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Physical Activity, Pregnancy and Mental Well-Being: Focusing on Women at Risk for Gestational Diabetes

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PHYSICAL ACTIVITY, PREGNANCY AND MENTAL WELL-BEING:

FOCUSING ON WOMEN AT RISK FOR GESTATIONAL DIABETES

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ACADEMIC DISSERTATION

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ABSTRACT

BACKGROUND: Physical inactivity, mental health problems and obesity, whilst interrelated, each represent a major global health challenge. Furthermore, obesity substantially contributes to the increasing prevalence of gestational diabetes mellitus (GDM), an emerging worldwide epidemic amongst pregnant women. Life events such as pregnancy may affect leisure-time physical activity as well as mental well-being.

AIMS: This study aims 1) to systemically review the literature concerning the effects of life events, especially pregnancy, on physical activity; 2) to compare the prevalence of depressive symptoms in early pregnancy between women at high risk for GDM and women in the general pregnant population; 3) to examine the associations of cardiorespiratory fitness and physical activity with health-related quality of life amongst women planning a pregnancy and at high risk for GDM; and 4) to evaluate the effects of lifestyle counselling aimed at preventing GDM on self-rated health from early pregnancy throughout the first year following birth.

METHODS:

Design: This doctoral thesis consists of one published systematic literature review (study I) and three original study publications (studies II, III and IV). The data are from two randomised controlled trials: the Finnish Gestational Diabetes Prevention Study (RADIEL) and the Finnish Gestational Diabetes Prevention Study Part II: Autonomic Nervous System and Exercise (ANS-EXE).

Participants: The systematic review consisted of studies amongst healthy adults. The participants in the two trials consisted of 482 pregnant women and 39 women planning a pregnancy at high risk for GDM (a history of GDM or a prepregnancy body mass index [BMI] ≥ 29 kg/m^2 or both), and 358 pregnant women in the general Finnish population.

Measures: A systematic literature review from the PubMed MEDLINE and the OVID PsycINFO databases was performed to identify studies that assessed at least one major life event and a change in physical activity. Depressive symptoms were assessed using the Edinburgh Postnatal Depression Scale (EPDS) in pregnant women at risk for GDM, whilst health-related quality of life was measured using the 36-Item Short-Form Health Survey (SF-36) amongst women planning a pregnancy and at risk for GDM. Women at risk for GDM reported their self-rated health by means of a single question at six time points between early pregnancy and at one-year postpartum. Cardiorespiratory fitness was assessed by measuring the maximal oxygen consumption (VO_{2max}) during a cycle ergometer test in

women planning a pregnancy, and leisure-time physical activity was measured through a self-report questionnaire.

Lifestyle intervention: The intervention consisted of diet and physical activity counselling delivered by trained trial nurses (six meetings) and dieticians (three group meetings) from early pregnancy to one-year postpartum.

RESULTS: The studies included in the systematic review showed statistically significant changes in leisure-time physical activity after life events. Changes varied according to different life events and the age and gender of the study population (study I). Physical activity decreased both from prepregnancy to pregnancy, and from prepregnancy to the postpartum period (study I). Pregnant women at risk for GDM exhibited higher depression scale scores compared to pregnant women in the general population during early pregnancy, but this difference disappeared after adjusting for age, BMI and income (study II). In addition, cardiorespiratory fitness and leisure-time physical activity were positively associated with the self-rated general health and physical well-being domains of health-related quality of life in women planning a pregnancy and at risk for GDM, which held when controlling for BMI (study III). Furthermore, self-rated general health and physical well-being differed between those women with very poor or poor cardiorespiratory fitness (study III). The self-rated health of women at risk for GDM tended to improve amongst the lifestyle counselling group and to deteriorate in the control group from pregnancy to one-year postpartum, although the difference between groups was not statistically significant (study IV).

CONCLUSIONS: Life events affect leisure-time physical activity; for example, pregnancy tends to decrease physical activity levels. Consequently, pregnant women and women planning a pregnancy could be an important target group for physical activity promotion. The prevalence of depressive symptoms during early pregnancy is higher amongst women at risk for GDM compared to women in the general pregnant population. The higher prevalence seems to be explained by characteristics such as age, BMI and income. Moreover, even a slightly better cardiorespiratory fitness could be beneficial for the health-related quality of life amongst women at risk for GDM who are planning a pregnancy. The effectiveness of lifestyle counselling for high-risk pregnant women aimed at improving self-rated well-being requires further research.

TIIVISTELMÄ

TAUSTA: Vähäinen liikunta, mielenterveyden ongelmat ja lihavuus ovat maailmanlaajuisesti merkittäviä väestön terveyteen liittyviä haasteita, jotka ovat myös yhteydessä toisiinsa. Lihavuus puolestaan on läheisesti yhteydessä raskausdiabetekseen, joka on niin ikään kehittymässä maailmanlaajuiseksi epidemiaksi raskaana olevien naisten keskuudessa. Raskauden kaltaiset elämäntapahtumat saattavat vaikuttaa sekä liikunta-aktiivisuuteen että henkiseen hyvinvointiin.

TAVOITTEET: Väitöskirjan tavoitteena on 1) koota systemaattisesti yhteen tutkimusnäyttö merkittävien elämäntapahtumien, erityisesti raskauden, vaikutuksista liikunta-aktiivisuuteen, 2) verrata alkuraskauden masennusoireiden esiintyvyyttä raskausdiabeteksen riskiryhmään kuuluvien naisten ja yleisesti raskaana olevien naisten välillä, 3) tutkia hengitys- ja verenkiertoelimistön kunnon ja liikunta-aktiivisuuden yhteyttä elämänlaatuun niiden raskausdiabeteksen riskiryhmään kuuluvien naisten keskuudessa, jotka suunnittelevat raskaaksi tulemista 4) sekä selvittää raskausdiabeteksen ehkäisyyn tähtäävän elintapaohjauksen vaikutuksia koettuun terveyteen alkuraskaudesta siihen asti, kun synnytyksestä on kulunut vuosi.

MENETELMÄT:

Asetelma: Väitöstutkimus koostuu neljästä osatyöstä: yhdestä julkaistusta systemaattisesta kirjallisuuskatsauksesta (osatyö I) ja kolmesta tutkimusjulkaisusta (osatyöt II, III ja IV). Tutkimusjulkaisuissa käytettiin kahden satunnaistetun kontrolloidun kokeen aineistoja: Raskausdiabetes ja elintavat (RADIEL) sekä Raskausdiabetes ja elintavat osa II (ANS-EXE).

Tutkittavat: Systemaattisen kirjallisuuskatsauksen aineistoissa tutkittavat olivat terveitä aikuisia. Kahdessa kontrolloidussa kokeessa oli mukana 482 raskaana olevaa ja 39 raskautta suunnittelevaa naista, joilla oli suurentunut raskausdiabeteksen riski (raskausdiabetes aiemmassa raskaudessa ja/tai raskautta edeltävä painoindeksi ≥ 29 kg/m^2), sekä 358 Suomen yleiseen väestöön kuuluvaa raskaana olevaa naista.

Mittarit: Kirjallisuuskatsaus perustuu PubMed MEDLINE ja OVID PsycINFO -tietokannoissa tehdyn systemaattisen kirjallisuushaun tuloksiin. Mukaan hyväksyttiin tutkimukset, joissa selvitettiin vähintään yhden elämäntapahtuman vaikutusta liikunta-aktiivisuuteen. Raskausdiabeteksen riskiryhmään kuuluvien raskaana olevien naisten masennusoireet kysyttiin Edinburgh Postnatal Depression Scale -lomakkeella ja raskautta suunnittelevien naisten terveyteen liittyvä elämänlaatu SF-36 Health Survey -lomakkeella. Koettu terveys selvitettiin yhdellä kysymyksellä yhteensä kuusi

kertaa raskauden aikana ja synnytyksen jälkeen siihen saakka, kun synnytyksestä oli kulunut vuosi. Raskautta suunnittelevien naisten hengitys- ja verenkiertoelimistön kunto mitattiin polkupyöräergometritestin aikana mittaamalla maksimaalinen hapenottokyky (VO_{2max}), ja tutkittavat vastasivat vapaa-ajan liikunta-aktiivisuutta kartoittaviin lomakekysymyksiin.

Elintapainterventio: Koulutetut tutkimushoitajat antoivat ravitsemus- ja liikuntaohjausta (kuusi henkilökohtaista tapaamista) ja lisäksi ravitsemusterapeutti ohjasi kolme ryhmätapaamista alkuraskaudesta siihen asti, kun synnytyksestä oli kulunut vuosi.

TULOKSET: Systemaattinen kirjallisuuskatsaus osoitti, että elämäntapahtumat vaikuttavat vapaa-ajan liikunta-aktiivisuuteen (osatyö I). Raskaus vähentää liikunta-aktiivisuutta; raskautta edeltävä liikunta väheni sekä raskauden aikana että synnytyksen jälkeen (osatyö I). Raskausdiabeteksen riskiryhmään kuuluvilla naisilla oli enemmän alkuraskauden masennusoireita kuin yleisesti raskaana olevilla naisilla. Ero ryhmien välillä ei ollut enää merkitsevä iällä, painoindeksillä ja tulotasolla vakioinnin jälkeen (osatyö II). Raskausdiabeteksen riskiryhmään kuuluvilla raskautta suunnittelevilla naisilla hengitys- ja verenkiertoelimistön kunto ja vapaa-ajan liikunta-aktiivisuus olivat positiivisesti yhteydessä terveyteen liittyvän elämänlaadun osa-alueista koettuun terveyteen ja koettuun fyysiseen hyvinvointiin, myös painoindeksillä vakioinnin jälkeen (osatyö III). Naiset, joilla oli hyvin huono kunto, kokivat terveytensä ja fyysisen hyvinvointinsa kaikkein huonoimmaksi, jopa verrattuna naisiin, joilla oli huono kunto (osatyö III). Koettu terveys näytti paranevan alkuraskaudesta siihen asti, kun synnytyksestä oli kulunut vuosi raskausdiabeteksen riskiryhmään kuuluvilla naisilla, jotka saivat elintapaohjausta. Koettu terveys näytti sen sijaan huononevan kontrolliryhmässä. Ero ryhmien välillä ei kuitenkaan ollut tilastollisesti merkitsevä (osatyö IV).

JOHTOPÄÄTÖKSET: Merkittävät elämäntapahtumat, kuten raskaus, vaikuttavat vapaa-ajan liikunta-aktiivisuuteen, joten elämäntapahtumat voisivat olla otollinen aika liikunta-aktiivisuuden edistämiselle. Raskaus vähentää liikunta-aktiivisuutta yleisessä väestössä. Raskausdiabeteksen riskiryhmään kuuluvilla naisilla on enemmän masennusoireita kuin naisilla yleisesti alkuraskaudessa, mutta ero näyttäisi selittyvän taustatekijöillä, kuten iällä, painoindeksillä ja tulotasolla. Raskausdiabeteksen riskiryhmään kuuluvilla raskautta suunnittelevilla naisilla jo hieman parempi hengitys-ja verenkiertoelimistön kunto saattaisi parantaa terveyteen liittyvää elämänlaatua. Lisää tutkimuksia tarvitaan selvittämään, voidaanko raskausdiabeteksen riskiryhmään kuuluvien naisten koettua hyvinvointia parantaa elintapaohjauksella.

CONTENTS

LIST OF ORIGINAL PUBLICATIONS

This doctoral thesis is based on the following publications:

I Engberg E, Alén M, Kukkonen-Harjula K, Peltonen JE, Tikkanen HO, Pekkarinen H. Life events and change in leisure time physical activity: A systematic review. *Sports Medicine* 2012; 42:433–447.

II Engberg E, Stach-Lempinen B, Sahrakorpi N, Rönö K, Roine RP, Kautiainen H, Eriksson JG, Koivusalo SB. A cross-sectional study of antenatal depressive symptoms in women at high risk for gestational diabetes mellitus. *Journal of Psychosomatic Research* 2015; 79:646–650.

III Engberg E, Tikkanen HO, Koponen A, Hägglund H, Kukkonen-Harjula K, Tiitinen A, Peltonen JE, Pöyhönen-Alho M. Cardiorespiratory fitness and health-related quality of life in women at risk for gestational diabetes. *Scandinavian Journal of Medicine & Science in Sports* 2018; 28:203–2011.

IV Engberg E, Stach-Lempinen B, Rönö K, Kautiainen H, Eriksson JG, Koivusalo SB. A randomized lifestyle intervention preventing gestational diabetes: effects on self-rated health from pregnancy to postpartum. *Journal of Psychosomatic Obstetrics & Gynecology* 2018; 39:1–6.

The publications are referred to by their roman numerals in the text. The publications are reprinted with the permission of the copyright holders. In addition, some unpublished results are presented (in an update to study I).

ABBREVIATIONS

15D	15-dimensional Health-related Quality of Life Instrument
ACOG	American College of Obstetricians and Gynaecologists
ADA	American Diabetes Association
AHA	American Heart Association
ANS-EXE	Finnish Gestational Diabetes Prevention Study Part II: Autonomic Nervous System & Exercise
BMI	Body mass index
CESD	Centre for Epidemiologic Studies Depression Scale
CI	Confidence interval
DASS	Depression Anxiety Stress Scale
EPDS	Edinburgh Postnatal Depression Scale
GDM	Gestational diabetes mellitus
GLTEQ	Godin Leisure-Time Exercise Questionnaire
HAPO	Hyperglycaemia and Adverse Pregnancy Outcome study
HRQoL	Health-related quality of life
IADPSG	International Association of Diabetes and Pregnancy Study Groups
IQR	Interquartile range
KPAS	Kaiser Physical Activity Survey
LTPA	Leisure-time physical activity
MeSH	Medical Subject Headings
MET	Metabolic equivalent
OGTT	Oral glucose tolerance test
PA	Physical activity
PASE	Physical Activity Scale for the Elderly
PPAQ	Pregnancy Physical Activity Questionnaire
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RADIEL	Finnish Gestational Diabetes Prevention Study
RCT	Randomised controlled trial
SD	Standard deviation
SF-36	36-Item Short Form Health Survey
UPBEAT	UK Pregnancies Better Eating and Activity
USDHH	U.S. Department of Health and Human Services
VO_{2max}	Maximal oxygen consumption
WHO	World Health Organization

1 INTRODUCTION

Physical inactivity, mental health disorders and obesity, whilst interrelated, each represent significant global health challenges (1–3). While globally almost 40% of all women are overweight (body mass index [BMI] ≥ 25 kg/m^2) or obese (BMI ≥ 30 kg/m^2), even higher rates are found in developed countries (4). Amongst women of childbearing age, the prevalence of obesity alone is 37% in the Unites States (5), whereas amongst women who gave birth in 2015 in Finland, 35% were overweight and 13% were obese (6). Life events throughout the lifespan, such as pregnancy and having a child, may have an important impact on both physical activity (PA) and mental well-being. Life events may create joy, emotional distress and physical changes, and may disrupt a person's daily routine.

According to the World Health Organization (WHO), physical inactivity is the fourth leading risk factor for global mortality, whilst PA levels continue to decline in many countries (7). Physical inactivity is recognised as a global pandemic, and thus should be a public health priority (8). In addition to a range of chronic diseases and early deaths, physical inactivity also causes a substantial economic burden (9, 10). PA during pregnancy benefits most women and carries minimal risks. However, normal anatomic and physiologic changes related to pregnancy as well as foetal requirements may require some modifications to the physical activities performed (11). In an uncomplicated pregnancy, aerobic and strength-conditioning PA are encouraged before, during and after pregnancy (11).

WHO estimates that neuropsychiatric conditions, particularly depression, are amongst the most important conditions affecting overall disability-adjusted life years and years lived with a disability in all regions (12). Moreover, depression during pregnancy is garnering additional attention, as we expand our understanding of the harmful consequences of depressive symptoms and antidepressant medication to both the mother and the child (13, 14).

Health-related quality of life (HRQoL) refers to how health impacts an individual's ability to function — that is, an individual's perceived physical, mental and social well-being. Self-rated health represents one domain of HRQoL, as well as a widely used measure of health status itself, and is often assessed using a single question. Both HRQoL and self-rated health strongly predict morbidity and mortality, sometimes even more so than objective measures of health (15–19). In addition, higher levels of PA are associated with a better HRQoL in the general population (20).

In addition to other adverse consequences, being overweight and obesity substantially contribute to the increasing prevalence of gestational diabetes mellitus (GDM) (21), defined as an impaired glucose tolerance with an onset

or first recognition during pregnancy (22). In addition to a high BMI, a history of GDM represents another major risk factor for GDM in a subsequent pregnancy (21, 23–25). Alarmingly, the prevalence of GDM is increasing worldwide (26). In Finland, 18% of women who gave birth in 2016 had an abnormal glucose tolerance (6), whilst in the USA almost one in five women develops GDM during pregnancy (27). This increasing prevalence of GDM is worrying due to its negative health consequences, including adverse pregnancy outcomes and an exceptionally high risk of developing type 2 diabetes for both the mother and the child in future (26, 28–30). Depression is more common in people with type 1 or type 2 diabetes compared to those without (31), but the prevalence of depressive symptoms amongst women with GDM has not been extensively studied (32). GDM, however, has been associated with an adverse HRQoL (33).

GDM represents an emerging global epidemic amongst pregnant women, and women with GDM may be vulnerable to a poor mental well-being. A poor mental well-being, in turn, may affect adherence to GDM prevention strategies, such as lifestyle changes or later to the treatment of GDM. However, little is known about depressive symptoms or factors associated with an adverse HRQoL amongst women with or at risk for disease. Moreover, far too little attention has been paid to identifying effective methods to improve self-rated well-being amongst high-risk pregnant and postpartum women.

Thus, this doctoral thesis examines the effects of life events, particularly pregnancy, on PA. Furthermore, this thesis examines mental well-being, PA and cardiorespiratory fitness, as well as their associations with each other, amongst women at high risk for GDM. Finally, this thesis evaluates whether lifestyle counselling for women at risk for GDM improves their self-rated health during pregnancy and throughout the first year following birth.

2 REVIEW OF THE LITERATURE

2.1 LIFE EVENTS

Life experiences that may greatly influence an individual's daily routine are referred to as life-changing events (34). Life-changing events or life events are defined as 'those occurrences, including social, psychological and environmental, which require an adjustment or effect a change in an individual's pattern of living' (35). Life events include the beginning of a study programme, a change in marital status, moving to a new environment, a major change in one's financial situation, obtaining a new job, obtaining a new family member, the death of a friend or family member, illness or injury and pregnancy.

2.2 PREGNANCY AS A LIFE EVENT

Pregnancy is a common life event amongst women of reproductive age. In addition, pregnancy is accompanied by cardiovascular, metabolic, respiratory, musculoskeletal, endocrine and emotional changes. These changes cause a weight gain of 8 to 15 kg in a normal pregnancy, body aches, constipation, dizziness, fatigue, sleep problems, morning sickness, swelling, a lower haemoglobin and blood pressure, a faster heart rate, a worsened mood, excitement and fears (36). Furthermore, these symptoms may have a major impact on the life of the woman and her family. Prenatal care is provided within primary care to all pregnant women in Finland, aimed at improving the chance of a healthy pregnancy both for the mother and the foetus. Pregnancy lasts about 40 weeks, and the weeks are grouped into three trimesters — the first trimester (weeks 1 to 12), the second trimester (weeks 13 to 28) and the third trimester (weeks 29 to 40) (36).

2.3 LIFE EVENTS AND PHYSICAL ACTIVITY

The experience of stress impairs efforts to be physically active (37). Stressful events such as family demands and time pressures at work may affect PA and other health behaviours either by disrupting an individual's ability to engage in such behaviours or by increasing unhealthy behaviours. However, studies examining the association between minor hassles or stressful daily events and PA show conflicting results. For example, one study collected exercise

diaries and weekly stress inventories amongst women for eight weeks. In that study, researchers found that during weeks with a high frequency of minor stressful events (daily inconveniences, frustrations and hassles) women exercised less and their exercise-related cognitions, such as exercise enjoyment, were disrupted (38). By contrast, a longitudinal study showed that an increase in daily hassles (minor irritations) over a two-year period was associated with an increase in daily PA amongst women and men aged 27 to 29 years, even though the magnitude of the change was quite small (39). Moreover, another study found no difference in the number of daily stressors between exercise days and no exercise days across a sample of women and men, although those with a low-trait anxiety reported fewer stressful events on exercise days than on no-exercise days. In addition, those with strong personal motives for exercise (health, mood or physical appearance) reported more stressful daily events overall, and experienced more potentially stressful events as non-stressful on the days they exercised (40).

Major life events, including getting married, a divorce, the death of a family member and pregnancy, may create emotional distress or eustress and disrupt a person's daily routine, thus impacting health behaviours. Previous cross-sectional studies have examined the associations between the number of major life events during a specific time period and subsequent PA at one time point (41–43). Two studies reported no association between PA and the number of life events experienced during five years amongst adults (43), and during three months amongst adolescents (41). However, one study showed that life events among 1 859 men were associated with lower levels of PA (44). By contrast, another study reported small associations between the presence of life events and higher levels of PA in men, and between the presence of life events and lower levels of PA in women (42).

A systematic review on life events and PA was published in 2008. That paper reviewed 19 articles published between 1984 and 2006, and concluded that life events do affect PA (45). The cross-sectional and longitudinal studies included in the review showed that beginning paid work, marriage and a change in residential status associated with a decrease in PA amongst young women. In addition, the cross-sectional studies included showed associations between widowhood and lower levels of PA amongst men. Furthermore, a divorce reduced PA in men. A serious illness during childhood was associated with a decrease in PA in adulthood, and a cancer diagnosis was similarly associated with lower levels of PA. The systematic review included five studies examining pregnancy or having a child as a life event, concluding pregnancy had no major effect on PA, although parenthood was associated with lower levels of PA, particularly amongst women (45). However, two studies examining pregnancy (46, 47) did not assess PA before pregnancy. Therefore, the studies did not actually examine the change in PA caused by pregnancy. Furthermore, the proportion of pregnant women meeting the PA

recommendation of at least 150 minutes of aerobic PA per week varies widely across studies. For example, 23% of pregnant women met the recommendation in a study conducted in the USA (48), whereas 47% of women in early pregnancy met the PA recommendation in Sweden (49).

2.4 PHYSICAL ACTIVITY

2.4.1 DEFINITIONS

PA is defined as 'any bodily movement produced by skeletal muscles, which increases energy expenditure (50, 51) above the basal level' (52). PA can be categorised in various ways, such as according to type, intensity and purpose. PA categorised by the context in which it occurs includes occupational, household, transportation and leisure-time activity (52). Leisure-time physical activity (LTPA) refers to a variety of activities resulting in substantial energy expenditure, but the intensity and duration of the activities can vary considerably. LTPA includes walking, hiking, gardening, dance, competitive sports, resistance training and structured exercise training amongst others (51). Exercise is defined as PA that is planned, structured, repetitive and purposive, the objective of which is to improve or maintain one or more components of physical fitness (50, 51).

Aerobic PA (or endurance activity or cardiorespiratory activity) is activity in which the body's large muscles move in a rhythmic manner for a sustained period of time, causing a person's heart to beat faster than normal (51). Examples include brisk walking, running, cycling and swimming. Aerobic PA has three components: intensity, frequency and duration. The intensity of aerobic PA is often divided into light, moderate and vigorous intensities (51). Health-enhancing PA refers to activity that, when added to baseline activity (light-intensity activities of daily life, such as standing, walking slowly and lifting lightweight objects), produces health benefits (53).

Physical inactivity is defined as 'an insufficient PA level to meet present PA recommendations' (54). Sedentary behaviour (from the Latin *sedere*, 'to sit') refers to 'those activities that do not increase energy expenditure substantially above the resting level' (55). Sedentary behaviour is more precisely defined as 'any waking behaviour characterised by an energy expenditure ≤ 1.5 metabolic equivalents (METs) while in a sitting, reclining or lying posture' (54). Typical sedentary behaviours consist of sleeping, lying down, watching TV, other forms of screen-based entertainment and sitting in an automobile.

Traditionally, PA has been assessed through self-reported questionnaires. PA questionnaires are inexpensive and feasible when examining large study populations. However, self-reported PA may be biased due to under- and

overreporting, either deliberately (social desirability) or resulting from cognitive limitations related to comprehension or recall (56–58). PA questionnaires typically measure multiple dimensions of PA, including the type, domain, location, time spent in activities and intensity. In addition, PA questionnaires vary in length. Single-item PA measures as similar with short PA questionnaires when it comes to reliability and validity (59). Other self-reported PA assessment methods include interviews and diaries. Currently, studies more frequently use objective assessment methods for PA, such as accelerometers (60).

2.4.2 HEALTH BENEFITS

Physical inactivity is estimated to cause as many global deaths per year as smoking; inactivity causes 9% of premature mortality. Moreover, physical inactivity is estimated to cause 6% of the burden of disease from coronary heart disease, 7% from type 2 diabetes, 10% from breast cancer and 10% from colon cancer (9). Higher levels of PA reduce the risk of breast cancer, colon cancer, diabetes, ischemic heart disease and ischemic stroke events (61). Furthermore, PA is associated with a lower risk of mortality and cardiovascular disease events globally (62). The Women's Health Study in the USA examined more than 16 000 women and found that the association between overall volume of PA and the reduction in all-cause mortality was even stronger (60–70%) when PA was assessed objectively using accelerometers compared to estimates from meta-analyses of studies using self-reported PA (20–30%) (63). In addition, exercise interventions suggest that PA can improve mental health and decrease symptoms of depression, anxiety and stress (64, 65).

2.4.3 GUIDELINES FOR ADULTS

The US Department of Health and Human Services (USDHHS) recommends that, in addition to baseline light-intensity daily activities (such as self-care, casual walking or grocery shopping), adults should do at least 2.5 hours of moderate-intensity aerobic PA a week, or 1.25 hours of vigorous-intensity aerobic PA a week to gain substantial health benefits. Alternatively, an equivalent combination of moderate- and vigorous-intensity aerobic PA can be performed. Aerobic PA should be completed in episodes of ten minutes or longer; preferably, PA should be spread throughout the week. In addition, adults should increase their aerobic PA to five hours a week of moderate-intensity, or 2.5 hours a week of vigorous-intensity aerobic PA (or an equivalent combination of moderate- and vigorous-intensity activity) to gain additional and more extensive health benefits. Alongside aerobic PA, adults should complete moderate- or high-intensity muscle-strengthening activities

that involve all major muscle groups on two or more days a week. As such, USDHHS recommends that all adults should avoid inactivity, and that some PA is better than none (53).

The USDHHS guidelines for PA are based on the Physical Activity Guidelines Advisory Committee's extensive analysis of scientific evidence on PA and health. The benefits of PA are seen in generally healthy people, in people at risk of developing chronic diseases and in people with current chronic conditions or disabilities. Some health benefits seem to begin with even smaller amounts of PA, but research shows that meeting the PA guidelines consistently reduces the risk of many chronic diseases and other adverse health outcomes (53). Adults with chronic medical conditions and symptoms and adults with disabilities not able to meet the PA guidelines should engage in regular PA according to their abilities, and should consult healthcare personnel about the types and amounts of PA appropriate for them.

The USDHHS PA guidelines for health were adopted by WHO in its *Global Recommendations on Physical Activity and Health* (7), and by different countries in their national PA guidelines, including Finland (66, 67). The American Heart Association (AHA) recommends following the USDHHS PA guidelines for adults to improve overall cardiovascular health. To lower elevated blood pressure and plasma cholesterol, AHA recommends an average of 40 minutes of moderate- to vigorous-intensity aerobic activity three or four times a week (68). The current USDHHS PA guidelines were released in 2008, with the second edition currently in preparation. As such, the 2018 Physical Activity Guidelines Advisory Committee submitted its Scientific Report to the Secretary of Health and Human Services in February 2018 (69). Based on the expanding evidence base resulting from ten years of research, the committee views PA as providing even more health benefits, benefits which can be achieved in more flexible ways than those recommended in the 2008 guidelines. For example, bouts or episodes of moderate-to-vigorous PA of any duration provide health benefits (69).

2.4.4 HEALTH BENEFITS FOR PREGNANT WOMEN

Regular aerobic PA during pregnancy improves or maintains cardiorespiratory fitness, prevents lower back pain and urinary incontinence, possibly reduces symptoms of depression and improves weight gain control (11, 70–72). To gain these benefits, the intensity of PA should be mild or moderate for previously sedentary women and moderate to vigorous for previously physically active women (71). Moreover, resistance training combined with aerobic PA improves cardiorespiratory fitness and prevents urinary incontinence (73). A systematic review in 2015 showed that PA during pregnancy may prevent excessive maternal weight gain and the development of GDM, independent of other health behaviours such as eating

a healthy or unhealthy diet (74, 75). In addition, PA reduces the risk of preeclampsia and caesarean deliveries, and modestly increases the chance of a normal delivery (11, 76). PA during pregnancy is not associated with a lower birth weight or preterm birth (71), but reduces the chance of an excessive birth weight (77). In addition, aerobic PA in lactating women appears to improve maternal cardiovascular fitness without a detrimental effect on milk production and composition, infant growth or development or maternal health (78). Current evidence related to the benefits of PA during pregnancy remains limited, but there is no evidence of harm when not contraindicated (11). Further research is needed to examine the effects of PA on pregnancy-related outcomes, and to identify the most effective behavioural counselling methods as well as the optimal frequency and intensity of PA during pregnancy (11).

2.4.5 GUIDELINES FOR PREGNANT WOMEN

In 1985, the American College of Obstetricians and Gynaecologists (ACOG) published its first guidelines on exercise during pregnancy and the postpartum period. These guidelines were based on the limited evidence published at that time. Pregnant women were advised, for example, to limit their heart rate to 140 beats per minute and not to perform intense activity continuously for more than 15 minutes (79, 80). Subsequently, most studies demonstrated that any effects of PA during pregnancy were likely to benefit the mother and the foetus (79, 80). Therefore, more recent guidelines paid more attention to the benefits of PA during pregnancy and less to any concern for adverse outcomes.

The most recent update to the ACOG PA and exercise guidelines for pregnant and postpartum women was published in 2015 (11). ACOG now argues that PA during pregnancy carries minimal risks and largely benefits most women. However, some modifications to exercise routines may be necessary because of the anatomical and physiological changes as well as foetal requirements during pregnancy. The major changes during pregnancy are an increased weight gain and a shift in the point of gravity, leading to progressive lordosis. Therefore, an increase in the forces across the joints and the spine occurs during weight-bearing exercise (11). As a result, more than 60% of pregnant women suffer from low-back pain (81). Normally, blood volume, heart rate, stroke volume and cardiac output increase during pregnancy, whilst vascular resistance decreases (11). In addition, pregnancy causes respiratory changes. These consist of minute ventilation increases of up to 50%, mostly because of the increased tidal volume. The pulmonary reserve decreases and, thus, pregnant women's ability to exercise anaerobically is impaired and the oxygen availability consistently lags during strenuous aerobic exercise and an increased work load (11).

Nevertheless, engaging in aerobic and strength-conditioning exercises before, during and after pregnancy should be encouraged amongst women with uncomplicated pregnancies. Women with medical or obstetric complications should be evaluated by obstetrician-gynaecologists and other obstetric care providers before making any PA recommendations (11). ACOG recommends developing a PA programme with the pregnant woman and adjusting it as medically indicated, leading to an eventual goal of moderate-intensity PA for at least 20 to 30 minutes per day on most or all days of the week (11). Following pregnancy, exercise routines can be gradually resumed as soon as it is medically safe. The mode of delivery and the presence or absence of medical or surgical complications impact the timing and intensity for resuming exercise routines. Some women may return to their physical activities within days of delivery. This has not been associated with adverse effects in the absence of medical or surgical complications (11).

Moreover, USDHHS recommends healthy pregnant women not already highly active or engaging in vigorous-intensity PA before pregnancy engage in at least 2.5 hours of moderate-intensity aerobic PA a week during pregnancy and the postpartum period. Pregnant women who are highly active or habitually engage in vigorous-intensity aerobic PA can continue PA during pregnancy and the postpartum period if they remain healthy and discuss their PA with a healthcare provider (53). Many countries have country-specific guidelines on PA during pregnancy. Most guidelines support moderate-intensity PA and initiating an exercise programme during pregnancy, and rule-out exercise that carries a risk of falling, trauma or collisions (82). In Finland, pregnant and postpartum women are encouraged to be physically active according to the general PA guidelines for adults (at least 2.5 hours a week of moderate-intensity aerobic PA) with some modifications similar to those listed in the ACOG guidelines (66).

The types of exercise that should be avoided during pregnancy include those with a risk of trauma — that is, contact sports, ice hockey and downhill ski racing as well as diving because the foetus is not protected from problems associated with decompression (83). Motionless postures, including certain yoga positions and the supine position, should also be avoided because these may result in a decreased venous return and hypotension (84). When exercising, pregnant women should stay well-hydrated, wear loose-fitting clothing and avoid high heat and humidity to protect against heat stress (11).

2.5 CARDIORESPIRATORY FITNESS

2.5.1 DEFINITIONS

Physical fitness is defined as 'a set of attributes that people have or achieve that relate to the ability to perform PA' (51). Physical fitness contributes to the ability to carry out daily tasks with vigour and alertness, without too much fatigue and the energy to enjoy leisure-time pursuits and to meet unforeseen emergencies (52). Physical fitness includes cardiorespiratory endurance, skeletal muscular endurance, skeletal muscular strength, skeletal muscular power, speed, reaction time, agility, flexibility, balance and body composition. These attributes differ in their importance when it comes to either health or athletic performance; therefore, a distinction between health-related fitness and performance-related fitness has been made. As such, health-related fitness includes cardiorespiratory fitness, muscular strength and endurance, body composition and flexibility, attributes important to public health (50). However, other attributes related to performance-related fitness, such as balance, can also play an important role in health.

Cardiorespiratory fitness (or aerobic fitness) refers to the maximal capacity of the cardiorespiratory system to take up and use oxygen. This is typically expressed in millilitres of oxygen per minute adjusted for total body mass or fat-free mass, expressed in kilograms. Cardiorespiratory fitness is usually measured in a laboratory setting using indirect calorimetry (analysis of O^2 and CO^2 in respiratory gases) as the maximal aerobic power or maximal oxygen consumption (VO_{2max}) during a maximal cycle ergometer or treadmill test until voluntary fatigue. VO_{2max} is the highest rate of oxygen uptake achieved during heavy dynamic exercise. Cardiorespiratory fitness can be estimated from the peak power achieved on a cycle ergometer or time spent on a standard treadmill test. Submaximal tests, in which the heart rate response is extrapolated to an age-predicted endpoint, provide a less precise estimation (51).

2.5.2 HEALTH BENEFITS

Cardiorespiratory fitness and PA play important and independent albeit overlapping roles in cardiovascular health (85). Longitudinal studies demonstrated that cardiorespiratory fitness, determined during submaximal or maximal exercise tests, and self-reported PA are associated with greater longevity and better physical health (86, 87). PA and cardiorespiratory fitness are closely related; cardiorespiratory fitness is primarily, although not entirely, determined by aerobic PA during recent weeks or months. Cardiorespiratory fitness is also determined by genetic factors, but probably

more by environmental factors, principally PA (88). Some longitudinal studies report that cardiorespiratory fitness, determined using a maximal treadmill test, more strongly associated with all-cause mortality than self-reported PA (89).

2.6 GESTATIONAL DIABETES MELLITUS (GDM)

2.6.1 DEFINITION AND PREVALENCE

Gestational diabetes mellitus (GDM) is commonly defined as an impaired glucose tolerance with onset or first recognition during pregnancy (22). The International Association of Diabetes and Pregnancy Study Groups (IADPSG) Consensus Panel in 2010 defined GDM as 'any degree of glucose intolerance with onset or first recognition during pregnancy that is not clearly overt diabetes' (90). This definition distinguishes between women with overt diabetes — that is, women with type 2 diabetes previously undiagnosed or not treated outside pregnancy — and women with GDM that resolves after pregnancy. Normal pregnancy is associated with insulin resistance, which leads to an increased insulin demand. GDM occurs when the woman's body cannot make enough insulin in order to meet its extra needs during pregnancy. The high blood glucose values associated with GDM typically return to normal levels following birth. It is important to differentiate between the two groups of women because of the increased risk of both obstetrical and diabetes complications as well as the congenital malformations of newborns common amongst pregnant women with type 2 diabetes diagnosed initially during pregnancy; such women require appropriate monitoring and treatment during pregnancy (91–93). Moreover, the ongoing epidemics of obesity and diabetes have resulted in an increasing prevalence of type 2 diabetes in young women and, thus, the number of undiagnosed type 2 diabetes before pregnancy is increasing (93, 94).

IADPSG, the American Diabetes Association (ADA) and WHO recommend that all pregnant women be screened for GDM between 24- to 28-weeks gestation (22, 90, 95). The recommended diagnostic thresholds in a 75-g 2-h oral glucose tolerance test (OGTT) are as follows: a fasting plasma glucose ≥ 5.1 mmol/l, 1-h value ≥ 10.0 mmol/l and 2-h value ≥ 8.5 mmol/l. In addition, IADPSG, ADA and WHO recommend that high-risk women should be screened during the first trimester of pregnancy, and diagnosed with overt, non-gestational diabetes if their glucose values from OGTT exceed the threshold values for diabetes in non-pregnant individuals (22, 90, 95). Regardless of the recommendations, the criteria for the diagnosis of GDM vary between and within countries (96). In Finland, all pregnant women (except women younger than 25, with BMI < 25 kg/m^2 and with no

family history of GDM) have been screened for GDM since 2008. GDM screening occurs between gestational weeks 24 and 28, and is diagnosed if one or more glucose value is pathological in a 75-g 2-h OGTT. The diagnostic thresholds in Finland are as follows: a fasting plasma glucose ≥ 5.3 mmol/l, a 1-h value ≥ 10.0 mmol/l and a 2-h value ≥ 8.6 mmol/l (97). In addition, high-risk women (e.g., BMI ≥ 35 kg/m², GDM in a previous pregnancy, type 2 diabetes diagnosed in close relatives) are screened at between gestational weeks 12 and 16 (97).

The Hyperglycaemia and Adverse Pregnancy Outcome (HAPO) study included more than 23 000 women from 15 centres and nine countries between 2000 and 2006; the overall prevalence of GDM reached 17.8% when using the IADPSG diagnostic criteria from 2010 (98). The prevalence was highest in California, USA (25.5%) and lowest in Brisbane, Australia (12.4%) (98). Along with obesity (2), the prevalence of GDM has also been increasing worldwide (26). However, comparisons of prevalence across countries or regions remain challenging because of the heterogeneity in screening practices and diagnostic criteria (26, 96). In Finland, 9.6% of women who delivered in 2008 had a pathological OGTT result, whilst the percentage increased to 12.7% in 2012, 15.9% in 2015 and 17.5% in 2016 (6). However, the percentage of women with GDM would be even higher if the IADOSG diagnostic criteria for GDM were applied in Finland.

2.6.2 RISK FACTORS

The primary risk factors for GDM include a high BMI, a history of GDM, a high maternal age and a family history of diabetes (24, 25, 99–101). Being overweight (BMI ≥ 25 kg/m²) and obesity (BMI ≥ 30 kg/m²) contribute substantially to the increasing prevalence of GDM (21). Globally, almost 40% of all women are overweight, and even higher rates are found in developed countries (4). Amongst women of childbearing age, the prevalence of obesity alone was 37% in 2013 to 2014 in the USA (5), whereas 35% of women who gave birth in 2015 in Finland were overweight and 13% were obese (6). A history of GDM represents another major risk factor for GDM during a subsequent pregnancy (23–25).

The prevalence of GDM varies between ethnic groups. In a study conducted in California, prevalence was highest among Filipinas and Asians, intermediate among Hispanics and lowest among non-Hispanic whites and African-Americans (102). Moreover, ethnic minority women in Europe as well as migrant women in several countries are at an increased risk of GDM (103, 104). In addition, the recurrence rate of GDM is higher amongst Hispanic, African-American and Asian women compared with non-Hispanic white women (105). Epidemiological studies suggest that PA before and during pregnancy, as well as a healthy pregravid diet, may be related to a

lower GDM risk (106). GDM is also associated with social deprivation, a history of macrosomia and a history of perinatal complications (99, 100).

2.6.3 HEALTH CONSEQUENCES

Although GDM usually resolves following pregnancy, it is associated with significant short- and long-term morbidities both amongst mothers and their infants. Hyperglycaemia (high blood sugar) and GDM during pregnancy increase the risk of pregnancy complications, including pre-eclampsia, labour induction and caesarean section (107, 108). Moreover, hyperglycaemia and GDM are associated with adverse neonatal outcomes, including large for gestational age, macrosomia (infant body weight ≥ 4000 g), shoulder dystocia and infant adiposity (107–109). In the long-term, women with a history of GDM are at an increased risk for GDM recurrence (25). Furthermore, GDM is associated with an exceptionally high risk of developing type 2 diabetes in both the mother and the child in future (26, 28–30, 110). For instance, women diagnosed with GDM have at least a seven-fold increased risk for type 2 diabetes (28). Type 2 diabetes, in turn, carries adverse consequences including atherosclerotic cardiovascular disease (111).

2.7 DEPRESSIVE SYMPTOMS DURING PREGNANCY

2.7.1 DEFINITIONS

Depression, or a major depressive disorder, is a mental illness that negatively affects the way a person feels, thinks and acts. Depressive symptoms can vary from mild to severe. The symptoms include feelings of sadness or a depressed mood, a loss of interest in activities previously enjoyed, changes in appetite, trouble sleeping or sleeping too much, a loss of energy, feeling worthless or guilty, difficulty thinking, making decisions or concentrating and thoughts of death or suicide (112). In diagnosed depression, severe symptoms cause noticeable problems in relationships with others or in daily activities, and symptoms must be present for at least two weeks (112).

Peripartum depression refers to depression during pregnancy or after child birth (113). The term peripartum recognises that depression related to having a child often begins during pregnancy (113). Depression occurring during pregnancy is also known as antenatal or prenatal depression. The term postpartum depression, in turn, refers to depression occurring within the first year after giving birth. Whilst major depression is diagnosed by a

physician, depressive symptoms can be assessed using scales or questionnaires.

2.7.2 PREVALENCE, HEALTH CONSEQUENCES AND RISK FACTORS

Major depression affects more than 300 million people worldwide (114). In turn, depression represents the leading cause of disability, contributing substantially to the overall burden of disease (114). Furthermore, the burden of depression and other mental health problems is increasing globally (114, 115). Depression is more common amongst women than men (112, 114, 116). The highest risk period amongst women is from early adolescence to the mid-50s (116). Vulnerability to depression may increase during pregnancy and the postpartum period, and women with a history of depression are at risk for recurrent episodes or relapse during those life events (116, 117). Systematic reviews report prevalence rates of 7% and 11% for depression during the first trimester, and 9% and 13% during the second and third trimesters of pregnancy, respectively (117, 118). Postpartum depression is estimated to affect 10% to 20% of women following birth (117, 119, 120).

Depression during pregnancy is associated with preterm birth, a low birth weight and decreased breastfeeding initiation, amongst other negative health consequences for both the mother and the child (121–123). A Finnish study found major depression during pregnancy associated with several adverse perinatal outcomes, such as stillbirth, preterm birth, a low birth weight, small for gestational age and major congenital abnormalities (124). Another prospective Finnish study of more than 2 000 women and their children at 2 to 6 years of age demonstrated that higher maternal depressive symptoms during pregnancy predicted a child's psychiatric problems during early childhood (125).

In addition, depression during pregnancy is one of the greatest risk factors for postpartum depression (126, 127). Postpartum depression, in turn, is associated with paternal depression, poor maternal–infant interactions, impaired emotional development and delayed cognitive skills in infants (128–131). The most important risk factors for depression during pregnancy consist of a history of mental illness, stressful life events and stress, a lack of partner or social support, a history of abuse or domestic violence, an unplanned or unwanted pregnancy, present or past pregnancy complications and pregnancy loss (132, 133).

2.7.3 DEPRESSIVE SYMPTOMS AND GESTATIONAL DIABETES

Individuals with type 1 or type 2 diabetes experience more depression compared to people without diabetes (31). Many of those with type 2 diabetes as well as GDM are overweight or obese. According to a meta-analysis, obese

persons have a 55% increased risk of developing depression over time, whereas depressed persons have a 58% increased risk of becoming obese. The association between depression and obesity (BMI ≥ 30) is stronger than the association between depression and being overweight (BMI = 25–29.9) (134). Whilst GDM and depression are both common conditions during pregnancy, depression amongst women with or at risk for GDM has not been extensively studied (32).

Previous studies examining the relationship between GDM and depressive symptoms during pregnancy provide contradictory results (135–145). Most studies report no difference in the occurrence of depression or depressive symptoms between pregnant women diagnosed with GDM and pregnant control women, that is, pregnant women without GDM (135–142). A cross-sectional study assessed depressive symptoms using the Edinburgh Postnatal Depression Scale (EPDS) between 24- and 40-weeks gestation, and found no significant difference in the mean scores between 65 women with GDM [6.5, standard deviation (SD) 6.2] and 70 pregnant controls (5.9, SD 5.3) (140). Another cross-sectional study from the USA examined 425 women with GDM, 226 women with pre-existing diabetes and 1 747 controls with a mean gestational age of 23 weeks, and reported no difference between women in terms of depressive symptoms assessed using the Patient Health Questionnaire-9 (mean scores of 3.73 vs. 4.38 vs. 3.5) or in the current use of antidepressants (135). Furthermore, a prospective study conducted in the USA showed no difference in relation to increasing depressive symptoms assessed using the Centre for Epidemiological Studies-Depression Scale (CESD) measured from prepregnancy to postpartum comparing 64 women with GDM to 1 233 control women (137). In addition, two cross-sectional studies also from the USA, with 206 and 68 women with GDM, respectively, found no difference between women with GDM and non-diabetic pregnant controls in terms of the mood states assessed using the Mood States–Bipolar Form profile (136, 141). Another prospective study conducted in the USA found no difference in the mean level of OGTT or in the proportion of abnormal GDM screens at 26- to 28-weeks gestation between 41 women with a past major depressive disorder, 39 women with a current major depressive disorder, 50 women with a bipolar disorder and 62 healthy controls (142).

By contrast, three previous studies found a higher prevalence of depressive symptoms in women with GDM compared to controls (143–145). A case–control study conducted in Canada reported a higher mean EPDS score in 26 women with diagnosed GDM compared to 26 pregnant control women matched for gestational age, BMI and age (6.8, SD 4.0 vs. 4.2, SD 2.6) (143). A retrospective cohort study from the USA with a large sample size of low-income women found that 657 women with type 1, type 2 or gestational diabetes were significantly more likely to have a depression diagnosis or to take an antidepressant compared to 10 367 women without diabetes during pregnancy [5.8% (95% confidence interval (CI) 4.0–7.6) vs.

2.7% (95% CI 2.4–3.0)] and postpartum [13.1% (95% CI 10.5–15.7) vs. 7.3% (95% CI 6.8–7.8)] (144). Furthermore, a cross-sectional pilot study conducted in Ireland found that compared to 25 non-diabetic pregnant women, 25 women with GDM had a higher depression score [median 6 (range 0–28) vs. median 2 (range 0–38), effect size r = 0.31] assessed using the Depression Anxiety Stress Scale (DASS) at a mean of 32-weeks gestation (145).

We found only one previous study that examined depressive symptoms in women at risk for GDM. This study was a secondary analysis of a GDM prevention trial conducted in maternity clinics in Finland, consisting of 338 women at risk for GDM. The study found that 16.3% of women experienced depressive symptoms in early pregnancy (146). However, the study included no reference group of pregnant women from the general population and assessed depressive symptoms using the 15-dimension generic HRQoL instrument (15D) including questions on depressive symptoms, rather than a validated depression scale.

To conclude, some studies found no differences in the occurrence of depression or depressive symptoms between pregnant women diagnosed with GDM and pregnant women without GDM (135–142), whereas other studies found a higher prevalence of depressive symptoms in women with GDM (143–145).

2.8 HEALTH-RELATED QUALITY OF LIFE (HRQOL) AND SELF-RATED HEALTH

2.8.1 DEFINITIONS

HRQoL refers to the individual evaluation of one's own health status (147). More precisely, HRQoL refers to how health impacts an individual's ability to function — that is, an individual's perceived physical, mental and social well-being. HRQoL is a more powerful predictor of mortality and morbidity than many objective measures of health (16). HRQoL can be measured either through disease-specific questionnaires or using generic questionnaires, such as the 36-Item Short-Form Health Survey (SF-36), which is the most widely used HRQoL measure (148, 149).

Self-rated health is one domain normally included in HRQoL questionnaires. In addition, it is a widely used measure of health status on its own, and is often assessed using a single question with five response alternatives ranging from poor to excellent. Self-rated health strongly predicts a change in functional ability, the use of health services, morbidity, and mortality even after adjusting for key covariates such as comorbidity (15, 17–19, 150, 151). A poorer self-rated health status is, for example, associated

with a higher risk for type 2 diabetes (152, 153). Moreover, self-rated health has shown a good test–retest reliability (154, 155), and is associated with both clinical risk factors and psychological well-being (156, 157). Both HRQoL and self-rated health take into account an individual's own perception, which is fundamental when defining and understanding well-being.

2.8.2 HEALTH-RELATED QUALITY OF LIFE AND PREGNANCY

HRQoL changes during the course of a pregnancy; as such, studies suggest that HRQoL and self-rated health decrease during pregnancy, improve after childbirth and may decrease again postpartum (158, 159). In a multiethnic sample of 1 809 women, the physical functioning domain of HRQoL, as assessed using SF-36, declined significantly from prepregnancy to 24- to 28- and 32- to 36-weeks gestation, improving again at 8- to 12-weeks postpartum; the vitality domain of HRQoL declined from prepregnancy to pregnancy, and did not improve to prepregnancy levels at postpartum (158).

Physical and mental self-rated health, both assessed using a single question, varied significantly over time from mid-pregnancy to one-year postpartum amongst Swedish women (159). The proportion of women with a poor physical self-rated health was 20.4% at mid-pregnancy, 36.9% in late pregnancy, 19.9% at two-months postpartum and 33.7% at one-year postpartum. Self-rated mental health showed a similar pattern (159). HRQoL and self-rated health appear poorer amongst obese pregnant women compared to non-obese pregnant women (158, 160). Furthermore, a higher BMI, a higher weight gain during pregnancy and pregnancy complications have been identified as determinants of poorer self-rated physical well-being amongst pregnant women (160).

2.8.3 HEALTH-RELATED QUALITY OF LIFE AND GESTATIONAL DIABETES

A recent systematic review included ten studies evaluating HRQoL amongst women with GDM, concluding that women with GDM have a poorer HRQoL in both the short- and long-term (33). Furthermore, a prospective cohort study assessed HRQoL using SF-36 amongst 64 women with GDM and 1 233 control women; a significantly greater proportion of women with GDM compared to controls had poor or fair physical functioning (20% vs. 9%) and self-rated health (22% vs. 12%) domains for HRQoL prior to pregnancy, as recalled at 12- to 20-weeks gestation (137).

GDM is associated with adverse self-rated health during pregnancy and up to three to five years after diagnosis (137, 158, 161–164). Amongst 1 809 pregnant women, those with GDM were significantly more likely to report

poor or fair self-rated health compared to those without GDM (158). Moreover, women with a history of GDM had a worse self-rated health than women without a history of GDM amongst 177 420 women aged 18 to 44 (162). A greater proportion of women with GDM had a poor or fair self-rated health at 8- to 12-weeks postpartum (19% vs. 10%). The decline from prepregnancy to postpartum in the self-rated health and other domains of HRQoL were, however, similar in both groups. Amongst women with GDM, 11% reported a decline in self-rated health (137).

2.8.4 ASSOCIATIONS BETWEEN HEALTH-RELATED QUALITY OF LIFE, PHYSICAL ACTIVITY AND FITNESS

Systematic reviews including mostly cross-sectional studies conclude that self-reported LTPA is associated with better HRQoL in the general population (20, 165). Moreover, longitudinal studies suggest that an increase in LTPA leads to improvements in HRQoL in the general population (166, 167).

Similarly, higher levels of LTPA have been associated with better HRQoL in women before pregnancy, during pregnancy and at postpartum. In a prospective study of 1 809 women in the general population, no exercise prior to pregnancy was associated with a poor or fair self-rated health and poor physical functioning domains for HRQoL, as assessed using SF-36 (158). Moreover, no exercise during pregnancy was associated with a poor or fair self-rated health, poor physical functioning and poor vitality domains for HRQoL. At 8- to 12-weeks postpartum, no exercise was associated with poor physical functioning and poor vitality (158). However, one small randomised controlled trial (RCT) and one small longitudinal survey study reported no association between HRQoL and LTPA during pregnancy, either amongst healthy or overweight and obese women (168, 169). One previous Finnish intervention study examined women at risk for GDM and the associations between LTPA and HRQoL as assessed using 15D (146). The study included 399 women, and found that at-risk women who met the PA guidelines (at least 150 minutes of moderate-intensity LTPA per week) at the end of their pregnancy had a better HRQoL at the end of pregnancy, but not at the beginning of pregnancy, when compared to women who did not meet the guidelines (146).

A limited number of cross-sectional studies have examined the association between cardiorespiratory fitness and HRQoL. An even smaller number of studies have examined the association between HRQoL and objectively measured VO_{2max}, the gold standard for assessing cardiorespiratory fitness (170). Previous studies reported cross-sectional associations between higher levels of measured cardiorespiratory fitness and better HRQoL in middle- and older-aged women and men, in healthy young men, in patients with McArdle disease and in women at high risk for

cardiovascular disease (171–175). In addition, an association was found between a higher cardiorespiratory fitness assessed by the peak oxygen uptake in a maximal treadmill test, and better HRQoL in adults with and without type 2 diabetes (176). Existing studies suggest that cardiorespiratory fitness is most often associated with the physical domains of HRQoL (171–176). Studies examining the associations between HRQoL and cardiorespiratory fitness amongst women with or at risk for GDM remain lacking.

2.9 LIFESTYLE INTERVENTIONS AND GESTATIONAL DIABETES

The most important method to prevent GDM amongst women at risk remains lifestyle changes, such as diet and exercise. Likewise, the main treatment for GDM is lifestyle changes. Lifestyle interventions including healthy eating and PA aim to prevent GDM amongst at-risk women. Amongst women with GDM, PA helps maintain blood glucose concentrations within a target range and improve health outcomes for the mother and the baby.

A systematic review published in 2017 examined the combined effect of diet and exercise interventions for preventing GDM, and included 23 RCTs (177). The lifestyle interventions included in the review showed a possible reduced risk of GDM and caesarean section amongst the diet and exercise groups compared to the standard care groups. The review found no clear effects of the interventions on pre-eclampsia, pregnancy-induced hypertension or hypertension, perinatal mortality or babies born large for gestational age (177). Moreover, a meta-analysis of individual participant data from RCTs, which synthesised evidence on the effects of diet and PA interventions during pregnancy, was also published in 2017. The results revealed that across individual interventions those based primarily on PA showed a reduction in GDM (75).

Another recent systematic review included 15 RCTs of lifestyle interventions for the treatment of women with GDM (178). The review concluded that, for babies, lifestyle interventions were associated with a lower risk of being born large for gestational age, and that birth weight and the prevalence of macrosomia were lower in the lifestyle intervention groups. For mothers, lifestyle interventions did not have a clear effect on pre-eclampsia, caesarean section, the induction of labour, perineal trauma or tearing or developing type 2 diabetes in the ten years following birth. However, lifestyle interventions helped women to meet their weight goals one year after giving birth, and single studies showed a decrease in the risk of depression after giving birth (178). In addition, two systematic reviews published in 2016 and 2017, both including the same 11 RCTs, concluded that

exercise interventions for pregnant women with GDM reduce fasting and postprandial blood glucose concentrations (179, 180). However, the data are currently insufficient to determine any other benefits of exercise programmes for woman with GDM and for the infant (179).

2.10 EFFECTS OF LIFESTYLE INTERVENTIONS DURING PREGNANCY ON SUBJECTIVE WELL-BEING

A randomised controlled three-month exercise trial in pregnant women improved HRQoL, specifically, the physical function, bodily pain and general health domains of HRQoL (181). By contrast, another RCT reported no effect from an exercise intervention on HRQoL during pregnancy amongst overweight and obese women (182). Similarly, two randomised controlled exercise interventions in pregnant women in the general population showed conflicting results for self-rated health (183, 184).

A systematic review published in 2015 identified only two trials of the combined effect of diet and exercise interventions aimed at preventing GDM, which reported subjective well-being as an outcome (185). The studies found no effect of the interventions on stress, sleep, depressive symptoms, quality of life and self-rated health during pregnancy (186, 187).

2.11 SUMMARY

Life events, such as pregnancy, throughout the lifespan may have an important impact on both PA and mental well-being. PA during pregnancy and the postpartum period is safe and recommended, and results in several benefits for most women.

Obesity, GDM and depressive symptoms are common during pregnancy. Considering the increasing prevalence and negative consequences of GDM, the subjective well-being of at-risk women should be examined. Identifying the prevalence of depressive symptoms amongst women at risk for GDM is of importance because depressive feelings may affect adherence to prevention strategies such as lifestyle changes and later on the treatment of GDM. Furthermore, identifying factors associated with subjective well-being amongst high-risk women would be beneficial when planning effective programmes to prevent GDM. Moreover, the associations between HRQoL, PA and cardiorespiratory fitness remain unknown amongst women with or at risk for GDM.

Women's HRQoL and perceptions of health prior to, during and after pregnancy may have an extensive impact on the mother's own health, the

maternal–infant interaction, the ability to return to the labour market and on the use of healthcare services amongst other issues. Methods of improving self-rated health in pregnant women with or at risk for GDM requires further research. In particular, most previous lifestyle intervention trials aimed at preventing GDM have not reported maternal psychological well-being as an outcome.

3 AIMS OF THE STUDY

This doctoral dissertation examines the associations between life events — particularly pregnancy —, physical activity, cardiorespiratory fitness, depressive symptoms and health-related quality of life, and focuses on women at risk for gestational diabetes.

The specific aims are:

1. To systemically review the evidence concerning the effects of major life events, particularly pregnancy, on changes in leisure-time physical activity (study I and the update to the literature review).

2. To compare the prevalence of depressive symptoms in early pregnancy between women at risk for gestational diabetes and women in the general pregnant population (study II).

3. To examine the associations of cardiorespiratory fitness and leisure-time physical activity with health-related quality of life amongst women planning a pregnancy and at risk for gestational diabetes mellitus (study III).

4. To examine the effects of lifestyle counselling on self-rated health from the first trimester of pregnancy to one-year postpartum amongst women at risk for gestational diabetes (study IV).

4 MATERIALS AND METHODS

4.1 SYSTEMATIC LITERATURE REVIEW (STUDY I)

4.1.1 DATABASE SEARCHES AND ASSESSMENT OF LITERATURE

For the systematic literature review, we searched the PubMed MEDLINE and the OVID PsycINFO databases for all available literature published in English through January 2011. In MEDLINE, we used the Medical Subject Heading (MeSH) search terms 'life-change events', 'motor activity', 'exercise' and 'health behaviour' and the keyword 'physical activity'. In PsycINFO, we used the subject heading terms 'physical activity', 'exercise' and 'life experiences or life changes' and the keyword 'life event'. The author, Elina Engberg, scanned all titles and abstracts resulting from the searches to exclude articles beyond the scope of this study, and chose articles that focused on the effects of life events on changes in PA. The inclusion criteria were (i) studies assessing at least one major change in life circumstances and (ii) PA collected at a minimum of two time points (before and after the life event). In addition, we included studies that assessed PA before the life event through a retrospective design. Studies were excluded if they (i) did not include a life event; (ii) did not assess a change in PA by assessing PA at a minimum of two time points (before and after the life event); (iii) assessed a disease as a life-change event; (iv) were abstracts or unpublished dissertations; or (v) were non-English publications. In addition, the author reviewed the references of selected articles and the related citations in MEDLINE to find other potentially relevant articles. The authors Elina Engberg and Heikki Tikkanen reviewed the selected articles, and discussed and resolved any disagreements regarding their inclusion. The systematic review was primarily performed and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines (188).

The systematic review on life events and PA was published in 2012. In 2017, an updated literature search, restricted to pregnancy as a life event and a change in PA, was prepared for this doctoral thesis. For the updated literature review, the PubMed MEDLINE database was searched for available literature from January 2011 to December 2017. Different searches were performed using the MeSH search terms 'pregnancy' and 'exercise', and the keyword 'physical activity'. In addition, the references from selected articles were reviewed to find more eligible studies. The inclusion criteria were: (i) studies that assessed pregnancy and (ii) PA at a minimum of two time points (before pregnancy and during pregnancy or postpartum). Studies that assessed PA before pregnancy with a retrospective design were also included.

The exclusion criteria were: (i) studies which did not include pregnancy or (ii) did not assess a change in PA by assessing PA at a minimum of two time points (before pregnancy and during pregnancy or postpartum); (iii) (randomised) controlled trials (iv); and non-English publications. Figure 1 illustrates the yield of publications in the literature search. Elina Engberg described and evaluated the included studies based on study components, as shown in Table 1.

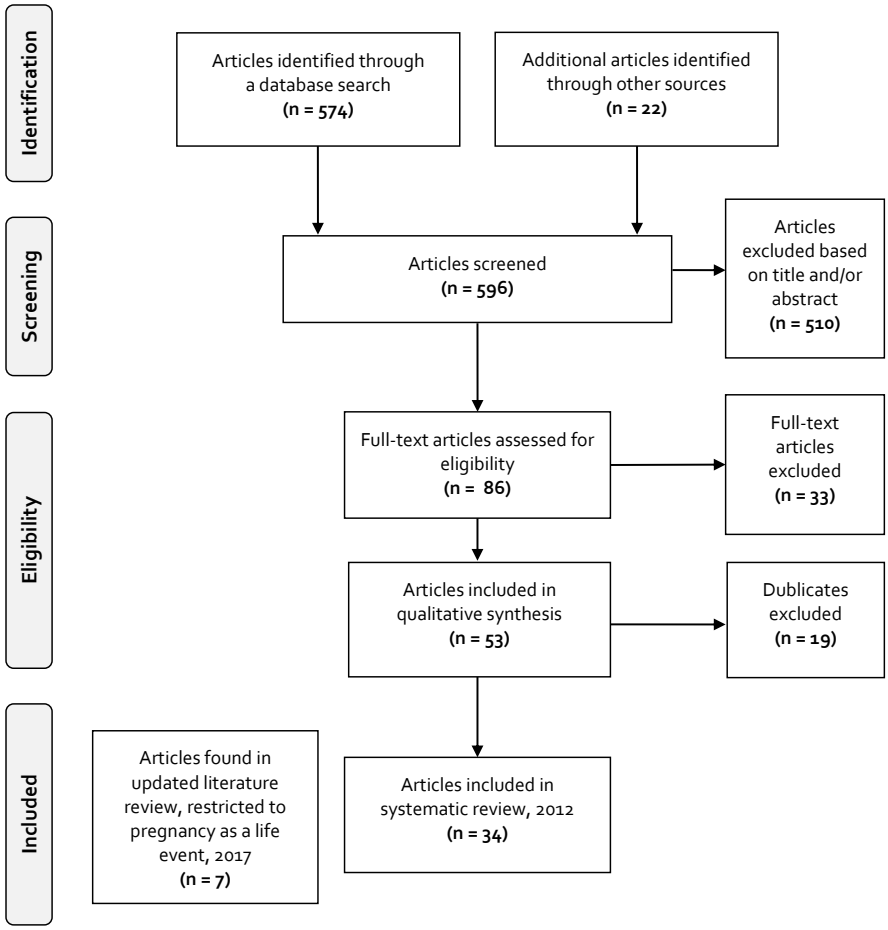

Figure 1. Flow chart of the systematic literature search in 2012 and publications found in the updated literature search in 2017. Numbers refer to the number of publications identified.

Table 1. Described components of studies included in the systematic literature review in 2012 and in the updated literature review in 2017.

The described study components
• Study design – (randomised) controlled trial,[a] prospective longitudinal, retrospective cross-sectional
• Study duration
• Study population
• Outcome measures
• Limitations of the studies

[a]Randomised controlled trials were included only in the systematic literature review in 2012.

4.2 THE FINNISH GESTATIONAL DIABETES PREVENTION STUDY (RADIEL) (STUDIES II & IV)

4.2.1 STUDY DESIGN

The RADIEL study is a multi-centre RCT. It was conducted between 2008 and 2014 in maternity hospitals in the Helsinki metropolitan area (Department of Obstetrics and Gynaecology, Helsinki University Central Hospital; Kätilöopisto Maternity Hospital; and Jorvi Hospital) and in the South Karelia Central Hospital in Lappeenranta in Finland. The main objective of the RADIEL study was to assess the efficacy of a lifestyle intervention towards preventing GDM. The detailed study protocol and the primary results appear elsewhere (189). The Ethics Committees of the Helsinki University Central Hospital (14 September 2006, Dnro 300/ E9/06) and the South Karelia Central Hospital (11 September 2008, Dnro M06/08) approved the RADIEL study protocol, which was registered at clinicaltrials.gov (NCT01698385).

4.2.2 RECRUITMENT

The eligible participants for the RADIEL study consisted of women planning a pregnancy or already pregnant, and at high risk for GDM. This doctoral dissertation only included women recruited when pregnant. The high risk for GDM was defined as having a history of GDM or a prepregnancy BMI ≥ 30 kg/m^2 or both. Women with a history of GDM were recruited through personal invitation letters sent based on hospital registries, and women with a prepregnancy BMI ≥ 30kg/m^2 were recruited in maternity hospitals when

attending the first ultrasound examination. In addition, notices in maternity hospitals, in newspapers and via social media were distributed during the recruitment process.

Pregnant women in the general population

Between August 2011 and August 2012, 750 pregnant women in the general population were invited to participate in a separate study in the same maternity hospitals where RADIEL participants were recruited. Women were recruited when they attended the first ultrasound examination, performed between gestational weeks 10 and 13. The ultrasound examination is part of the public antenatal care programme in Finland and offered to all pregnant women. Women were given background information, depression and HRQoL (not assessed in this dissertation) questionnaires and a stamped envelope to return completed questionnaires. The inclusion criteria were 1) a healthy pregnancy at gestational weeks < 14 and 2) the ability to read the Finnish or Swedish version of the questionnaires. In study II, we included pregnant women who completed the depression questionnaire at < 20 weeks gestation to allow better matching with the group of women at risk for GDM. A more detailed description of the study amongst pregnant women in the general population was reported elsewhere (190, 191). We did not exclude women with BMI ≥ 30 km^2 or with a history of GDM from the analysis. Instead, we aimed to compare the RADIEL women at risk for GDM with the general pregnant population, which naturally includes some women with risk factors for GDM. The pregnant women in the general population were only included in study II of this doctoral dissertation.

All participants received information about the studies and completed an informed consent form. They were informed of their ability to discontinue the study at any point and for any reason. Table 2 presents the inclusion and exclusion criteria for those RADIEL participants and pregnant women in the general population included in this doctoral dissertation.

Table 2. Inclusion and exclusion criteria for participants in the RADIEL studies included in this doctoral dissertation.

	Inclusion criteria	Exclusion criteria
Cross-sectional study (study II)		
Women at risk for GDM	• pregnant at < 20-weeks gestation and • ≥ 18 years old and • a history of GDM and/or a prepregnancy BMI ≥ 30 kg/m²	type 1 diabetes, type 2 diabetes or GDM diagnosed before pregnancy, medication influencing glucose metabolism (e.g., oral cortisone and metformin), multiple pregnancy, physical disability, current substance use, severe psychiatric disorder, significant co-operation difficulties (e.g., inadequate Finnish language skills)
Women in the general population	• pregnant at < 20-weeks gestation and • ≥ 18 years old	
Randomised controlled trial (study IV)		
Women at risk for GDM	• pregnant at < 20-weeks gestation and • ≥ 18 years old and • a history of GDM and/or a prepregnancy BMI ≥ 30 kg/m²	type 1 diabetes, type 2 diabetes or GDM diagnosed before pregnancy or before 20-weeks gestation, medication influencing glucose metabolism (e.g., oral cortisone and metformin), multiple pregnancy, physical disability, current substance use, severe psychiatric disorder, significant co-operation difficulties (e.g., inadequate Finnish language skills)

BMI = body mass index; GDM = gestational diabetes mellitus.

4.2.3 PARTICIPANTS

Between 2008 and 2011, 540 pregnant women at high risk for GDM were assessed for eligibility in the RADIEL study. Of the 492 eligible women recruited based on a high risk for GDM, 482 (98%) completed the depression questionnaire before gestational week 20. Of the 750 pregnant women in the general population who received the depression questionnaire, 395 (53%) returned the questionnaire, amongst whom 358 completed the questionnaire before gestational week 20. Consequently, we included 482 pregnant women at high risk for GDM and 358 pregnant women in the general population in the cross-sectional analysis (study II).

Amongst the 269 women at high risk for GDM included in the RADIEL lifestyle intervention trial, 266 completed the question on self-rated health at baseline, and thus were included in study IV. Figure 2 illustrates the selection of participants at high risk for GDM in studies II and IV. Figure 3 provides a flow chart of participants who completed the question on self-rated health from the first trimester of pregnancy to 12-months postpartum (study IV).

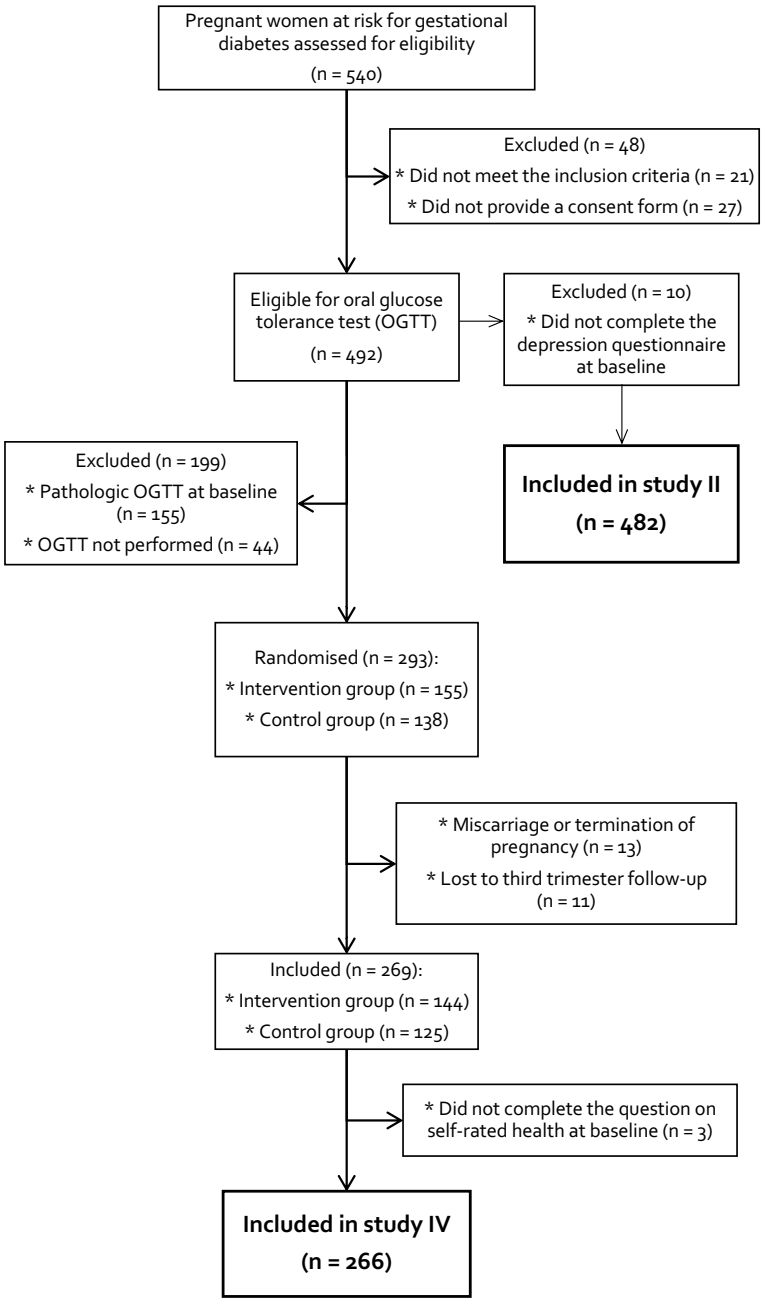

Figure 2. Flow chart of participants at high risk for gestational diabetes mellitus in studies II and IV. In addition, a group of pregnant women in the general population (n = 358) were included in study II.

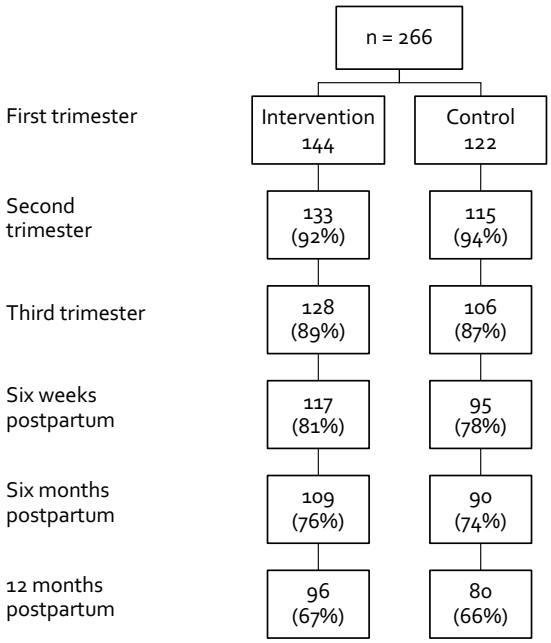

Figure 3. Flow chart of women who participated in the RADIEL lifestyle intervention and answered the question on self-rated health, that is, participants included in study IV.

4.2.4 LIFESTYLE INTERVENTION

We randomised pregnant women at risk for GDM included in the RCT into two groups: a lifestyle group and a control group. Participants in the lifestyle group received individualised counselling on diet, PA and weight management by trained study nurses beginning in early pregnancy to one-year postpartum at six time points: during the first trimester (median 13-weeks gestation), the second trimester (median 23-weeks gestation) and the third trimester of pregnancy (median 35-weeks gestation), and at 6-weeks, 6-months and 12-months postpartum. In addition, participants in the lifestyle group attended three group meetings lead by a dietician: at the time of study enrolment, and at 6- and 12-months postpartum. The study nurses recommended no weight gain during the first and second trimesters of pregnancy to those women with a prepregnancy BMI ≥ 30 kg/m^2. Dietary counselling focused on optimising participants' consumption of vegetables, fruits and berries, whole-grain products rich in fibre, low-fat dairy products, vegetable fats high in unsaturated fatty acids, fish and low-fat meat products and on lowering the intake of sugar-rich foods. Dietary counselling adhered to the Nordic Nutrition Recommendations (192).

PA counselling aimed to result in at least 150 minutes of moderate-intensity aerobic PA per week (53, 193). In addition, the study nurse encouraged women to adopt an overall active lifestyle. The study nurse and each participant planned a PA programme together, and updated the programme during pregnancy and the postpartum period when needed. Adherence to the diet and PA advice was supported through various strategies, including the self-monitoring of behaviour (via food diaries and PA log books) and by providing of free-of-charge access to swimming pools and exercise classes in local municipalities once a week.

The control group received standard antenatal care including general information leaflets on diet and PA. Participants in the control group also visited the study nurse at six time points from early pregnancy to one-year postpartum for various measurements, which were conducted for both groups, and completed several questionnaires. In addition, all participants visited antenatal clinics according to the standard national practice. Other studies present more detailed descriptions of the RADIEL intervention and results concerning the effects of the intervention on PA and diet (189, 194, 195).

4.2.5 MEASUREMENTS

4.2.5.1 Demographics

We collected data on the self-reported prepregnancy weight, the number of previous deliveries and a history of GDM amongst women at risk for GDM from antenatal clinic records, and the study nurse measured their baseline weight and height during the first study visit. Women in the general pregnant population reported their prepregnancy weight and height through a questionnaire. In addition, all women provided information on socioeconomic status, the use of medications, self-reported morbidity and smoking status by answering a questionnaire, or during an interview with a study nurse amongst women at risk for GDM. In addition, the questionnaire included the following question: 'How many minutes per week do you (on average) currently engage in PA that leaves you at least slightly out of breath and sweaty?'

4.2.5.2 Depressive symptoms

We assessed depressive symptoms using EPDS during early pregnancy (before gestational week 20) amongst pregnant women at risk for GDM and amongst pregnant women in the general population (196). EPDS was designed to screen for postpartum depression, but was also validated in

pregnant women (197–199). Specifically, EPDS consists of 10 items, each scored from 0 to 3. Thus, the total score ranges from 0 to 30, whereby a higher score indicates a higher prevalence of depressive symptoms. A wide range of cut-off scores has been recommended to indicate the risk for major depression (196–199). We used a cut-off score of ≥ 10, which has an 87% sensitivity (correctly identifying true cases) and a 95% specificity (correctly identifying individuals without the condition) when assessed at 12-weeks gestation (182). The RADIEL study nurses referred a participant for further assessment for depression if she reached a total EPDS score of ≥ 10 or responded positively to the question 'in the past seven days, the thought of harming myself has occurred to me'. For women at risk for GDM, an open-ended response option was added to EPDS items 4 and 5. That is, women were able to provide the specific reasons for feeling anxious or worried or for feeling scared or panicky, respectively. Some women completed only the open-ended responses and not the standard response options for these items, leading to missing values in the standard EPDS. Therefore, those responses were considered missing data in the analyses.

4.2.5.3 Self-rated health

We assessed self-rated health using a single question: 'How well do you rate your general health at the moment?' Participants responded using a five-point scale: good (1), quite good (2), fair (3), quite poor (4) and poor (5). We assessed self-rated health at six time points between early pregnancy and one-year postpartum: during the first trimester, the second trimester and the third trimester of pregnancy, and at 6-weeks, 6-months and 12-months postpartum. The question was included in a questionnaire, which was sent or given to the participant, who was asked to complete it before each visit to the study nurse.

4.3 THE FINNISH GESTATIONAL DIABETES PREVENTION STUDY PART II (ANS-EXE) (STUDY III)

4.3.1 STUDY DESIGN

The Finnish Gestational Diabetes Prevention Study Part II: Autonomic Nervous System & Exercise (ANS-EXE) is a RCT conducted between the 2011 and 2016 at maternity hospitals in the Helsinki metropolitan area (Department of Obstetrics and Gynaecology, Helsinki University Central Hospital; Kätilöopisto Maternity Hospital; and Jorvi Hospital) and in the Department of Sports and Exercise Medicine, University of Helsinki in Finland. The primary objective of the ANS-EXE study was to examine the

effects of a lifestyle counselling and exercise training intervention on aerobic capacity amongst women at high risk for GDM. The University of Helsinki Ethics Board approved the study protocol (300/E9/06), and the study was registered at clinicaltrials.gov (NCT01675271).

4.3.2 RECRUITMENT

Women planning a pregnancy and at high risk for GDM, that is, women with either a history of GDM or BMI > 29 kg/m^2 or both, were recruited between 2011 and 2015. We chose a BMI cut-off of > 29 kg/m^2 in this study because women close to the WHO obesity criteria are also at risk for GDM. Women with a history of GDM were identified through searches of hospital registries, and received invitation letters to participate in the study. Media notices were also used in order to recruit women to participate in the study. Table 3 shows the inclusion and exclusion criteria for participants. We excluded smokers because the ANS-EXE study includes measurements not addressed in this doctoral dissertation affected by smoking. All participants received information about the study and provided an informed consent form. They understood that they could discontinue participation at any point and for any reason.

Table 3. Inclusion and exclusion criteria for participants in the ANS-EXE study.

	Inclusion criteria	**Exclusion criteria**
Women at risk for GDM	• 18 to 45 years old and • planning a pregnancy and • a history of GDM and/or BMI > 29 kg/m^2	medication influencing glucose metabolism, type 2 diabetes, physical disability preventing exercise training, psychiatric medication or a severe disorder, current substance use, co-operation difficulties (e.g., inadequate Finnish language skills), smoking

BMI = body mass index; GDM = gestational diabetes mellitus

4.3.3 PARTICIPANTS

In total, 524 women with a history of GDM received the invitation letter to participate in the study. Amongst these, 65 women either replied to the invitation or contacted us because of media notices. Before the exercise test, 14 women discontinued their participation without providing a specific reason. In addition, one woman moved away, four became pregnant and one was not able to participate due to personal circumstances. Finally, 45 women

completed the cycle ergometer test, amongst whom 39 completed the quality-of-life questionnaire, and were, therefore, included in baseline analyses.

4.3.4 MEASUREMENTS

4.3.4.1 Demographics

Using a questionnaire, participants reported information on their socioeconomic status, morbidity and the number of children in the household . Participants' weight and height were measured in the laboratory.

4.3.4.2 Cardiorespiratory fitness

Firstly, a physician examined participants to ensure their suitability to perform the test. Secondly, exercise physiologists assessed their cardiorespiratory fitness by measuring VO_{2max} during incremental (30W·3 min^{-1}) cycle ergometer (Monark Ergomedic 839E, Monark Exercise AB, Vansbro, Sweden) exercise until voluntary fatigue. Breath-by-breath ventilation was measured using respiratory mass spectrometry (AMIS 2000, Innovision A/S, Odense, Denmark) and with a low resistance turbine (Triple V, Jaeger Mijnhardt, Bunnik, The Netherlands) in the raw data mode. Alveolar gas exchange was calculated using the AMIS algorithms. VO_{2max} was determined as the highest one-minute average value, and was normalised for body mass ($mL \cdot kg^{-1} \cdot min^{-1}$).

We divided participants into cardiovascular fitness categories based on their VO_{2max} and the fitness level classification from a study by Shvartz et al. (200). The fitness categories were very poor, poor, fair, average, good, very good and excellent. This classification provided categories based on VO_{2max} norms for different age groups, and for men and women separately. Therefore, we used the norms for each participant individually in her corresponding age group.

4.3.4.3 Leisure-time physical activity (LTPA)

Before the exercise test, the participants completed a background information questionnaire including a single question on LTPA: 'When you think about the past three months and take into account all LTPA or physical exertion lasting at least 20 minutes at a time, on average how many times per week and for how long each time did you engage in PA?' These answers provided information on the hours per week of LTPA. In addition, we divided women into two groups based on their PA levels: those who were physically

active ≥ 2.5 hours per week and those who were physically active < 2.5 hours per week. The current guidelines recommend a minimum of 2.5 hours per week of at least moderate intensity PA (53). Our PA question did not, however, assess the intensity of PA. Therefore, our categorisation does not directly refer to meeting the current PA guidelines.

4.3.4.4 Health-related quality of life (HRQoL)

We assessed quality of life using the 36-Item Short-Form Health Survey (SF-36) version 1, a generic and valid measurement for HRQoL (148, 149). SF-36 contains 36 questions and yields 8 health domain scales, which range from 0 to 100, with 0 indicating the worst situation and 100 indicating the best situation across domains. The physical component summary (including physical functioning, role – physical, bodily pain and general health) and the mental component summary (including vitality, social functioning, mental health and role – emotional) can be calculated from the eight domain scales (149). Figure 4 shows the health domains and summary components of SF-36.

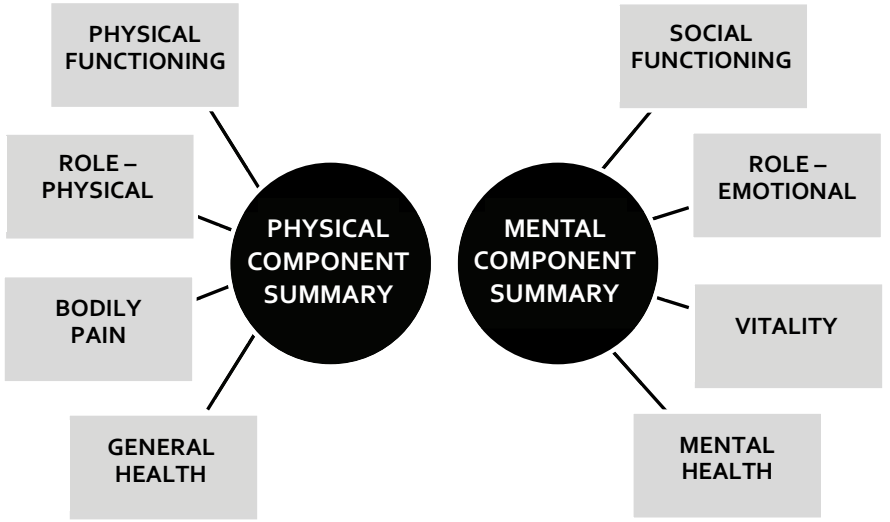

Figure 4. Health domains and summary components of the SF-36 Health Survey.

4.4 STATISTICAL ANALYSES

Statistical analyses were performed using the SPSS software program, version 21.0 (SPSS Inc., Chicago, IL, USA) and the Stata statistical software program, releases 13.1 and 14.0 (StataCorp, College Station, TX, USA). We present the descriptive statistics as means with standard deviations (SD), as medians with the interquartile ranges (IQR) or as counts with percentages (%). Statistical significance was accepted at $P < 0.05$.

Study I

We did not conduct a meta-analysis for the systematic review given the substantial heterogeneity in the outcome measures (PA and life events) and the data reporting methods across studies. This also stems from the small number of existing studies examining the effects of certain life events on PA.

Study II

We compared characteristics between women at risk for gestational diabetes mellitus (GDM) and women in the general pregnant population using the t-test, the bootstrapped type t-test, the permutation test, the chi-square test or the Fisher–Freeman–Halton test when appropriate. We also applied a multiple imputation (multivariate imputation by chained equations) method to fill in missing values for EPDS (98 in item 4 and 50 in item 5); we independently analysed five copies of the data, each with missing values suitably imputed, in the multivariate ordinal logistic regression analyses. We tested the difference between women at risk for GDM and pregnant women in the general population as a proportion of women with an EPDS score ≥ 10 and the total EPDS score using the bootstrapped type t-test. We calculated the effect size ('d') using the Hedges' method. We considered an effect size of 0.20 as small, 0.50 as medium and 0.80 as large. We obtained CIs for the effect size using bias-corrected bootstrapping (5 000 replications). When adjusting for age, prepregnancy BMI and income, we used logistic regression analysis and the bootstrapped type analysis of covariance using Hochberg's approach for multiple comparisons.

Study III

We tested whether variables were normally distributed using the Kolmogorov–Smirnov test and visually using histograms. We determined associations between demographic and health characteristics using SF-36 scales and summaries using the Pearson's correlation coefficients, Spearman's rank-order correlation coefficients, two-sample t-tests, the Mann-Whitney U test and the Kruskal-Wallis test when appropriate. BMI was associated with some SF-36 scales and summaries at $P < 0.05$, and was selected as a confounding variable when examining the associations between

cardiorespiratory fitness and LTPA using those SF-36 components in further analyses. BMI is often associated with fitness and PA as well.

We used the Spearman's correlation coefficients (r_s) or Spearman's partial correlation coefficients for non-normally distributed variables, and the Pearson's correlation coefficients (r_p) or Pearson's partial correlation coefficients for normally distributed variables to examine the associations of VO_{2max} and LTPA with SF-36. In addition, we performed linear regression analyses when the residuals were normally distributed. We included the SF-36 scales and summaries as dependent variables, and the LTPA and VO_{2max} as independent variables in the linear regression models. We combined fitness categories 3 (fair), 4 (average) and 5 (good), and thus used three final fitness categories in the analyses: 1) very poor, 2) poor and 3) fair, average or good. We analysed the differences in the SF-36 scales and summaries between the fitness categories using a one-way analysis of variance with the Tukey's test in pairwise comparisons for normally distributed variables, and the Kruskal-Wallis test with the Mann-Whitney U test applying Bonferroni corrections in pairwise comparisons for non-normally distributed variables. We compared the differences between those who were physically active ≥ 2.5 hours/week to those who were less active using the two-sample t-test for normally distributed variables, and the Mann-Whitney U test for non-normally distributed variables.

Study IV

We compared baseline self-rated health between the intervention and the control groups using the bootstrapped type t-test. We assessed the mean changes in self-rated health as a continuous variable using a mixed model for repeated measure methods with an unstructured correlation structure. We replicated the analysis by treating self-rated health as a dichotomous variable: good (response options 1 and 2) versus poor (response options 3, 4 and 5), and assessed the changes in the proportion of women with a good self-rated health using the mixed-effects probit regression model with an unstructured correlation structure. The fixed effects in the analyses were group, time and group–time interaction.

5 RESULTS

5.1 LIFE EVENTS AND CHANGE IN PHYSICAL ACTIVITY (STUDY I)

5.1.1 CHARACTERISTICS OF THE STUDIES

Based on the inclusion and exclusion criteria, we included 34 articles in our systematic review (48–81). We categorised the included life events as follows: transition to university; change in employment status (beginning work, changing work conditions, changes in income or retirement); marital transitions and changes in relationships (starting a new close personal relationship, moving in with someone, marriage, separation, divorce, widowhood or interpersonal loss); pregnancy or having a child; experiencing harassment at work, violence (being pushed, grabbed, shoved, kicked or hit) or a disaster; moving into an institution; and multiple life events. Four of the included studies examined more than one life event category, and the studies included were published between 1992 and 2012. The sample size in the studies varied from 26 to 80 944 participants, and the mean age of the study populations ranged from 17 to 70 years. The study duration varied between 5 months and 13 years amongst prospective longitudinal studies, and one to two years in the RCTs included. In total, 17 studies assessed PA using an unvalidated questionnaire, 8 studies relied on a validated PA questionnaire, 6 studies used an interview, 1 used a questionnaire and group discussion and 1 consisted of participating in exercise sessions and self-reported exercise logs. Table 4 summarises the characteristics of the included studies.

Table 4. Summary of characteristics of studies included in the systematic review in 2012 and in the updated literature review in 2017.

Study characteristics	Number of studies
Life events examined	
Transition to university	6
Change in employment status	11
Marital transitions and changes in relationships	12
Pregnancy or having a child	8 (7)[a]
Experiencing harassment at work, violence or urban disaster	2
Moving into an institution	1
Multiple life events	3
Study design	
Cross-sectional retrospective	7
Prospective longitudinal	25
Randomised controlled trial	2
Participants	
Women and men	19
Women only	12
Men only	3

[a]The number in brackets refers to studies included in the updated literature review in 2017.

5.1.2 LIFE EVENTS AND CHANGE IN PHYSICAL ACTIVITY

The studies included in the systematic review (study I) showed statistically significant changes in LTPA from before to after life events. Amongst women and men, the transition to university (201–204), having a child (205–207), remarriage (208, 209) and a mass urban disaster (210) decreased PA levels, while retirement increased PA (207, 211–216). Amongst young women, beginning work (206), changing work conditions (207), changing from being single to cohabitating (207, 217), getting married (206, 207, 217), pregnancy (206, 207, 218–220), a divorce or separation and a reduced income (207) decreased PA. By contrast, starting a new personal relationship (207), returning to study (206) and harassment at work (207) increased PA amongst young women. Amongst middle-aged women, changing work conditions (207), a reduced income (207), personal achievement (207) and the death of a spouse or partner (207) increased PA, whilst experiencing violence and the arrest or incarceration of a family member decreased PA (207). Amongst older women, moving into an institution (207) and an

interpersonal loss decreased PA (221), whilst longer-term widowhood increased PA (209). In addition, experiencing multiple life events simultaneously decreased PA in both men and women (221, 222).

We found contradictory results regarding the effects of divorce or separation on PA in young women (206, 207, 223). In addition, one study found no difference in PA from maternity leave to returning to work (46), and one study found no association between getting married or cohabitating and a change in PA amongst young women and men (205). Moreover, three longitudinal studies found no association between PA and getting married, divorced or separated or becoming widowed (224–226). Finally, one longitudinal study found no relationship between changes in the number of life events and changes in PA (39).

5.2 PREGNANCY AS A LIFE EVENT AND CHANGE IN PHYSICAL ACTIVITY (STUDY I AND THE UPDATE)

5.2.1 CHARACTERISTICS OF THE STUDIES

In terms of the relationship between life events and PA, this doctoral thesis focuses on studies examining pregnancy as a life event and a change in PA. Eight studies in our systematic review in 2012 examined pregnancy as a life event. In addition, seven were included based on the updated literature search on pregnancy and a change in PA in 2017. Table 5 summarises the characteristics of these studies, which examined the effects of pregnancy as a life event on PA and which we included in the systematic review published in 2012 (study I) as well as the results from the updated literature search.

Table 5. Summary of characteristics of studies examining pregnancy and a change in physical activity.

Study characteristics	Number of studies	
	Systematic literature review 2012	Updated literature review 2017
Studies included	8	7
Study design		
Cross-sectional retrospective	4	7
Prospective longitudinal	4	0
Assessment method of physical activity		
Self-reported	4	7
Objective	0	0

5.2.2 PREGNANCY AND CHANGE IN PHYSICAL ACTIVITY

Table 6 summarises the characteristics and results of studies on pregnancy and a change in PA included in the systematic review published in 2012 (study I), as well as the studies from the updated literature review performed in 2017. The eight studies included in the systematic review in 2012 showed that pregnancy decreases LTPA. These studies found a significant decrease in PA from prepregnancy to pregnancy (219, 220) and from prepregnancy to postpartum (206, 207, 218–220). One study reported a decrease in PA from prepregnancy to pregnancy, with a partial rebound at postpartum (220). Two studies reported no significant differences in total PA (227), or sports and exercise and active-living habits (228) from prepregnancy to postpartum. However, walking, conditioning exercises, water activities, sports, occupational activities, home activities and time engaged in dancing and bicycling decreased at postpartum (227). Three longitudinal studies illustrated that having a child decreased PA in women (206, 207) and in women and men (205). One longitudinal study showed that having a first or a second child decreased PA in women (207). However, another longitudinal study found that, amongst women, having a first child did not affect PA, whilst having a subsequent child decreased PA. By contrast, amongst men, having a first child decreased PA, whilst having a subsequent child did not affect PA (205).

The updated literature review performed in 2017 includes seven additional studies on the effects of pregnancy on PA. All seven studies reported decreases in PA after pregnancy (229–235), whilst three studies showed statistically significant decreases in PA from prepregnancy to pregnancy (233, 235) and from pregnancy to postpartum (230).

Table 6. Studies on pregnancy and a change in physical activity included in the systematic literature review in 2012 and in the updated literature review in 2017.

Study, year	Origin	Study design	N	Timing of PA assessment, mean (SD)	Assessment method of PA (and fitness)	Change in PA
Systematic literature review, 2012						
Brown and Trost (206), 2003[a]	Australia	Prospective longitudinal, 4-year follow-up	7 281	At the beginning and at the end of the study period	Questionnaire: moderate and vigorous leisure PA	Women who reported having their first ($P < 0.0001$) or another baby ($P < 0.0001$) were significantly more likely to be 'inactive' (vigorous exercise < three times/wk, or less vigorous exercise < five times/wk) at follow-up than those who did not report these events. When adjusted for demographic variables, and for follow-up BMI and baseline PA status, giving birth to a first ($P < 0.0001$) or subsequent child ($P = 0.004$) remained significant predictors of decreased PA at follow-up.
Blum et al. (228), 2004	USA	Cross-sectional retrospective	91	At 4 (3) months postpartum (recall of prepregnancy PA)	Questionnaire: Kaiser Physical Activity Survey (KPAS) (activities included household and caregiving, occupation, active-living habits and sports/exercise)	No significant differences between the prepregnancy and postpartum in sports or exercise and active-living habits for all subjects. Women with infants ≥6 months old increased household or caregiving activities compared to women with infants <6 months old (0.29 ± 0.45 SD vs. 0.04 ± 0.45; $P < 0.05$). Women with no other children increased household or caregiving activities compared to women with ≥1 other child (0.32 ± 0.57 vs. 0.02 ± 0.34; $P < 0.05$). Women

						with infants ≥ 6 months old decreased occupational activities less than women with infants < 6 months old (0.49 ± 1.4 vs. 1.33 ± 1.4, $P < 0.05$). Women with no other children decreased occupational activities less than women with ≥1 other child (1.5 ± 1.6 vs. 0.67 ± 1.3, $P < 0.05$).
	Symons Downs and Hausenblas (219), 2004	USA	Cross-sectional retrospective	74	Between 6-days to 5-months (mean 3.5 months) postpartum (recall of prepregnancy and pregnancy PA)	Questionnaire: Godin Leisure-Time Exercise Questionnaire (GLTEQ)	Significant differences across time from prepregnancy to pregnancy to postpartum were found for strenuous exercise ($P = 0.01$), moderate exercise ($P = 0.01$) and mild exercise ($P = 0.05$), with follow-up pairwise comparisons indicating that the levels of prepregnancy strenuous, moderate and mild exercise were higher than pregnancy and postpartum levels. No significant differences in mild, moderate and strenuous exercise behaviours were found when comparing pregnancy to postpartum ($P = 0.05$).
	Albright et al. (218), 2005	USA	Cross-sectional retrospective	79 multiethnic women	At 8- (4-) months postpartum (recall of prepregnancy PA)	Questionnaire: leisure PA, group discussion	22% were inactive before and after childbirth; 23% were active before and after; 13% were inactive before, but active after childbirth; and 43% were active before, but inactive or irregularly active postpartum ($P < 0.0003$).
	Treuth et al. (227), 2005	USA	Prospective longitudinal, 19-month	63	At 3 time points: before pregnancy, at 6-wk postpartum	Questionnaire: leisure and occupational activities, maximal	Total monthly METs did not differ between the prepartum and postpartum time intervals. However, significant time effects ($P < 0.05$) were observed for specific activities;

			follow-up		and at 27-wk postpartum	cycle ergometer with respiratory gas analysis, 1 repetition maximum strength tests	walking, conditioning exercises, water activities, sports, occupational activities and home activities, with lower values observed postpartum. Time dancing and bicycling were significantly lower at 6-wks postpartum compared with baseline (P = 0.03).
	Pereira et al. (220), 2007	USA	Cross-sectional retrospective + 18-month follow-up	1 242	At 3 time points: during first trimester (recall of prepregnancy PA), second trimester and at 6-months postpartum	Questionnaire: a modification of leisure activity using the Physical Activity Scale for the Elderly (PASE)	The decrease in mean total LTPA was from 9.6 h/wk prepregnancy to 6.9 h/wk during pregnancy and to 8.0 h/wk postpartum. The decrease from prepregnancy to 6-months postpartum was –1.4 (95% CI –1.0 to –1.9) h/wk, and represented decreases in moderate and vigorous PA, but not walking, which decreased slightly from prepregnancy to the second trimester (–0.4 h/wk; 95% CI – 0.7 to – 0.2), but rebounded at 6-months postpartum to the prepregnancy level. The proportion of women with an insufficiently active lifestyle (<150 min/wk of total activity) increased from 12.6% before pregnancy to 21.6% during pregnancy and to 21.7% during the postpartum period. OR for becoming insufficiently active during pregnancy was 1.58 (95% CI 1.07–2.32) in women with at least 1 child compared with women with no children.
	Brown et al. (207), 2009[a]	Australia	Prospective longitudinal, 3-year follow-up	7 173	At the beginning and at the end of the study period	Questionnaire: moderate and vigorous LTPA	Birth of a first (P < 0.0001) or a second child (P = 0.027) associated with an increased odds of decreasing PA at follow-up.

Hull et al. (205), 2010	USA	Prospective longitudinal, 2-year follow-up	646: 54% women and 46% men 638 included in the final analyses	At the beginning and at the end of the study period	Questionnaire: LTPA during the past year	Individuals who had a first or a subsequent child decreased their LTPA more (3.7 [6.0] h/wk) compared to those who stayed childless (−0.8 (7.3) h/wk) (F [1,517] = 6.7, *P* =0 .01, d = 0.41). Individuals who had a first child decreased LTPA more (3.9 [5.6] h/wk) compared to those who did not have a child (−0.80 (7.3) h/wk) (F [1,465] = 5.4, *P* = 0.02, d = 0.43). Individuals who had a subsequent child decreased LTPA more (3.5 [6.4] h/wk) compared with those who did not have a child (−0.4 [7.1] h/wk) (F[1,167] = 6.1, *P* = 0.02, d = 0.46). There was a significant difference in PA change between individuals who had a first child (−3.9 [5.6] h/wk) and those who had a subsequent child (−3.5 [6.4] h/wk). No significant difference found in PA change (*P* = 0.26) between women who stayed childless (−0.11 (6.4) h/wk) and those who had a first child (−2.4 (3.0) h/wk). Women who had a subsequent child decreased LTPA more (2.7 [5.3] h/wk) compared with women who did not have a child during the study period (0.3 [6.8] h/wk) (F [1,117] = 4.7, *P* = 0.03, d = 0.52). Men who had a first child decreased their PA more (5.0 [6.8] h/wk) compared with men who did not have a child (−1.5 (8.0) h/wk) (F [1,240] = 3.8, *P* = 0.05, d = 0.45). There was no significant difference in PA change between men who had a subsequent child

						(−5.5 [8.3] h/wk) and those who did not have a child (−2.1 [7.5] h/wk).
Updated literature review, 2017						
Hegaard et al. (231), 2011	Denmark	Cross-sectional retrospective	4 718	Gestational wk 37: recall of prepregnancy PA and PA during pregnancy	Questionnaire (unvalidated): LTPA was categorised as competitive sports, moderate-to-heavy, light or sedentary	The number of women practicing competitive sports decreased from prepregnancy (4.0%) to the third trimester (0.1%) and those practicing moderate-to-heavy activities from 25% to 2.4%. The proportion of women engaging in light activities remained stable from 65% prepregnancy to 67% in the third trimester, whilst the proportion of women with sedentary activity increased from 6% to 29%.
Liu et al. (232) 2011	England	Cross-sectional retrospective + follow-up during pregnancy (32-wks gestation)	9 889	At 18-wks gestation (change in PA from prepregnancy) and at 32-wks gestation	Question on changes in PA since becoming pregnant (yes, increased a lot/a little; no, changed a little; yes, decreased a lot; yes, decreased)	633 (6%) women increased PA from prepregnancy to pregnancy, 3 328 (34%) had no change or changed a little, 4 830 (49%) decreased a lot and 1 026 (10%) decreased. At 18-wks gestation, 67% of women engaged in some strenuous PA at least once/wk, 49% 3 or more h/wk (95% CI 47.8–49.8). At 32-wk, 66% and 49%, respectively (no significant difference during pregnancy).
Lynch et al. (233), 2012	USA	Cross-sectional retrospective + follow-up during pregnancy	1 355 Hispanic women	Early, mid- and late pregnancy (recall of prepregnancy PA)	Pregnancy Physical Activity Questionnaire (PPAQ) (activity categories: household/caregiving, occupational, sports or exercise,	25% performed PA ≥30 min/day of at least a moderate intensity on most days of the wk prepregnancy, and 7% in early pregnancy. Within-woman decreases for all activity-intensity and activity-domain categories occurred from prepregnancy to early pregnancy ($P < 0.01$).

					transportation and inactivity)	
Amezcua–Prieto et al. (229), 2013	Spain	Cross-sectional retrospective	1 175	Between 20- and 22-wks gestation: recall of PA 1-year before pregnancy	Interview questionnaire: Paffenbarger Physical Activity Questionnaire (LTPA)	Walking increased during pregnancy, whilst other types of LTPA decreased, with the exception of gardening (no change). 28% and 19% of women met LTPA recommendations (a minimum of 450 MET min/wk) prior to pregnancy and during pregnancy; 13% of women meeting recommendations prior to pregnancy did not meet those recommendations during gestation, and 5% showed a reverse trend.
Nascimento et al. (235), 2015	Brazil	Cross-sectional retrospective	1 279	Between 12- and 72-h postpartum (recall of exercise and PA before and during pregnancy)	Interview questionnaires (unvalidated) on physical exercise during pregnancy and PPAQ	23% of women reported some type of exercise during pregnancy (≥ 2 times/wk at least 30 min/session), 55% stopped exercising during pregnancy, 29% maintained and 16% decreased the intensity and frequency of exercise. Exercise decreased from prepregnancy to pregnancy ($P = 0.01$): 20% of women reported practicing exercise during some period of pregnancy. 14% exercised during the first trimester, 18% during the second trimester and 13% during the third trimester ($P < 0.0001$), whilst only 8% of women remained active throughout all three trimesters. The proportion of women who completed the minimum of 150 min of aerobic exercise/wk was 7%, 8% and 5% in the first, second and third trimesters, respectively.

Coll et al. (230), 2016	Brazil	Cross-sectional retrospective	3 906	Soon after delivery (recall of PA for 3 months prior to pregnancy and for the first, second and third trimesters of pregnancy) and at 3 months after delivery	Interview using a structured questionnaire: type, frequency and mean duration of each session of LTPA in a typical wk during each time period. Women were asked not to report commuting, household or occupational activities. The total LTPA score was generated by the sum of min/wk spent on each physical activity.	The proportion of women reporting LTPA ≥ 150 min/wk declined from 11% in the prepregnancy period to 2% during pregnancy and 0.1% in the postpartum period (*P* for trend < 0.001). Women with any LTPA declined from 15% to 4% and 8% (*P* for trend < 0.001), respectively.
Merkx et al. (234), 2017	The Netherlands	Cross-sectional retrospective	455	At mean (SD) gestational wk 28.2 (8.3) (recall of prepregnancy PA)	Questionnaire: prepregnancy activity (1 = not active at all, 7 = very active) and whether they reduced their PA during pregnancy	203 (45%) women maintained their PA, 17 (4%) women increased their PA and 235 women (52%) reduced their PA from prepregnancy to pregnancy.

h = hours; LTPA = leisure-time physical activity; MET = metabolic equivalent; min = minutes; OR = odds ratio; PA = physical activity; SD = standard deviation; wk = week

5.3 DEPRESSIVE SYMPTOMS IN PREGNANT WOMEN AT RISK FOR GESTATIONAL DIABETES (STUDY II)

5.3.1 PARTICIPANT CHARACTERISTICS

Of the 482 included women at high risk for gestational diabetes mellitus (GDM), 195 (40%) were recruited based on a history of GDM and 287 (60%) based on prepregnancy obesity (BMI ≥ 30 kg/m²). Of the 195 women with a history of GDM, 69 had prepregnancy obesity; thus, 14% of the women met both inclusion criteria for being at high risk for GDM. Altogether, 356 (74%) of women at high risk for GDM and 36 (10%) of pregnant women in the general population were obese before pregnancy. Women at high risk for GDM completed the depression questionnaire between gestational weeks 5 and 18 (mean 12.3), and pregnant women in the general population between gestational weeks 8 and 19 (mean 12.0). One woman at high risk for GDM had too many missing responses in the depression questionnaire, and was thus excluded from further analysis.

Table 7 provides the characteristics of pregnant women at high risk for GDM and pregnant women in the general population in study II. Women at high risk for GDM were significantly older, less educated, had a lower annual household income, a higher prepregnancy BMI and more chronic diseases compared to women in the general pregnant population. In addition, the two groups of women differed in terms of gestational weeks, but the difference was not clinically significant.

Table 7. Characteristics of women at high risk for gestational diabetes and pregnant women in the general population in early pregnancy (study II).

Characteristics	Pregnant women at risk for GDM (n = 482)	Pregnant women in the general population (n = 358)	*P*[a]
Age (years), mean (SD)	32 (5)	31 (5)	<0.001
Marital status, n (%)			0.46
Married/co-habitating	461 (96)	340 (95)	
Other	19 (4)	18 (5)	
Education, n (%)			0.001
No professional education or a vocational course/school/apprenticeship	214 (45)	113 (32)	
Vocational diploma/degree	118 (25)	105 (30)	
Lower or higher academic degree	142 (30)	136 (38)	
Annual household income (EUR), n (%)			0.046
≤20 000	24 (5)	13 (4)	
20 001–50 000	165 (36)	104 (30)	
50 001–100 000	245 (54)	204 (59)	
>100 000	21 (5)	28 (8)	
Prepregnancy BMI (kg/m²), mean (SD)	32 (6)	24 (5)	<0.001
Prepregnancy BMI (kg/m²), n (%)			
Normal or underweight (≤24.9)	68 (14)	258 (72)	
Overweight (25.0–29.9)	56 (12)	62 (17)	
Moderately obese (30.0–34.9)	219 (45)	23 (6)	
Severely obese (35.0–39.9)	101 (21)	10 (3)	
Very severely obese (≥40.0)	36 (8)	3 (1)	
Chronic disease (allergies and atopia not included), n (%)			<0.001
No	340 (71)	300 (84)	
Yes	142 (30)	56 (16)	
Psychotropic medication, n (%)			0.104
No	465 (97)	352 (98)	
Yes	17 (4)	6 (2)	
Current smoking, n (%)			0.093
No	452 (94)	344 (96)	
Yes (regularly or occasionally)	30 (6)	13 (4)	
Gestational weeks, mean (SD)	12.3 (2.0)	12.0 (1.4)	0.025

Continues.

Table 7. continued.

Information is self-reported, except for age and gestational weeks.

[a]Results from t-test, bootstrapped type t-test, permutation test, chi-square test or Fisher–Freeman–Halton test.

BMI = body mass index; EPDS = Edinburgh Postnatal Depression Scale; SD = standard deviation.

5.3.2 DEPRESSIVE SYMPTOMS

Table 8 shows the primary results regarding depressive symptoms in early pregnancy amongst women at risk for GDM. In total, 17% of pregnant women at risk for GDM compared to 11% of pregnant women in the general population had an EPDS score ≥ 10, indicative of a risk for depression. Moreover, the mean EPDS score was higher amongst women at risk for GDM compared to pregnant women in the general population. When adjusted for age, prepregnancy BMI and income, the statistically significant difference between the groups in the proportion of women having an EPDS score ≥ 10 and in the mean EPDS score disappeared.

Table 8. Depressive symptoms in early pregnancy amongst women at risk for gestational diabetes and women in the general pregnant population.

	Pregnant women at risk for gestational diabetes (n = 481)	**Pregnant women in the general population (n = 358)**	***P*[a]**	***P*[b]** adjusted for age, prepregnancy BMI and income
EPDS score, mean (SD)	5.5 (4.5)	4.6 (3.9)	0.004[c]	0.39
EPDS score ≥ 10, n (%)	80 (16.6)	40 (11.2)	0.025	0.59

[a] Results from the bootstrapped type t-test or chi-square test.

[b]Results from logistic regression analysis and bootstrapped-type analysis of covariance using the Hochberg approach for multiple comparisons.

[c]Effect size 0.21 (95% CI 0.07–0.34).

BMI = body mass index; EPDS = Edinburgh Postnatal Depression Scale; SD = standard deviation.

5.4 CARDIORESPIRATORY FITNESS AND HEALTH-RELATED QUALITY OF LIFE AMONGST WOMEN PLANNING A PREGNANCY AND AT RISK FOR GESTATIONAL DIABETES (STUDY III)

5.4.1 PARTICIPANT CHARACTERISTICS

Amongst the women included (n = 39), 33 (85%) were recruited based on a history of GDM and six (15%) based on a BMI > 29 kg/m². Of the 33 women with a history of GDM, 10 (26% of all participants) had a BMI > 29 kg/m², thus meeting both inclusion criteria. The women ranged in age from 24 to 43 years old, whilst BMI ranged from 21 to 42 kg/m². Table 9 shows the characteristics of participants.

Table 9. Baseline characteristics of the women planning a pregnancy and at high risk for gestational diabetes (n = 39; study III).

Characteristics	
Age (years), mean (SD)	32 (4)
Education, n (%)	
No professional education or a vocational course or apprenticeship	10 (26)
Vocational diploma or degree	19 (49)
Lower or higher academic degree	10 (26)
Married or cohabiting, n (%)	35 (95)
Annual family income (Euros), n (%)	
≤ 50 000	20 (51)
50 001–100 000	12 (31)
> 100 000	7 (18)
Number of children in the household, n (%)	
0	5 (13)
1	28 (72)
2	6 (15)
BMI (kg/m²), mean (SD)	28.0 (5.6)
Obese (BMI > 29 kg/m²), n (%)	16 (41)
Chronic disease (mostly atopy and allergies), n (%)	9 (23)

BMI = body mass index; SD = standard deviation

5.4.2 CARDIOVASCULAR FITNESS, PHYSICAL ACTIVITY AND HEALTH-RELATED QUALITY OF LIFE

Table 10 shows the cardiovascular fitness (i.e., VO_{2max}), LTPA and HRQoL of women planning a pregnancy and at high risk for gestational diabetes mellitus (GDM).

Table 10. Cardiovascular fitness (VO_{2max}), leisure-time physical activity and health-related quality of life (SF-36) amongst women planning a pregnancy and at risk for gestational diabetes (n = 39).

Characteristic	
VO_{2max} ($mL \cdot kg^{-1} \cdot min^{-1}$), mean (SD)	27.1 (5.8)
Cardiovascular fitness category[a], n (%)	
1 Very poor	12 (31)
2 Poor	14 (36)
3 Fair	8 (21)
4 Average	4 (10)
5 Good	1 (3)
6 Very good	0 (0)
7 Excellent	0 (0)
Leisure-time physical activity (h/wk), mean (SD)	2.6 (1.7)
Leisure-time physical activity ≥ 2.5 h/wk[b], n (%)	16 (41)
SF-36 scales[c] and summaries, mean (SD)	
Physical functioning	96.4 (6.9)
General health	73.3 (18.3)
Vitality	64.7 (14.8)
Mental health	78.6 (10.6)
Role – physical	82.1 (29.8)
Role – emotional	91.5 (19.8)
Social functioning	90.1 (16.8)
Bodily pain	78.6 (19.4)
Physical component summary	51.8 (5.8)
Mental component summary	52.2 (6.8)

[a]The classification is based on VO_{2max} ($mL \cdot kg^{-1} \cdot min^{-1}$) norms for women in the age group of each participant (200).

[b]All leisure-time physical activity lasting for at least 20 minutes at a time.

[c]The scales range from 0 to 100, with 0 indicating the worst situation and 100 indicating the best situation in the domains.

h = hour; SD = standard deviation; SF-36 = 36-Item Short-Form Health Survey; wk = week

BMI was the only demographic or health characteristic associated with SF-36; a higher BMI was associated with poorer physical functioning ($r_s = -0.34$, $P = 0.032$) and general health ($r_s = -0.41$, $P = 0.009$) from SF-36, and with more bodily pain from SF-36 ($r_s = -0.45$, $P = 0.004$). We controlled for BMI when examining the associations of cardiorespiratory fitness (i.e., VO_{2max}) and LTPA with those SF-36 scales.

Table 11 shows the correlation and linear regression coefficients between VO_{2max} or LTPA and SF-36, controlling for BMI when appropriate. VO_{2max} was positively associated with the general health scale and the physical component summary from SF-36, whereas LTPA was positively associated with the physical functioning and general health scales, and with the physical component summary from SF-36. Each one-unit increment in VO_{2max} increased the general health domain score by an average of 1.27 points and the physical component summary by an average of 0.48 points. Each 1 hour/week increment in LTPA increased the general health domain score by an average of 3.7 points and the physical component summary by an average of 1.1 points. The crude correlations of VO_{2max} and LTPA with the general health scale and the physical and mental component summaries of SF-36 are illustrated in Figures 5 and 6.

Table 11. Correlation and regression coefficients of cardiorespiratory fitness (VO_{2max}) and leisure-time physical activity (LTPA) with health-related quality of life (SF-36) amongst women planning a pregnancy and at risk for gestational diabetes (n = 39).

SF-36†	VO_{2max} (mL·kg^{-1}·min^{-1})	LTPA (h/wk)
Physical functioning	$r_s = 0.11^a$	$r_s = 0.34^a$
	$P = 0.518$	$P = 0.039$*
General health	$r_p = 0.34^a$	$r_s = 0.38^a$
	$P = 0.035$*	$P = 0.018$*
	β 1.27 (0.09, 2.44)^a	β 3.74 (0.64, 6.84)^a
	$P = 0.035$*	$P = 0.020$*
Vitality	$r_p = 0.05$	$r_s = 0.21$
	$P = 0.757$	$P = 0.196$
	β 0.13 (–0.72, 0.98)	β 1.14 (–1.68, 3.96)
	$P = 0.757$	$P = 0.418$
Mental Health	$r_p = 0.07$	$r_s = 0.07$
	$P = 0.654$	$P = 0.662$
	β 0.14 (–0.47, 0.75)	β 0.21 (–1.83, 2.25)
	$P = 0.654$	$P = 0.836$
Role – physical	$r_s = 0.23$	$r_s = 0.31$
	$P = 0.158$	$P = 0.056$
Role – emotional	$r_s = -0.13$	$r_s = 0.17$
	$P = 0.431$	$P = 0.292$
Social functioning	$r_s = -0.06$	$r_s = 0.14$
	$P = 0.720$	$P = 0.387$
Bodily pain	$r_s = 0.08^a$	$r_s = 0.09^a$
	$P = 0.617$	$P = 0.587$
	β 1.11 (–0.13, 2.35)^a	β 1.90 (–1.50, 5.31)^a
	$P = 0.077$	$P = 0.264$
Physical component summary	$r_s = 0.33^a$	$r_s = 0.30^a$
	$P = 0.042$*	$P = 0.064$
	β 0.48 (0.14, 0.82)^a	β 1.13 (0.19, 2.06)^a
	$P = 0.007$*	$P = 0.020$*
Mental component summary	$r_s = -0.17$	$r_s = 0.09$
	$P = 0.295$	$P = 0.579$

Continues.

Table 11. continued.

r_s = Spearman's correlation or partial correlation.

r_p = Pearson's correlation or partial correlation.

Otherwise data are β coefficients (95% CI).

[a]Controlled for body mass index.

*P < 0.05 (two-tailed).

†Regression performed only for variables for which the residuals were normally distributed.

h = hour; LTPA = leisure-time physical activity; SF-36 = 36-Item Short-Form Health Survey; wk = week

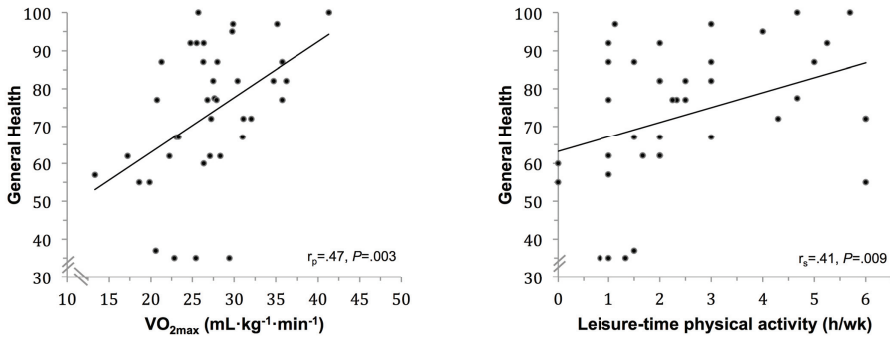

Figure 5. Spearman's (r_s) and Pearson's (r_p) crude correlations of measured cardiorespiratory fitness (VO_{2max}) and self-reported leisure-time physical activity using the SF-36 general health domain score. Reproduced with permission from *the Scandinavian Journal of Medicine & Science in Sports*. Engberg E. et al., 2018.

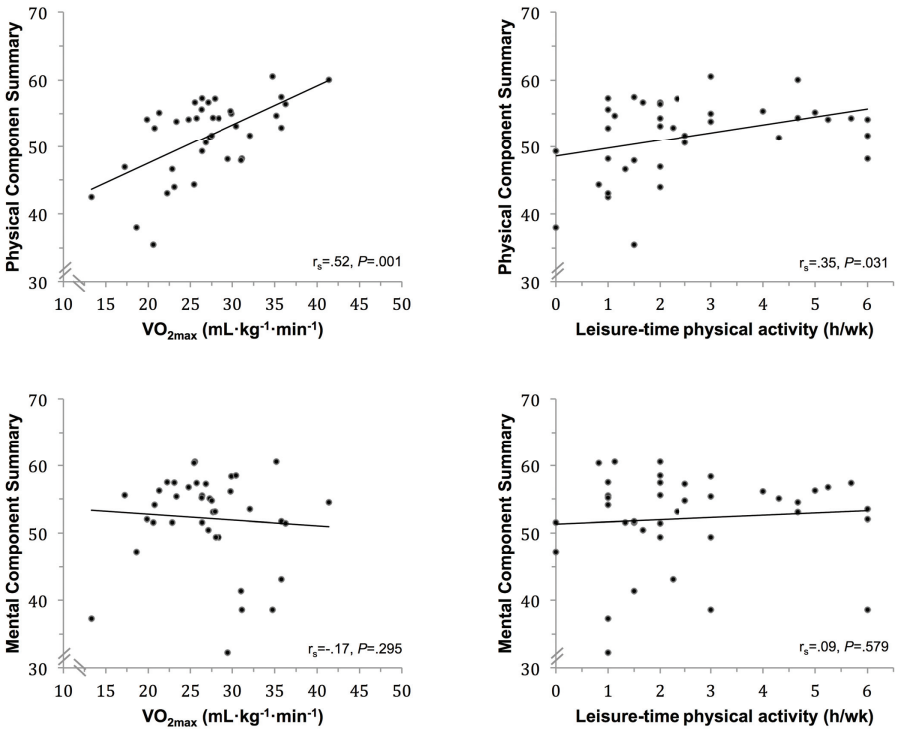

Figure 6. Spearman's crude correlations (r_s) of measured cardiorespiratory fitness (VO_{2max}) and self-reported leisure-time physical activity using the SF-36 physical and mental component summary score. Reproduced with permission from the *Scandinavian Journal of Medicine & Science in Sports*. Engberg E. et al., 2018.

Furthermore, Table 12 shows that the SF-36 general health domain and the SF-36 physical component summary differed between fitness categories 1 (very poor), 2 (poor) and 3 (fair, average or good). The pairwise comparisons showed that the differences in the SF-36 general health scale and the physical component summary were significant between fitness categories 1 (very poor) and 2 (poor) (P = 0.033 and P = 0.035, respectively), and between fitness categories 1 (very poor) and 3 (fair, average or good) (P = 0.005 and P = 0.014, respectively), but not between fitness categories 2 (poor) and 3 (fair, average or good). The SF-36 general health scale score also differed between women who were physically active ≥ 2.5 hours/week (mean 82.2, SD 12.9) and women who were physically active < 2.5 hours/week (mean 67.2, SD 19.1) (P = 0.010).

Table 12. Health-related quality of life (SF-36) by cardiorespiratory fitness categories of women planning a pregnancy and at risk for gestational diabetes.

	Cardiorespiratory fitness category[a]			
	Very poor (n = 12)	**Poor (n = 14)**	**Fair, average or good (n = 13)**	***P*[c]**
SF-36 general health[b], mean (SD)	60.1 (18.9)	76.8 (17.2)	81.8 (11.8)	0.005
SF-36 physical component summary, mean (SD)	47.2 (6.8)	53.1 (4.0)	54.7 (4.0)	0.007

[a]The classification is based on VO_{2max} ($mL \cdot kg^{-1} \cdot min^{-1}$) norms for women in the age group of each participant (200).

[b]The scale ranges from 0 to 100, with 0 indicating the worst situation and 100 indicating the best situation in the domains.

[c]Results from one-way analysis of variance or the Kruskal–Wallis test.

SD = standard deviation; SF-36 = 36-Item Short-Form Health Survey

5.5 EFFECTS OF LIFESTYLE COUNSELLING ON SELF-RATED HEALTH AMONGST WOMEN AT RISK FOR GESTATIONAL DIABETES (STUDY IV)

5.5.1 PARTICIPANT CHARACTERISTICS

Table 13 summarises the baseline characteristics (before gestational week 20) of women at high risk for GDM included in the randomised lifestyle intervention trial.

Table 13. Baseline characteristics of women at high risk for gestational diabetes in the intervention and control groups (study IV).

Characteristics	Intervention (n = 144)	Control (n = 122)
Age (years), mean (SD)	32.3 (4.9)	32.6 (4.4)
Body mass index (kg/m²), mean (SD)		
Prepregnancy	31.5 (6.0)	31.9 (5.5)
At baseline	32.1 (5.9)	32.3 (5.4)
Education (years), mean (SD)	14.0 (2.6)	14.1 (2.5)
Annual household income (EUR), n (%)		
≤ 20 000	9 (7)	6 (5)
21 001–50 000	51 (37)	39 (34)
51 001–100 000	75 (54)	61 (54)
> 100 000	4 (3)	8 (7)
Married/cohabitating, n (%)	139 (97)	116 (91)
Gestational weeks, median (IQR)	13.2 (12.3, 14.7)	13.1 (11.9, 14.4)
At least one previous delivery, n (%)	83 (58)	70 (57)
A history of gestational diabetes, n (%)	50 (35)	36 (30)
Current smoking (regularly or occasionally), n (%)	6 (4)	4 (3)
Dietary index, mean (SD)[a]	10.1 (2.8)	9.7 (2.6)
Leisure-time physical activity min/week, median (IQR)	60 (30, 140)	60 (30, 150)
Leisure-time physical activity, n (%)		
≥ 4 times/week	13 (10)	15 (13)
2–3 times/week	43 (34)	35 (30)
Once/week	36 (28)	27 (23)
A few times/month	16 (13)	15 (13)
About once/month	5 (4)	6 (5)
Less than once/month	14 (11)	18 (16)

Information is self-reported, except for age, baseline BMI, gestational weeks, previous deliveries and a history of GDM.

[a]Dietary index was developed based on a food frequency questionnaire. Higher scores indicate better diet quality (237).

IQR = interquartile range; SD = standard deviation

5.5.2 SELF-RATED HEALTH

Table 14 presents the baseline self-rated health (assessed before 20-weeks gestation) amongst women at high risk for gestational diabetes mellitus (GDM) in the lifestyle counselling group and in the control group. Women in the lifestyle group rated their health significantly better, that is, they had a lower mean score, compared with women in the control group. We found that 86% of the women in the lifestyle group and 68% of the women in the control group rated their health as either good or quite good, whereas 6% and 8%, respectively, rated their health as quite poor or poor.

Table 14. Baseline self-rated health (assessed before 20-weeks gestation) amongst pregnant women at high risk for gestational diabetes in the intervention and control groups.

Self-rated health[a]	Lifestyle counselling group (n = 144)	Control group (n = 122)	*P*[b]
Mean (SD)[c]	1.8 (0.8)	2.1 (09)	0.006
1 Good, n (%)	53 (37)	33 (27)	
2 Quite good, n (%)	71 (49)	50 (41)	
3 Fair, n (%)	12 (8)	29 (24)	
4 Quite poor, n (%)	7 (5)	10 (8)	
5 Poor, n (%)	1 (1)	0 (0)	

[a]Assessed by a single question: 'How good do you regard your general health at the moment?' Participants responded using a five-point scale: good (1), quite good (2), fair (3), quite poor (4) and poor (5).

[b]Results from the bootstrapped type t-test.

[c]A lower score indicates a better self-rated health.

SD = standard deviation

Figure 7 illustrates that self-rated health as a continuous variable changed over time from the first trimester of pregnancy to 12-months postpartum across the entire sample (time effect, $P < 0.001$), but the difference between groups was not statistically significant (group effect, $P = 0.064$). Moreover, changes in the proportion of women with a good self-rated health status were similar (group effect, $P = 0.056$; time effect, $P < 0.001$; group–time interaction, $P = 0.94$).

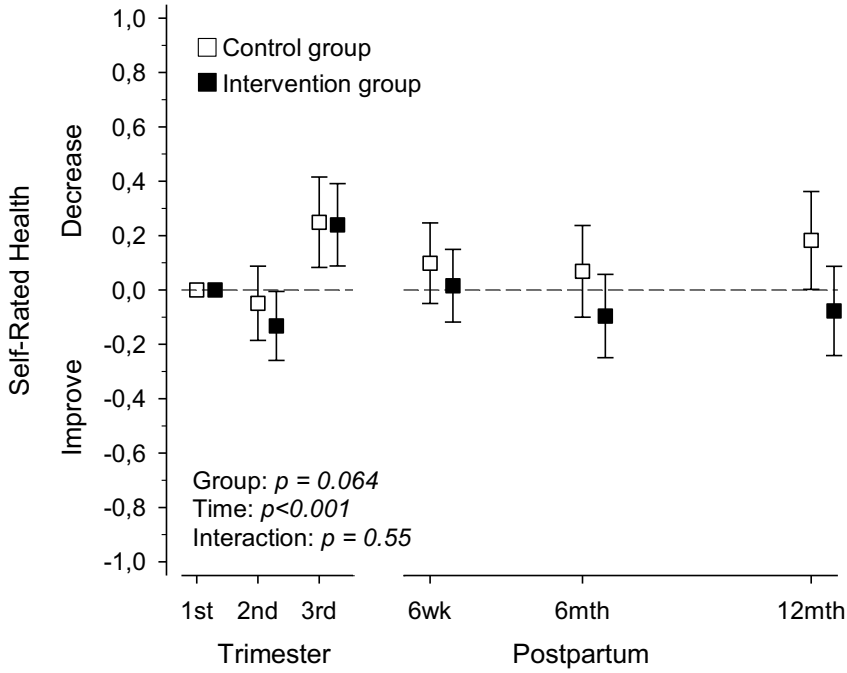

Figure 7. Change in self-rated health (mean and standard deviation) in the intervention group and control group from the first trimester of pregnancy to 12-months postpartum. Adjusted for baseline values. A lower score indicates a better self-rated health status. Reproduced with permission from the *Journal of Psychosomatic Obstetrics & Gynecology*. Engberg E. et al., 2018.

6 DISCUSSION

Gestational diabetes mellitus (GDM) is emerging as a worldwide epidemic amongst pregnant women. This doctoral thesis examined the effects of life events, particularly pregnancy, on PA. Thus, it also examined depressive symptoms amongst women at high risk for GDM during early pregnancy, as well as the associations of cardiorespiratory fitness and PA using HRQoL amongst women at high risk for GDM planning a pregnancy. Finally, this thesis also evaluated the effects of a randomised lifestyle intervention aimed at preventing GDM in high-risk women on self-rated health from pregnancy to one year after giving birth.

This doctoral thesis consists of one systematic literature review article and three research articles. The studies included in the systematic review (study I) showed changes in LTPA from before to after life events. Moreover, studies on the effects of pregnancy on PA (study I and the updated literature review) showed that LTPA decreases both from prepregnancy to pregnancy, and from prepregnancy to postpartum. Study II showed that pregnant women at risk for GDM had higher depression scale scores when compared with pregnant women in the general population during early pregnancy, but the difference between groups disappeared after adjusting for age, BMI and income. Study III showed that cardiorespiratory fitness and LTPA were positively associated with the self-rated general health and physical well-being domains of HRQoL amongst women planning a pregnancy and at risk for GDM, even after controlling for BMI. Self-rated general health and physical well-being differed between those with very poor and poor cardiorespiratory fitness, suggesting that even a small improvement in cardiorespiratory fitness could be beneficial for perceived well-being. Study IV showed that the self-rated health of women at risk for GDM seemed to improve in the lifestyle counselling group and deteriorated in the control group from pregnancy to one-year postpartum, although that difference between groups did not reach statistical significance.

6.1 LIFE EVENTS AND CHANGES IN PHYSICAL ACTIVITY (STUDY I)

The systematic review (study I) showed that major life events affect PA. Emerging adulthood seems to be a critical phase for a PA change, particularly amongst women, due to the many events typically occurring during this time (transition to university, start of one's working life, starting to live with someone, marriage and having children).

A possible reason for the relationship between life events and PA behaviour may be that stress related to life events impairs efforts to be physically active (37). Major life events often create emotional distress and disrupt a person's daily routine, thus affecting PA behaviour. An earlier systematic review on life events and PA by Allender et al. published in 2008 reviewed 19 articles and similarly concluded that life events do affect PA (45). In accordance with our more recent systematic review, cross-sectional and longitudinal studies included in the previous review indicated that initiating paid work, marriage and a change in residential status all associated with a decrease in PA amongst young women (45). In contrast to our results, however, Allender et al. concluded that pregnancy had no major effect on PA. Parenthood was associated with lower levels of PA, particularly amongst women, also according to Allender et al. (45). The review by Allender et al. showed, based on cross-sectional studies, that widowhood and divorce associated with lower levels of PA amongst men, whilst one prospective study included in our review showed that divorce improved fitness in men (238). Likewise, another longitudinal study included in our review showed that widowhood increased PA in women (209). The review by Allender et al. included studies that reported associations between serious illness during childhood and decreasing PA in adulthood, whilst a cancer diagnosis resulted in lower levels of PA (45). We excluded illnesses and injuries as life events in our systematic review. Yet, our systematic review includes 27 articles that were not included in the previous systematic review about the topic; 13 of the 27 additional articles were published after the previous systematic review, and 14 were not identified in the previous review. Another difference between the two reviews is that all of the articles we included assessed PA both before and after a life event.

Similar to our findings, one systematic review including both cross-sectional and longitudinal studies on retirement and PA concluded that exercise and LTPA increase after retirement (239). In addition, the review concluded that findings regarding the association between retirement and total PA remain inconsistent (239). However, a more recent longitudinal study also found a decrease in total PA after retirement (240). An association between retirement and increased PA, as assessed with an accelerometer, has also been reported following the publication of our systematic review (241).

An umbrella systematic review by Condello et al. published in 2017 examined behavioural determinants of PA across the life course, and included 17 systematic reviews or meta-analyses. In accordance with our results, they concluded that the transition to university and pregnancy or having a child showed probable negative associations with PA (242). Moreover, a systematic review published in 2016 examined correlates of sedentary behaviour in adults, and found studies with conflicting results regarding the association between sedentary time and being married or cohabitating, whilst having children resulted in less total sitting time in

several studies (243). In conclusion, the results of study I as well as other evidence show that major life events affect PA, and that the impact differs according to different life events and the age and sex of the study participants.

6.2 PREGNANCY AS A LIFE EVENT AND CHANGES IN PHYSICAL ACTIVITY (STUDY I AND THE UPDATE)

The systematic literature review in 2012 (study I) and the updated literature review in 2017 together included 15 studies which examined pregnancy and a change in PA. Six of the eight studies included in the systematic literature review in 2012 were conducted in the USA and two in Australia. However, the participants in the seven studies included in the updated literature review in 2017 consisted of various nationalities — that is, Brazil, Denmark, England, the Netherlands, Spain and the USA. These 15 studies showed that PA decreases from prepregnancy to pregnancy, and from prepregnancy to postpartum. Our findings are consistent with two previous literature reviews indicating that pregnancy decreases PA (244, 245). A review published in 2006 included both cross-sectional and longitudinal studies, and found that both leisure and work-related PA decreases throughout pregnancy. LTPA decreased both during pregnancy compared to prepregnancy, and at the end of a pregnancy compared to the beginning of a pregnancy (244). Another literature review from 2011 included 25 studies published between 1986 to 2009, indicating that pregnant women are less active than non-pregnant women and that pregnancy leads to a decrease in PA (245). In addition, the included studies showed that higher exercise participation during pregnancy associated with a higher level of education and income, not having other children at home, being Caucasian and being more active prior to pregnancy (245). Yet, one other review on PA amongst pregnant women before, during and after pregnancy was published in 2015. That review included 24 cohort, descriptive and cross-sectional studies, and concluded that pregnancy decreases the amount and type of moderate to strenuous PA, which does not always increase again postpartum (246). The difference between the three other reviews (244–246) on pregnancy and PA compared to study I and the updated literature review of this doctoral dissertation is that none of the previous literature reviews included studies merely assessing a change in PA from before pregnancy to pregnancy or postpartum. Rather, most involved comparative cross-sectional studies. Thus, study I and the updated literature review of this doctoral dissertation include a fewer number of studies than the other reviews, since all of the studies included in study I and in the update assessed PA both before and during pregnancy or postpartum, either longitudinally or with a cross-sectional retrospective design. Furthermore,

this dissertation includes more recent studies than those included in previous reviews.

One study included in our systematic review suggests that PA decreases from prepregnancy to pregnancy, but partially rebounds postpartum (220). Similarly, a longitudinal study followed 471 US women from pregnancy to postpartum, and reported that overall PA decreased from 17- to 22-weeks gestation to 27- to 30-weeks gestation, but rebounded at 3-months postpartum remaining stable at 12-months postpartum (247). The study did not, however, assess prepregnancy PA.

No study included in the systematic literature review or in the updated review of this doctoral thesis on pregnancy and a change in PA assessed PA using an objective measurement. A pedometer and accelerometer had moderate to strong reliability and a moderate validity for measuring PA during pregnancy and at 12-weeks postpartum in a recent study comparing PA devices, placed at the right hip and ankle and left triceps, with energy expenditure (VO^2) estimated using indirect calorimetry (Oxycon Mobile portable metabolic analyser) amongst 33 women (248). By contrast, another prospective study of 57 women reported that PA decreased similarly from the second to third trimester of pregnancy, assessed using both a self-report interview and an accelerometry placed on the non-dominant ankle. The correlation between the two measures declined as pregnancy progressed, and compliance with the accelerometers declined significantly from 90% at 12-weeks to 47% at 34-weeks gestation, whilst compliance with the self-report interviews was 100% (249).

A systematic review published in 2017 included 26 studies on sedentary behaviour during pregnancy, concluding that pregnant women spend more than 50% of their waking time in sedentary behaviours, similar to reports amongst the general population (250). Thus, decreases in LTPA due to pregnancy do not appear to be compensated by decreases in sedentary behaviour, potentially leading to increases in light-intensity, everyday activities. The results from study I and the update show, in accordance with previous literature reviews on the topic, that PA decreases from prepregnancy to pregnancy and from prepregnancy to postpartum. Our review strengthens this evidence by including only studies that assess the change in PA by measuring PA both before pregnancy and during pregnancy or the postpartum period or during both periods.

6.3 DEPRESSIVE SYMPTOMS IN PREGNANT WOMEN AT RISK FOR GESTATIONAL DIABETES (STUDY II)

Study II showed that a greater proportion (17%) of pregnant women at high risk for GDM compared to pregnant women in the general population (11%)

were at risk for depression during early pregnancy. In addition, the mean depression score was higher amongst women at high risk for GDM, although the difference was small based on the effect size.

After we adjusted for age, prepregnancy BMI and income, the differences in the proportion of women at risk for depression and in the mean depression score were no longer statistically significant between the two groups of women. Previous studies found that an older age, obesity and lower socioeconomic status are associated with GDM (251), and, thus, these can be viewed as the characteristics of women with or at risk for GDM.

Furthermore, previous studies showed that individuals with type 1 or type 2 diabetes experience more depression compared with those without, which may be related to poorer glycaemic control and insulin resistance (31). A smaller number of previous studies, however, examined the association between GDM and depressive symptoms (135–145). Most studies found no difference between pregnant women diagnosed with GDM and pregnant control women without GDM when assessing depression or depressive symptoms (135–142).

Similar to our study amongst women at risk for GDM, another cross-sectional study examined depressive symptoms using EPDS, but reported no difference in the mean depression score between 65 women with GDM and 70 pregnant controls in an unadjusted analysis assessed between 24- and 40-weeks gestation (140). Another cross-sectional study found no difference between 425 women with GDM, 226 women with prepregnancy diabetes and 1 747 controls in terms of depressive symptoms assessed using the Patient Health Questionnaire-9 or current use of antidepressants during a mean gestational week of 23. GDM was not associated with an increased risk for any depression or major depression in either unadjusted or adjusted analyses (using demographic characteristics) (135). Furthermore, a prospective study assessed depressive symptoms using CESD, and found no differences between 64 women with GDM and 1 233 control women in the increase of depressive symptoms from prepregnancy to postpartum in an unadjusted analysis or in analyses adjusted using multiple confounders (137). Furthermore, two cross-sectional studies examining 68 and 206 women with GDM reported no difference between women with GDM and non-diabetic controls in mood states assessed using the profile of Mood States–Bipolar Form in an unadjusted analysis (141) or in either unadjusted analysis or after adjusting for maternal age, weight and marital status (136). In addition, a prospective study reported no difference in unadjusted or adjusted analyses (using multiple sociodemographic and health characteristics) on abnormal GDM screens between 41 women with a past major depressive disorder, 39 women with a current major depressive disorder, 50 women with bipolar disorder and 62 healthy controls (142). Previous studies showing no difference in depressive symptoms between women with GDM and pregnant control women had several limitations, such as using an unvalidated method

to assess depressive symptoms amongst pregnant women (135, 136, 141), not assessing depressive symptoms at the same time point during pregnancy for the entire sample (135), a retrospective recall of depressive symptoms (137) and a rather small sample size of only 11 (138) and 30 (139) women with GDM.

Conversely, three previous studies found a higher prevalence of depressive symptoms amongst women with GDM compared to pregnant control women (143–145). A case–control study reported a higher mean EPDS score in 26 women with GDM (6.8, SD 4.0) compared to 26 pregnant control women matched for gestational age, age and BMI (4.2, SD 2.6) (143). A retrospective cohort study with a large sample size found that 657 women with type 1, type 2 or gestational diabetes were significantly more likely to have a depression diagnosis or take an antidepressant compared to 10 367 women without diabetes during pregnancy (5.8% [CI 4.0–7.6] vs. 2.7% [2.4–3.0]) and postpartum (13.1% [10.5–15.7] vs. 7.3% [6.8–7.8]) (144). Finally, a cross-sectional pilot study found that 25 women with GDM had a higher depression score compared to 25 non-diabetic pregnant women (median 6 [0–28] vs. median 2 [0–38], effect size r = 0.31) assessed using DASS (145). Two of the three previous studies reporting a higher prevalence of depressive symptoms amongst women with GDM had a small sample size (143, 145). Moreover, one of the studies did not control for any other variables (145) and two did not control for BMI (144, 145).

Consistent with our results, another Finnish study reported that 16% of women at risk for GDM experienced depressive symptoms in early pregnancy (146). Compared to our study, they assessed depressive symptoms using the 15D scale, a generic HRQoL instrument and not a validated depression scale. Furthermore, that study included no comparative group of pregnant women in the general population, and used slightly different inclusion criteria for women at risk for GDM.

A recent longitudinal study conducted in 12 US clinical centres followed women (without psychiatric disorders, diabetes or other chronic conditions before pregnancy) throughout pregnancy (n = 2 477) and up to six months postpartum (n = 162) (252). They found a modest association between depressive symptoms during early pregnancy and an increased risk of GDM, and between GDM and subsequent postpartum depression assessed by an EPDS score of ≥ 10 (252). A systematic review on depression and diabetes in pregnancy (type 1, type 2 or gestational) was published in 2016 (253). That review included 48 studies, most of which were observational and 12 studies required a clinical depression diagnosis. The authors concluded that the overall quality of the studies was poor, no clear consensus exists on whether women with diabetes in pregnancy are more likely to develop depression than pregnant women without diabetes or whether women with depression are more likely to develop GDM (253). More high-quality research is needed to examine the relationship between depression and diabetes in pregnancy.

6.4 CARDIORESPIRATORY FITNESS AND HEALTH-RELATED QUALITY OF LIFE AMONGST WOMEN PLANNING A PREGNANCY AND AT RISK FOR GESTATIONAL DIABETES (STUDY III)

Study III showed that both cardiorespiratory fitness and LTPA positively associated with the self-rated general health and physical well-being dimensions of HRQoL independent of BMI. The levels of cardiorespiratory fitness and LTPA were generally low amongst participants. Women with very poor cardiorespiratory fitness reported the worst perceptions of their health and physical well-being, even when compared to women with poor cardiorespiratory fitness. In addition, self-rated health and physical well-being were poorer amongst those who were physically active less than 2.5 hours per week compared to those who were physically active 2.5 hours per week or more.

In accordance with our results, previous cross-sectional studies found associations between cardiorespiratory fitness and the general health or physical dimensions of HRQoL amongst hypertensive individuals with and without type 2 diabetes (176), individuals at risk for cardiovascular disease (171), adults with McArdle disease (174), men in the United States Navy (172) and middle-aged and elderly women and men (175). In addition, a study of healthy and predominantly young men reported an association between physical fitness index, comprised of cardiorespiratory fitness and muscle fitness as well as the general health and physical functioning dimensions of HRQoL (173).

Our results regarding the positive association of LTPA with the general health and physical dimensions of HRQoL are similar to previous cross-sectional and longitudinal studies that revealed similar associations in the general population (20, 166). One previous trial, consisting of 399 Finnish women at risk for GDM, reported that women who met the PA guidelines at the end of their pregnancy had a better overall HRQoL at the end of pregnancy, but not at the beginning of pregnancy, after controlling for age, parity, education and prepregnancy BMI (146). More physically active women had a better mobility, ability to handle their usual activities and vitality dimension of HRQoL assessed using the 15D questionnaire (146). A cross-sectional Swedish study, in turn, found that higher levels of LTPA were associated with a better self-rated health amongst 3 868 pregnant women (49).

A number of previous studies of the general population reported associations between higher levels of LTPA and better mental dimensions of HRQoL, in addition to the physical dimensions of HRQoL (20). Moreover, studies have reported a positive association between cardiorespiratory fitness and the mental dimensions of HRQoL amongst hypertensive individuals with and without type 2 diabetes (176) and amongst healthy men (172, 173). A

recently published study found that cardiorespiratory fitness, measured as VO_{2max} during a cycle ergometer test, was associated with both the physical and mental HRQoL, as assessed using SF-36 amongst 20 outpatients with bipolar disorder (254). Cardiorespiratory fitness and HRQoL, however, were not associated in 20 healthy controls, whilst persons with bipolar disorder had a lower HRQoL, lower cardiorespiratory fitness and were more sedentary. Objectively measured PA was not associated with HRQoL in either group (254).

Other studies have reported results similar to ours. Specifically, cardiorespiratory fitness was not associated with the mental well-being dimensions of HRQoL amongst patients with McArdle disease, individuals at risk for cardiovascular disease and middle-aged and elderly men and women (171, 174, 175). The possible reasons for finding no associations between the mental well-being dimensions of HRQoL and LTPA or cardiorespiratory fitness in our study include the small sample size and the predominantly low aerobic fitness levels amongst this sample of women. Another possible explanation is that the average mental well-being amongst the women in our study may have been poorer than amongst women in the general population. Hence, women with a history of GDM or prepregnancy obesity or both appear to experience more depressive symptoms compared to women in the general pregnant population at least during early pregnancy (study II).

We found that cardiorespiratory fitness and LTPA were associated with the general health domain of HRQoL amongst women with lower average VO_{2max} levels. This finding further highlights the importance of PA and cardiorespiratory fitness amongst women at risk for GDM, since self-rated health appears to predict both morbidity and mortality (15, 18). Moreover, self-rated general health and physical well-being differed even between those with very poor and poor fitness levels amongst the women in our study, indicating that even a slightly better cardiorespiratory fitness benefits well-being.

According to previous studies, GDM is related to an adverse HRQoL and self-rated health (137, 161), but the factors affecting subjective well-being amongst women with GDM are less known. Although exercise training improves HRQoL in individuals with medical conditions, such as coronary heart disease, breast cancer, asthma, chronic obstructive pulmonary disease, Parkinson's disease and schizophrenia (255), a systematic review updated in 2017 on studies aimed at preventing GDM found only four RCTs employing combined diet and exercise interventions that examined subjective well-being (177). Three of these studies found no effect from the intervention on sleep, stress, depressive symptoms, HRQoL and self-rated health during pregnancy (177, 186, 187, 256). However, one study reported no effect from a lifestyle advice intervention on the risk of depression, anxiety or HRQoL amongst overweight or obese women, yet the intervention improved knowledge regarding healthy food choices and exercise as well as reassurance

about their own and their baby's health (257). That intervention also increased the self-reported PA amongst women (258). The three interventions which had no effect on subjective well-being slightly increased self-reported PA (187), had no effect on objectively measured PA (186) and reduced the decrease in the self-reported PA during pregnancy (259). We do not know whether the interventions improved the measured cardiorespiratory fitness, and whether that would have affected the subjective well-being of participants, since these trials did not assess exercise capacity.

Our results indicate that cardiorespiratory fitness and LTPA are alarmingly low amongst women planning a pregnancy and at risk for GDM. Most of the women in our study (67%) had a very poor or poor aerobic fitness level compared to normal values for women (200). For instance, 88% of the women fell below the average aerobic fitness level for their age (200), thus increasing the cardiovascular disease risk (260). In addition, only 41% of the women reported engaging in any LTPA for at least 2.5 hours per week. The recommended amount to achieve health benefits is at least 2.5 hours of moderate-intensity aerobic PA per week, in addition to muscle-strengthening activities performed at least twice per week (53). Another Finnish trial reported that amongst women at risk for GDM, 52% engaged in the recommended amount of LTPA prior to pregnancy, as recalled at the beginning of the pregnancy (261).

Our results amongst women at risk for GDM agree with results from studies on the general population and some patient groups regarding the positive association between cardiorespiratory fitness and LTPA with the physical dimensions of HRQoL. Unlike our study, some studies also found a positive association between cardiorespiratory fitness or LTPA with the mental dimensions of HRQoL. Hence, our study appears to be the first to examine these relationships amongst women planning a pregnancy and at high risk for GDM.

6.5 EFFECTS OF LIFESTYLE COUNSELLING ON SELF-RATED HEALTH AMONGST WOMEN AT RISK FOR GESTATIONAL DIABETES (STUDY IV)

The RCT RADIEL study aimed to prevent GDM using lifestyle counselling. The secondary analysis from the RADIEL study (study IV) showed that self-rated health varied over time from early pregnancy to one-year postpartum, and was poorest during the third trimester. Self-rated health seemed to improve in the lifestyle counselling group and deteriorate in the control

group, although the difference between groups was not statistically significant.

Previous studies also reported changes in HRQoL and self-rated health over the course of a pregnancy. For example, a larger study amongst 1 809 multiethnic women showed that the physical functioning domain of SF-36 declined significantly from prepregnancy to 24- to 28-weeks and 32- to 36-weeks gestation, but improved again at 8- to 12-weeks postpartum. The vitality domain of SF-36 declined from prepregnancy to pregnancy, but did not return to prepregnancy levels postpartum (158). Amongst Swedish women, physical and mental self-rated health, both assessed through a single question, varied over time from mid-pregnancy to one-year postpartum. The proportion of women with a poor self-rated physical health increased from mid-pregnancy to late pregnancy, then decreased at two-months postpartum and increased again at one-year postpartum. Self-rated mental health showed a similar pattern (159). The results from our study on the change in self-rated health during pregnancy amongst women at risk for GDM agree with a previous Finnish study that reported an overall decrease in HRQoL during the course of pregnancy amongst women at risk for GDM (146).

A previous randomised controlled PA intervention during pregnancy improved self-rated health amongst 80 healthy women (184). Conversely, another RCT amongst 183 obese pregnant women reported no differences in either GDM or self-rated health between a group that received dietary and PA advice and the control group (186). Furthermore, results from a randomised controlled 12-week exercise intervention amongst 855 healthy pregnant women showed, similar to our results, that all women experienced a deterioration in self-rated health during the third trimester. In addition, the exercise programme had no effect on preventing GDM or on the general psychological well-being and self-reported health (183, 262).

In 2017, the Cochrane systematic review on combined diet and exercise interventions to prevent GDM was updated (177). That review includes 23 RCTs (including the RADIEL study) amongst 8 918 women and 8 709 infants, and found a possible reduced risk of GDM and caesarean section in the diet and exercise groups compared to the standard care groups. Furthermore, the review found no clear effect for pre-eclampsia, pregnancy-induced hypertension or hypertension, perinatal mortality or large for gestational age (177). The review identified four randomised controlled combined diet and exercise interventions aimed at preventing GDM, which reported subjective well-being as a secondary outcome (177). One study, the LIMIT study conducted in Australia, reported no difference in the risk of depression, anxiety or HRQoL amongst overweight and obese women between the group receiving a lifestyle advice intervention (n = 976) and the group receiving standard antenatal care (n = 957) from early pregnancy to four-months postpartum. However, women receiving lifestyle advice improved their knowledge of healthy food choices and exercise as well as

improved reassurances about their own and their baby's health (257). In agreement with our results, three of the four trials on combined diet and exercise interventions aimed at preventing GDM and reporting on subjective well-being found no effect from the interventions on stress, sleep, depressive symptoms, quality of life and self-rated health during pregnancy (186, 187, 256). The Finnish NELLI study found no difference in the change of HRQoL or self-rated health between the lifestyle counselling group and the standard antenatal care group from early pregnancy to 36- to 37-weeks gestation (177, 256). Similarly, the UK Pregnancies Better Eating and Activity (UPBEAT) trial reported no effect of the diet and PA intervention on quality of life or depressive symptoms amongst obese women from early pregnancy to 28-weeks gestation (186). Finally, the Fit for Delivery intervention conducted in the USA had no effect on depressive symptoms, stress and sleep from early pregnancy to late pregnancy, or to 6- or 12-months postpartum (187).

RADIEL lifestyle counselling reduced the incidence of GDM by 39% during the second trimester; GDM was diagnosed in 20 of 144 women in the intervention group and 27 of 125 women in the control group (189). Moreover, RADIEL lifestyle counselling during pregnancy and the first postpartum year reduced the incidence of impaired glucose regulation (impaired fasting glucose, impaired glucose tolerance or type 2 diabetes) at six-weeks or one-year postpartum, but had no effect on weight retention, PA or diet at one-year postpartum (195). Furthermore, as the results of this doctoral thesis indicate, the RADIEL lifestyle counselling intervention did not significantly improve self-rated health from pregnancy to one-year postpartum. Participants in the RADIEL trial who reached a total EPDS score of ≥ 10 or who had self-harm thoughts were referred for further assessment and treatment for depression. However, RADIEL lifestyle counselling included no specific psychological intervention. This may explain why we detected no effect on self-rated health because the self-rated health of pregnant and postpartum women is, in addition to physiological and lifestyle factors, also associated with psychological factors (263–265). The effectiveness of motivational interviewing, for example, was demonstrated in promoting lifestyle changes in healthcare (266, 267). In addition, motivational interviewing improved certain domains of HRQoL, including self-rated general health, when included in a PA lifestyle intervention amongst individuals with chronic heart failure (268). A psychological intervention may have been beneficial in the RADIEL study, considering that women at high risk for GDM appear vulnerable to depressive symptoms (study II), and a low mental well-being is common amongst overweight and obese European women during early pregnancy (269). Depressive symptoms during early pregnancy, in turn, may predict the development of GDM (270).

Other possible reasons for detecting no effect from the lifestyle intervention on self-rated health include that both the intervention and control groups met study nurses on several occasions during the study period

for measurements. Thus, the nurse–participant relationship may have influenced both groups. In addition, both groups received standard antenatal care, including general information leaflets on diet and PA. Therefore, there was no real control group in the RADIEL study. It is commonly known that, in lifestyle interventions in addition to the intervention group, the control group usually also benefits to some extent from participation in a study and from the study measurements. The so-called Hawthorne effect, which in lifestyle interventions equates with regular follow-up and appointments with healthcare professionals, may also affect the control group, thus diluting the differences between the intervention and the control groups (271). Another possible reason for the lack of group difference in the self-rated health is that the majority of women in the study (86% in the intervention group and 68% in the control group) rated their health either as good or quite good at the beginning of the study. Therefore, the improvement in self-rated health may have been difficult to detect, particularly in the intervention group. In the general Finnish population, 74% of women aged 20 to 54 rated their health either as good or quite good in 2017 (272).

There are a limited number of GDM prevention studies examining the effects of lifestyle interventions on subjective well-being. Study IV and other existing studies relied on different assessment methods to measure well-being, and, thus, show conflicting results.

6.6 LIMITATIONS AND STRENGTHS

6.6.1 SYSTEMATIC LITERATURE REVIEW (STUDY I)

A major limitation of the systematic review is that most of the studies included used self-reported questionnaires when assessing PA. Self-reported PA data are likely to be somewhat limited due to, for example, perceived social desirability and recall error (58). Furthermore, the studies reviewed used different PA questionnaires or interviews, and only some studies used validated PA questionnaires. Depending on the PA assessment method used, the studies examined different aspects of PA dose (frequency, duration, intensity) and type. In addition to leisure time PA, some studies assessed occupational and transportation PA rendering comparisons between studies difficult. Furthermore, data on PA before, during and after a life event were collected at different times across studies. For example, some studies collected data on women's PA behaviour after pregnancy at different times during the postpartum period. A further limitation is that 7 of the 34 studies included in the review used a retrospective method, thus relying on recall when assessing PA before the life event. Recall of PA may be affected by memory. Another limitation in retrospective studies lies in the possible

cross-contamination of responses when PA before and after a life event is assessed simultaneously.

Participants in the studies included in the review consisted primarily of well-educated Caucasian adults. Thus, generalising the study findings is limited because PA and life events may vary between countries, between ethnic groups and between people with a different socioeconomic status. In addition, cultural and social norms, as well as social insurance benefits (e.g., the duration of maternity leave) may affect PA changes during life events across population groups. The effects of life events on PA may also differ between sexes, and a larger number of studies included in the review assessed the effects of life events on PA amongst women than amongst men.

Further limitations include the limited details on PA reported across the studies included in the review. Some studies did not statistically analyse the magnitude of the change in PA from before and after a life event (238, 273, 274). In addition, any non-response bias may have affected the results of the original studies. Another important limitation is that life events tend to overlap, for example, marriage and pregnancy may closely follow each other. Therefore, examining the effects of one specific life event on health behaviour may be difficult. Finally, although a life event may influence PA, other simultaneous physical, psychological and social factors are likely to also affect an individual's behaviour. Finally, no meta-analysis was conducted for the systematic review because of the small number of included studies examining the same life events, and because of the heterogeneity of existing studies on the topic.

The strength of our systematic review primarily consists of the inclusion of 27 additional articles compared to the previous systematic review on the topic (45). In total, 13 of the 27 additional articles were published after the original systematic review, and 14 were not found by the previous review. Therefore, our review broadens our understanding of the effects of life events on PA. Another strength lies in that all of the articles included in our review assessed PA both before and after a life event, and thus we can draw conclusions on causality better than cross-sectional studies assessing a life event and PA at one only time point. Another key strength is that we conducted the literature search systematically.

6.6.2 UPDATED LITERATURE REVIEW ON PREGNANCY AND PHYSICAL ACTIVITY

For this doctoral thesis, an updated literature review was conducted in 2017 regarding studies examining the effects of pregnancy on PA. The updated literature review was conducted only by one author (Elina Engberg). Other limitations of the updated literature review include that three out of the seven studies did not examine the magnitude of the change in PA statistically. Moreover, the studies included in the updated review assessed

PA with self-reported measures, which may result in under- or overreporting of PA behaviour (58). Objective PA measures, such as accelerometers, have been shown to have a moderate to strong reliability and moderate validity for measuring PA during pregnancy and postpartum (248). However, when changes in PA during pregnancy have been assessed with accelerometry, similar decreases in PA were found both in self-reported PA and in PA assessed with accelerometry (249). In addition, the compliance to PA assessment has been shown to be better with self-reported measure (249). The advantages of objective PA measures include a more precise estimation of PA intensity and short bouts, and the elimination of recall bias. One weakness of an accelerometer is its inability to accurately measure activities involving upper-body movement, pushing or carrying a load and stationary exercise (e.g., cycling or strength training). Moreover, accelerometers are not suitable for measuring water-based activities, which may become more popular during pregnancy. The key strength of the updated literature review is that recent studies on the topic were found. A further strength of the systematic literature review (study I) and the updated literature review of this doctoral thesis is including only studies assessing PA both before and after becoming pregnant, and thus examining a change in PA due to pregnancy.

6.6.3 DEPRESSIVE SYMPTOMS IN PREGNANT WOMEN AT RISK FOR GESTATIONAL DIABETES (STUDY II)

The limitations of study II primarily lie in how we obtained the sample of pregnant women in the general population. Specifically, we obtained a sample that may not be representative of the entire pregnant population, because only 52.7% of the women who received EPDS returned the questionnaire. Furthermore, the women at risk for GDM recruited were motivated to participate in a lifestyle intervention study, and we also excluded high-risk women with severe psychiatric disorders. Therefore, the prevalence of depressive symptoms during pregnancy amongst women at risk for GDM may be even greater than suggested by our findings. A further limitation is that we used no clinical diagnostic criteria for depression, and the participants mostly consisted of native Finnish women. Finally, because the study was cross-sectional, we cannot determine the direction of causality.

The important strengths of our study include that depressive symptoms were assessed during early pregnancy for all women in our study, unlike in many previous studies that examined depressive symptoms amongst women with GDM. Moreover, when we assessed depressive symptoms, the women in our study were not diagnosed with GDM. Thus, a GDM diagnosis could not have affected depressive symptoms amongst the pregnant women. By contrast, many previous studies compared depressive symptoms between women with a GDM diagnosis and pregnant control women. The women in

our study were, however, aware of their risk for GDM. Other strengths of our study include the larger sample size compared with most previous studies, and the use of a validated measure (EPDS) to assess depressive symptoms amongst pregnant women.

6.6.4 CARDIORESPIRATORY FITNESS AND HEALTH-RELATED QUALITY OF LIFE AMONGST WOMEN PLANNING A PREGNANCY AND AT RISK FOR GESTATIONAL DIABETES (STUDY III)

The limitations to study III relate to the participants themselves. We recruited participants who were interested in participating in a lifestyle intervention, and thus they may have been more motivated to engage in physical activities than those women at risk for GDM who did not participate in the study. Consequently, LTPA and cardiorespiratory fitness levels may be even lower amongst all women planning a pregnancy and at risk for GDM. A major limitation of the study is that we did not use an objective measure for LTPA, such as accelerometry. Furthermore, we assessed LTPA using a single self-reported item and not through a validated questionnaire. However, single-item PA measurements assess PA as well as short questionnaires in terms of their reliability and validity (59).

A further limitation lies in the small sample size. In addition, only a small subset of the women invited actually participated in the study. It was challenging to recruit women during this busy phase of life for a trial including several time-consuming clinical measurements, which we did not address in this doctoral dissertation. Another reason that rendered recruitment challenging was that, despite having risk factors for GDM, those young women did not consider themselves at risk at this stage and thus were not that interested in participating in a lifestyle intervention. Another limitation is that study III was cross-sectional (baseline RCT data were used), and therefore no causal conclusions can be drawn.

The strengths of the study include that we examined the association of HRQoL using both self-reported LTPA and objectively measured cardiorespiratory fitness. We assessed cardiorespiratory fitness by measuring VO_{2max}, the gold standard method for determining cardiorespiratory fitness (170). We measured VO_{2max} during a maximal exercise test using a breath-by-breath technique, a reproducible and precise measurement of cardiorespiratory fitness. Less precise methods, such as an estimation of multiple METs based on the treadmill grade and speed in a submaximal exercise test (171, 172) and an estimation of VO_{2max} based on the heart rate and power during a maximal test on a cycle ergometer (173) were used in some previous studies examining HRQoL and cardiorespiratory fitness. Moreover, in our analyses we used an aerobic fitness level classification, which takes into account the age and sex of participants (200). A further

strength is that we controlled the analyses for BMI, the only demographic or health variable associated with HRQoL in our study.

6.6.5 EFFECTS OF LIFESTYLE COUNSELLING ON SELF-RATED HEALTH FROM PREGNANCY TO POSTPARTUM (STUDY IV)

One limitation to study IV lies in the 30% of randomised participants who dropped out during follow-up, potentially affecting our results. Our follow-up period was, however, quite long and lasted from the first trimester of pregnancy to one-year postpartum. A previous study compared drop-outs to those who continued in the RADIEL study during the first year postpartum and reported no differences in age, BMI, family history of diabetes and GDM, finding that drop-outs in the control group were, however, significantly younger than those who continued (195). The number of drop-outs was not exactly the same as in study IV due to the different outcome measures. Drop-outs may have had the lowest motivation for a lifestyle intervention and the poorest self-rated health, also potentially affecting the results. Another explanation for detecting no significant difference in the self-rated health between the intervention and control groups may be that the follow-up time in the RADIEL study still remained too short, since the difference between the intervention and the control groups increased with time. A major limitation of our study is the risk of contamination between the intervention and control groups. Women in the control group visited the study nurse and completed the health and well-being questionnaires at six time points as well, possibly affecting their well-being.

The key strength was that the RADIEL study was a randomised controlled trial, and thus suitable for examining the effects of lifestyle counselling on self-rated health as a secondary outcome. Furthermore, we assessed self-rated health at six time points during a pregnancy and the postpartum period. Thus, we could follow changes across several time points. We followed women from early pregnancy up to one year after giving birth, representing a rather long follow-up time. Our study is one of the very few RCTs aimed at preventing GDM, which examined subjective well-being as an outcome (177). Furthermore, the follow-up in our study is longer than in most other studies reporting on subjective well-being (177). An additional strength lies in adopting a participant-centred measure of health status, thus offering a broader understanding of maternal health and well-being than traditionally used markers of morbidity.

7 CONCLUSIONS

This doctoral dissertation examined the associations between life events — particularly pregnancy —, leisure-time physical activity, cardiorespiratory fitness, depressive symptoms and health-related quality of life, focussing specifically on women at risk for gestational diabetes mellitus.

The main conclusions are:

1. Major life events affect leisure-time physical activity behaviour, whereby physical activity decreases from prepregnancy to pregnancy and from prepregnancy to postpartum. Consequently, individuals experiencing life events could be an important target group for physical activity promotion.

2. The prevalence of depressive symptoms in early pregnancy is higher amongst women at risk for gestational diabetes compared to women in the general pregnant population. These differences appear to be explained by characteristics such as a higher age and BMI and a lower income amongst women at risk for gestational diabetes. Screening for depression amongst pregnant high-risk women as well as treating depressive symptoms in antenatal care requires attention.

3. Better cardiorespiratory fitness and higher levels of leisure-time physical activity are associated with a better health-related quality of life amongst women planning a pregnancy and at risk for gestational diabetes. Even a slightly better cardiorespiratory fitness could be beneficial for self-rated well-being amongst these women. In addition to several other health benefits, increasing physical activity could improve the health-related quality of life of women at risk for gestational diabetes.

4. Improving the self-rated health of women at risk for gestational diabetes through lifestyle counselling from pregnancy to postpartum calls for further research. Future studies should examine the effects of lifestyle counselling combined with psychological support to improve self-rated well-being amongst high-risk pregnant women.

8 PERSPECTIVES

When considering previous studies in the fields of PA, pregnancy and mental well-being, the major strengths of this doctoral dissertation include using a validated measure to assess depressive symptoms during pregnancy amongst a rather large sample of women, the objective measurement method of cardiorespiratory fitness and examining the effects of lifestyle counselling on subjective well-being from early pregnancy to one-year postpartum using a RCT study design. This doctoral dissertation primarily included Caucasian participants, and, therefore, the generalisability of the results to other ethnic groups remains limited. Furthermore, the women at risk for GDM included in this dissertation represented women of Finnish origin, perhaps further limiting the generalisability of the results to other countries.

This dissertation demonstrated that major life events affect PA. The effects depend on different life events, and on the age and sex of those experiencing the life events. The systematic review on life events and PA included in this dissertation includes a greater number of studies than the previously published systematic review on the topic, thus broadening our knowledge of the relationship between life events and PA. Amongst life events, this dissertation focused specifically on the effects of pregnancy on PA. Unlike previous literature reviews on the topic, this dissertation examined merely within-woman changes in PA caused by pregnancy by including only studies assessing PA both before and after becoming pregnant. Thus, this doctoral dissertation strengthens the evidence demonstrating that PA levels decrease from prepregnancy to pregnancy, and from prepregnancy to postpartum. In order to avoid the risks related to physical inactivity and to gain the health and well-being benefits of regular PA, antenatal care providers should advise women on the importance and safety of PA during pregnancy and the postpartum period, as well as encourage and motivate them to be physically active.

GDM is an emerging global epidemic amongst pregnant women, leading to negative health consequences for both the mother and the child. Previous studies have shown that depression is more common amongst people with type 1 or type 2 diabetes compared to those without, yet the prevalence of depressive symptoms amongst women with GDM has not been studied as extensively. The results of this doctoral dissertation add to that evidence by showing that the prevalence of depressive symptoms during early pregnancy is higher amongst women at high risk for GDM compared to women in the general pregnant population in Finland. The higher prevalence of depressive symptoms amongst high-risk women seems to be explained by characteristics such as age, BMI and income. Regardless of the factors affecting or mechanisms behind the higher prevalence, the adverse mental

well-being of high-risk women should be the focus of research as well as clinical practice, thus, affecting adherence to GDM prevention strategies, such as lifestyle changes or later to the treatment of GDM. Depressive symptoms should be screened not only in postpartum care, but also in antenatal care, considering the adverse consequences for both the mother and the child.

Previous studies suggest that GDM is related to adverse HRQoL and self-rated health, whereas factors associated with a poorer HRQoL need to be identified. To our knowledge, this dissertation represents the first examination of whether measured cardiorespiratory fitness and self-reported LTPA associate with HRQoL amongst women planning a pregnancy and at risk for GDM. Our results are similar to previous studies examining other populations regarding the positive association between LTPA and HRQoL. The results of this dissertation agree with a limited number of previous studies examining measured cardiovascular fitness and HRQoL showing positive associations on cardiovascular fitness mainly related to the physical domains of HRQoL. The results of this dissertation identified no associations between LTPA or cardiorespiratory fitness and the mental dimensions of HRQoL, which may result from the small sample size in that particular study. In addition, this dissertation suggests that even a slightly better cardiorespiratory fitness could benefit self-rated health and the physical well-being of women planning a pregnancy and at risk for GDM. Studies have shown that lifestyle and PA interventions can prevent GDM, although the role of objectively measured cardiorespiratory fitness in this remains unclear. GDM prevention programmes should assess and aim to improve cardiorespiratory fitness.

Currently, only a small number of lifestyle intervention studies aimed at preventing GDM have examined whether the intervention also affects the subjective well-being of the women. In accordance with these few previous studies, the randomised controlled lifestyle intervention aimed at preventing GDM included in this dissertation had no significant effect on the self-rated health of the participants. The drop-out rate of 30% during the study period, lasting from early pregnancy to one-year postpartum, may have affected this result. Further research is needed to identify effective methods to improve the subjective well-being amongst women at risk for gestational diabetes during pregnancy and the postpartum period. Lifestyle programmes combined with psychological interventions could be effective both in the prevention of GDM and in improving the mental well-being of women at risk. Mental well-being should be taken into account when planning and implementing GDM prevention studies and programmes.

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