of the present design, therefore, was that it enabled studying disease risk factors for pregnant humans and their children within an ethically acceptable framework.

7.5 Future perspectives

7.5.1 Clinical implications

Paper I had a more theoretical than clinical focus. The results showed weak associations, and the regression models explained a small portion of the variance. Thus, the clinical relevance to increasing social support to reduce the intake of sugary beverages seems limited. Nevertheless, social integration may be an issue discussed when consulting individuals who want to reduce their sugar intake. Thus, this paper can contribute to a greater focus on social integration as part of lifestyle education, in addition to traditional topics, such as eating behaviours and exercise.

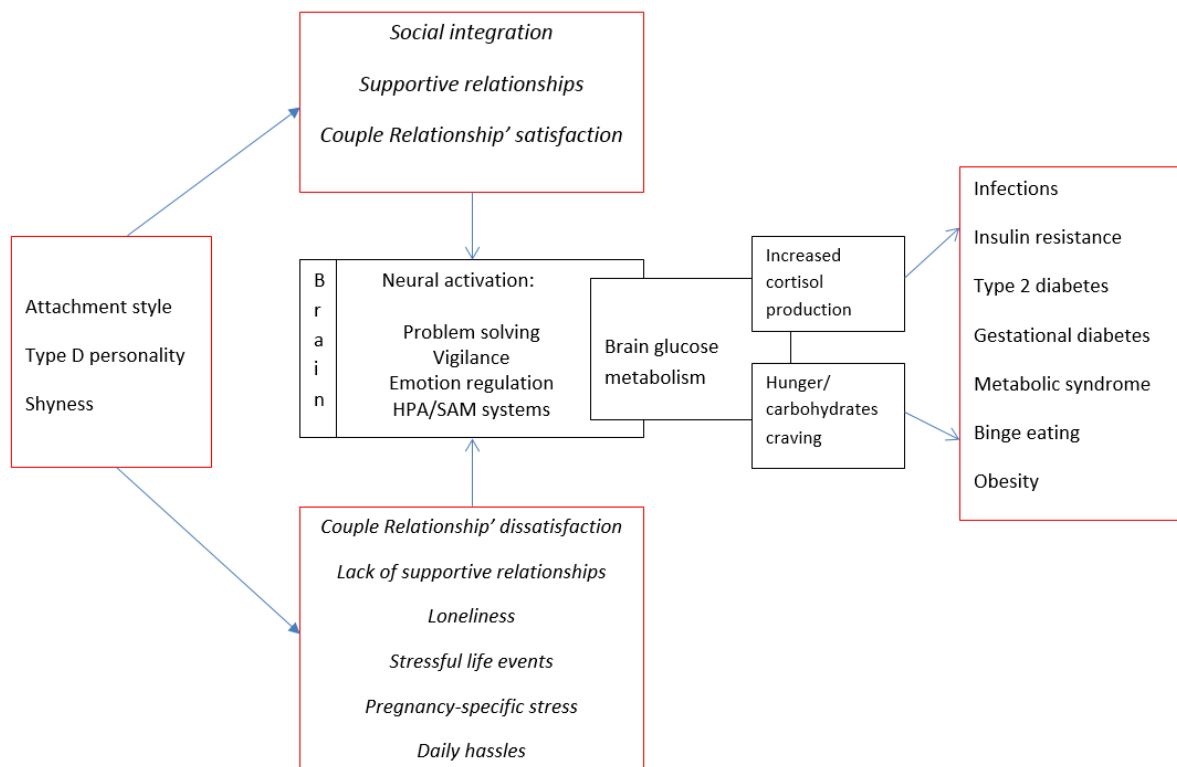
Papers II and III assessed clinical endpoints in terms of manifested infectious diseases in pregnant woman and their children. On the level of society, improvement of couples' relationships might reduce the incidence of infectious diseases in these two groups. However, to what degree interventions, such as couples' relationship therapy, can reduce infection risk remains to be investigated. Overall, the findings suggest that

stress levels and dissatisfaction with a partner during pregnancy should have similar status as risk factors in reproductive health.

7.5.2 Implications for future research

The results generally supported the main hypotheses of the present work and were in line with the theoretical model (Figure 1) that guided the hypotheses. This model was based on elements from CATS, social baseline theory and selfish brain theory. In sum, a combination of these approaches suggests a model for social regulation of physiological stress responses, brain glucose metabolism and clinical outcomes. This model could be useful not only to illustrate the rationale underlying the present studies but also to guide future studies investigating the influence of social relationships on a variety of outcomes related to HPA activation, metabolism and feeding behaviour. Examples of such outcomes are insulin resistance, type 2 diabetes, gestational diabetes, metabolic syndrome, binge eating and obesity. The model (Figure 1) applied for the present hypotheses could also include other predictor variables related to stress and social relationships. Candidates are measurements of daily hassles or pregnancy-specific stress [96, 97] and personality traits related to social inhibition, such as type D personality [79], adult attachment style [56] and shyness [98]. Figure 2 illustrates how these suggestions for future research could build on this theoretical model. The model is not restricted to the pregnant population but may be applicable to all genders and age groups.

Figure 2. Model for social regulation of physiological stress responses, brain glucose metabolism and clinical outcomes.



7.6 Conclusions

The findings of the present project add to the existing literature on the links between social relationships and health. The original contribution of Papers II and III was to show that couples' relationship dissatisfaction during pregnancy was associated with the risk of manifested infectious diseases in both mother and children. Another contribution was to demonstrate that loneliness, social integration and relationship quality were associated with the level of consumption of sugary beverages. This finding supported the hypothesis derived from social baseline theory that relative social isolation leads to increased levels of sugar intake.

An additional contribution of the present project was the creation of a model that illustrates how increased infectious disease risk and sugar intake, both predicted by stress and unsatisfying social relationships, may have shared pathways and mechanisms.

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Loneliness, Social Integration and Consumption of Sugar-Containing Beverages: Testing the Social Baseline Theory

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Abstract

Objective: Social Baseline Theory (SBT) proposes that close relationships aid in metabolic resource management and that individuals without significant relationships may experience more demands on their own neural metabolic resources on a daily basis when solving problems, remaining vigilant against potential threats and regulating emotional responses. This study tests a hypothesised consequence derived from SBT: relative social isolation leads to increased levels of sugar intake.

Methods: Based on cross-sectional, self-reported data from the Norwegian Mother and Child Cohort Study (N = 90 084), information on social integration and the consumption of both sugar-sweetened and artificially sweetened sodas and juices was obtained from a large number of women in early pregnancy. Multiple regression analyses were conducted to assess whether loneliness, marital status, relationship satisfaction, advice from others than partner, and cohesion at work is associated with consumption of sodas and juices.

Results: Perceived loneliness was associated with elevated intake of all sugary beverages, while relationship satisfaction was negatively associated with all sugary beverages. Being married or cohabitating, having supportive friends, and having a sense of togetherness at work were associated with lower intake of two out of three sugar-containing beverages. These associations were significant, even after controlling for factors such as body mass index, weight related self-image, depression, physical activity, educational level, age and income. In comparison, a statistically significant relationship emerged between relationship satisfaction and artificially sweetened cola. No other predictor variables were significantly associated with any type of artificially sweetened beverage.

Conclusions: This study indicates that loneliness and social integration influence the level of consumption of sugary beverages. The results support the hypothesis derived from the Social Baseline Theory that relative social isolation leads to increased levels of sugar intake.

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Data Availability: The authors confirm that, for approved reasons, some access restrictions apply to the data underlying the findings. The data underlying the findings of this manuscript are held by the Norwegian Institute of Public Health (NIPH). Access to the data is therefore restricted by the policies of NIPH. Before data can be released a full application must be submitted and in most cases a contract must be signed with the Norwegian Institute of Public Health. To apply for statistical data in the form of ready-made tables use this application form: <http://www.fhi.no/dokumenter/aabd86f88b.doc> Additional information about access to data from the Norwegian Mother and Child Cohort Study are obtained from the Norwegian Institute of Public Health (www.fhi.no). All enquiries about access to data should be sent to datatilgang@fhi.no.

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Introduction

This study examines whether there is an association between social integration and sugar intake, as proposed by the Social Baseline Theory [1].

The brain is the most metabolically active organ of the human body. Even in a resting state of non-specific neural activity, it counts for as much as 20% of the body's total energy utilization [2]. The adult human brain is almost completely dependent on

glucose as a source for energy. Unlike other organs, the brain has very little metabolic reserve because it oxidizes glucose at relatively close to its maximum rate. Because more than 85% of the glucose is utilized by neurons, the rate at which the brain oxidizes glucose is proportional to neuronal activity [2,3]. This implies that specific neural effort must be followed by a rapid supply of glucose from the blood in an amount that corresponds with the metabolic cost of the specific effort [3]. In an illustrative study, Scholey, Harper

and Kennedy [4] showed that a cognitively demanding subtraction task was followed by an immediate, significant fall in peripheral blood glucose. Moreover, by offering a glucose-containing drink to one group and a placebo drink to the other, they also demonstrated that glucose intake after a fall in blood glucose level was associated with better performance on a subsequent cognitively demanding task. Similar studies were performed by Gailliot and colleagues [5], who found that different types of mental effort, such as thought suppression, attention control and emotion regulation, were followed by an immediate fall in peripheral blood glucose levels.

Restoring the blood glucose to normal levels after a drop is of high biological priority. Even a few seconds without cerebral glucose oxidation will lead to unconsciousness, and after a few minutes, the death of neurons will occur. In order to counteract a dangerous glucose shortage in the brain, humans possess a highly sophisticated glucose regulatory system [6]. In addition to the role of hepatic glycogen in counter-regulation of hypoglycemia [7], the brain has the ability to rapidly sense a drop in circulating glucose and induce a range of other counter-regulatory responses. These include the secretion of galanin and GABA, which minimizes the chance of glucose deprivation by inhibiting neural activity, as well as stimulating cortisol release, which aims to increase blood sugar through gluconeogenesis in the liver [2,6]. In addition, cortisol has been shown to suppress insulin secretion from pancreatic β -cells and impair insulin initiated translocation of the intracellular glucose transporter, GLUT 4 [8–10]. This leads to decreased insulin-dependent glucose uptake into peripheral cells and makes glucose available to the brain via glucose transporter GLUT 1 [3,10,11]. Another set of regulatory mechanisms involves directed behavior. Naturally, most efficient are behavioral actions that regulate glucose levels by facilitating exogenous supplies of carbohydrates from nutritional sources. Indeed, a substantial body of research has linked different types of demanding mental work to the subsequent intake of food, with a significant preference for foods high in carbohydrates [12–13]. This point is thoroughly discussed by Peters, Kubera, Hubold and Langemann [19] who have developed a model called the Cerebral Supply-Chain Model, which explains how both cortisol-induced and eating-induced supplies of glucose are initiated by the brain during times of energy-demanding psychosocial stress.

During periods of evolutionary pressure, it is likely that individuals with efficient glucose regulatory responses have been evolutionarily favored. Social Baseline Theory (SBT) [1,20,21] argues that in order to conserve metabolic resources, the human brain is phylogenetically designed to benefit from social networks when engaging in demanding mental activities, such as effortful decision making, creative problem solving and emotion regulation. SBT uses the principles of risk distribution and load sharing to explain the brain's metabolic benefit from social interaction. *Risk distribution* refers to how individuals in a group perceive and react to environmental risk, as opposed to how the corresponding risk would be handled by socially isolated individuals. For example, as a group has more eyes and ears than a single individual, effort toward vigilance against possible dangers in the environment are distributed across the group. In this way, fewer neural resources are needed for each group member as compared with the cost of the precautions and worries solitary individuals must engage in to ensure a similar safety level. In close relationships, participants receive benefits beyond those associated with risk distribution. *Load sharing* refers to the energy-conserving effects of trust and interdependence, which are found between, for example, romantic partners, family members and close friends. In close relationships, the members tend to engage in behaviors that facilitate one

another's well-being, for example, sharing resources, sharing goals and assisting in problem solving [22]. Central to SBT is the notion that "as an individual becomes accustomed to load sharing, his social system becomes an extension of the way his brain interacts with the world" [1]. The theory proposes that such "outsourcing" of mental work is particularly beneficial in the regulation of emotional responses because self-regulating processes supported by the prefrontal cortex are believed to be more metabolically costly than most other cognitive processes. Thus, socially mediated forms of emotion regulation may have significant energy-conserving advantages [1,23,24]. According to SBT, due to the evolutionary benefits of adjusting to the principles of risk distribution and load sharing, the human brain leans on social resources as a default strategy: "the human brain is designed to assume that it is embedded within a relatively predictable social network characterized by familiarity, joint attention, shared goals, and interdependence" [1]. A violation of this "baseline assumption", however, signals the need for increased threat-related vigilance and reactivity. Thus, socially isolated individuals regulate their emotions at a higher metabolic expense compared with socially integrated individuals. In sum, SBT predicts that relative social isolation requires more neural metabolic resources in order to both manage daily life routines and to regulate emotions. This hypothesis builds on research showing that neural systems that support self-regulatory efforts are less active when social support is provided [20,24]. Furthermore, in a context in which social support is provided, the down-regulation of neural response is a function of relational quality. In an fMRI-study conducted by Coan, Schaefer and Davidson [25], 16 women were confronted with the threat of a mild electric shock while either alone, holding a stranger's hand, or holding their partners' hands. While holding their partners' hands, the women in the highest-quality relationships showed the least threat-related brain activity. When holding a stranger's hand, the level of threat-related activity increased as compared with holding the partners' hands. Finally, when exposed to the threat of shock without the support of handholding, the threat-related brain activity reached its highest level.

Given that socially isolated individuals frequently demand extra supplies of glucose from the blood to maintain optimal brain function, one might expect elevated intake of food and beverages that rapidly elevate blood glucose in this group [19]. This assumption is consistent with findings showing that low levels of emotional support predict the higher intake of carbohydrates [26]. On the basis of these findings and in accordance with the framework of SBT, we expect to find a covariance between loneliness and social connectedness on the one hand and consumption of sugar on the other.

Hypotheses

Sodas and juices contain high amounts of sugar and are highly available in western societies, easy to grab and convenient to drink. The per capita consumption of soda and juice in Norway is among the highest in the world [27]. Therefore, sugar-containing sodas and juices are likely to work well as an indicator of intake of sugar that has the ability to quickly provide glucose to the bloodstream. The main hypothesis (H^1) of the present study is thereby that degree of loneliness and social connectedness are associated with degree of intake of sugar – in the form of sugar-containing sodas and juices. However, sugary beverages consist of more than just sugar. If the null hypothesis of H^1 should be rejected, indicating that less socially connected people consume more soda and juice than their more socially integrated counterparts, sugar may not necessarily be the reason for the higher intake (it could be the sweet taste, the water, the citric acid, or any of the other

components that sodas and juices consist of). To clarify the role of sugar in the potential relationship between social connectedness and intake of sugar-containing drinks, an additional hypothesis may be useful (H^2): degree of social connectedness is associated with degree of intake of artificially *sweetened* sodas and juices. If the null hypotheses of both H^1 and H^2 should be rejected, we cannot claim that intake of sugary soda and juice related to social connectedness necessarily is an expression of attractiveness to sugar. If, however, we reject the null hypothesis of H^1 but not the one of H^2 , indicating that less socially connected people consume more sugary drinks but not more artificially sweetened drinks, we can conclude that there is a strong indication that sugar is the key-component of these relationships. In this study, we were able to extract these variables from a huge pregnancy cohort.

Methods

The Norwegian Mother and Child Cohort Study (MoBa) is a prospective population-based pregnancy cohort study conducted by the Norwegian Institute of Public Health [28]. In the period 1999–2008, all hospitals in Norway (except two) with more than 100 births per year invited pregnant women to participate in the study provided that they could read Norwegian. They received a postal invitation three weeks before the ultrasound examination routinely offered to all pregnant women in Norway. 38.7% of invited women consented to participate, and the cohort now includes 109 000 children, 91 000 mothers and 71 700 fathers. Blood samples were obtained from both parents during pregnancy and from mothers and children (umbilical cord) at birth. Follow-up is conducted by questionnaires at regular intervals and by linkage to national health registries. Several sub-studies are conducting additional collections of data and biological materials. The current study is based on version 7 of the quality-assured data files released for research on October 17th 2012. Informed consent was obtained from each MoBa participant upon recruitment. The study was approved by The Regional Committee for Medical Research Ethics in Western Norway.

Participants

The present study includes women participating in the MoBa study for the first time. Women who participated multiple times only provided data regarding their first participating pregnancies, and participants with diabetes type 1 were excluded. The included participants ($N=90\ 084$) had a mean age of 29.2 years (std. deviation 4.40). Among them, 46.5% were married, 50.7% were cohabitating, and 2.8% were single. The average level of education was higher for the sample than for the general population of women aged between 16–49 years (official statistics from 2008 in brackets): compulsory school, 3.3% (28.1%); vocational school/three-year college, 34.9% (34.8%), and university/higher education, 61.7% (34.4%). The full sample has been compared with the general population of pregnant women in Norway and is described in more detail elsewhere [29].

Measures

MoBa collects many diverse variables. Of special interest for this study were sugar-containing beverages and five factors reflecting aspects of social connectedness: loneliness, marital status, couple relationship quality, social support from others than the partner and perceived cohesion at work.

To measure the consumption of sugar-containing sodas and juices, participants were asked three questions. They were asked to report how many glasses of 1) *sugar-containing cola*, 2) *other sugar-containing soda products*, and 3) *sugar-containing juices*

they had been drinking daily during the last 17 weeks. To be able to assess whether potential associations between social connectedness and sugar-containing beverages are related to attractiveness to sugar, we also included reports on how many glasses of 1) *artificially sweetened cola*, 2) *other artificially sweetened sodas*, and 3) *artificially sweetened juices* the participants had been drinking daily during the same period. A table for converting bottles and large glasses into the standardized study unit (1 glass \approx 2cl) was given in brackets next to the questions. For the purpose of this paper, the numbers of reported units of the six groups of beverages were respectively divided into seven categories spanning from '0 units' to '6 or more units'.

Loneliness was measured by a five-point scale spanning from "almost never" to "almost always" based on a single item: "Do you often feel lonesome?"

Marital status was measured via the following categories: "married", "co-habiting", "single" and "separated/divorced". To group the participants that were not in a relationship, "single" and "separated/divorced" were collapsed into one category.

The full ten-item version of the *Relationship Satisfaction Scale* was used to assess the quality of the co-habiting or married participants' relationships. The scale was developed for the MoBa and based on core items used in previously developed measures of marital satisfaction and relationship quality [30–32]. The scale has a six-step scoring format spanning from 1, "totally agree", to 6, "don't agree at all". Examples of items are as follows: "My partner and I have problems in our relationship", "I am very happy in my relationship" and "My partner is generally very understanding". In the current sample, the scale had a Cronbach's Alpha of 0.90. This scale has been used in previous studies [33,34].

Social support from other than the partner was measured via one item: "Do you have anyone other than your husband/partner whom you can ask for advice in a difficult situation?" There were three response categories: "no", "yes, one to two people" and "yes, more than two people".

Perceived cohesion at work was measured by one statement: "There is a great cohesion at work", and four response categories spanning from 'agree' to 'not agree at all'. For the purpose of the present analysis, the scoring scale was reversed.

Control variables

Eight control variables that may influence the level of intake of sodas or juices were included: participation in sports, physical strain at work, body mass index, weight related self-image, depression, age, level of education and income.

Because sport activities and other physical strain increase thirst and energy utilization, they may influence the level of soda or juice consumption. We therefore included measures for engagement in sports and other physical activities, as well as physical strain at work. *Sports* was measured by 14 items covering activities such as, "running", "biking", "horse riding", "dancing", "walking" and "fitness studio". The respondents were asked how often they had exercised during the first 17 weeks of the current pregnancy. There were five response categories: "never", "1–3 times per month", "once per week", "twice per week" and "3 times or more per week". *Physical strain at work* was based on a single item, "My work is physically hard", and was measured on a four-point scale spanning from "correct" to "not correct".

Individuals with high body mass index (BMI) scores tend to have elevated carbohydrate intake in the absence of hunger compared with normal-weight subjects [35]. Thus, specific mechanisms related to overweight may account for some of the variance in the consumption of sugar-containing beverages. We therefore included BMI as a control variable. BMI scores were

calculated on the basis of self-reported height and weight at the beginning of pregnancy.

Weight concerns related to self-perceptions, for example, internalization of the “thin ideal”, may impact eating behaviors and dieting [36]. We therefore included a single-item variable reflecting weight concerns motivated by self-image: “*Is it important for your self-image that you keep a certain weight?*” There were three response categories: “Yes, very important”, “Yes, somewhat important” and “No, not particularly important”.

Depression has been linked to a desire for sweet foods [37,38] and may therefore explain a potential association between social interaction and consumption of sweet beverages. Depression was measured based on one item from a checklist covering a wide range of diseases and health problems. The respondents were asked to mark whether they had or had had ongoing depression during the first 17 weeks of the current pregnancy.

Age is associated with the level of soda consumption, with young people consuming more [39,40]. In this study, age was measured as age in years at the point of the study.

Higher educational levels are associated with lower consumption of sugar-containing soda [39]. *Educational level* was measured by six categories, from public school to >4 years of university/college.

A low level of income has been associated with high consumption of sugary drinks [40,41]. Here, we measured *maternal income* by dividing it into seven categories, from 1 = no income to 7 \geq NOK 500,000 (\approx EUR 66,000).

Statistical analyses

All statistical analyses were conducted using the IBM SPSS Version 21. To determine the bivariate associations between the main predictor variables and the outcome variables, Pearson product moment correlations were computed. The associations between the main predictor variables and consumption of cola, soda and juice (sugar- and artificially sweetened) were tested via six separate linear multiple regression analysis, one for each type of beverage as an outcome variable. The analyses were performed with the simultaneous entry of all predictor variables, including the following control variables: participation in sports, physical strain at work, body mass index, weight related self-image, depression, age, level of education and income. Because the participants did not necessarily report on all questions concerning consumption of beverages, the different models are based on different sample sizes.

Results

First, bivariate correlations were computed between scores for loneliness, relationship satisfaction, advice from others and cohesion at work, and the six outcome variables. Pearson product moment coefficients as well as mean scores and standard deviations of scores for consumption of soda, cola and juice are given in Table 1. The results of the bivariate correlational analysis showed that all social factors were significantly correlated with scores on all sugar-containing beverages in the predicted direction. The social factors were also significantly correlated with scores on most of the artificially sweetened beverages. All correlations were generally weak, but consistently stronger between the predictor variables and the scores for sugar-containing beverages than between the predictor variables and the scores for artificially sweetened beverages. Next, a series of regression analysis was performed (see Table 2) to develop three separate models for predicting scores for the intake of sugar-containing cola, sugar-containing sodas (other than cola) and sugar-containing juices, from scores for loneliness, marital status (co-habiting and married),

relationship satisfaction, advice from others and cohesion at work. All models were statistically significant; Model 1: (dependent variable: sugar-containing sodas) $F(14, 28494) = 205.395, p < .001$; Model 2: (dependent variable: sugar-containing cola) $F(14, 25655) = 150.331, p < .001$; Model 3: (dependent variable: sugar-containing juices) $F(14, 50040) = 71.502, p < .001$. The models explained 7.5% (adjusted $R^2 = .075$), 9.1% (adjusted $R^2 = .091$), and 1.9% (adjusted $R^2 = .019$) of the variance in consumption of the beverages, respectively. Results from the regression analysis showed that high levels of perceived loneliness were positively associated with high levels of intake of sugar-containing soda. Significantly negative relationships emerged between both relationship satisfaction and advice from others than partner, and sugar-containing soda. Marital status and cohesion at work were not statistically significantly associated with consumption of sugar-containing soda. As shown in Table 2, all six variables related to social interaction were significantly associated with self-reported levels of intake of sugar-containing cola. A high level of perceived loneliness was associated with high levels of cola intake. Negative associations were found between cola intake and relationship satisfaction, being married (compared with being single), cohabitating (compared with being single), the possibility of seeking advice from others than the partner, and perceived cohesion at work. Table 2 also shows that high levels of perceived loneliness were associated with high levels of consumption of sugar-containing juices. Negative associations were found between relationship satisfaction, being married (compared with being single), cohabitating (compared with being single), and perceived cohesion at work on the one hand, and consumption of sugar-containing juices on the other. In this analysis, the possibility of seeking advice from others than the partner was not significantly associated with consumption of sugar-containing juices.

Finally, three equivalent analyses, with the inclusion of the same control variables as included in the models above, were conducted for artificially sweetened soda (other than cola), cola and juice as outcome variables. The models were statistically significant: Model 4: (dependent variable: artificially sweetened soda) $F(14, 24208) = 74.772, p < .001$; Model 5: (dependent variable: artificially sweetened cola) $F(14, 29282) = 177.886, p < .001$; Model 6: (dependent variable: artificially sweetened juices) $F(14, 26603) = 62.250, p < .001$. The models explained 4.1% (adjusted $R^2 = .041$), 7.8% (adjusted $R^2 = .078$), and 3.1% (adjusted $R^2 = .031$) of the variance in consumption of the three types of artificially sweetened beverages, respectively. Table 2 shows that none social factors were significantly associated with consumption of artificially sweetened soda (other than cola) or juices. A significant negative association was found between relationship satisfaction and consumption of artificially sweetened cola. No other social factors were significantly associated with consumption of artificially sweetened cola.

Discussion

Overall, our results confirmed that perceived loneliness was associated with elevated intake of sugar in the form of soda, cola and juice. High levels of relationship satisfaction, on the other hand, was negatively associated with all three types of sugary beverages. Other aspects of social connectedness such as being married, having supportive friends, and having a sense of togetherness at work were associated with lower intake of two out of three types of sugar-containing beverages. These associations were statistically significant, even after controlling for factors such as body mass index, weight-related self-image, depression, physical activity, educational level, age and income.

Table 1. Mean scores, standard deviations of scores, and Pearson product moment coefficients for inter-correlations of scores for main predictor variables and consumption of soda, cola and juice.

	Mean	SD	Sugar-sweetened			Artificially sweetened		
			Soda	Cola	Juice	Soda	Cola	Juice
Loneliness	1.77	0.86	.095**	.107**	.047**	.021**	.025**	.033**
Relationship satisfaction	5.32	0.65	-.060**	-.078**	-.023**	-.031**	-.044**	-.015**
Advise from others	2.49	0.57	-.078**	-.078**	-.022**	-.035**	-.023**	-.006
Cohesion at work	3.36	0.71	-.026**	-.037**	-.016**	-.013**	-.017**	-.014**

** Correlation is significant at the 0.01 level (2 tailed).
 * Correlation is significant at the 0.05 level (2 tailed).
 N varies from n=29010 (lowest) to n = 65693 (highest).
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Although the associations were weak, all of the five tested social factors were significantly associated with consumption of at least two types of sugar-sweetened beverages. In the regression analyses, statistically significant relationships did emerge as predicted in 14 out of 18 cases. The systematic structure of these results suggests that the associations found in this sample were not coincidental. Hence, these results support the main hypothesis of the study proposing that perceived social isolation, as well as perceived social integration, influence consumption of sugar-containing sodas and juices. The assumption that sugar is a key component of the relationship between relative social isolation and intake of sugary beverages is supported by the analyses that included artificially sweetened beverages as outcome variables. Most of the variables were significantly correlated in the bivariate analyses. However, in the regression analyses, after isolating the unique contribution of the predictor variables by controlling for scores on BMI, physical activity, weight-related self-image, depression, and demographic variables, a statistically significant association with an artificially sweetened beverage emerged in only one out of 18 cases. These results are in a striking contrast to the number of statistically significant relationships that emerged for scores on sugar-sweetened drinks. This may be interpreted as a strong indication that the associations between social connectedness and sugar-containing beverages in a great part are counted for by the sugar, and to a less extent by any of the other components that soda and juices consist of. However, these findings do not rule out the possibility that other components than sugar may also come into play. One candidate is the caffeine in cola. Caffeine is a central-nervous-system stimulant that has been shown to increase vigilance, alertness, mood, ability to concentrate and ability to solve problems [42]. As the results show, sugar-containing cola is the only variable that was significantly associated with all main predictor variables. In addition, there was a significantly negative association between high levels of relationship satisfaction and artificially sweetened cola. Moreover, the independent variables had a greater effect on sugar-containing cola than on the other dependent study variables. This may be taken as an indication that caffeine might partly count for the associations found between social connectedness and cola. However, the general pattern of the present findings indicates that sugar is the factor mainly responsible for the associations between social connectedness and intake of sugary sodas and juices.

To date, very few studies have focused on the associations between social integration and intake of sugar-sweetened beverages. One exception is a study by Cacioppo and colleagues [43], in which no significant association was found between loneliness and soda consumption. This finding was based on data from a group of 89 participants and might have suffered from insufficient statistical power. A number of studies, however, have found significant associations between social factors and food consumption. For example, in an experimental study by Baumeister and colleagues [44], it was found that social rejection caused participants to eat more sweet food than non-rejected participants. In a population-based cohort study conducted in Finland, it was found that low levels of emotional support (among women) and being single or divorced (among men) were the strongest predictors of elevated levels of high-carbohydrate food consumption [26]. Moreover, researchers have also found significant associations between loneliness and overeating [45,46]. Thus, the present results seem to be consistent with previous research on the links between social factors and nutritional intake.

The dataset used in this study did not include information on brain metabolism or blood glucose levels. Nevertheless, Social Baseline Theory [1] provides a possible explanation for the

Table 2. Multiple regression analyses: predicted scores for consumption of soda (other than cola), cola and juices from scores for loneliness, marital status (co-habiting and married), relationship satisfaction, advice from others, and cohesion at work.

	Sugar-sweetened			Artificially sweetened		
	Soda	Cola	Juice	Soda	Cola	Juice
Loneliness	.02**	.03**	.02**	-.00	-.00	.01
Married	-.05	-.12**	-.09**	-.00	.00	-.05
Cohabiting	-.02	-.09**	-.07*	.03	.02	.01
Relationship satisfaction	-.02*	-.04**	-.01*	-.01	-.03**	-.00
Advice from others	-.03**	-.02**	-.00	-.01	.00	.01
Cohesion at work	-.01	-.02**	-.01*	-.01	-.01	-.01
Mean	0.48	0.65	1.84	0.41	1.22	0.70
SD	1.00	1.22	1.36	1.14	1.84	1.30
N	25670	28509	50055	24223	29297	26618

Results are adjusted for scores on participation in sports, physical strain at work, body mass index, weight related self-image, depression, age, level of education and income.

** Correlation is significant at the 0.01 level (2 tailed).

* Correlation is significant at the 0.05 level (2 tailed).

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association between loneliness and intake of sugar-containing beverages that is related to relative neuronal hypoglycemia. The theory proposes that the human brain is phylogenetically designed to utilize support from social networks to save metabolic resources when engaging in demanding mental activities. As a logical consequence, individuals who perceive themselves as socially isolated must spend more neural resources on a daily basis due to the metabolic expenses of solitary strategies for problem-solving, emotion regulation and vigilance against threats. As pointed out previously in this article, when neural metabolic activity and brain glucose utilization is high, then the rapid restoration of glucose supplies is required. Lonely people may have higher neuronal metabolic activity, which requires greater glucose supplies, and hence consume more sugar than their more socially connected counterparts. Because sodas and juices are easily accessible sources of sugar, the observed associations between relative social isolation and intake of sugar-containing beverages may reflect an expression of brain glucose regulatory mechanisms [2]. In contrast, consistent with the hypothesis that individuals profit metabolically from the energy-conserving effects of close relationships, the present results showed that perceiving ones' romantic relationship as satisfying was significantly associated with lower levels of consumption of sugar-containing beverages. This corresponds with an fMRI based study of social regulation of the threat-related brain activity demonstrating that down-regulation of neural response was a function of marital quality [25]. Further support for the hypothesis that individuals profit metabolically from social relationships is provided by the findings that being in a relationship, having supportive friends, and experiencing cohesion at work were associated with lower levels of consumption of two out of three types of sugar-containing beverages.

Some limitations of the present study should be acknowledged. The analyses were conducted based on the expectation that social factors predict the intake of sugar-containing beverages to some degree. However, a cross-sectional design does not make it possible to determine the causal relationships between research variables. On the other hand, the fact that casual directions have been demonstrated in corresponding experimental studies makes it reasonable to interpret the present results as done above.

Moreover, it is challenging to see how a weak tendency to consume soda should, for example, cause changes in marital status or cohesion at work. Another concern is that despite the inclusion of several control variables, we cannot rule out the possibility that the present results may be partly explained by confounding variables not taken into account in this study. Another limitation is that this sample consisted of women in early pregnancy. The fact that pregnancy is associated with food craving [47] suggests that the scores for consumption of sweet beverages may differ between pregnant and non-pregnant woman. It should be noted that this is a limitation in terms of the generalizability of the findings, but not a limitation in terms of the assessment of the main hypothesis. However, pregnancy may be a period when women require more social support in terms of emotion regulation and practical preparations for the future. The lack of social support during pregnancy may therefore lead to a higher degree of neural activation than would otherwise occur. The associations between social factors and sugar intake may therefore be lower in the population of non-pregnant women. Gender differences may also come into play because men, in general, report a lower level of craving for sweet foods than women [18,48,49]. Future studies should therefore be based on samples including men and non-pregnant women, and also include consumption of non-sweet carbohydrates as outcome variables. Another limitation is that this study was based on self-report questionnaires and the data may therefore be subject to reporting bias.

Conclusions

The aim of this study was to test a hypothesis derived from the Social Baseline Theory that relative social isolation and social connectedness influence the level of consumption of sugar. The results from a series of regression analyses support the hypothesis by showing that loneliness and social connectedness is associated with degree of sugar consumption in the form of sugar-containing sodas and juices. This is the first time the present hypothesis has been tested in a large-scale study.

Supporting Information Tables S1 to S6 show data from the multiple regression analyses additional to the information given in Table 2. This includes mean scores and standard deviations of the main predictor variables, as well as unstandardized and standardized regression coefficients, t-test values and p-values.

Table S1 Predicted scores for consumption of sugar-containing soda (other than cola) from scores for loneliness, marital status (co-habiting and married), relationship satisfaction, advice from others, and cohesion at work. Results are adjusted for scores on participation in sports, physical strain at work, body mass index, weight related self-image, depression, age, level of education and income. (DOCX)

Table S2 Predicted scores for consumption of sugar-containing cola from scores for loneliness, marital status (co-habiting and married), relationship satisfaction, advice from others, and cohesion at work. Results are adjusted for scores on participation in sports, physical strain at work, body mass index, weight related self-image, depression, age, level of education and income. (DOCX)

Table S3 Predicted scores for consumption of sugar-containing juice from scores for loneliness, marital status (co-habiting and married), relationship satisfaction, advice from others, and cohesion at work. Results are adjusted for scores on participation in sports, physical strain at work, body mass index, weight related self-image, depression, age, level of education and income. (DOCX)

Table S4 Predicted scores for consumption of artificially sweetened soda (other than cola) from scores for loneliness, marital status (co-habiting and married), relationship satisfaction, advice from others, and cohesion at work. Results are adjusted for scores on participation in sports, physical strain at work, body mass index, weight related self-image, depression, age, level of education and income. (DOCX)

Table S5 Predicted scores for consumption of artificially sweetened cola from scores for loneliness, marital status (co-habiting and married), relationship satisfaction, advice from others, and cohesion at work. Results are adjusted for scores on participation in sports, physical strain at work, body mass index, weight related self-image, depression, age, level of education and income. (DOCX)

Table S6 Predicted scores for consumption of artificially sweetened juice from scores for loneliness, marital status (co-habiting and married), relationship satisfaction, advice from others, and cohesion at work. Results are adjusted for scores on participation in sports, physical strain at work, body mass index, weight related self-image, depression, age, level of education and income. (DOCX)

Author Contributions

Conceived and designed the experiments: REH. Performed the experiments: REH. Analyzed the data: REH TT FT. Contributed reagents/materials/analysis tools: REH FT TT. Contributed to the writing of the manuscript: REH.

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Table S1. Multiple regression analysis: predicted scores for consumption of sugar-containing soda (other than cola) from scores for loneliness, marital status (co-habiting and married), relationship satisfaction, advice from others, and cohesion at work. Results are adjusted for scores on participation in sports, physical strain at work, body mass index, weight related self-image, depression, age, level of education and income.

Model 1	Mean	SD	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
			B	Std. Error	Beta		
Loneliness	1.72	.83	.026	.008	.022	3.289	.001
Married	0.47	.50	-.108	.066	-.054	-1.631	.103
Cohabiting	0.52	.50	-.049	.066	-.024	-.745	.456
Relationship satisfaction	5.35	.62	-.033	.011	-.021	-3.114	.002
Advice from others	2.52	.55	-.060	.011	-.033	-5.296	.000
Cohesion at work	3.36	.71	-.015	.009	-.010	-1.683	.092

Dependent Variable: sugar-containing soda (other than cola)

N = 25670

Table S2. Multiple regression analysis: predicted scores for consumption of sugar-containing cola from scores for loneliness, marital status (co-habiting and married), relationship satisfaction, advice from others, and cohesion at work. Results are adjusted for scores on participation in sports, physical strain at work, body mass index, weight related self-image, depression, age, level of education and income.

Model 2	Mean	SD	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
			B	Std. Error	Beta		
Loneliness	1.7	.84	.049	.009	.034	5.406	.000
Married	.46	.50	-.296	.073	-.121	-4.066	.000
Cohabiting	.53	.50	-.215	.072	-.088	-2.970	.003
Relationship satisfaction	5.35	.63	-.071	.012	-.037	-5.886	.000
Advice from others	2.51	.56	-.039	.013	-.018	-2.999	.003
Cohesion at work	3.36	.71	-.030	.010	-.018	-3.064	.002

Dependent Variable: sugar-containing cola

N = 28509

Table S3. Multiple regression analysis: predicted scores for consumption of sugar-containing juice from scores for loneliness, marital status (co-habiting and married), relationship satisfaction, advice from others, and cohesion at work. Results are adjusted for scores on participation in sports, physical strain at work, body mass index, weight related self-image, depression, age, level of education and income.

Model 3	Mean	SD	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
			B	Std. Error	Beta		
Loneliness	1.72	.83	.028	.008	.017	3.563	.000
Married	.48	.50	-.256	.068	-.094	-3.763	.000
Cohabiting	.52	.50	-.180	.068	-.066	-2.654	.008
Relationship satisfaction	5.34	.62	-.023	.011	-.011	-2.196	.028
Advice from others	2.51	.55	-.006	.011	-.002	-.531	.595
Cohesion at work	3.36	.70	-.021	.009	-.011	-2.353	.019

Dependent variable: Sugar-containing juice

N = 50055

Table S4. Multiple regression analysis: predicted scores for consumption of artificially sweetened soda (other than cola) from scores for loneliness, marital status (co-habiting and married), relationship satisfaction, advice from others, and cohesion at work. Results are adjusted for scores on participation in sports, physical strain at work, body mass index, weight related self-image, depression, age, level of education and income.

Model 4	Mean	SD	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
			B	Std. Error	Beta		
Loneliness	1.7	.83	-.001	.010	-.001	-.074	.941
Married	.48	.50	-.003	.082	-.002	-.043	.966
Cohabiting	.52	.50	.074	.081	.032	.917	.359
Relationship satisfaction	5.34	.61	-.009	.013	-.005	-.725	.468
Advice from others	2.52	.55	-.011	.014	-.005	-.773	.440
Cohesion at work	3.36	.70	-.008	.010	-.005	-.800	.423

Dependent variable: Artificially sweetened soda (other than cola)

N = 24223

Table S5. Multiple regression analysis: predicted scores for consumption of artificially sweetened cola from scores for loneliness, marital status (co-habiting and married), relationship satisfaction, advice from others, and cohesion at work. Results are adjusted for scores on participation in sports, physical strain at work, body mass index, weight related self-image, depression, age, level of education and income.

Model 5	Mean score	SD	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
			B	Std. Error	Beta		
Loneliness	1.71	.82	-.003	.014	-.001	-.202	.840
Married	.48	.50	.002	.123	.000	.013	.990
Cohabiting	.52	.50	.076	.122	.021	.626	.531
Relationship satisfaction	5.35	.62	-.078	.018	-.026	-4.262	.000
Advice from others	2.52	.55	.006	.020	.002	.321	.748
Cohesion at work	3.36	.70	-.013	.015	-.005	-.843	.399

Dependent Variable: Artificially sweetened cola
N = 29297

Table S6. Multiple regression analysis: predicted scores for consumption of artificially sweetened juice from scores for loneliness, marital status (co-habiting and married), relationship satisfaction, advice from others, and cohesion at work. Results are adjusted for scores on participation in sports, physical strain at work, body mass index, weight related self-image, depression, age, level of education and income.

Model 6	Mean	SD	Unstandardized		Standardized		t	Sig.
			B	Std. Error	Beta			
Loneliness	1.71	.83	.014	.010	.009	1.383	.167	
Married	.47	.50	-.128	.090	-.049	-1.430	.153	
Cohabiting	.52	.50	.019	.089	.007	.217	.828	
Relationship satisfaction	5.36	.61	-.004	.014	-.002	-.310	.757	
Advice from others	2.52	.55	.021	.015	.009	1.398	.162	
Cohesion at work	3.37	.70	-.015	.011	-.008	-1.323	.186	

Dependent Variable: Artificially sweetened juice
 N = 26618

RESEARCH ARTICLE

Relationship Satisfaction Reduces the Risk of Maternal Infectious Diseases in Pregnancy: The Norwegian Mother and Child Cohort Study

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Data Availability Statement: Data are unsuitable for public deposition due to ethical restrictions from the Norwegian Institute of Public Health (NIPH). Before data can be released, a full application must be submitted and, in most cases, a contract must be signed with the NIPH. To apply for statistical data in the form of ready-made tables, this form should be used: <http://www.fhi.no/dokumenter/aabd86f88b.doc>. Additional information about access to data from the Norwegian Mother and Child Cohort Study are obtained from the NIPH: www.fhi.no. All enquiries about access to data should be sent to: datatilgang@fhi.no. The persons responsible for handling enquiries sent

Abstract

Objectives

The aims of this study were to explore the degree to which relationship satisfaction predicts the risk of infectious diseases during pregnancy and to examine whether relationship satisfaction moderates the association between stressful life events and the risk of infections.

Methods

This was a prospective study based on data from the Norwegian Mother and Child Cohort Study (MoBa) conducted by the Norwegian Institute of Public Health. Pregnant women (n = 67,244) completed questionnaires concerning relationship satisfaction and nine different categories of infectious diseases as well as socioeconomic characteristics and stressful life events. Associations between the predictor variables and the infectious diseases were assessed by logistic regression analyses. A multiple regression analysis was performed to assess a possible interaction of relationship satisfaction with stressful life events on the risk for infectious diseases.

Results

After controlling for marital status, age, education, income, and stressful life events, high levels of relationship satisfaction at week 15 of gestation were found to predict a significantly lower risk for eight categories of infectious diseases at gestational weeks 17–30. No significant interaction effect was found between relationship satisfaction and stressful life events on the risk for infections.

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Introduction

This study examines to what degree partner satisfaction predicts the risk for infectious diseases in pregnancy. Maternal infectious disease during pregnancy has been recognized as an important risk factor for adverse foetal outcomes. Influenza during pregnancy is associated with an increased risk of preterm birth and low birth weight [1]. Urinary tract infection has been shown to increase the risk for preeclampsia [2]. Other possible consequences include the harmful impact on foetal development of the central nervous system. Evidence demonstrates that prenatal exposure to maternal influenza and genital infections are associated with an increased risk for schizophrenia [3,4]. Evidence also suggests that maternal infection and immune dysfunction may be associated with autism [4]. In addition to potentially harmful outcomes for mother and child, pregnant women are at an increased risk of hospitalization related to complications from an infectious disease compared with nonpregnant women [1]. Increased knowledge on factors that may reduce the prevalence of infectious diseases during pregnancy is of great importance for individuals as well as for society.

Relationships with family and friends are important factors in explaining inequalities in individuals' health outcomes. Evidence clearly shows that individuals who perceive their social relationships as satisfying or supportive have better health and longer life expectancies than those who report less perceived support from others [5–7]. In adulthood, romantic relationships have been recognized to be particularly important in predicting health outcomes, and several studies have demonstrated the health benefits of being married compared to living alone [8–10]. Although couple relationships seem to be generally health promoting, research also shows that the advantage of being married depends on the quality of the relationship [11–16]. This applies to a number of diseases and health conditions, including infectious diseases. For instance, Phillips and colleagues [17] demonstrated a positive relationship between a high degree of marital satisfaction and a higher antibody response to influenza vaccination in a sample of elderly individuals. Given that antibody response to vaccination is a reliable indicator of susceptibility to infectious diseases, the study suggests that individuals who score high on relationship satisfaction experience lower rates of infectious diseases.

Several possible mechanisms have been proposed to explain how the quality of romantic relationships may influence health, and a number of studies support that couple relationship quality influences health outcomes through both main effects and moderating effects [18–20]. An adverse main effect may result from the tendency that individuals in low-quality relationships struggle with negative aspects related to spousal hostility and conflicts [21]. As with several other sources of psychosocial stress, marital distress has been linked to impairment of the immune system [22,23]. For instance, in a laboratory-based study, Kiecolt-Glaser and colleagues [23] found that married individuals who demonstrated hostile behaviour during a monitored discussion showed higher serum levels of pro-inflammatory cytokines, including interleukin-6 and tumour necrosis factor, compared to baseline levels. In addition to the direct effects mentioned above, relationship quality may moderate the adverse effects of other stressful experiences. It is well established that stressful life events predict alterations in the immune system and susceptibility to infectious diseases [24–28]. Stressful experiences activate the hypothalamic–pituitary–adrenal–cortical system (HPA axis), which leads to the release of cortisol that, in turn, affects the immune system [29,30]. When exposed to a stressful event, support from the partner may reduce the stress-induced activation of the HPA axis [31]. A recent study found that partner support downregulated the effects of psychological distress on maternal cortisol secretion during pregnancy [32]. Interestingly, it seems that the level of partner-related moderation of stress-responses is a function of relationship quality. It has repeatedly been demonstrated that the stress-buffering effect of partner support tends to be stronger when the

relationship quality is high [31–33]. For example, an experiment conducted by Coan, Schaefer and Davidson [31] demonstrates how holding a partner's hand during a stressful event influences activation in the neural systems supporting emotional and behavioural threat responses. 16 women were confronted with the threat of a mild electric shock while either holding their partners' hands, holding a stranger's hand, or alone. When exposed to the threat of shock without the support of handholding, the threat-related brain activity reached its highest level. When holding a stranger's hand, the level of threat-related activity decreased as compared with receiving no support of handholding. While holding their partners' hands, the participants showed the lowest levels of threat-related brain activity. Interestingly, the effects varied as a function of marital quality, with higher marital quality predicting less activation in the neuro-psychological pathways associated with physiological stress responses.

In summary, the published studies suggest at least two sets of reasons why couple relationship quality may influence susceptibility to infections. First, individuals in the low-quality relationship group are likely to suffer from relational distress and the potentially harmful physiological stress responses that follow. Second, compared with individuals in high-quality relationships, those in low-quality relationships experience less efficient reduction of stress-induced activation in the HPA axis and therefore greater impairment of the immune system's ability to fight infections. On the basis of the existing literature, we hypothesize that low levels of relationship satisfaction increases the risk for infectious diseases during pregnancy. We further hypothesize that the rate of stressful life events predicts the risk of infectious diseases and that the level of relationship satisfaction moderates this correlation.

Previous research on the general population has provided valuable information on the association between romantic relationship satisfaction and biomarkers that indicate susceptibility to infectious diseases [34]. Corresponding studies on the pregnant population are limited. Previous studies assessing the potentially health-protecting effects of relationship quality in pregnancy have focused on birth outcomes and maternal mental health [35–38]. Therefore, the purpose of the present study is to extend the available knowledge regarding the effects of relationship satisfaction on manifested infectious diseases in pregnancy.

Materials and Methods

The Norwegian Mother and Child Cohort Study (MoBa) is a prospective population-based pregnancy cohort study conducted by the Norwegian Institute of Public Health [39]. In the period 1999–2008, all (except two) hospitals in Norway with more than 100 births per year invited pregnant women to participate in the study provided they could read Norwegian. They received a postal invitation three weeks before the ultrasound examination routinely offered to all pregnant women in Norway. Of the invited women, 40.6% consented to participate, and the cohort now includes 114,500 children, 95,200 mothers, and 75,200 fathers. Blood samples were obtained from both parents during pregnancy and from mothers and children (umbilical cord) at birth. Follow-up is conducted by questionnaires at regular intervals and by linkage to national health registries. Several sub-studies are conducting additional collections of data and biological materials. The current study is based on version 7 of the quality-assured data files released for research on 17 October 2012. A written informed consent was obtained from each MoBa participant upon recruitment. The study has obtained a licence from the Norwegian Data Inspectorate and was approved by The Regional Committee for Medical Research Ethics.

Participants

The present study includes married and cohabiting women participating in the MoBa study for the first time ($n = 75,730$). Thus, multi-time participating mothers were included with only

their first participating pregnancy, and mothers living alone were excluded. Among those, 67,244 participants answered all questions of concern for the present study. This means that 8486 participants were excluded from the multivariate analyses due to missing values at one or more of the research variables. The participants had a mean age of 29.6 years (standard deviation [SD] 4.55); 52.1% were married, 47.9% were cohabiting, and the average duration of the couple relationships was 6.3 years (SD 4.33). The average level of education was higher for the sample than for the general population of women aged between 16–49 years (official statistics from 2008 in brackets): compulsory school 7.0% (28.1%), vocational school 26.7% (35.7%), three-year college 39.2% (29.8%), and university/higher education 21.9% (6.4%). The full sample has been compared with the general population of pregnant women in Norway and is described in more detail elsewhere [40].

Measures

Relationship satisfaction (RS) was measured during week 15 of the current pregnancy, using the full 10-items version of the Relationship Satisfaction Scale. The scale was developed for the MoBa and is based on core items used in previously developed measures of marital satisfaction and relationship quality [41–43]. The scale has a six-step scoring format spanning from 1 ‘totally agree’ to 6 ‘don’t agree at all’. Examples of items are: ‘My partner and I have problems in our relationship’; ‘I am very happy in my relationship’; ‘My partner is generally very understanding’; and ‘I am satisfied with my relationship with my partner’. In the current sample the scale had a Cronbach’s alpha of 0.90. This scale has been used in previous studies [37,44]. In the logistic regression analyses, the scale was reversed and indexed to achieve a maximum score of 1 (low RS) and a minimum score of 0 (high RS).

Infectious diseases were measured during week 30 of the current pregnancy. The measure is based on a checklist covering nine different categories of infectious diseases: influenza, pneumonia/bronchitis, diarrhea/gastric flu, common cold, throat infection, sinusitis/ear infection, vaginal thrush, vaginal catarrh and bladder infection. The respondents were asked to mark whether they had (= 1) or had not (= 0) experienced the respective disease between weeks 17 and 30 of the current pregnancy. In order to examine the effect of relationship satisfaction and stressful life events on the total number of self-reported infections, a scale was constructed based on sum scores of the reported diseases.

Stressful Life Events (SLE) were measured during week 30 of the current pregnancy and consisted of 11 questions concerning different types of demanding experiences. Participants were asked to report whether they had experienced any of the listed situations during the preceding 12 months. Examples of questions are: ‘Have you had financial problems?’, ‘Have you had problems or conflict with your family, friends, or neighbours?’, ‘Has anyone close to you been seriously ill or injured?’, ‘Have you been involved in a serious accident, fire, or robbery?’ and ‘Have you lost someone close to you?’. The scoring format for each question was no (0) or yes (1). A scale was constructed based on sum scores reflecting the number of reported stressful life events, ranging from 0 to 8.

Control variables

Socioeconomic factors are, in general, known to predict physical health outcomes and were therefore included as control variables. These variables included age, marital status (married versus cohabiting), maternal income (scored from 1 = no income to 7 \geq NOK 500,000 \approx EUR 66,000), and educational level (six categories from public school to >4 years at university/college).

Table 1. Associations between relationship satisfaction^a and self-reported infectious diseases.

Infections	Prevalence % of n = 67,244	OR unadjusted 95% CI		OR adjusted * 95% CI	
		Exp (B)	(Lower–Upper)	Exp (B)	(Lower–Upper)
Influenza	5.7	2.5	(1.98–3.25)	2.4	(1.81–3.01)
Pneumonia/bronchitis	1.9	2.5	(1.65–3.82)	2.0	(1.27–3.01)
Common cold	33.5	1.5	(1.36–1.76)	1.6	(1.38–1.80)
Throat infection	3.4	3.4	(2.51–4.61)	2.8	(2.01–3.80)
Sinusitis/ear infection	5.0	2.9	(2.24–3.75)	2.4	(1.85–3.15)
Diarrhea/gastric flu	11.7	2.5	(2.07–2.97)	2.3	(1.93–2.80)
Vaginal thrush	19.8	2.1	(1.77–2.40)	1.8	(1.54–2.10)
Vaginal catarrh	3.9	4.3	(3.26–5.69)	3.3	(2.51–4.46)
Urinary bladder infection	5.1	1.1	(0.81–1.43)	0.9	(0.69–1.23)
At least one infection	53.7	2.1	(1.86–2.40)	2.0	(1.74–2.25)

* Odds ratios were adjusted for age, level of education, income, marital status, and stressful life events
 Note. a. Index from 0 (high RS) to 1 (low RS).

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Statistical analyses

All statistical analyses were conducted using IBM SPSS, version 21. The associations between relationship satisfaction and infectious diseases were first tested by performance of separate bivariate logistic regression analyses for each of the nine different infectious diseases as the dependent variable and relationship satisfaction as the predictor variable. In order to assess the unique contribution of relationship satisfaction in the full model, nine additional multivariable logistic regression analyses were performed with the inclusion of the following independent control variables: age, marital status, education, income, and stressful life events. One logistic regression analysis was also conducted with all nine infections collapsed into one dichotomized variable (no infections versus one or more infections). To assess a possible interaction of relationship satisfaction with stressful life events on the number of self-reported infectious diseases, a hierarchical multiple regression analysis was performed by first entering the main predictor variables based on the continuous relationship satisfaction and stressful life events scores, with marital status, age, education, and income included as control variables. An interaction term based on the continuous relationship satisfaction and stressful life events scores was then added. In order to avoid collinearity between the main effects and the interaction term, both variables were centered on their means before multiplied together.

Results

Descriptive analyses showed that the majority of the sample reported high levels of relationship satisfaction ($M = 5.37$, $SD = 0.61$). At least one infectious disease ($M = 1.14$, $SD = 1.54$) was experienced by 53.7% of the participants between week 17–30 of the current pregnancy. Stressful life events was experienced by 56.1% of the participants (1 SLE: 30.2%; 2 SLEs: 16.9%; 3 SLEs: 6.5%; 4 SLEs: 2.0%). Only 0.6% of the participants reported 5 or more SLEs). The mean number of reported stressful life events was 0.95 ($SD = 1.07$), ranging from 0 to 8. The results from the bivariate and multivariate logistic regression analyses and the prevalence of each disease are displayed in Table 1. The bivariate analyses showed a significant association between relationship satisfaction and eight of the infectious diseases, with odds ratios varying between 1.5 and 4.3 (95% CI). After adjusting for scores on stressful life events the odds ratios of the eight infections varied between 1.4 and 3.4, a decrease by an average of 0.38 ($SD = 0.25$) as compared

with the unadjusted ORs. After adjusting for marital status, age, income, education, and stressful life events, the level of relationship satisfaction was still significantly associated with eight of the disease variables, with odds ratios varying between 1.6 and 3.3 (95% CI). When all nine groups of infections were collapsed into one dichotomized variable, the odds ratio was 2.1 (95% CI 1.86–2.40) in the bivariate analysis, 1.9 (95% CI 1.63–2.10) when adjusting for stressful life events, and 2.0 (95% CI 1.74–2.25) when adjusting for stressful life events, marital status, age, income, and education.

A hierarchical multiple regression analysis was conducted that examined the interaction-effect of relationship satisfaction and stressful life events on the total number of self-reported infectious diseases. Model 1 included RS and SLE as the main predictor variables and age, income, education and marital status as control variables. The model explained 1.6% of the variance (adjusted $R^2 = .016$, $F(6,67237) = 182.494$, $p < .001$). There was a significant positive association between the level of stressful life events and infectious diseases (unstandardized $B = .125$, standardized $\beta = .087$, $p < .001$) and a significant negative association between relationship satisfaction and infectious diseases (unstandardized $B = -.174$, standardized $\beta = -.069$, $p < .001$). In Model 2 the interaction term $RS \times SLE$ was added. No statistically significant interaction effect was found between relationship satisfaction and stressful life events on the risk of infectious diseases (unstandardized $B = -.015$, standardized $\beta = -.007$, $p = .066$). By adding the interaction term, the R square did not change significantly (R^2 change < 0.0001 , $F(1,67236) = 3.382$, $p = .066$), and the explained variance of the model remained 1.6% ($R^2 = .016$, $F(7,67236) = 156.912$, $p < .001$).

Discussion

The present study examined the associations between relationship satisfaction and nine different groups of self-reported infectious diseases among married and cohabiting women in mid-pregnancy. The results from the logistic regression analyses showed that relationship satisfaction measured in week 15 of pregnancy is significantly associated with eight out of nine infectious diseases experienced between weeks 17–30 of pregnancy. The results persisted after controlling for scores on marital status, age, income, education, and stressful life events. Among the infections assessed in this study, only urinary bladder infection was not significantly associated with relationship satisfaction. All other groups of infectious diseases (influenza, pneumonia/bronchitis, diarrhea/gastric flu, common cold, throat infection, sinusitis/ear infection, vaginal thrush, and vaginal catarrh) were significantly negatively associated with relationship satisfaction. The data available for this study do not provide an explanation why urinary bladder infection did not follow the same pattern as the other infections. However, it is well documented that high frequency of sexual intercourse is the most important risk factor for urinary tract infections [45]. A possible explanation for the negative finding in the present study might be that woman reporting poor relationship satisfaction are less sexually active and therefore not exposed to the same risk for bladder infections than their more satisfied counterparts.

Overall, the odds of experiencing an infection for pregnant women with low relationship satisfaction were twice as high compared with pregnant woman reporting high relationship satisfaction. The results support our hypothesis that the level of relationship satisfaction predicts the risk for infectious diseases in pregnancy. These findings are noteworthy because infectious diseases have a potential for harming both the mother and the developing foetus when occurring during pregnancy [1–4]. Because the present study did not measure couple behaviour or neuropsychological responses related to relationship satisfaction, we cannot conclude how relationship quality influences the risk of infections. However, based on previous research in the general population the present results may be partly explained by the direct immune-impairing

effects of hostility and conflicts that more frequently occur in dysfunctional relationships [21,23]. It has also been suggested that partner support may be beneficial because it decreases biological sensitivity to psychological distress [32]. Indeed, emotion-regulation has been linked to activation of the HPA axis and researchers have suggested that emotion-regulation may be a key factor in links between marital quality and health [19,32,46,47]. Anyhow, the direct effect of relationship satisfaction on the level of self-reported infections found in the present study do harmonize with previous research showing that marital quality is linked to biomarkers of stress known to impair immune function [48,49]. Also in line with previous studies [24–28], the present results show that stressful life events significantly predicted the risk of infectious diseases.

The hypothesis that relationship quality moderates the adverse effects of stressful life events was not supported by the results. Contrary to our expectations, the results showed a very weak interaction coefficient at a non-significant level between relationship satisfaction and stressful life events on the number of reported infectious diseases. Our hypothesis of interaction was based on previous research indicating that partner support has a moderating effect on biomarkers associated with stress and immune function, such as cortisol and pro-inflammatory cytokines [15,29,32,50]. For example, it was recently demonstrated that effective partner support during pregnancy has the potential to reduce maternal neuroendocrine responses to negative emotional experiences [32]. It should be noted that the present findings are not contradictory to these studies. As we did measure clinical endpoints and not changes in mediating biomarkers, we cannot report on whether relationship quality did moderate stress-related responses or not. We can only conclude that there seem to be no prominent interaction-effect between marital satisfaction and stressful life events on the level of self-reported infections. This is currently a noteworthy finding because the present study is among the first to investigate such a potential interaction-effect on clinical endpoints [34]. This is also the first population-based study to assess the direct association between relationship satisfaction and manifested infectious disease during pregnancy [34]. More comprehensive studies are needed to illuminate how and to what degree the quality of close relationships may moderate the clinical health consequences of chronic stress, as well as documenting central causal pathways between relationship quality and infections [19,51]. One idea would be to utilize blood samples from the current cohort study, and examine immune-related parameters such as cytokines, lymphocytes functions, or telomere length to look for correlations with the present data. This would allow us first to examine whether relationship satisfaction and stressful life events has direct effects on physiological processes and then to examine to what degree individuals who exhibit physiological changes are more likely to develop infectious diseases.

A strength of the present study is its large number of participants; this allows for assessing relative small effects within a narrow confidence interval. Nevertheless, these data must be interpreted with caution. One important limitation is the study's reliance on self-report questionnaires as the data may be subject to reporting bias. In this respect, the validity and reliability of the outcome measure might be of particular concern. For instance, we cannot know whether the participants based their self-reported diseases on medical diagnoses or self-assessments of experienced symptoms. Moreover, because the respondents were not asked how many times each disease occurred during the 14 weeks period assessed, the current study did not distinguish between single and multiple occurring infections. Nor was it distinguished between mild infections and long-lasting severe infections. It should also be mentioned that the scores of the main study variables were not normally distributed. In small samples this may lead to problems with the interpretation of the statistical tests used in this study. In large samples, however, non-normality of the residuals does not violate the interpretation of significance tests or confidence intervals [52]. Although it may be a concern that only 40% of the invited women consented to participate, a potential impact of selection bias on exposure and outcome variables was

evaluated in a previous study [40]. Testing eight different exposure–outcome associations, the authors found no statistically significant differences in association measures between participants in the MoBa and the total population. This indicates that the generalizability of this study is not violated by selection bias.

To conclude, the current study contributes toward a better understanding of the association between relationship quality and manifested infectious disease. The main findings indicate that women with the lowest relationship satisfaction experience about twice as many infectious diseases than women with the highest relationship satisfaction. Although the current findings seem to be clinically interesting it remains to examine how, for whom, and to what degree relationship management and improvement of relationship quality may lead to less infectious diseases [34]. Because very few studies describe associations between relationship quality and clinical endpoints [34], future studies should replicate our findings with the use of subjective self-reports as well as medical diagnoses as outcome variables. To document the causal pathways between relationship quality and infections, a longitudinal study including both biomarkers and clinical endpoints is recommended. Another important next step will be to examine the associations between maternal relationship satisfaction and postpartum outcomes.

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Author Contributions

Conceived and designed the experiments: REH. Performed the experiments: REH. Analyzed the data: REH TT FT. Contributed reagents/materials/analysis tools: REH TT FT. Wrote the paper: REH.

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RESEARCH ARTICLE

Marital Quality and Stress in Pregnancy Predict the Risk of Infectious Disease in the Offspring: The Norwegian Mother and Child Cohort Study

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Abstract

Objectives

The aim of this study was to explore the degree to which couples' relationship dissatisfaction and stressful life events during pregnancy predict the risk of infectious disease in the offspring during their first year of life.

Methods

Data were obtained from the Norwegian Mother and Child Cohort Study, conducted by the Norwegian Institute of Public Health. Pregnant women completed questionnaires in week 30 of pregnancy concerning the couples' relationship satisfaction and stressful life events. In follow-up questionnaires, the women reported whether their children ($n = 74,801$) had been subject to various categories of infectious disease: the common cold, throat infection, bronchitis, RS virus, pneumonia, pseudocroup, gastric flu, ear infection, conjunctivitis and urinary tract infection. Reports from two age groups of infants were used. Associations between the predictor and outcome variables were assessed via logistic regression and linear regression analyses.

Results

Separate logistic regression analyses for each disease and age group showed that prenatal relationship dissatisfaction and stressful life events were significantly associated with all reported categories of infectious disease. After controlling for socioeconomic factors, social support, smoking, breastfeeding, maternal depression, the sex of the offspring, and use of child care, 29 out of 32 tested associations were statistically significant. Finally, multivariate linear regression analyses showed that prenatal relationship dissatisfaction and stressful life events were significantly associated with the frequency, as well as the variety, of infectious disease in the offspring.

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Data Availability Statement: Data are unsuitable for public deposition due to ethical restrictions from the Norwegian Institute of Public Health (NIPH). Before data can be released, a full application must be submitted and, in most cases, a contract must be signed with the NIPH. To apply for statistical data in the form of ready-made tables, this form should be used: <http://www.fhi.no/dokumenter/aabd86f88b.doc>. Additional information about access to data from the Norwegian Mother and Child Cohort Study are obtained from the NIPH: www.fhi.no. All enquiries about access to data should be sent to: datatilgang@fhi.no. The persons responsible for

handling enquiries sent to this address are Anita Haugan and Kristine Vejrup, Division of Epidemiology, Norwegian Institute of Public Health.

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Introduction

Although child morbidity has been significantly reduced worldwide since the 1990s, infectious disease in infants remains a serious public health concern [1]. As it is the leading cause of hospitalization [2] and one of the main causes of death in infants [1,3], there is a strong need to identify factors that can reduce the likelihood of infant infections [1]. Moreover, early-life infections have been linked to long-term effects, such as adverse immune system development and an increased risk of asthma and allergies later in life [4,5]. The main purpose of this study was to examine to what degree the level of maternal relationship satisfaction during pregnancy predicts the risk of infectious disease in children during their first year of life. A second aim was to examine to what degree stressful prenatal life events predict the risk of infectious disease in the offspring.

Research has established that social relationships are essential for maintaining physical health [6]. In adulthood, romantic relationships have been recognized as being particularly important in predicting health outcomes [7–10]. It has, for instance, been shown that relationship quality predicts the risk of maternal infectious disease in pregnancy [11]. One likely explanation may be that individuals in low-quality relationships are more often subject to emotional distress related to spousal hostility and conflicts [12]. Hostile marital interactions and the physiological stress response that follows have, in turn, been linked to the impairment of the immune system [13]. Although no studies have yet examined whether maternal relationship quality during pregnancy is linked to the risk of infectious disease in the offspring, there is growing evidence from animal models that a link exists between prenatal maternal stress and a wide range of adverse health outcomes in the offspring, including immune dysfunction and infectious diseases [14,15]. Only a few studies on humans have investigated whether prenatal maternal stress and emotional distress compromise immune responses or predict infectious disease in the offspring [16–19]. The findings thus far are very much in line with findings in animal studies. For example, Nielsen and colleagues [17] found that in a Danish cohort study, women's experiences of seriously stressful life events, such as the death of a spouse, the death of an older child, or divorce during pregnancy, were associated with a significantly higher risk of infections in their children. In a population-based cohort study, Tegethoff and colleagues [19] included measures of both emotional stress and stressful life events during pregnancy and found that both factors were associated with an increased risk of infectious disease in the offspring. In another study, Beijers and colleagues [18] found that maternal prenatal anxiety and pregnancy specific difficulties, such as the fear of giving birth and the fear of bearing a child with disabilities, were related to infant respiratory infections, as well as to the use of antibiotics in the first year of life. A similar link may exist between prenatal maternal relationship dissatisfaction and the offspring's risk of infectious diseases.

Although it remains unclear exactly how maternal experiences of stress during pregnancy affect the immune systems of infants, there is a consensus that the maternal hypothalamic-pituitary-adrenocortical (HPA) axis plays a key role [20]. The regulation of stress and negative emotions increases the release of corticotrophin-releasing hormone (CRH) from the hypothalamus, leading to the release of adrenocorticotrophic hormone (ACTH) from the pituitary gland [21,22]. ACTH travels to the adrenal cortex, where it stimulates the release of glucocorticoids, which in turn affect the immune system [23,24]. Animal studies have shown that maternal HPA axis activation not only affects the maternal immune system but also the offspring's immune system [20,25,26]. Hence, any factor that may regulate HPA responses in pregnancy is interesting to investigate with regard to infant health. In the present study, our main interest is to investigate the potential impact of marital relationship quality during pregnancy. Several studies based on the general population show that marital distress may activate the HPA axis

and predict adverse effects on maternal immune function [13,27,28]. Satisfaction with the partner, on the other hand, may reduce the stress-related activation of the HPA axis [29]. Similar research in the pregnant population is scarce. However, in a recent study, it was found that support from the partner down-regulated the effects of emotional distress on the release of cortisol in pregnant woman [30]. We therefore hypothesized that lower levels of prenatal maternal relationship satisfaction are associated with a higher risk of infectious disease in infants. A second aim of this study was to replicate the few existing studies in humans that investigate the relationship between stressful prenatal life events and the risk of infectious disease in the offspring. In order to test the hypotheses, we utilized data from the Norwegian Mother and Child Cohort Study.

Materials and Methods

The Norwegian Mother and Child Cohort Study (MoBa) is a prospective population-based pregnancy cohort study conducted by the Norwegian Institute of Public Health. During the period from 1999 to 2008, all hospitals in Norway with more than 100 births per year, except two, invited pregnant women to participate in the study provided that they could read Norwegian [31]. They received a postal invitation three weeks before the ultrasound examination that was routinely offered to all pregnant women in Norway. Of the invited women, 40.6% consented to participate, and the cohort now includes 114,500 children, 95,200 mothers and 75,200 fathers. Blood samples were obtained from both parents during pregnancy and from mothers and children (umbilical cord) at birth. Follow-up was conducted via questionnaires at regular intervals and via linkage to national health registries. Several sub-studies were conducted to collect additional data and biological materials. The current study was based on Version 7 of the quality-assured data files released for research on 17 October 2012. Written informed consent was obtained from each MoBa participant upon recruitment. The study has obtained a license from the Norwegian Data Inspectorate and was approved by the Regional Committee for Medical Research Ethics.

Participants

This study included married and cohabiting women participating in the Norwegian Mother and Child Cohort Study ($n = 90,912$) and their participating children ($n = 100,027$). Because we were interested in relationship quality, single and widowed mothers (and their children) were excluded. Some participants were also excluded from the multivariate analyses due to missing values for one or more of the research variables. Data from an average of 58,530 children were obtained for each category of infectious disease. It should be noted that the dataset contained very few data on the category 'throat infection' for 6- to 11 months old children. Thus, only 8,788 participants were included in the respective analysis. The participating women had a mean age of 29.6 years (standard deviation [SD] 4.55). In the general population in Norway, the mean maternal age at delivery was 29.5 between the years 2000–06 [32]. In the study population, 52% were married and 48% were cohabiting. In the total population of Norwegian women giving birth between the years 2000–06, 49% of all couples were married, and 43% were cohabiting [32]. In the study population, the average duration of the couples' relationships was 6.3 years (SD 4.33). The average level of education was higher for the sample than for the general population of women aged between 16 and 49 years (official statistics from 2008 in brackets): compulsory school 7.0% (28.1%), vocational school 26.7% (35.7%), three-year college 39.2% (29.8%) and university/higher education 21.9% (6.4%). The full sample has been compared with the general population of pregnant women in Norway and is described in more detail elsewhere [32].

Measures

Relationship satisfaction (RS) was measured during week 30 of the pregnancy using the full ten-item version of the relationship satisfaction scale. The scale was developed for the MoBa and is based on core items used in previously developed measures of marital satisfaction and relationship quality [33–35]. The scale has a six-step scoring format from 1 ‘totally agree’ to 6 ‘don’t agree at all’. Examples of items include the following: ‘My partner and I have problems in our relationship’, ‘I am very happy in my relationship’, ‘My partner is generally very understanding’ and ‘I am satisfied with my relationship with my partner.’ In the current sample, the scale had a Cronbach’s alpha of 0.90. This scale has been used in previous studies [11,36]. Prior to the logistic regression analyses and the linear regression analyses, the negative items were reverse coded so that all went in the same direction. As the highest score represents the lowest level of relationship satisfaction, this measure is referred to as ‘Relationship dissatisfaction’ in the tables and the results section.

Stressful life events (SLEs) were measured during week 30 of the current pregnancy and consisted of nine questions concerning different types of demanding experiences. The questions were inspired by the list in Coddington [37], and adapted to adult respondents. Participants were asked to report whether they had experienced any of the listed situations during the preceding 12 months. The questions include the following: ‘Have you had problems at work or where you study?’, ‘Have you had financial problems?’, ‘Have you been divorced, separated or ended your relationship with your partner?’, ‘Have you had problems or conflict with your family, friends, or neighbours?’, ‘Have you been seriously ill or injured?’, ‘Has anyone close to you been seriously ill or injured?’, ‘Have you been involved in a serious accident, fire or robbery?’, ‘Have you lost someone close to you?’, and ‘Other?’. The scoring format for each item was no (0) or yes (1). A scale was constructed based on sum scores. This scale reflects the number of stressful life events reported, ranging from 0 to 8. The scale has been used in a previous study [11].

Incidents of infectious diseases were recorded at six months after birth for the period when the child was less than six months old. Incidents of infectious diseases for the period when the child was between six and eleven months old were recorded eighteen months after birth. Due to the scope of the present study, only data from the first year of life was used. The recording was based on a checklist covering eight categories of infectious disease: the common cold, throat infection, pneumonia/RS-virus/bronchitis, diarrhea/gastric flu, ear infection, pseudocroup, urinary tract infection and conjunctivitis. The checklist was marked by the mothers, who were asked whether their children had or had not experienced a disease when the child was less than six months old and when it was between six and eleven months old. To measure the variety of diseases within each subject, a scale was constructed based on the number of categories of infectious diseases that were reported. To measure the frequency of diseases within each subject, another scale was constructed based on sum scores of how many times each disease had occurred during the given period of time.

Control variables

Socioeconomic factors are possible confounding variables that are known to predict physical health outcomes and were therefore included as control variables. These variables included age, marital status (married versus cohabiting), household income (scored from 1 = no income to 7 = NOK 1,000,000 \approx EUR 114,000) and educational level (six categories from public school to >4 years at university/college).

Smoking during pregnancy is associated with infant respiratory infections [38]. A dichotomized variable was constructed based on smoking sometimes, daily (= smoking) or not at all.

The breastfeeding of infants has been shown to reduce the risk of infectious disease in infancy [39]. For the purpose of the present study, a variable based on the sum scores for the number of months of breastfeeding was constructed.

Social support may buffer stress-related HPA responses [40], and the adverse consequences of poor social relationships on immune-functioning have been well-documented [41]. To control for this, we measured the frequency of contact with family and close friends, as well as the possibility of seeking advice from people other than the husband/partner in a difficult situation. A scale with a three-step scoring format was constructed based on the following questions: 'Do you have anyone other than your husband/partner you can ask for advice in a difficult situation?' and 'How frequently do you meet or talk on the telephone with your family (other than your husband/partner and children) or close friends?'

The sex of the offspring was included as a possible confounding factor because prenatal stress has been shown to have sex-specific effects on the developing fetus [15].

Maternal depression and relationship dissatisfaction frequently co-occur [42]. Moreover, maternal depression may have adverse effects on the fetal development [43]. Maternal depression was therefore included as a possible confounding factor. Depression was measured based on one item from a checklist covering a wide range of diseases and health problems. The respondents were asked to mark whether they had or had had ongoing depression between the following weeks of the current pregnancy: 13–16, 17–20, 21–24, 25–28, 29+. A variable was constructed based on the mean scores of each time interval (scoring format: no depression = 0, depression = 1).

Finally, the use of kindergarten or other child care facilities was included as a control variable because child care is associated with higher exposure to virus and bacteria [44]. Because child care facilities were not used for < 6-month-old infants, this variable was only included in analyses based on the group of 6- to 11-month-old infants.

Statistical analyses

All statistical analyses were conducted using IBM SPSS, Version 22. Descriptive analyses were conducted to examine the nature of the study variables. Because maternal antibodies (IgG) may protect the offspring during the first 6 months of life [45], the data for the two age groups of infants were analyzed separately. The associations between the level of maternal relationship satisfaction and infectious disease in the group of < 6-month-old infants were first tested by performing separate bivariate logistic regression analyses for each of the eight infectious diseases as the dependent variable, using the level of relationship satisfaction as the predictor variable. This procedure was repeated for the group of 6- to 11-month-old infants. In order to assess the unique contribution of the level of relationship satisfaction, multivariable logistic regression analyses were performed with the following independent control variables: stressful life events, maternal age, level of education, income, marital status, social support, breastfeeding, smoking during pregnancy, maternal depression and the sex of the offspring. For the analyses based on the group of 6- to 11-month-old infants, use of child care was also included as a control variable. The same procedure was used to test the associations between prenatal stressful life events and infectious diseases in the offspring, except that maternal relationship satisfaction was included as a control variable in the multivariable analyses. Multiple linear regression analyses were conducted to examine the associations between prenatal relationship satisfaction and stressful life events, and the frequency of reported episodes of infectious disease in the offspring. Finally, multiple linear regression analyses were conducted to examine the associations between prenatal relationship satisfaction and stressful life events, and the variety of infectious

diseases in the offspring. The analyses were conducted separately for each of the two age groups of infants: less than 6 months old and 6- to 11 months old.

Results

The descriptive analyses showed that at least one infectious disease was reported in 99.9% of the infants in both age groups. The mean number of types of infectious diseases was 1.21 (SD = 0.92) in the youngest infants (< 6 months old) and 1.71 (SD = 2.68) in the oldest infants (6- to 11 months old). The mean number of reported infectious disease episodes (across all types) was 2.66 (SD = 2.48) in the youngest infants (< 6 months old) and 3.34 (SD = 2.68) in the oldest infants (6- to 11 months old). The incidences of each disease are displayed in [Table 1](#) for the youngest infants and [Table 2](#) for the oldest infants.

The majority of pregnant women reported low levels of relationship dissatisfaction (M = 1.65, SD = 0.65). At least one stressful life event (SLE) within the 12 months before gestational week 30 was experienced by 56% of the pregnant women (one SLE: 27.9%; two SLEs: 15.8%; three SLEs: 6.1%; four SLEs: 2.0%). Only 0.6% of the participants reported five or more SLEs). The mean number of reported stressful life events was 0.95 (SD = 1.09) and ranged from 0 to 8. Within the group of young infants, the bivariate logistic regression analyses showed a significant association between maternal relationship dissatisfaction and all eight infectious diseases ([Table 1](#)). Among the older infants, all diseases except one were significantly related to relationship dissatisfaction ([Table 2](#)). The associations remained significant within a 95% level of confidence for both age groups after adjusting for scores regarding prenatal stressful life events, age, education, income, marital status, social support, smoking, maternal depression, breastfeeding, and the sex of the offspring. For the 6- to 11-month-old children, the use of child-care was also included as a control variable. Bivariate and multivariate logistic regression analyses were performed to test the associations between stressful prenatal life events and infectious diseases. As shown in [Tables 1](#) and [2](#), the results from the bivariate logistic regression analyses showed a significant association with all eight infectious diseases in both age groups of infants. After adjusting for scores regarding prenatal relationship dissatisfaction, age,

Table 1. Associations between stressful life events and relationship dissatisfaction in pregnancy, and infectious diseases in the less-than-6-month-old children.

Category of infection	Incidence %	N	Stressful life events			Relationship dissatisfaction,		
			unadjusted OR	adjusted OR ¹	95% CI ¹	unadjusted OR	adjusted OR ²	95% CI ²
Common cold	76.7	68,168	1.06*	1.05*	1.04–1.07	1.25*	1.31*	1.27–1.35
Throat infection	3.0	67,123	1.16*	1.14*	1.09–1.18	1.30*	1.25*	1.17–1.34
Ear infection	4.6	67,124	1.08*	1.05*	1.02–1.09	1.24*	1.23*	1.16–1.30
Pseudocroup	2.2	67,109	1.07*	1.06*	1.01–1.12	1.14*	1.14*	1.05–1.24
Bronchitis /RS virus/ Pneumonia	4.9	67,173	1.04*	1.02	0.99–1.05	1.24*	1.26*	1.19–1.33
Gastric flu / diarrhea	11.3	67,165	1.13*	1.13*	1.10–1.15	1.12*	1.11*	1.07–1.15
Urinary tract infection	0.9	67,067	1.11*	1.08*	1.00–1.17	1.15*	1.17*	1.03–1.34
Conjunctivitis	25.9	67,247	1.05*	1.05*	1.03–1.07	1.19*	1.21*	1.17–1.24

¹ Odds ratio adjusted for relationship dissatisfaction, age, level of education, income, marital status, social support other than partner, smoking, maternal depression, breastfeeding and the sex of the offspring

² Odds ratio adjusted for stressful life events, age, level of education, income, marital status, social support other than partner, smoking, maternal depression, breastfeeding and the sex of the offspring

* Unadjusted Odds ratio = p < 0.05

Table 2. Associations between stressful life events and relationship dissatisfaction in pregnancy, and infectious diseases in the 6- to 11-month-old children.

Category of infection	Incidence %	N	Stressful life events			Relationship dissatisfaction,		
			unadjusted OR	adjusted OR ¹	95% CI ¹	unadjusted OR	adjusted OR ²	95% CI ²
Common cold	87.8	56,457	1.04*	1.03*	1.00–1.05	1.18*	1.23*	1.18–1.29
Throat infection	7.5	8,788	1.11*	1.09*	1.02–1.18	1.18*	1.18*	1.03–1.34
Ear infection	15.5	55,478	1.09*	1.07*	1.05–1.09	1.16*	1.16*	1.11–1.20
Pseudocroup	6.1	56,218	1.07*	1.07*	1.03–1.11	1.08*	1.10*	1.04–1.17
Bronchitis /RS virus/ Pneumonia	6.2	55,956	1.08*	1.06*	1.02–1.09	1.17*	1.19*	1.12–1.26
Gastric flu / diarrhea	31.6	54,028	1.08*	1.07*	1.06–1.09	1.15*	1.16*	1.12–1.19
Urinary tract infection	1.5	56,452	1.09*	1.06	0.99–1.13	1.09 ^o	1.09	0.98–1.22
Conjunctivitis	25.3	55,020	1.05*	1.04*	1.02–1.06	1.18*	1.21*	1.17–1.25

¹ Odds ratio adjusted for relationship dissatisfaction, age, level of education, income, marital status, social support other than partner, smoking, maternal depression, breastfeeding, the sex of the offspring, and use of childcare.

² Odds ratio adjusted for stressful life events, age, level of education, income, marital status, social support other than partner, smoking, maternal depression, breastfeeding, the sex of the offspring, and use of childcare.

* Unadjusted Odds ratio = $p < 0.05$

^o Unadjusted Odds ratio = $p = 0.121$

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education, income, marital status, social support, smoking, breastfeeding, maternal depression, the sex of the offspring and the use of child-care (for the 6- to 11-month-old), the statistical significance of the associations persisted for seven out of eight diseases in the youngest group (Table 1), and for seven out of eight diseases in the oldest group (Table 2).

Multiple linear regression analyses were conducted to examine the association between relationship dissatisfaction, stressful life events and the frequency and variety of infectious diseases reported. The two main predictor variables and the control variables were entered simultaneously. The control variables were the same as used before on the two groups of children. Two models were constructed to examine the association between relationship dissatisfaction, stressful life events and the frequency of reported episodes of infectious diseases within the two age groups of infants: less than 6 months old and 6- to 11 months old. After the inclusion of the control variables, the model of the youngest group explained 0.9% of the variance (adjusted $R^2 = .009$, $F(11,55649) = 48.048$, $p < .001$). The model of the oldest group explained 1.6% of the variance (adjusted $R^2 = .016$, $F(12,50868) = 71.563$, $p < .001$). The results showed that both main predictor variables were significantly associated with the frequency of infectious diseases in the offspring. The results are displayed in Table 3. Two additional models were constructed to examine the associations between relationship dissatisfaction, stressful life events and the number of various infectious diseases in the offspring. After the inclusion of the control variables, the model of the less-than-6-month-old infants explained 1.7% of the variance (adjusted $R^2 = .017$, $F(11,68578) = 108.981$, $p < .001$). The model of the 6- to 11 month-old infants explained 1.8% of the variance (adjusted $R^2 = .018$, $F(12,57353) = 88.271$, $p < .001$). As shown in Table 3, prenatal relationship dissatisfaction, as well as stressful life events, were significantly associated with the number of infectious diseases in the offspring.

Discussion

This study examined the degree to which prenatal maternal relationship dissatisfaction and stressful life events predict the risk of infectious disease in the offspring in their first year of life. The study was based on a nationwide Norwegian pregnancy cohort. Data on four groups of

Table 3. Unstandardised and standardised regression coefficients for relationship dissatisfaction and stressful life events in pregnancy on number of infectious diseases in the offspring.

	Frequency of infections ¹					Variety of infections ²				
	B	SE B	β	T	p	B	SE B	β	t	p
Less-than-6-month-old infants (n = 55,660)										
Relationship dissatisfaction	.263 ^a	.018	.064 ^a	14.623	< .001	.124 ^a	.006	.081 ^a	20.479	< .001
Stressful life events	.092 ^b	.010	.039 ^b	9.118	< .001	.041 ^b	.003	.047 ^b	12.124	< .001
6- to 11-month-old infants (n = 50,880)										
Relationship dissatisfaction	.280 ^c	.020	.063 ^c	13.690	< .001	.125 ^c	.008	.069 ^c	16.114	< .001
Stressful life events	.105 ^d	.011	.041 ^d	9.230	< .001	.043 ^d	.004	.042 ^d	10.004	< .001

¹ Frequency = the number of reported episodes of infections across the eight categories of diseases.

² Variety = the number of categories of infectious diseases that were reported.

^a Adjusted for scores on stressful life events, age, level of education, income, marital status, social support, smoking, maternal depression, breastfeeding and sex of the offspring.

^b Adjusted for scores on relationship dissatisfaction, age, level of education, income, marital status, social support, smoking, maternal depression, breastfeeding and sex of the offspring.

^c Adjusted for scores on stressful life events, age, level of education, income, marital status, social support, smoking, maternal depression, breastfeeding, sex of the offspring and use of childcare.

^d Adjusted for scores on relationship dissatisfaction, age, level of education, income, marital status, social support, smoking, maternal depression, breastfeeding, sex of the offspring and use of childcare.

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respiratory tract infections and four other groups of infections were included in the linear and logistic regression analyses. We found that maternal relationship dissatisfaction was significantly associated with all eight infectious diseases among the less-than-6-month-old infants. Within the group of 6- to 11-month-old infants, maternal relationship dissatisfaction was associated with seven out of eight infection categories. The only exception was urinary tract infection. We also found that women who reported higher degrees of relationship dissatisfaction during pregnancy reported both a higher frequency, as well as a higher variety, of infectious diseases in their offspring. The associations were generally weak but consistent across the age groups. This suggests that relationship dissatisfaction was not only associated with reoccurring symptoms of a specific infectious disease but also with a general susceptibility to various infectious diseases.

The present results contribute to new knowledge suggesting that marital dissatisfaction in pregnancy is a factor that affects the risk of infectious diseases in infants. On average, for each one-point increase in relationship dissatisfaction, the odds of reporting one infectious disease increased by a factor of 1.21. This means that the children of mothers who reported the highest possible scores on relationship dissatisfaction during pregnancy had, on average, 2.6 times higher odds of suffering from an infectious disease as compared with the children of mothers who reported the lowest possible scores. We were not able to find any previous studies that had focused on couples' relationship quality during pregnancy and its impact on the occurrence of infectious disease in the offspring. It is interesting to note, however, that the magnitude of the associations in this study were similar to those found in a recent study that examined the associations between maternal relationship satisfaction in early pregnancy and self-reported infectious diseases later in pregnancy [11].

The associations between stressful life events and infections followed a similar pattern as the associations between relationship dissatisfaction and infections. The logistic regression analyses showed that stressful prenatal life events were significantly associated with seven out of eight categories of infectious diseases in the young infants. The exception was for the

bronchitis/RS virus/pneumonia category. Among the oldest infants, stressful life events were also significantly associated with seven out of eight categories of disease. The exception was urinary tract infection. As with lower marital satisfaction, based on linear regression analyses, the association between stressful life events and infections showed that prenatal stressful life events predicted both higher frequency and a greater variety of infectious diseases during the first year of life. These findings are generally in line with previous studies showing that stressful prenatal life events predict infectious disease in infants, as well as in older children [17–19]. Interestingly, we found that the associations were stronger for marital dissatisfaction than for stressful life events. The difference may be due to the periodic nature of stressful life events versus the chronicity of marital difficulties. A measure of daily stress may be more appropriate for a comparison with the effects of relationship dissatisfaction.

The present study did not provide data about underlying physiological mechanisms. However, one of the major proposed mechanisms to account for the relationship between prenatal psychosocial stress and the offspring's susceptibility to infections is the secretion of cortisol, which is regulated by the maternal HPA axis and the placenta [14,20]. Both animal and human studies suggest that stress-related maternal cortisol increases the fetus's exposure of cortisol and subsequently affect the development of the fetus's immune domains [26,46]. Very few studies, however, have investigated the link between maternal cortisol and infectious diseases in infants [47]. One exception is the work of Beijers and colleagues [18] who found that higher evening cortisol levels and flattened diurnal cortisol rhythms in late pregnancy were related to increased infant respiratory infections. They also found a significant correlation between pregnancy-specific distress and evening cortisol levels. Indeed, other researchers have demonstrated that both stressful life events and partner support can regulate cortisol levels in pregnant women [30,48,49]. Thus, the physiological mechanisms underlying the associations found in the present study may be linked to maternal HPA axis activation.

The causal pathways described above may apply for relationship dissatisfaction, as well as for stressful life events. However, there are other possible explanations for the findings. For instance, it is possible that stress-related emotional distress and maternal relationship dissatisfaction persist after delivery. This could provide a stressful environment for the offspring by affecting mother-child interactions and infant stress reactivity [50]. The infant may respond with the heightened secretion of glucocorticoids, leading to adverse immune-regulation and an increased risk of infections as a consequence. Unfortunately, the dataset did not allow us to control for this possibility. A comprehensive review of additional potential mechanisms is provided by Beijers and colleagues [20].

The present study utilized a large amount of data from a large number of participants. This allowed for assessing relatively small effect sizes within a narrow confidence interval. At any rate, the results must be interpreted with some caution. One concern is that the study relied on self-report questionnaires. It is, for example, possible that the validity and reliability of the outcome measure were weakened by inaccurate interpretations of the children's symptoms. Another limitation was that bronchitis, RS virus and pneumonia were collapsed into one category. Moreover, we were unable to control the timing of the impact of the predictor variables. For instance, we do not know whether the stressful life events occurred before or during pregnancy. This was due to the design of the questionnaire. Also, the data did not allow for evaluating whether the effects of stressful life events and relationship dissatisfaction were related to chronic stress or time-limited distress. It has been suggested that the timing may be significant because the development of the fetal immune system is affected differently depending on gestational stage [25]. Another limitation was that the data did not allow for controlling for the effect of other children in the household. Having a child is linked with poorer relationship satisfaction [51], and is also naturally linked with whether or not the baby is exposed to illnesses

from a sibling. Thus, the number of children in the household may be a confounding variable. It should also be mentioned that only 40% of the invited women consented to participate. However, the potential impact of selection bias on exposure and outcome variables was evaluated in a study that tested eight different exposure—outcome associations [32]. The authors found no statistically significant differences in association measures between participants in the Norwegian Mother and Child Cohort Study and the total population, indicating that the generalizability of this study is not violated by selection bias. Finally, it is a concern that the scores for the main predictor variables were not normally distributed. In small samples, this may lead to problems with the interpretation of tests of statistical significance. However, in large sample sizes, the non-normality of the residuals will not hamper the interpretation of confidence intervals [52].

To conclude, our study provides empirical evidence that links stressful prenatal life events with the risk of infectious diseases in the infant offspring. Moreover, we found that lower levels of relationship satisfaction during pregnancy increased the risk, as well as the frequency and variety, of infectious diseases in infants. This may have implications for public health policy. However, statistically significant findings in large samples does not necessarily yield clinical significance. It remains to examine whether relationship management before or during pregnancy may reduce the risk of diseases in the offspring. Future studies should aim to increase our understanding of how and to what degree the prenatal social environment influences the physical health of the offspring over their lifespans.

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Author Contributions

Conceived and designed the experiments: REH FT. Performed the experiments: REH. Analyzed the data: REH. Contributed reagents/materials/analysis tools: REH FT. Wrote the paper: REH.

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- Skjæveland, Oddvar, Dr. psychol. Relationships between spatial-physical neighborhood attributes and social relations among neighbors.
- Zewdie, Tekla, Dr. philos. Mother-child relational patterns in Ethiopia. Issues of developmental theories and intervention programs.
- Wilhelmsen, Britt Unni, Dr. philos. Development and evaluation of two educational programmes designed to prevent alcohol use among adolescents.
- Manger, Terje, Dr. philos. Gender differences in mathematical achievement among Norwegian elementary school students.
- 1998**
- V Lindstrøm, Torill Christine, Dr. philos. «Good Grief»: Adapting to Bereavement.
- Skogstad, Anders, Dr. philos. Effects of leadership behaviour on job satisfaction, health and efficiency.
- Haldorsen, Ellen M. Håland, Dr. psychol. Return to work in low back pain patients.
- Besemer, Susan P., Dr. philos. Creative Product Analysis: The Search for a Valid Model for Understanding Creativity in Products.
- H Winje, Dagfinn, Dr. psychol. Psychological adjustment after severe trauma. A longitudinal study of adults' and children's posttraumatic reactions and coping after the bus accident in Måbødalen, Norway 1988.
- Vosburg, Suzanne K., Dr. philos. The effects of mood on creative problem solving.
- Eriksen, Hege R., Dr. philos. Stress and coping: Does it really matter for subjective health complaints?
- Jakobsen, Reidar, Dr. psychol. Empiriske studier av kunnskap og holdninger om hiv/aids og den normative seksuelle utvikling i ungdomsårene.
- 1999**
- V Mikkelsen, Aslaug, Dr. philos. Effects of learning opportunities and learning climate on occupational health.
- Samdal, Oddrun, Dr. philos. The school environment as a risk or resource for students' health-related behaviours and subjective well-being.
- Friestad, Christine, Dr. philos. Social psychological approaches to smoking.

	Ekeland, Tor-Johan, Dr. philos.	Meining som medisin. Ein analyse av placebofenomenet og implikasjoner for terapi og terapeutiske teoriar.
H	Saban, Sara, Dr. psychol.	Brain Asymmetry and Attention: Classical Conditioning Experiments.
	Carlsten, Carl Thomas, Dr. philos.	God lesing – God læring. En aksjonsrettet studie av undervisning i fagtekstlesing.
	Dundas, Ingrid, Dr. psychol.	Functional and dysfunctional closeness. Family interaction and children's adjustment.
	Engen, Liv, Dr. philos.	Kartlegging av leseferdighet på småskoletrinnet og vurdering av faktorer som kan være av betydning for optimal leseutvikling.
2000		
V	Hovland, Ole Johan, Dr. philos.	Transforming a self-preserving "alarm" reaction into a self-defeating emotional response: Toward an integrative approach to anxiety as a human phenomenon.
	Lillejord, Sølvi, Dr. philos.	Handlingsrasjonalitet og spesialundervisning. En analyse av aktørperspektiver.
	Sandell, Ove, Dr. philos.	Den varme kunnskapen.
	Oftedal, Marit Petersen, Dr. philos.	Diagnostisering av ordavkodingsvansker: En prosessanalytisk tilnæringsmåte.
H	Sandbak, Tone, Dr. psychol.	Alcohol consumption and preference in the rat: The significance of individual differences and relationships to stress pathology
	Eid, Jarle, Dr. psychol.	Early predictors of PTSD symptom reporting; The significance of contextual and individual factors.
2001		
V	Skinstad, Anne Helene, Dr. philos.	Substance dependence and borderline personality disorders.
	Binder, Per-Einar, Dr. psychol.	Individet og den meningsbærende andre. En teoretisk undersøkelse av de mellommenneskelige forutsetningene for psykisk liv og utvikling med utgangspunkt i Donald Winnicotts teori.
	Roald, Ingvild K., Dr. philos.	Building of concepts. A study of Physics concepts of Norwegian deaf students.
H	Fekadu, Zelalem W., Dr. philos.	Predicting contraceptive use and intention among a sample of adolescent girls. An application of the theory of planned behaviour in Ethiopian context.
	Melesse, Fantu, Dr. philos.	The more intelligent and sensitive child (MISC) mediational intervention in an Ethiopian context: An evaluation study.
	Råheim, Målfrid, Dr. philos.	Kvinnerens kroppserfaring og livssammenheng. En fenomenologisk – hermeneutisk studie av friske kvinner og kvinner med kroniske muskelsmerter.
	Engelsen, Birthe Kari, Dr. psychol.	Measurement of the eating problem construct.
	Lau, Bjørn, Dr. philos.	Weight and eating concerns in adolescence.

2002

- V Ihlebæk, Camilla, Dr. philos. Epidemiological studies of subjective health complaints.
- Rosén, Gunnar O. R., Dr. philos. The phantom limb experience. Models for understanding and treatment of pain with hypnosis.
- Høines, Marit Johnsen, Dr. philos. Fleksible språkrrom. Matematikk læring som tekstutvikling.
- Anthun, Roald Andor, Dr. philos. School psychology service quality. Consumer appraisal, quality dimensions, and collaborative improvement potential
- Pallesen, Ståle, Dr. psychol. Insomnia in the elderly. Epidemiology, psychological characteristics and treatment.
- Midthassel, Unni Vere, Dr. philos. Teacher involvement in school development activity. A study of teachers in Norwegian compulsory schools
- Kallestad, Jan Helge, Dr. philos. Teachers, schools and implementation of the Olweus Bullying Prevention Program.

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- Ofte, Sonja Helgesen, Dr. psychol. Right-left discrimination in adults and children.
- Netland, Marit, Dr. psychol. Exposure to political violence. The need to estimate our estimations.
- Diseth, Åge, Dr. psychol. Approaches to learning: Validity and prediction of academic performance.
- Bjuland, Raymond, Dr. philos. Problem solving in geometry. Reasoning processes of student teachers working in small groups: A dialogical approach.

2003

- V Arefjord, Kjersti, Dr. psychol. After the myocardial infarction – the wives' view. Short- and long-term adjustment in wives of myocardial infarction patients.
- Ingjaldsson, Jón Þorvaldur, Dr. psychol. Unconscious Processes and Vagal Activity in Alcohol Dependency.
- Holden, Børge, Dr. philos. Følger av atferdsanalytiske forklaringer for atferdsanalysens tilnærming til utforming av behandling.
- Holsen, Ingrid, Dr. philos. Depressed mood from adolescence to 'emerging adulthood'. Course and longitudinal influences of body image and parent-adolescent relationship.
- Hammar, Åsa Karin, Dr. psychol. Major depression and cognitive dysfunction- An experimental study of the cognitive effort hypothesis.
- Sprugevica, Ieva, Dr. philos. The impact of enabling skills on early reading acquisition.
- Gabrielsen, Egil, Dr. philos. LESE FOR LIVET. Lesekompetansen i den norske voksenbefolkningen sett i lys av visjonen om en enhetsskole.
- H Hansen, Anita Lill, Dr. psychol. The influence of heart rate variability in the regulation of attentional and memory processes.
- Dyregrov, Kari, Dr. philos. The loss of child by suicide, SIDS, and accidents: Consequences, needs and provisions of help.

2004

- V Torsheim, Torbjørn, Dr. psychol. Student role strain and subjective health complaints: Individual, contextual, and longitudinal perspectives.
- Haugland, Bente Storm Mowatt Dr. psychol. Parental alcohol abuse. Family functioning and child adjustment.
- Milde, Anne Marita, Dr. psychol. Ulcerative colitis and the role of stress. Animal studies of psychobiological factors in relationship to experimentally induced colitis.
- Stornes, Tor, Dr. philos. Socio-moral behaviour in sport. An investigation of perceptions of sportspersonship in handball related to important factors of socio-moral influence.
- Mæhle, Magne, Dr. philos. Re-inventing the child in family therapy: An investigation of the relevance and applicability of theory and research in child development for family therapy involving children.
- Kobbeltvedt, Therese, Dr. psychol. Risk and feelings: A field approach.

**2004
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- Thomsen, Tormod, Dr. psychol. Localization of attention in the brain.
- Løberg, Else-Marie, Dr. psychol. Functional laterality and attention modulation in schizophrenia: Effects of clinical variables.
- Kyrkjebø, Jane Mikkelsen, Dr. philos. Learning to improve: Integrating continuous quality improvement learning into nursing education.
- Laumann, Karin, Dr. psychol. Restorative and stress-reducing effects of natural environments: Experiential, behavioural and cardiovascular indices.
- Holgersen, Helge, PhD Mellom oss - Essay i relasjonell psykoanalyse.

2005

- V Hetland, Hilde, Dr. psychol. Leading to the extraordinary? Antecedents and outcomes of transformational leadership.
- Iversen, Anette Christine, Dr. philos. Social differences in health behaviour: the motivational role of perceived control and coping.

**2005
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- Mathisen, Gro Ellen, PhD Climates for creativity and innovation: Definitions, measurement, predictors and consequences.
- Sævi, Tone, Dr. philos. Seeing disability pedagogically – The lived experience of disability in the pedagogical encounter.
- Wiiium, Nora, PhD Intrapersonal factors, family and school norms: combined and interactive influence on adolescent smoking behaviour.
- Kanagaratnam, Pushpa, PhD Subjective and objective correlates of Posttraumatic Stress in immigrants/refugees exposed to political violence.
- Larsen, Torill M. B. , PhD Evaluating principals` and teachers` implementation of Second Step. A case study of four Norwegian primary schools.
- Bancila, Delia, PhD Psychosocial stress and distress among Romanian adolescents and adults.

2006

V

- Hillestad, Torgeir Martin, Dr. philos. Normalitet og avvik. Forutsetninger for et objektivt psykopatologisk avviksbegrep. En psykologisk, sosial, erkjennelsesteoretisk og teorihistorisk framstilling.
- Nordanger, Dag Øystein, Dr. psychol. Psychosocial discourses and responses to political violence in post-war Tigray, Ethiopia.
- Rimol, Lars Morten, PhD Behavioral and fMRI studies of auditory laterality and speech sound processing.
- Krumsvik, Rune Johan, Dr. philos. ICT in the school. ICT-initiated school development in lower secondary school.
- Norman, Elisabeth, Dr. psychol. Gut feelings and unconscious thought: An exploration of fringe consciousness in implicit cognition.
- Israel, K Pravin, Dr. psychol. Parent involvement in the mental health care of children and adolescents. Empirical studies from clinical care setting.
- Glasø, Lars, PhD Affects and emotional regulation in leader-subordinate relationships.
- Knutsen, Ketil, Dr. philos. HISTORIER UNGDOM LEVER – En studie av hvordan ungdommer bruker historie for å gjøre livet meningsfullt.
- Matthiesen, Stig Berge, PhD Bullying at work. Antecedents and outcomes.

2006

H

- Gramstad, Arne, PhD Neuropsychological assessment of cognitive and emotional functioning in patients with epilepsy.
- Bendixen, Mons, PhD Antisocial behaviour in early adolescence: Methodological and substantive issues.
- Mrumbi, Khalifa Maulid, PhD Parental illness and loss to HIV/AIDS as experienced by AIDS orphans aged between 12-17 years from Temeke District, Dar es Salaam, Tanzania: A study of the children's psychosocial health and coping responses.
- Hetland, Jørn, Dr. psychol. The nature of subjective health complaints in adolescence: Dimensionality, stability, and psychosocial predictors
- Kakoko, Deodatus Conatus Vitalis, PhD Voluntary HIV counselling and testing service uptake among primary school teachers in Mwanza, Tanzania: assessment of socio-demographic, psychosocial and socio-cognitive aspects
- Mykletun, Arnstein, Dr. psychol. Mortality and work-related disability as long-term consequences of anxiety and depression: Historical cohort designs based on the HUNT-2 study
- Sivertsen, Børge, PhD Insomnia in older adults. Consequences, assessment and treatment.

2007

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- Singhammer, John, Dr. philos. Social conditions from before birth to early adulthood – the influence on health and health behaviour
- Janvin, Carmen Ani Cristea, PhD Cognitive impairment in patients with Parkinson's disease: profiles and implications for prognosis

	Braarud, Hanne Cecilie, Dr.psychol.	Infant regulation of distress: A longitudinal study of transactions between mothers and infants
	Tveito, Torill Helene, PhD	Sick Leave and Subjective Health Complaints
	Magnussen, Liv Heide, PhD	Returning disability pensioners with back pain to work
	Thuen, Elin Marie, Dr.philos.	Learning environment, students' coping styles and emotional and behavioural problems. A study of Norwegian secondary school students.
	Solberg, Ole Asbjørn, PhD	Peacekeeping warriors – A longitudinal study of Norwegian peacekeepers in Kosovo
2007		
H	Søreide, Gunn Elisabeth, Dr.philos.	Narrative construction of teacher identity
	Svensen, Erling, PhD	WORK & HEALTH. Cognitive Activation Theory of Stress applied in an organisational setting.
	Øverland, Simon Nygaard, PhD	Mental health and impairment in disability benefits. Studies applying linkages between health surveys and administrative registries.
	Eichele, Tom, PhD	Electrophysiological and Hemodynamic Correlates of Expectancy in Target Processing
	Børhaug, Kjetil, Dr.philos.	Oppseding til demokrati. Ein studie av politisk oppseding i norsk skule.
	Eikeland, Thorleif, Dr.philos.	Om å vokse opp på barnehjem og på sykehus. En undersøkelse av barnehjemsbarns opplevelser på barnehjem sammenholdt med sanatoriebarns beskrivelse av langvarige sykehusopphold – og et forsøk på forklaring.
	Wadel, Carl Cato, Dr.philos.	Medarbeidersamhandling og medarbeiderledelse i en lagbasert organisasjon
	Vinje, Hege Forbech, PhD	Thriving despite adversity: Job engagement and self-care among community nurses
	Noort, Maurits van den, PhD	Working memory capacity and foreign language acquisition
2008		
V	Breivik, Kyrre, Dr.psychol.	The Adjustment of Children and Adolescents in Different Post-Divorce Family Structures. A Norwegian Study of Risks and Mechanisms.
	Johnsen, Grethe E., PhD	Memory impairment in patients with posttraumatic stress disorder
	Sætrevik, Bjørn, PhD	Cognitive Control in Auditory Processing
	Carvalho, Susana Fonseca, PhD	Prevention of bullying in schools: an ecological model
2008		
H	Brønnick, Kolbjørn Selvåg	Attentional dysfunction in dementia associated with Parkinson's disease.

	Posserud, Maj-Britt Rocio	Epidemiology of autism spectrum disorders
	Haug, Ellen	Multilevel correlates of physical activity in the school setting
	Skjerve, Arvid	Assessing mild dementia – a study of brief cognitive tests.
	Kjønniksen, Lise	The association between adolescent experiences in physical activity and leisure time physical activity in adulthood: a ten year longitudinal study
	Gundersen, Hilde	The effects of alcohol and expectancy on brain function
	Omvik, Siri	Insomnia – a night and day problem
2009		
V	Molde, Helge	Pathological gambling: prevalence, mechanisms and treatment outcome.
	Foss, Else	Den omsorgsfulle væremåte. En studie av voksnes væremåte i forhold til barn i barnehagen.
	Westrheim, Kariane	Education in a Political Context: A study of Knowledge Processes and Learning Sites in the PKK.
	Wehling, Eike	Cognitive and olfactory changes in aging
	Wangberg, Silje C.	Internet based interventions to support health behaviours: The role of self-efficacy.
	Nielsen, Morten B.	Methodological issues in research on workplace bullying. Operationalisations, measurements and samples.
	Sandu, Anca Larisa	MRI measures of brain volume and cortical complexity in clinical groups and during development.
	Guribye, Eugene	Refugees and mental health interventions
	Sørensen, Lin	Emotional problems in inattentive children – effects on cognitive control functions.
	Tjomsland, Hege E.	Health promotion with teachers. Evaluation of the Norwegian Network of Health Promoting Schools: Quantitative and qualitative analyses of predisposing, reinforcing and enabling conditions related to teacher participation and program sustainability.
	Helleve, Ingrid	Productive interactions in ICT supported communities of learners
2009		
H	Skorpen, Aina Øye, Christine	Dagliglivet i en psykiatrisk institusjon: En analyse av miljøterapeutiske praksiser
	Andreassen, Cecilie Schou	WORKAHOLISM – Antecedents and Outcomes
	Stang, Ingun	Being in the same boat: An empowerment intervention in breast cancer self-help groups
	Sequeira, Sarah Dorothee Dos Santos	The effects of background noise on asymmetrical speech perception

	Kleiven, Jo, dr.philos.	The Lillehammer scales: Measuring common motives for vacation and leisure behavior
	Jónsdóttir, Guðrún	Dubito ergo sum? Ni jenter møter naturfaglig kunnskap.
	Hove, Oddbjørn	Mental health disorders in adults with intellectual disabilities - Methods of assessment and prevalence of mental health disorders and problem behaviour
	Wageningen, Heidi Karin van	The role of glutamate on brain function
	Bjørkvik, Jofrid	God nok? Selvaktelse og interpersonlig fungering hos pasienter innen psykisk helsevern: Forholdet til diagnoser, symptomer og behandlingsutbytte
	Andersson, Martin	A study of attention control in children and elderly using a forced-attention dichotic listening paradigm
	Almás, Aslaug Grov	Teachers in the Digital Network Society: Visions and Realities. A study of teachers' experiences with the use of ICT in teaching and learning.
	Ulvik, Marit	Lærerutdanning som dannning? Tre stemmer i diskusjonen
2010		
V	Skår, Randi	Læringsprosesser i sykepleieres profesjonsutøvelse. En studie av sykepleieres læringserfaringer.
	Roald, Knut	Kvalitetsvurdering som organisasjonslæring mellom skole og skoleeigar
	Lunde, Linn-Heidi	Chronic pain in older adults. Consequences, assessment and treatment.
	Danielsen, Anne Grete	Perceived psychosocial support, students' self-reported academic initiative and perceived life satisfaction
	Hysing, Mari	Mental health in children with chronic illness
	Olsen, Olav Kjellevold	Are good leaders moral leaders? The relationship between effective military operational leadership and morals
	Riese, Hanne	Friendship and learning. Entrepreneurship education through mini-enterprises.
	Holthe, Asle	Evaluating the implementation of the Norwegian guidelines for healthy school meals: A case study involving three secondary schools
H	Hauge, Lars Johan	Environmental antecedents of workplace bullying: A multi-design approach
	Bjørkelo, Brita	Whistleblowing at work: Antecedents and consequences
	Reme, Silje Endresen	Common Complaints – Common Cure? Psychiatric comorbidity and predictors of treatment outcome in low back pain and irritable bowel syndrome
	Helland, Wenche Andersen	Communication difficulties in children identified with psychiatric problems

Beneventi, Harald	Neuronal correlates of working memory in dyslexia
Thygesen, Elin	Subjective health and coping in care-dependent old persons living at home
Aanes, Mette Marthinussen	Poor social relationships as a threat to belongingness needs. Interpersonal stress and subjective health complaints: Mediating and moderating factors.
Anker, Morten Gustav	Client directed outcome informed couple therapy
Bull, Torill	Combining employment and child care: The subjective well-being of single women in Scandinavia and in Southern Europe
Viig, Nina Grieg	Tilrettelegging for læreres deltakelse i helsefremmende arbeid. En kvalitativ og kvantitativ analyse av sammenhengen mellom organisatoriske forhold og læreres deltakelse i utvikling og implementering av Europeisk Nettverk av Helsefremmende Skoler i Norge
Wolff, Katharina	To know or not to know? Attitudes towards receiving genetic information among patients and the general public.
Ogden, Terje, dr.philos.	Familiebasert behandling av alvorlige atferdsproblemer blant barn og ungdom. Evaluering og implementering av evidensbaserte behandlingsprogrammer i Norge.
Solberg, Mona Elin	Self-reported bullying and victimisation at school: Prevalence, overlap and psychosocial adjustment.
2011	
V	
Bye, Hege Høivik	Self-presentation in job interviews. Individual and cultural differences in applicant self-presentation during job interviews and hiring managers' evaluation
Notelaers, Guy	Workplace bullying. A risk control perspective.
Moltu, Christian	Being a therapist in difficult therapeutic impasses. A hermeneutic phenomenological analysis of skilled psychotherapists' experiences, needs, and strategies in difficult therapies ending well.
Myrseth, Helga	Pathological Gambling - Treatment and Personality Factors
Schanche, Elisabeth	From self-criticism to self-compassion. An empirical investigation of hypothesized change processes in the Affect Phobia Treatment Model of short-term dynamic psychotherapy for patients with Cluster C personality disorders.
Våpenstad, Eystein Victor, dr.philos.	Det tempererte nærvær. En teoretisk undersøkelse av psykoterapeutens subjektivitet i psykoanalyse og psykoanalytisk psykoterapi.
Haukebø, Kristin	Cognitive, behavioral and neural correlates of dental and intra-oral injection phobia. Results from one treatment and one fMRI study of randomized, controlled design.
Harris, Anette	Adaptation and health in extreme and isolated environments. From 78°N to 75°S.

	Bjørknes, Ragnhild	Parent Management Training-Oregon Model: intervention effects on maternal practice and child behavior in ethnic minority families
	Mamen, Asgeir	Aspects of using physical training in patients with substance dependence and additional mental distress
	Espevik, Roar	Expert teams: Do shared mental models of team members make a difference
	Haara, Frode Olav	Unveiling teachers' reasons for choosing practical activities in mathematics teaching
2011		
H	Hauge, Hans Abraham	How can employee empowerment be made conducive to both employee health and organisation performance? An empirical investigation of a tailor-made approach to organisation learning in a municipal public service organisation.
	Melkevik, Ole Rogstad	Screen-based sedentary behaviours: pastimes for the poor, inactive and overweight? A cross-national survey of children and adolescents in 39 countries.
	Vøllestad, Jon	Mindfulness-based treatment for anxiety disorders. A quantitative review of the evidence, results from a randomized controlled trial, and a qualitative exploration of patient experiences.
	Tolo, Astrid	Hvordan blir lærerkompetanse konstruert? En kvalitativ studie av PPU-studenters kunnskapsutvikling.
	Saus, Evelyn-Rose	Training effectiveness: Situation awareness training in simulators
	Nordgreen, Tine	Internet-based self-help for social anxiety disorder and panic disorder. Factors associated with effect and use of self-help.
	Munkvold, Linda Helen	Oppositional Defiant Disorder: Informant discrepancies, gender differences, co-occurring mental health problems and neurocognitive function.
	Christiansen, Øivin	Når barn plasseres utenfor hjemmet: beslutninger, forløp og relasjoner. Under barnevernets (ved)tak.
	Brunborg, Geir Scott	Conditionability and Reinforcement Sensitivity in Gambling Behaviour
	Hystad, Sigurd William	Measuring Psychological Resiliency: Validation of an Adapted Norwegian Hardiness Scale
2012		
V	Roness, Dag	Hvorfor bli lærer? Motivasjon for utdanning og utøving.
	Fjermestad, Krister Westlye	The therapeutic alliance in cognitive behavioural therapy for youth anxiety disorders
	Jenssen, Eirik Sørnes	Tilpasset opplæring i norsk skole: politikeres, skolelederes og læreres handlingsvalg
	Saksvik-Lehouillier, Ingvild	Shift work tolerance and adaptation to shift work among offshore workers and nurses

	Johansen, Venke Frederike	Når det intime blir offentlig. Om kvinners åpenhet om brystkreft og om markedsføring av brystkreftsaken.
	Herheim, Rune	Pupils collaborating in pairs at a computer in mathematics learning: investigating verbal communication patterns and qualities
	Vie, Tina Løkke	Cognitive appraisal, emotions and subjective health complaints among victims of workplace bullying: A stress-theoretical approach
	Jones, Lise Øen	Effects of reading skills, spelling skills and accompanying efficacy beliefs on participation in education. A study in Norwegian prisons.
2012		
H	Danielsen, Yngvild Sørebo	Childhood obesity – characteristics and treatment. Psychological perspectives.
	Horverak, Jøri Gytre	Sense or sensibility in hiring processes. Interviewee and interviewer characteristics as antecedents of immigrant applicants' employment probabilities. An experimental approach.
	Jøsendal, Ola	Development and evaluation of BE smokeFREE, a school-based smoking prevention program
	Osnes, Berge	Temporal and Posterior Frontal Involvement in Auditory Speech Perception
	Drageset, Sigrunn	Psychological distress, coping and social support in the diagnostic and preoperative phase of breast cancer
	Aasland, Merethe Schanke	Destructive leadership: Conceptualization, measurement, prevalence and outcomes
	Bakibinga, Pauline	The experience of job engagement and self-care among Ugandan nurses and midwives
	Skogen, Jens Christoffer	Foetal and early origins of old age health. Linkage between birth records and the old age cohort of the Hordaland Health Study (HUSK)
	Leveresen, Ingrid	Adolescents' leisure activity participation and their life satisfaction: The role of demographic characteristics and psychological processes
	Hanss, Daniel	Explaining sustainable consumption: Findings from cross-sectional and intervention approaches
	Rød, Per Arne	Barn i klem mellom foreldrekonflikter og samfunnsmessig beskyttelse
2013		
V	Mentzoni, Rune Aune	Structural Characteristics in Gambling
	Knudsen, Ann Kristin	Long-term sickness absence and disability pension award as consequences of common mental disorders. Epidemiological studies using a population-based health survey and official ill health benefit registries.
	Strand, Mari	Emotional information processing in recurrent MDD

	Veseth, Marius	Recovery in bipolar disorder. A reflexive-collaborative exploration of the lived experiences of healing and growth when battling a severe mental illness
	Mæland, Silje	Sick leave for patients with severe subjective health complaints. Challenges in general practice.
	Mjaaland, Thera	At the frontiers of change? Women and girls' pursuit of education in north-western Tigray, Ethiopia
	Odéen, Magnus	Coping at work. The role of knowledge and coping expectancies in health and sick leave.
	Hynninen, Kia Minna Johanna	Anxiety, depression and sleep disturbance in chronic obstructive pulmonary disease (COPD). Associations, prevalence and effect of psychological treatment.
	Flo, Elisabeth	Sleep and health in shift working nurses
	Aasen, Elin Margrethe	From paternalism to patient participation? The older patients undergoing hemodialysis, their next of kin and the nurses: a discursive perspective on perception of patient participation in dialysis units
	Ekorås, Belinda	Emotional and Behavioural Problems in Children: Self-perception, peer relationships, and motor abilities
	Corbin, J. Hope	North-South Partnerships for Health: Key Factors for Partnership Success from the Perspective of the KIWAKKUKI
	Birkeland, Marianne Skogbrott	Development of global self-esteem: The transition from adolescence to adulthood
2013	Gianella-Malca, Camila	Challenges in Implementing the Colombian Constitutional Court's Health-Care System Ruling of 2008
H	Hovland, Anders	Panic disorder – Treatment outcomes and psychophysiological concomitants
	Mortensen, Øystein	The transition to parenthood – Couple relationships put to the test
	Årdal, Guro	Major Depressive Disorder – a Ten Year Follow-up Study. Inhibition, Information Processing and Health Related Quality of Life
	Johansen, Rino Bandlitz	The impact of military identity on performance in the Norwegian armed forces
	Bøe, Tormod	Socioeconomic Status and Mental Health in Children and Adolescents
2014	Nordmo, Ivar	Gjennom nåløyet – studenters læringserfaringer i psykologutdanningen
V	Dovran, Anders	Childhood Trauma and Mental Health Problems in Adult Life
	Hegelstad, Wenche ten Velden	Early Detection and Intervention in Psychosis: A Long-Term Perspective
	Urheim, Ragnar	Forståelse av pasientagresjon og forklaringer på nedgang i voldsrate ved Regional sikkerhetsavdeling, Sandviken sykehus

	Kinn, Liv Grethe	Round-Trips to Work. Qualitative studies of how persons with severe mental illness experience work integration.
	Rød, Anne Marie Kinn	Consequences of social defeat stress for behaviour and sleep. Short-term and long-term assessments in rats.
	Nygård, Merethe	Schizophrenia – Cognitive Function, Brain Abnormalities, and Cannabis Use
	Tjora, Tore	Smoking from adolescence through adulthood: the role of family, friends, depression and socioeconomic status. Predictors of smoking from age 13 to 30 in the “The Norwegian Longitudinal Health Behaviour Study” (NLHB)
	Vangsnes, Vigdis	The Dramaturgy and Didactics of Computer Gaming. A Study of a Medium in the Educational Context of Kindergartens.
	Nordahl, Kristin Berg	Early Father-Child Interaction in a Father-Friendly Context: Gender Differences, Child Outcomes, and Protective Factors related to Fathers’ Parenting Behaviors with One-year-olds
2014 H	Sandvik, Asle Makoto	Psychopathy – the heterogeneity of the construct
	Skotheim, Siv	Maternal emotional distress and early mother-infant interaction: Psychological, social and nutritional contributions
	Halleland, Helene Barone	Executive Functioning in adult Attention Deficit Hyperactivity Disorder (ADHD). From basic mechanisms to functional outcome.
	Halvorsen, Kirsti Vindal	Partnerskap i lærerutdanning, sett fra et økologisk perspektiv
	Solbue, Vibeke	Dialogen som visker ut kategorier. En studie av hvilke erfaringer innvandererungdommer og norskfødte med innvanderforeldre har med videregående skole. Hva forteller ungdommenes erfaringer om videregående skoles håndtering av etniske ulikheter?
	Kvalevaag, Anne Lise	Fathers’ mental health and child development. The predictive value of fathers’ psychological distress during pregnancy for the social, emotional and behavioural development of their children
	Sandal, Ann Karin	Ungdom og utdanningsval. Om elevar sine opplevingar av val og overgangsprosessar.
	Haug, Thomas	Predictors and moderators of treatment outcome from high- and low-intensity cognitive behavioral therapy for anxiety disorders. Association between patient and process factors, and the outcome from guided self-help, stepped care, and face-to-face cognitive behavioral therapy.
	Sjølie, Hege	Experiences of Members of a Crisis Resolution Home Treatment Team. Personal history, professional role and emotional support in a CRHT team.
	Falkenberg, Liv Eggset	Neuronal underpinnings of healthy and dysfunctional cognitive control

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