MATERNAL PHYSICAL ACTIVITY:
INFLUENCE ON MATERNAL AND DELIVERY OUTCOMES.

By

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A THESIS

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DECLARATION

I, Estelle Dorothy Watson, hereby declare that this thesis is my own work. It is being submitted for the degree of Doctor of Philosophy at the University of the Witwatersrand, Johannesburg, South Africa. It has not been submitted before for any degree or examination at this, or any other, University.

Signed

This 21st day of October 2016, in Johannesburg.

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DEFINITIONS

Physical activity Physical activity is defined as any bodily movement produced by skeletal muscles that results in energy expenditure, and can occur in various domains such as recreational, occupational, transport, household or other activities (1).

Exercise Exercise is physical activity that is planned, structured and repetitive, with the aim of increasing or maintaining physical fitness levels (1).

Sedentary behaviour Sedentary behaviour is defined as activities requiring low levels of energy expenditure in the range of 1-1.5 Metabolic Equivalent of Task or METs (2).

ACRONYMS AND ABBREVIATIONS

ACSM	American College of Sports Medicine
ACOG	American College of Obstetricians and Gynaecologists
AGA	Appropriate for gestational age
BMI	Body mass index
CVD	Cardiovascular disease
EGWG	Excessive gestational weight gain
ENMO	Euclidean Norm Minus One
GDM	Gestational diabetes mellitus
GPAQ	Global Physical Activity Questionnaire
GWG	Gestational weight gain
HIC	High-income country
IOM	Institute of Medicine
NCDs	Non-communicable diseases
PA	Physical activity
LBW	Low birth weight
LGA	Large for gestational age
LMIC	Low-to-middle income country
METs	Metabolic Equivalents
MPs	Medical Practitioners
MVPA	Moderate-to-vigorous physical activity
SANHANES	South African National Health and Nutrition Examination Survey
SBQ	Sedentary Behaviour Questionnaire
SES	Socioeconomic status
SGA	Small for gestational age
T2D	Type 2 Diabetes mellitus
US	United States
VLBW	Very low birth weight
WHO	World Health Organisation

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To my wonderful husband, Damian – you are a constant source of support (both near and far), love, advice, friendship and laughter. You give me the confidence to push myself, but also to just be myself. Every day I am grateful that you chose me.

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To my Wonderful Counsellor, whose wisdom surpasses all things.

"For physical training is of some value, but godliness has value for all things, holding promise for both the present life and the life to come."1 Timothy 4:8New International Version (NIV)

PERSONAL PREFACE

My love for sport led me to pursue an undergraduate degree in Sport Science, with the aim to work with elite athletes. But it was my experiences in a little community exercise class in Soweto that made me realise that physical activity - and maybe life in general - is not only about achievement. Sometimes it is the smaller benefits, such as quality of life, health and enjoyment, which have the greatest importance.

I guess this PhD is a combination of my passion for physical activity, my fascination with pregnancy as a time to change behaviours and my quest to save the world. In their recent report in *the Lancet*, Hallal et al. (3) highlight the gap in physical activity surveillance research in low-to-middle-income countries, particularly in Africa. Lifestyle and environmental transitions have left South African women particularly vulnerable to issues of obesity and physical inactivity, however little research has been done in this population during pregnancy. Pregnancy presents a unique time in a women's life, and has been described as a "teachable moment" (4) for changing health behaviours, not only for the mother, but future generations as well. What a great life stage in which to conduct research!

I believe this thesis encompasses many of my burning formative questions that may help to build future interventions. I wanted to know how active women really are during pregnancy (Chapter 5), I wanted to know why they were active (Chapter 3), and if there were any benefits to being active (Chapter 6), and how could we go about changing behaviours (Chapter 4).

Many people asked me to justify the addition of qualitative research into my quantitatively-dominated study. The qualitative study made those numbers come alive, take on personality and a deeper meaning. It gave my research a name, and a face, and made me more determined than ever to change these women's lives. It also allowed me to peak through the window into many these women's lives:

"I enjoy coming here [to the research centre]...telling me about baby. I did not know that I could see my child … at the clinic they do not allow us to know if it is a boy or is it a girl…''[Qualitative research participant]. And so, sometimes it's the things we don't set out to discover - have nothing to do with the topic at hand - that have the most profound, long-lasting effect on us.

This has been a journey of both professional and personal development. It has been a journey of patience, and of personal discovery – much more than I ever expected. It has opened doors to meet wonderful people, both at home and overseas, to forge collaborations and, more importantly, friendships. It also provided me the opportunity to live in Graz, Austria for six months – a lesson in culture, language, hard work, "wissenschaft" and adventure.

I truly believe that physical activity is the hidden key to health and wellness, longevity and enjoyment of life. I have seen it with my own eyes, I have heard it from the stories of patients and participants alike, and I will continue to search for the evidence for it. I believe South Africans, maybe more than most populations, will benefit from an active lifestyle. We have a desperate need for our people to be healthy, our people have a desperate need for a thriving social community, but we have scarce resources in which to do this - could we not combine all these factors, and would it not be called physical activity?

"A good head and good heart are always a formidable combination. But when you add to that a literate tongue or pen, then you have something very special" Nelson Mandela

PEER REVIEWED PUBLICATIONS (PHD)

Chapter One

Section Two is based in part on: Pearson, J. T; Watson, E. D; Lambert, E. V. & Micklesfield, L. K. (2015) The role of physical activity during pregnancy in determining maternal and fetal outcomes. *South African Journal of Sports Medicine*, 24(4): 93-96.

Chapter Three

Watson, E.D, Norris, S. A., Draper, C. D., Jones, R.A., van Poppel, M. N. M &Micklesfield, L.K (2016) "Just because you're pregnant, doesn't mean you're sick!" A qualitative study of beliefs regarding physical activity in black South African women. *BMC Pregnancy and Childbirth,* 16:174.

Chapter Four

Watson, E.D; Oddie, B. & Constantinou, D. (2015) Exercise during pregnancy: knowledge and beliefs of medical practitioners in South Africa. *BMC Pregnancy and Childbirth*, 15:245

Chapter Five

Watson, E.D, van Poppel, M.N.M, Jones, R.A., Norris, S.A. & Micklesfield, L.K. Are South African Mom's Moving? Patterns and correlates of physical activity and sedentary behaviour in pregnant black South African women. *In press: Journal of Physical Activity and Health*

Chapter Six

Watson, E.D, Brage, S., White, T., Westgate, K., Norris, S.A., van Poppel, M.N.M. & Micklesfield, L.K. The influence of objectively measured physical activity during pregnancy on maternal and birth outcomes in black South African women. *Submitted to Maternal and Child Health Journal*

RELATED PEER REVIEWED PUBLICATIONS

Dietz, P., Watson, E.D., Sattler, M., Ruf, W., Titze, S. & Van Poppel, M. (2016) The influence of physical activity during pregnancy on maternal, fetal or infant heart rate variability: a systematic review. *In press BMC Pregnancy and Childbirth*

Khan, T., MacCaulay, S., Norris, S., Micklesfield, L. & Watson, E.D. (2016). Study Protocol: Physical activity and the risk for gestational diabetes mellitus amongst pregnant women living in Soweto. *BMC Women's Health*, 16:66.

Watson, E.D., Micklesfield, L.K., Van Poppel, M. Norris, S.A., Sattler, M.C. & Dietz, P. Validity of the Global Physical Activity (GPAQ) in assessing physical activity and sedentary behaviour in pregnant women. *Submitted to International Journal of Behavioural Nutrition and Physical Activity.*

CONFERENCE PRESENTATIONS

Oral presentation

Are our pregnant mom's exercising for two? Physical activity profiles of black South African pregnant women. *South African Sports Medicine Association (SASMA) Johannesburg, South Africa (2015)*

South African Doctor's Knowledge on Physical Activity During Pregnancy. *International Congress on Physical Activity and Public Health (ICPAPH) Rio de Janeiro, Brazil (2014)*

Poster presentation

“Just because you pregnant, doesn’t mean you’re sick” Assessing beliefs and attitudes towards physical activity during pregnancy in South African women *International Society for Behavioural Nutrition and Physical Activity (ISBNPA) Cape Town, South Africa (2016)*

Are our moms moving? Assessing physical activity levels during pregnancy in South African women. *International Society for Behavioural Nutrition and Physical Activity (ISBNPA) Edinburgh, UK (2015)*

A Pause Before Pregnancy? Pregravid Physical Activity and Weight Status of Urban Black South African Women. *International Congress on Physical Activity and Public Health (ICPAPH) Rio de Janeiro, Brazil (2014)*

Should Moms get moving? Maternal physical activity. *Wits Postgraduate Symposium, Johannesburg, South Africa (2013)*

Workshops

Prenatal exercise prescription. *Life Through Movement Conference (LTMC) Stellenbosch, South Africa (2014)*

Scientific Talks/Seminars

Maternal physical activity: Influences on maternal and delivery outcomes. *Postgraduate Lunchtime talks, University of the Witwatersrand Faculty of Health Sciences, Chris Hani Baragwanath Hospital (2013)*

Health effects of physical activity during pregnancy. *Human Genetics Seminar Series, University of the Witwatersrand Faculty of Health Sciences (2016)*

Media publications

Interview on running during pregnancy. *Modern Athlete Magazine (2015)*

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ABSTRACT

Background Physical activity is a potentially powerful tool for addressing the growing concern of non-communicable diseases in low-to-middle income countries. In South Africa, black women are particularly vulnerable to a high prevalence of overweight and obesity as well as low physical activity levels. During pregnancy, the physiological and psychological changes that occur during this unique period may put women at greater risk of being physically inactive and sedentary. Research from high-income countries has shown that, despite the benefits of physical activity during this period, the majority of women do not meet the physical activity recommendations (≥ 150 minutes of moderate physical activity per week), or reduce their activity levels during pregnancy. Several positive associations have been demonstrated between regular physical activity and maternal outcomes, such as improved cardiovascular and strength, as well as a reduced risk of gestational diabetes mellitus, excessive gestational weight gain, gestational hypertension and preeclampsia. Although research indicates the beneficial effects of physical activity during pregnancy on maternal health, controversy still exists regarding its influence on birth outcomes. The theory of metabolic programming provides insight into the potential influence of health behaviours during pregnancy and long term implications for the offspring. Therefore, pregnancy may be a critical time in which to assess, and change, health behaviours that may impact not only the mother, but the next generation as well.

Aim Despite the potential role of physical activity in improving maternal health, very little research has been done in a South African context. Therefore, the overall aim of this study is to understand and examine maternal physical activity during pregnancy, and determine its association with maternal and birth outcomes. This thesis is presented as five study components: 1) to provide a theoretical background of evidence examining the role of PA for health during the

prenatal period; 2) to examine the attitudes, beliefs and perceived barriers to PA during pregnancy in black South African women; 3) to assess the knowledge, attitudes and beliefs of South African medical practitioners towards exercise prescription during pregnancy; 4) to describe the patterns and correlates of self-reported PA levels during pregnancy in black South African women; and lastly 5) to objectively measure PA at two time points during pregnancy and examine its association with maternal outcomes and birth outcomes.

Methods Understanding the attitudes and beliefs of pregnant women and their healthcare providers was done through semi-structured interviews (n=13; 29-33 weeks gestation) and a questionnaire (n=96), respectively. A deductive thematic analysis was done for the qualitative data, based on the Theory of Planned Behaviour. The longitudinal observation of physical activity during pregnancy used both a self-report questionnaire, the Global Physical Activity Questionnaire, as well as a hip-mounted triaxial accelerometer (ActiGraph GT3X+). Physical activity was expressed as MET mins/wk (GPAQ) and gravity-based acceleration units (mg) (accelerometery). Physical activity was measured at two time points during pregnancy namely, 14-18 weeks (GPAQ: n=332; accelerometer, n=120) and 29-33 weeks (GPAQ: n=256; accelerometer: n=90) gestation. Maternal outcomes included both weight and weight change at 29-33 weeks gestation. Birth outcomes included gestational age, birth weight, ponderal index and Apgar score, measured within 48 hours of delivery.

Results Semi-structured interviews showed that although the majority of women believed that physical activity was beneficial, this did not appear to translate into behaviour. Reasons for this included pregnancy-related discomforts as well as lack of time, money and physical activity-related education, all of which can contribute to a reduced perceived control to become active.

Opportunities to participate in group exercise classes were a commonly reported facilitator for becoming active. In addition, women reported that influential role players, such as family, friends and healthcare providers, as well as cultural beliefs, provided vague, conflicting and often discouraging advice about physical activity during pregnancy.

From a health care provider's perspective, the majority (98% of the medical practitioners) believed that exercise during pregnancy is beneficial, and were knowledgeable on most of the expected benefits. Seventy-eight percent believed that providing exercise advice is an important part of prenatal care, however only 19% provided information pamphlets and few (24%) referred their patients to exercise specialists. A large majority (83%) were unaware of the American College of Obstetrician and Gynaecologists' recommended exercise guidelines. Although age and years of practice played no role in this awareness, practitioners who focused on obstetrics and gynaecology were more likely to be aware of the current ACOG guidelines, than those in general practice ($p<0.001$).

Both self-reported (GPAQ) and objectively measured (accelerometry) physical activity declined significantly from the second to the third trimester (600 MET mins/wk vs. 480 MET mins/wk; $p=0.01$ and 12.8 ± 4.1mg vs. 9.7 ± 3.6mg, $p=<0.01$). Longitudinal data analysis (GPAQ MET mins/wk, n=256) showed that 132 (52%) of the women were active (according to the ACOG guidelines) at 14-18 weeks gestation, and this decreased to 111 (43.4%) at 29-33 weeks gestation. The majority of physical activity time (as measured by the GPAQ) was spent in walking for transport (80%), and less than 2% in recreational activities. In both trimesters, married women were less likely to walk for transport (second trimester: $\beta= -0.12$; 95%CI=-0.31,-

0.02, third trimester: β=-0.17; 95%CI=-0.47, -0.07) and women who owned a car were more likely to engage in leisure time PA (second trimester:β= 0.16; 95%CI=0.02-0.32, third trimester: β=0.17; 95%CI=0.04-0.27), but less likely to walk for transport in their second trimester (β= -0.11; 95%CI=-0.31,-0.00). The women reported spending an average of five hours per day sitting (range=180-480minutes). Objectively measured physical activity at 29-33 weeks as well as change in physical activity was inversely associated with gestational weight change at the same time point (β= -0.24; 95%CI= -0.49; -0.00; p=0.05 and β= -0.36; 95%CI= -0.62; -0.10; p=0.01). No significant associations were found between physical activity and birth outcomes. Furthermore, a high prevalence of overweight and obesity in early pregnancy (67.9%, n=332) and self-reported HIV (23.5%, n=332) was found in this population.

Conclusion This study provides theoretical insight into the beliefs of urban South African women regarding physical activity during pregnancy. Findings from this study suggest that a holistic approach to improve physical activity compliance during pregnancy is needed, inclusive of physical activity education and exercise opportunities within a community setting. The role of healthcare providers in providing prenatal physical activity counselling should not be underestimated, and our study found that although the medical practitioners were largely positive towards exercise during pregnancy, their advice did not always align with the current guidelines. Therefore, better dissemination of available research is warranted, to bridge the gap between clinical knowledge and current recommendations for physical activity promotion. This is important since our study demonstrated low and declining levels of physical activity during pregnancy in this population, which is of concern. We demonstrated that physical activity during pregnancy may be an effective method to control gestational weight gain, whilst presenting no adverse risk for fetal development, in black South African women from a low-income setting. This is particularly important as most of this population appears to be overweight or obese at the start of their pregnancy. Therefore, interventions that include lifestyle education and provision of accessible recreational physical activity programmes for pregnant women are needed, and this study presents critical formative work upon which these contextually and culturally sensitive interventions can be developed.

Chapter One

LITERATURE REVIEW

"It is health that is real wealth and not pieces of gold and silver."

Mahatma Gandhi

Introduction

The burden of non-communicable diseases (NCDs) has been described in the literature as an epidemic (5) and a global crisis (6). These diseases, which include cardiovascular disease (CVD), some cancers, respiratory diseases and type 2 diabetes (T2D), are estimated to cause 60% of deaths globally (7). Predictions suggest a rise in NCD deaths from 59% in 2002 to 69% in 2030 (8), but the growth rate is so rapid that many estimations are rapidly becoming outdated (9, 10).

Low-to-middle income countries (LMICs) are particularly vulnerable to increasing rates of NCDs. In fact, 85% of all premature NCD deaths (before 70 years old) occur in LMICs. This, coupled with residual communicable diseases, such as HIV/Aids, tuberculosis and malaria, present a worrisome double-burden of disease. Although the cause of NCDs is a combination of genetic, behavioural and environmental factors, the rapid increase in the prevalence in recent years would also suggest a shift in health related behaviours (11). In particular, physical inactivity has been shown to be as detrimental as smoking and obesity in the development of NCDs (12). It is estimated that physical inactivity is associated with 9% of premature mortality and up to 10% of NCDs, worldwide (12), and therefore encouraging physical activity (PA) on a population basis may be an important area to intervene in the prevention and management of these diseases.

There is increasing evidence for the role of prenatal factors in the development of NCDs (13, 14). Research is currently exploring the effects of fetal exposure to specific risk factors, including overnutrition or undernutrition, and its long-lasting effect on the health of the offspring, termed *metabolic programming* (13-15). This exposure to an adverse fetal environment in early life is thought to disrupt normal growth and development, which leads to an adult phenotype that is susceptible to NCDs (16). Therefore, assessing maternal health risk, and addressing maternal lifestyle factors (such as smoking, diet and PA) is important in determining and preventing the development of disease not only in the mother, but also in her offspring (17).

Physical activity may play an important role in maternal and fetal health during pregnancy (18-20). In the absence of complications, it has been shown to be both safe and beneficial for the mother and the fetus, and pregnant women are recommended to participate in regular PA similar to their non-pregnant counterparts, and should aim for >=150 minutes of moderate intensity activity (or >=600 MET minutes) per week (19, 21-23).

Research has reported a positive association between regular PA and maternal outcomes, such as improved course of delivery, reduced incidence of gestational diabetes mellitus (GDM) (24), and a reduced risk of excessive gestational weight gain (EGWG) (25-28). Less is known about the effects of maternal PA on fetal growth and development in utero. Some studies have shown that moderate and high intensity occupational activities may retard fetal growth (29), while others have reported that recreational PA appears to have a protective effect (28, 30). However, there appears to be a consensus that light to moderate PA does not adversely affect birth weight and prematurity, and may even provide a protective effect (20, 28). Despite these recommendations, and the wealth of evidence to support the safety and benefits of participating in regular PA during pregnancy, many studies have shown that the majority of pregnant women are not physically active enough (31), tend to do less PA than their non-pregnant counterparts (32), and reduce their PA during pregnancy (18). In addition, a low socioeconomic status (SES) has been associated with lower PA levels during pregnancy (33, 34), making these women a particularly vulnerable population group.

However, despite the burden of disease in LMICs, and the potential modifying effects of PA during this crucial time in the lifespan, little is known about physical activity levels and its influence on maternal and birth outcomes during pregnancy in these populations. African women living in urban areas are particularly vulnerable to low levels of PA and overweight/obesity (35-37). In South Africa, just over half of all women of childbearing age are meeting the PA guidelines (38) and 45% were found to be physically unfit (39). Physical activity as a method to prevent and promote health is also attractive due to its cost effectiveness (40), especially within a limited resource setting, such as LMICs.

This chapter is presented in two sections. Firstly, the broader context of NCDs and its prevalence and burden in LMICs is discussed, with particular emphasis on South Africa. One causal modifiable risk factor for NCDs - specifically PA - is presented, and the section concludes with the role of early life factors in the development of NCDs. The conceptual framework for this section is presented in Figure 1 (41).

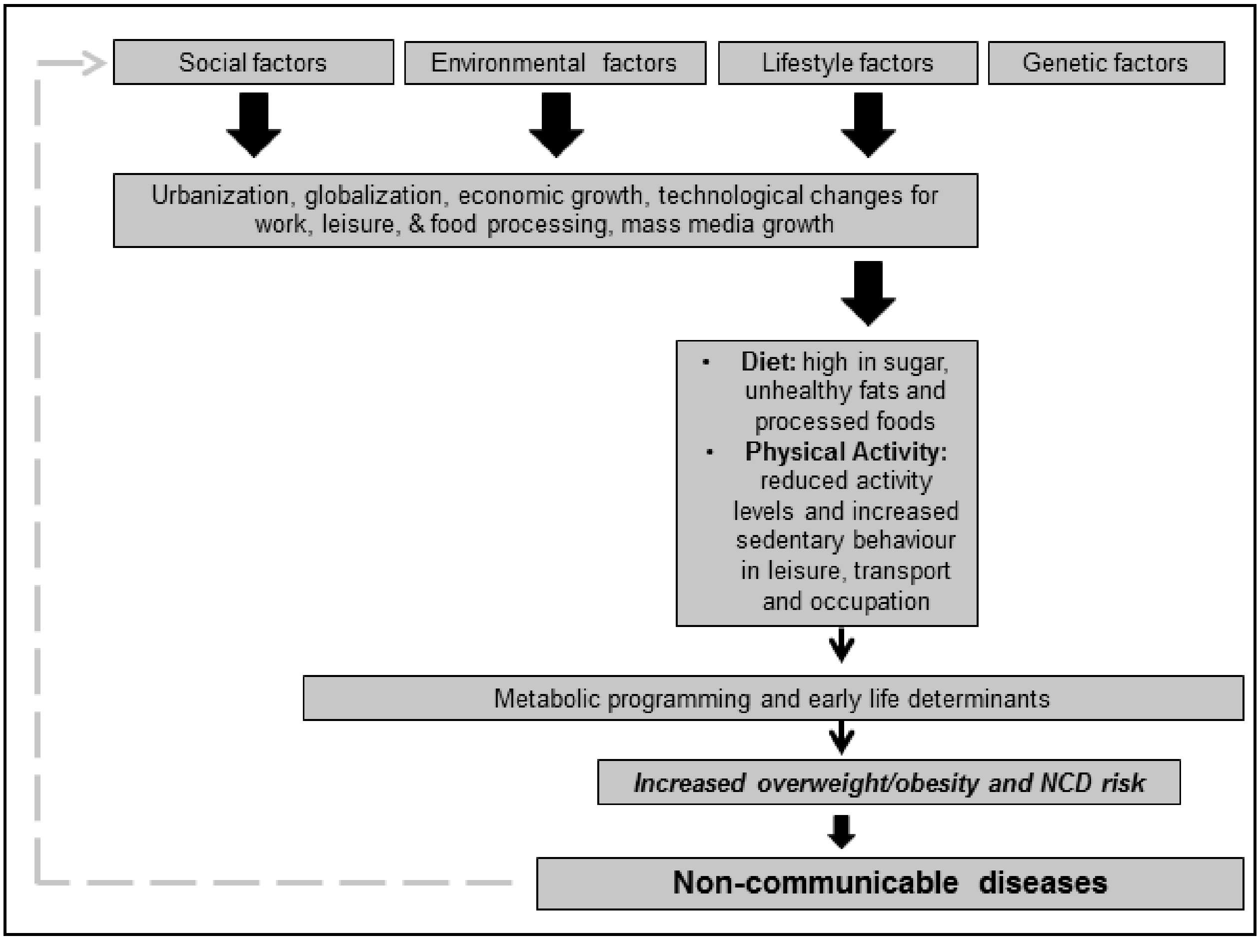

Figure 1 Conceptual Framework for understanding the causal factors of non-communicable disease (41)

The second section will address the complex issues regarding the influence of PA on maternal and birth outcomes. There are many different factors that contribute to beneficial and adverse pregnancy outcomes, and the complexities of these can be better understood through the conceptual framework presented in Figure 2 (20, 42, 43).

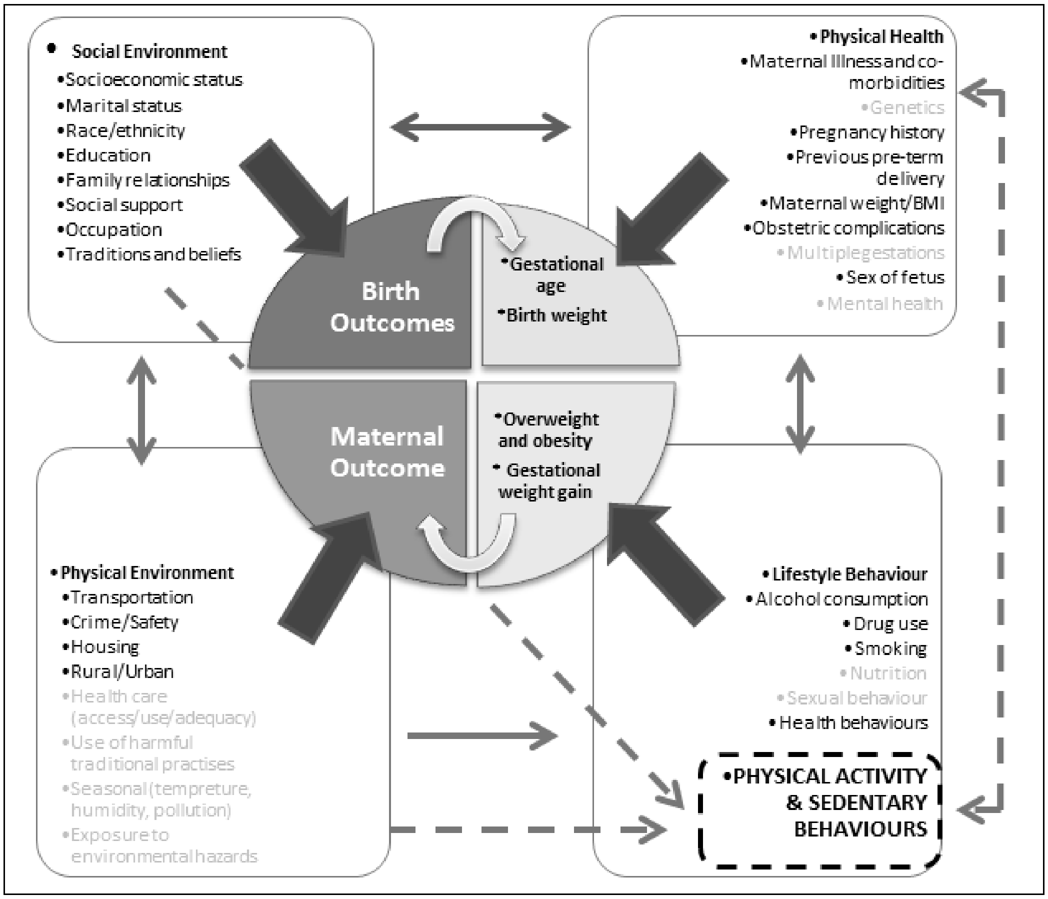

Figure 2 Conceptual Framework in understanding maternal physical activity (20, 42, 43)

The conceptual framework for this research considers the broad range of factors that have been shown to influence pregnancy outcomes and organizes them into categories to create a comprehensive model. Maternal and birth outcomes are affected by four main categories, namely *maternal physical health*, *maternal lifestyle behaviours* (including PA and sedentary behaviour), the *physical environment* and the *social environment* (44). In health-related epidemiology, biological mechanisms are essential to explain various disease related outcomes, and these are included in *maternal physical health*. From a public health perspective, the behavioural, environmental and social domains provide a useful framework to describe the wider influences on outcomes and behaviour (45). These four categories in turn are influenced by each other, and therefore can directly or indirectly influence maternal and birth outcomes. This model also identifies PA and sedentary behaviour as both an exposure and an outcome, as they directly affect maternal and birth outcomes, and are in turn influenced by the physical health of the mother, as well as the physical and social environment.

SECTION 1: THE BURDEN OF NON-COMMUNICABLE DISEASE IN SOUTH AFRICA

1.1. New age epidemic: the prevalence of non-communicable diseases

In South Africa, NCDs are estimated to have contributed to 28% of the burden of disease in 2004 (46), 32% in 2009 (47), and 43% in 2014 (48). According to recent World Health Organisation (WHO) data, the probability of premature death from NCDs in South Africa is as high as 27% (48). This high prevalence, coupled with chronic infectious disease and the HIV epidemic, presents a substantial economic burden to society and its health care systems, and the profound economic effects are globally underestimated (49). In Johannesburg, (the largest city in South Africa) ischemic heart and cerebrovascular diseases have even overtaken HIV/AIDS as the leading cause of death (47).

Indeed, issues of globalisation, inequality and urbanisation, all contribute towards the prevalence of NCDs in LMICs (50). Although many of the underlying causes of NCDs are well-known and the modifiable risk factors are shared amongst countries (6), in sub-Saharan Africa (SSA) these associations appear to differ between countries, between rural and urban populations, and within subpopulations (51). This suggests that the current evidence regarding NCDs, which originates mostly from high income countries, should be interpreted with caution, and not be indiscriminately applied to the African context (5, 51). It also highlights the need for contextually specific research within LMICs, and in Africa in particular, in order to understand the epidemiology of NCDs that will better inform interventions (51). Prevention and management of NCDs in LMICs needs to be prioritised, especially when the future of the NCD burden is considered, coupled with the already strained health care system (7, 52). To this end, risk factors, such as lifestyle behaviours, can be addressed with potentially minimum cost and maximum impact on disease risk (7)

Globally, there has been a shift in the last few decades from infectious diseases (associated with deficiencies in nutrition or poor environmental sanitation) to chronic and degenerative diseases (NCDs) (53-57). This transition describes the changing patterns in health, mortality, disease and fertility over time, and their interactions with socioeconomic, environmental, lifestyle, demographic, health care and technological factors (55, 56). More specifically, Popkin has described the "nutrition transition" (58, 59) as the effect of shifts in socioeconomics, demographics and health which results in changes in dietary and PA patterns, and ultimately an increase in NCDs (Figure 4). Diets rich in saturated fats, sugar and refined carbohydrates, coupled with lower occupational and recreational PA levels, have become the trend in modern societies (41, 60).

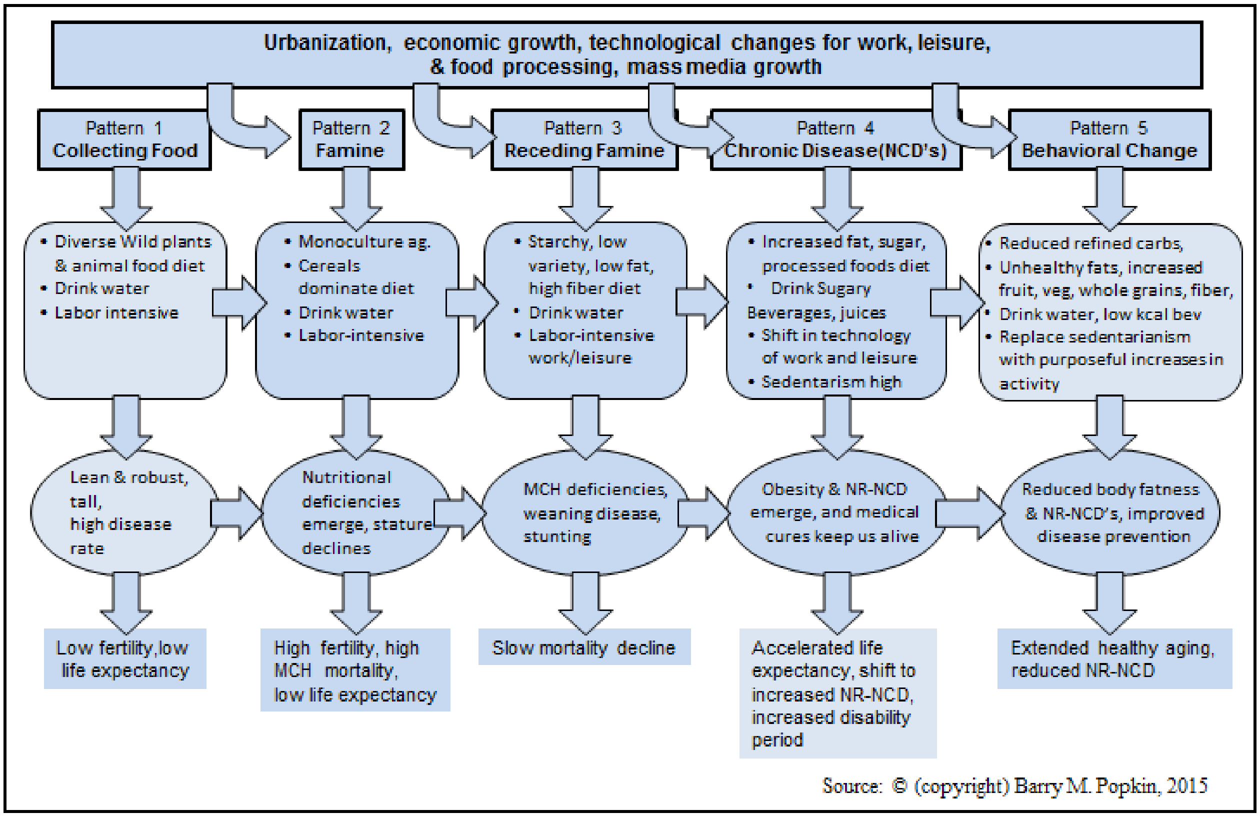

Figure 3 The stages of the nutrition transition (used with permission) (61)

In South Africa, evidence for this transition is demonstrated through the large differences in diets between urban and rural populations (37). Urban diets tend toward a higher consumption of energy dense food, sugar and refined carbohydrates, and saturated fats (58). Changes from more traditional diets in rural areas to “Western” diets (which are higher in saturated fats and refined carbohydrates) in urban areas have been noted (58, 62). This has resulted in a high prevalence of both under- and overweight within the same community, and often within one household, commonly found in LMICs (63-66). These changes in dietary intake are often coupled with changes in other lifestyle behaviours such as physical activity levels.

1.2. I like to move it! The role of physical activity

Physical inactivity has been identified as the fourth leading risk factor for NCDs worldwide (12, 67). There is strong and sufficient evidence to promote PA as a global public health priority (68). Its cost effectiveness, and role in preventing and managing disease, is indisputable (3, 67, 69). Making inactive people active has been shown to improve health outcomes, reduce death rates and relieve some of the economic burden of disease (12, 67, 70). In fact, 6-10% of all NCD deaths can be attributed to physical inactivity (71), and in South Africa, it has been shown to account for 3.3% of deaths per year and 1.1% of disability-adjusted-life-years (72), making it a costly burden to the healthcare system.

Indeed, there is a vast amount of research on the health benefits of PA for people of all ages, sexes and races. Perhaps one of the most popular pieces of evidence to support this is the Report of the Surgeon General (73), which emphasises the role of PA in the reduction of risk for premature mortality, as well as CVD, hypertension, some cancers and T2D. In fact, Warburton et al. (74) describes the evidence for the effectiveness of regular PA for the prevention of NCDs , and improvement in musculoskeletal and mental health, as *irrefutable*. The linear relationship between PA and health status appears to have a critical point at 150 minutes of moderate, or 75 minutes of vigorous (or a combination of the two) PA per week (74, 75), making these the global PA recommendations for health.

Yet despite these benefits, a significant portion of the world's population is not sufficiently active (67). Population estimates for physical inactivity range between 17-43%, and women are generally found to be more inactive than men across the globe (3). In Africa, an estimated 27.5%

of the population are not meeting the recommended guidelines for PA. South Africa also appears to be a relatively inactive nation (76), with an estimated 46% of South Africans not meeting the PA recommendations (77). More recent data from the South African National Health and Nutrition Examination Survey (SANHANES) and the Transition and Health during Urbanisation in South Africa (THUSA) study show that women are particularly vulnerable to low levels of physical fitness and activity (39, 78). According to the THUSA study, 59.6% of black women living in the North West Province of South Africa spend most of their leisure time in sedentary pursuits (78). Further, in studies of populations undergoing the nutrition transition, a 30-40% prevalence of inactivity during work or leisure time among women has been reported (37, 79). High risk groups for physical inactivity include young females (18-24 years of age) living in urban formal settlements (37, 39).

Not only is a third of the world's population inactive, but there appears to be a change in PA patterns (58, 80, 81). The prevalence of physical inactivity is on the increase (67) and in a review of five countries, Ng & Popkin (80) concluded that this trend appears to be similar across the globe. The authors estimated that the average American will only expend 142 MET minutes per week, with China and Brazil projected to reach the same levels in the near future. Similarly, Stamatakis et al. (82) assessed trends in PA levels in England from 1991 to 2004, and found a decline in work-related PA over that time. Data from the US has also captured declining rates of PA in the last 50 years, particularly with work-related and transportation activities (83).

Patterns of activity, and patterns of decline in activity, differ between countries. Although most countries have experienced a decline in walking and bicycling, in Europe (where the urban environment is more conductive to active transport) this decline is less severe (84). Brazil, China and India have all showed trends of increased vehicle ownership leading to reduced active travel (80). In South Africa, Mokonyama & Venter (85) have estimated an explosive growth in car ownership, particularly within urban, previously disadvantaged areas, which could lead to reduced PA levels in the near future. Furthermore, an increase in sedentary time throughout all these countries has been attributed to growth in media technologies such as television, computers and the internet (80). In a study of 977 black South African women, Gradidge et al. (86) found that car ownership was associated with less walking for transport, and TV ownership was associated with both lower MVPA and walking for transport. Indeed, many of these changes in societal behaviours are linked to the rise in obesity rates and nutrition-related NCDs (87-89).

1.3. The big outcome: The burden of overweight and obesity in South Africa

Although there is remarkable variation in the prevalence rates of overweight and obesity around the world, it is considered a global epidemic (90). Many studies have demonstrated the rapid shift in body composition and overweight/obesity status in recent years (58, 63, 91, 92). Worldwide, an estimated 36-38%, or 2 billion people, are overweight or obese (93, 94). National Health and Nutrition Estimation Survey (NHANES) data from the US estimates the overweight and obesity prevalence at around 68% (33% and 35% respectively) (95-97), and recent self-reported European data from 16 countries showed a 47.6% prevalence rate (98). Global trends have indicated an increase in overweight and obesity by up to 8% in adults and 5% in children from 2008-2013 (94), with alarming statistics from the US and UK showing an increase of obesity of up to 1% per annum (9).

In LMICs this increase in obesity rates appears to be worse than HICs, with Popkin and Doak (99) showing a 17% increase over a ten year period. In South Africa, obesity rates have shown a steeper than global increase of 3.7% between 2008 and 2012 (100). Recent national data from the SANHANES (2013) has reported an overall prevalence of overweight and obesity at 32.5% and 15.6% respectively (39). Although survey statistics and BMI classifications should always be interpreted with caution, it is more likely that inaccuracies will lead to an underestimation rather than an overestimation within populations (9). This rapid rise in overweight and obesity may be a natural consequence of the nutrition transition and changing lifestyle behaviour patterns in society (as shown in Figure 4) (9, 90, 101), with the sharp economic change and urbanisation contributing to the rise in obesity prevalence in South Africa (89).

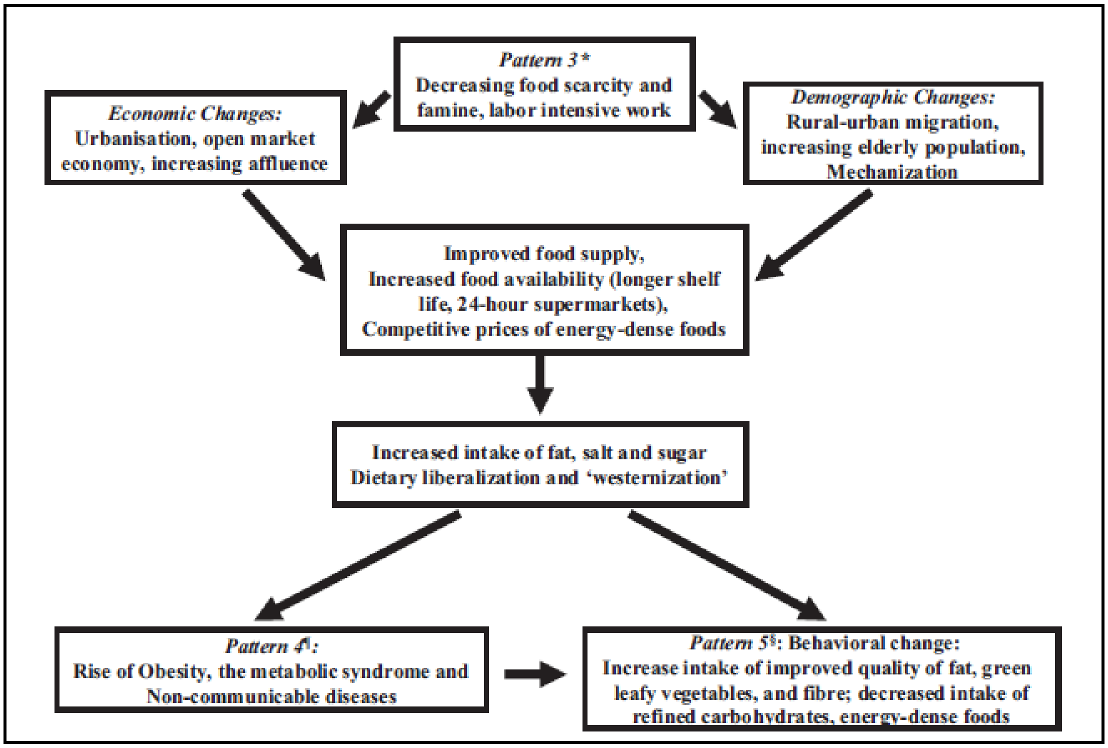

Figure 4 The link between nutrition transition, urbanisation and the rise in obesity prevalence (101).

The prevalence of overweight and obesity appear to be consistently more prominent in women than in men in LMICs (57, 89, 90, 94) and African countries are no exception (89). Statistics from Ghana, Morocco and South Africa show that overweight and obesity prevalence rates in women are 3-6 fold higher than in men (37, 102, 103). This gender divide was shown in South African national survey data as far back as 1998, where women had an overweight and obesity prevalence of 56.6%, which is a 27.4% higher rate than their male counterparts (103). The more recent SANHANES data in 2013 reports an overweight and obesity prevalence in women of 40.1% and 19.6% respectively, which is 23% higher than in men (9, 39, 103). The highest prevalence appears to be in black women (102, 104), living in urban areas (103), who are not sufficiently active (100). Although they had a relatively small sample size, Dugas et al. (105) reported that over half the women living in a peri-urban informal settlement in South Africa were overweight or obese, and that vigorous PA was inversely associated with adiposity. Similarly, in a review of three national surveys, Sartorius et al. (100) found that inactive black South African women living in formal or informal urban areas had the highest rates of obesity.

The relationship between the prevalence of overweight and obesity and PA levels or patterns, is a complex and multifaceted one, making these issues the topic of much debate (106, 107). There does, however, appear to be strong evidence for a cross-sectional relationship between PA levels and obesity prevalence (107), although the direction of this causal link may still be unclear. Using cross-sectional NHANES data, Dwyer-Lindgren et al. (108) found that PA levels inversely matched obesity levels in all US counties. They concluded that for every percentage increase in PA levels, obesity prevalence would decrease by 0.11%.

Recent data from the International Physical Activity and the Environment Network (IPEN) has shown support for promoting PA guidelines as a public health message to prevent weight gain in adults (109). This has been further substantiated by the Proactive trial cohort (110), where MVPA was found to be independently and inversely associated with body fat. An increase of 16.8 minutes of MVPA per day was associated with a reduction in 0.5-1.4kg in body weight at 1 and 7 years follow up respectively (95%CI: 0.2-1.4 and 0.7- 1.7). Furthermore, a reduction in 90 minutes of sedentary time was associated with a reduction in body weight of 1.4kg (95%CI: 0.7-2.4). Inversely, both waist circumference and fat mass was associated with a reduction in MVPA (95%CI:-0.36,-0.15 and -0.36, -0.18 respectively), further supporting the notion that this relationship may be bi-directional.

Similar findings have shown an association between physical inactivity and obesity (35), as well as non-insulin-dependent diabetes mellitus (79), in communities undergoing transition in South Africa. This shift in physical activity levels has significant consequences as PA has been shown to be a stronger correlate for obesity in women than many other socioeconomic factors (35). In a study by Kruger et al. (35), women with the highest physical activity levels were less likely to be obese (OR: -0.38; 95%CI: -0.22,-0.66), after adjusting for age, smoking and total household income. The same authors found a significant association between physical inactivity and numerous cardiovascular risk factors in South African women (78), making it a potentially important intervention and prevention strategy in our female population. Since obesity dysregulates metabolic processes, natural consequences are increased rates of metabolic syndrome, poor lipid and blood pressure profiles, leading to chronic disease and its associated burden (101). The high rates of physical inactivity, which are below the required levels for health enhancement, places LMIC populations at risk of clusters of chronic disease risk factors (101). Indeed, Dickie et al. (38) found that meeting the recommended PA guidelines was associated with lower body weight, body fat and insulin resistance markers over a 5 year period in black South African women. Similarly, Cook et al (111) found significant associations between steps per day, as measured by pedometer, and adiposity, with a reduced risk of obesity of 52% in women that did 10 000 steps per day.

There is also mounting evidence for the association between inactivity and sedentary behaviour and obesity and obesity-related health outcomes. There is emerging evidence to suggest that time spent in sedentary behaviours (activities requiring energy expenditure of 1-1.5 Metabolic Equivalent of Task or METs) (112), independent of PA, is associated with several deleterious health outcomes. For example, television (TV) viewing and total sitting time have been associated with chronic disease risk, and more specifically, central adiposity, insulin resistance and all-cause mortality (113, 114). Likewise, Sugiyama et al. (115) found in an Australian population that time spent in a car was associated with higher levels of adiposity and a poorer cardio-metabolic risk profile. They showed that people who spent more than one hour per day in the car had a greater BMI of $0.8kg/m^2$ and a 1.5cm greater waist circumference. Inversely, breaks in sedentary time have been associated with a reduction in inflammatory markers and body composition, such as waist circumference and adiposity (114, 116). According to Healy et al. (117) breaks in sedentary time, as measured by accelerometry, are associated with a reduction in BMI, waist circumference, triglycerides and fasting glucose. The authors found a significant inverse association between breaks in sedentary time and waist circumference, C-reactive protein and fasting plasma glucose, which were independent of total sedentary time. Furthermore, a recent study of T2D demonstrated the beneficial effects of increasing energy expenditure and reducing sedentary time on body composition (118). Those who increased their energy expenditure during the four year study reduced their waist circumference by 2.84cm (95%CI:-4.84, -0.85). In contrast, increases in sedentary time had the opposite effect, resulting in an increase in waist circumference of 3.20cm (95%CI: 0.84, 5.56).

In China, Popkin (119) has shown major shifts towards sedentary occupations especially in the urban populations, which has been linked to obesity rates (120). This is further supported by other authors (58, 121) who have found that these occupational shifts are associated with increased BMI and obesity rates. Prentice (9) also describes these behaviours as key mediators in the large gender differences seen in various populations. In particular, the role and work of women has changed with the introduction of electricity and improved convenience of domestic activities. Indeed, this pattern could explain the higher prevalence of PA in rural women in South Africa, who may participate in more active household, yard work or farming, than their urban counterparts (122).

1.4. Oh Baby! Metabolic programming and the importance of the prenatal period in future NCD risk

Emerging evidence suggests that the prevention of disease, and particularly overweight and obesity, can start as early as in utero and recent research has focused on early life environmental factors and their effects on future health. Some studies have shown that, although the genetics of disease cannot be ignored, early life factors may play an important role in the disease risk in the offspring (13, 14). This alludes to the fact that a woman's health status, both pre-pregnancy and during pregnancy, can significantly influence pregnancy outcomes and the long term health prospects of her child (13).

The 'Developmental Origins of Health and Disease' (DOHAD) hypothesis appears to be a double-edged sword. On the one hand, low birth weight (LBW), as a consequence of in utero undernutrition or stress, has been shown to increase susceptibility for adult diseases such as insulin resistance, T2D, hypertension and CVD, especially when exposed to a high fat diet later in life (123). On the other hand, maternal obesity and intrauterine overnutrition has also been associated with a greater risk of obesity, T2D and associated comorbidities in the offspring later in life (124). Therefore, the relationship between birth weight and adult BMI appears to be best described as a U-shaped curve (13, 15, 125). For both sides of the curve, there appears to be a strong implication for the process of a stimulus occurring at a critical development period that has a long-lasting effect, in other words, programming effects of the fetal environment termed *metabolic programming* (13-15). This exposure to an adverse fetal environment in early life is thought to disrupt normal growth and development (Figure 6), which leads to an adult phenotype that is more susceptible to disease (16).

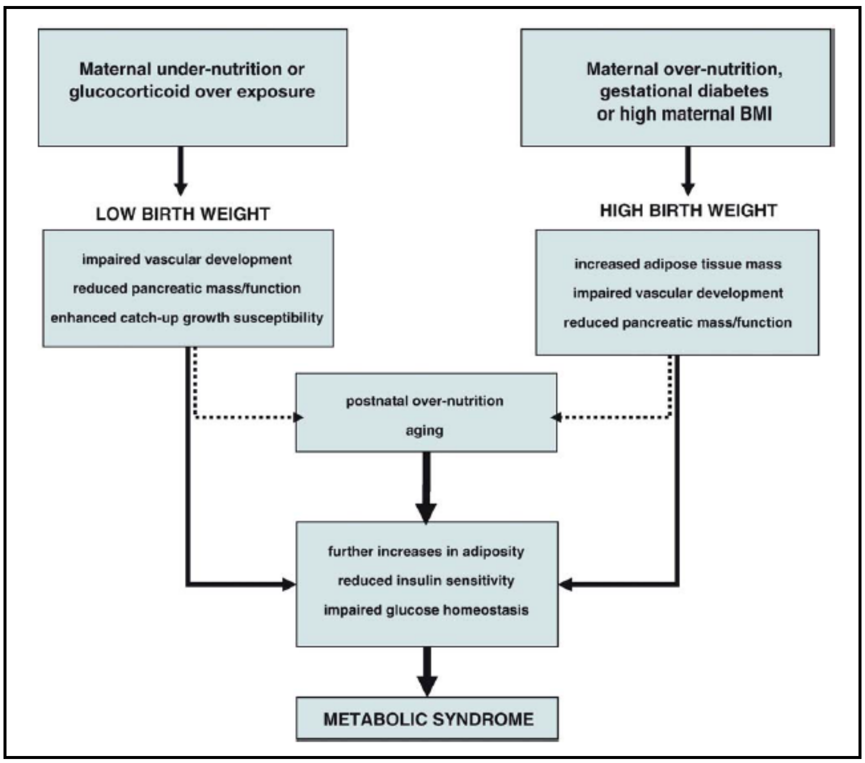

Figure 5 Summary of the dual spectrum birth weight issue in the development of adult disease (used with permission) (126)

The physiological mechanisms mediating the metabolic programming model are described by Taylor & Poston (16). Offspring born to nutrient-restricted mothers appear to have an increased sensitivity to cortisol as well as a reduction in glucose transporter 4 in the adipocyte tissue (125). Low birth weight has also been shown to be associated with increased β-cell proliferation, islet size and vascularisation as well as a reduction in islet cell function, thereby increasing the risk of insulin resistance when exposed to high fat diets later on in life (13, 123, 127). Furthermore, development of T2D in adulthood may potentially be traced back to deviant mitochondrial function during gestation (127). There is also some initial evidence that a restricted maternal diet may alter thyroid function and therefore change the basal metabolic rate in the offspring (16). Many of the effects of these hormonal and "programming" changes differ depending on the stage of gestation, and lead to different phenotypes which are in turn associated with particular patterns of metabolic abnormalities (14).

On the other side of the weight spectrum, gestational overfeeding may lead to "malprogramming" of the hypothalamus' appetite control. Secondly, the fuels available to the fetus in an obesogenic in utero environment (glucose, lipids and amino acids) play a role in the development of the pancreas structure and function as well as fat stores (13, 124). There is evidence for the in utero programming of adipogenesis, adipocyte morphology and metabolism, resulting in increased lipid storage, adipocyte hypertrophy and altered lipolysis (16). Epidemiological evidence in both animal and human studies support the notion that maternal nutrient excess and insulin exposure has long term effects on body weight regulation in the offspring (13). For example, Lawlor et al. (124) found that for every one standard deviation (SD) increase in maternal BMI, the BMI of 14-year old offspring increased by 0.362SD.

Interestingly, studies have assessed the role of metabolic programming and its effects on PA levels in the offspring (128). They have shown that maternal undernutrition, followed by postnatal overnutrition may result in hyperphagia and reduced locomotor activity in the offspring

(16). For example, Vickers et al. (128) found that LBW rat offspring from undernourished mothers were significantly less active than normal weight offspring. Furthermore, postnatal overnutrition in the same offspring exacerbated their sedentary behaviour. Similarly, Samuelsson et al. (129) found that offspring of obese mice were less physically active at 3 months of age. These findings provide the initial indicators that even lifestyle choices and behaviour may be programmed prenatally.

The detrimental relationship between birth weight and later life adiposity may be further exacerbated by postnatal social, economic and environmental factors (13). More specifically, the higher rates of obesity in transitioning African populations may be explained by poor fetal nutrition early in life that is followed by overnutrition and low PA levels during childhood (123). Moreover, it may explain why LBW children that follow a traditional diet and a physically active lifestyle remain lean and largely free of metabolic diseases (101). This data shows that although genes play a role in the development of metabolic diseases, that environmental and behavioural factors appear to be key mediators in the rise in obesity (41, 59, 61, 101).

The consequences of metabolic programming have been described by Ebbeling et al. (130) as having the potential to "*accelerate through successive generations independent of further genetic or environmental factors*". In order to stop the cycle of obesity, the prenatal period has been described by Lawlor & Chaturvedi (131) as a unique and crucial time to intervene. Women may also be more receptive to health promotion and behaviour change during this period (131). Since maternal weight status has been shown to influence child weight regulation, this may be a good starting point for interventions (132). Modifications in diet and initiation of a PA regime during pregnancy may be possible solutions to control the impending obesity epidemic in the offspring (15, 131).

In addition, a fine balance between the two ends of the metabolic programming spectrum needs to be achieved. For example, efforts to increase birth weight on the one hand may not be feasible and effective, and could potentially have a harmful effect (13), and the same may be true for reducing birth weight. Moreover, follow up research is needed to determine whether interventions during this period will improve long-term outcomes in the offspring (131). Nonetheless, addressing issues of GWG and postpartum weight retention will at the very least improve maternal health outcomes (133). Women that present with prenatal risk factors for future CVD should be screened and provided lifestyle modification counselling (134). Moreover, pregnancy is a unique period where women are seen on a regular basis by their healthcare provider, increasing the opportunity for frequent education and lifestyle counselling for behaviour change. Thus, primary health care providers are well placed to promote maternal PA and this has been shown to be a cost effective and successful method of improving activity levels (135, 136).

SECTION 2: MATERNAL PHYSICAL ACTIVITY [1]

1.5. Introduction

South African women appear to be particularly vulnerable to both weight gain and physical inactivity (35, 38). According to SANHANES data, it appears that the most significant increase in waist circumference, as well as overweight and obesity, occurs between 15 and 35 years of age (39). Since this represents childbearing age, it may be an opportune time to intervene to improve health behaviours (131), and contribute to the achievement of the WHO's Millennium goals of improving maternal health.

Despite the wealth of evidence to encourage PA in the prevention and management of chronic diseases, minimal research exists for the pregnant population, particularly in LMICs. It has been shown that women of lower educational and SES are particularly vulnerable to adverse pregnancy outcomes due to limited knowledge around pregnancy and health, including PA recommendations (137). Furthermore, since South African women are at risk for obesity and inactivity, it can be assumed that these trends may continue into the gestational period (35, 100).

1.6. Maternal obesity and maternal and birth outcomes

It is well known that pregnancy may be a trigger for gestational and long term obesity. According to Davis et al. (138), parous women had a 3.5 times higher risk of becoming obese

[1] *This section is based partly on the following publication:* **Pearson, J.T, Watson, E.D, Lambert, E.V & Micklesfield, L.K (2015)** The role of physical activity during pregnancy in determining maternal and foetal outcomes *Accepted: South African Journal of Sports Medicine,* 24(4): 93-96

over the next 5 years compared to nulliparous women. In a recent systematic review of studies from Africa, Onubi et al. (139) reported a maternal obesity prevalence rate of between 6.5% (at antenatal booking in the Democratic Republic of Congo) and 50.7% (third trimester in Nigeria). This is of concern, since maternal overweight and obesity have been linked to adverse pregnancy outcomes, as well as maternal morbidity and infant mortality (140). Pre-gravid overweight or obesity has been shown to increase the risk of hypertension, pre-eclampsia, GDM, perinatal mortality, macrosomia and delivery complications (141). In the same African review, obese mothers had a 1.8 times higher chance of having a macrosomic baby, and were 1.6 times more likely to have the neonate admitted into intensive/special care (139). Similarly in South Africa, Basu et al. (142) found a 44% prevalence of obesity in a sample of 767 pregnant women, which was associated with complications such as GDM, urinary tract infection and failed induction of labour (142). In addition, women who are overweight or obese prior to pregnancy have a greater risk of miscarriage compared to women with a normal BMI (141), and may also be at an increased risk of Caesarean section delivery (143). Consequently, women who enter pregnancy overweight or obese tend to stay in hospital longer and incur greater financial costs around the time of delivery and postpartum (141).

Not only is absolute weight a concern during this period, but excessive GWG is also associated with detrimental outcomes. The Institute of Medicine has provided guidelines for GWG based on pre-pregnancy weight (Table 1) as well as consideration of the welfare of both the mother and the baby (144, 145). These guidelines present a range of weight within which a positive outcome can be expected, and are designed to reflect diversity in age, race and ethnics within the population of child-bearing women.

Table 1 Recommendations for gestational weight gain during pregnancy (144, 145)

Pre-pregnancy BMI	**Total weight gain (kg)**	**Rates of weight gain 2nd to 3rd trimester (kg/week)**
	Range	*Mean (range)*
Underweight (<18.5 kg/m^2)	12.5-18	0.51 (0.44-0.58)
Normal weight (18.5-24.9 kg/m^2)	11.5-16	0.42 (0.35-0.50)
Overweight (25.0-29.9 kg/m^2)	7-11.5	0.28 (0.23-0.33)
Obese (≥30.0 kg/m^2)	5-9	0.22 (0.17-0.27)

Gaining weight beyond these guidelines, or excessive GWG is an important predictor of adverse maternal outcomes (146), including GDM, gestational hypertension, preeclampsia (143) and caesarean delivery (147).

Globally, approximately 10% of all pregnancies are complicated by hypertension, which is a major cause of both fetal and maternal morbidity and mortality (148). In South Africa, the latest Saving Mothers Report reported 622 maternal deaths related to hypertensive disorders from 2002-2005, with 55.3% from eclampsia, 28.3% from pre-eclampsia and 6.1% associated with chronic hypertension (149). According to this report, deaths from hypertensive disorders during pregnancy remain the most common direct cause of maternal death. As stated above, since hypertension is closely associated with overweight and obesity, as well as excessive GWG, there appears to be a need for continual education of women to reduce the risk of developing hypertension by reducing pre-pregnancy weight and limiting weight gain during pregnancy (149).

Similarly, women who enter pregnancy overweight or obese, or gain excessive weight during pregnancy, have an increased risk of developing GDM (141, 142). Although little is known about GDM in Africa, a recent systematic review reported a prevalence ranging from 0-13.9%, and an estimated 8.8% in South Africa (150). GDM not only increases the risk of maternal complications, but many studies have shown that children of women with GDM have a higher risk of childhood obesity and metabolic dysregulation later on in life (151). Certainly, in the GDM mother, there appears to be a greater risk of developing T2DM later on in life. The cumulative incidence of T2DM is shown in a review of 28 studies (Figure 6), and varies from 2.6-70% over a period of 6 weeks to 28 years postpartum (152).

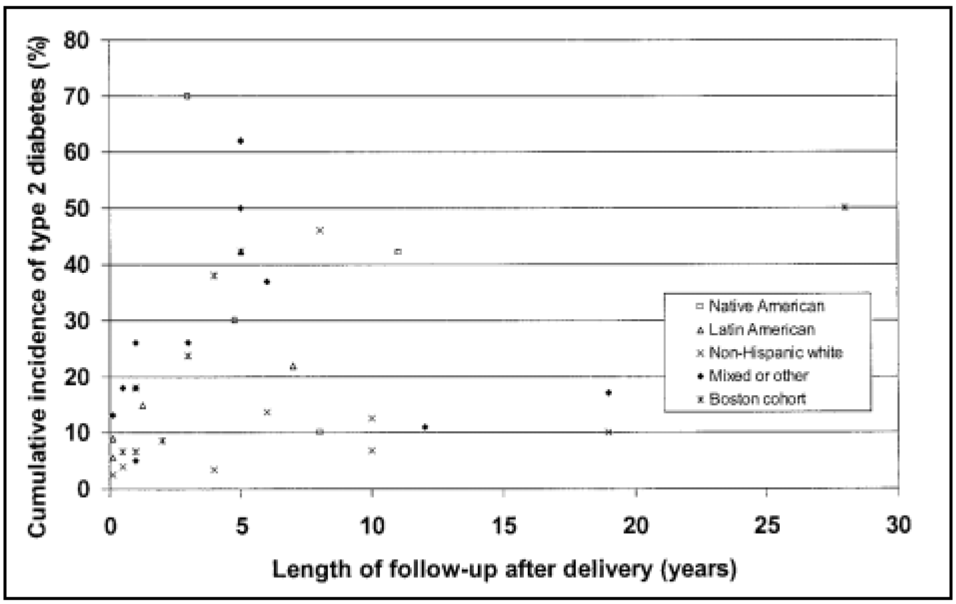

Figure 6 Review of the incidence of T2DM after a GDM pregnancy (152)

In another more recent review published in *the Lancet,* women with GDM were 7.5 times more likely to develop T2D in the future compared to those with a normo-glycaemic pregnancy (153). Women that were followed up over the longest period had an even higher risk (RR=9.34) and the largest study in the review (of over 650 000 women) had an even higher risk ratio (RR=12.6, 95%CI: 12.2; 13.2). In South Africa, women with GDM have a 40% greater risk of developing T2D within 15 years of giving birth (149).

Furthermore, in study by the ALSPAC team, women with high GWG were found to have higher body mass index (BMI) and blood pressure 16 years postpartum, and had three times greater risk of being overweight and having central adiposity (154). Therefore, GWG may represent one of the most important modifiable risk factors for pregnancy complications. An awareness of this increased risk may afford healthcare providers with a perfect opportunity in which to intervene and provide education on health promotion (155) which could potentially halt the development of future T2D, obesity and other complications (156). As Rhonda Bentley-Lewis states: *"In view of the compelling data that link gestational diabetes to the development of type 2 diabetes, we as clinicians are afforded the rare opportunity to alter the natural course of disease and change the future health of women today."* (156)

In addition to maternal outcomes, obesity during pregnancy has also been associated with adverse fetal outcomes. Pre-pregnancy BMI and GWG have been found to predict birth weight (141), with higher BMI being associated with greater risk of delivering large for gestational age infants (143). Several studies have shown that increased birth weight increases the risk of infant mortality and birth trauma, and is also associated with an increased risk of future overweight and obesity in the child (157). Furthermore, according to a meta-analysis by Chu et al. (158) women who are overweight and obese have a higher odds ratio (1.47 and 2.07, respectively) of having a stillbirth. Similarly, a recent meta-analysis of 22 studies found that maternal obesity significantly increases the risk of neural tube defects in the baby (159), and this has been found in previous reviews (160). In fact, the authors found that for every 1kg/m^2 increase in BMI in the mother, the odds of having a baby with a neural tube defect was 4% (OR=1.04; 95% CI 1.03,1.05) (159). It appears that the risks associated with maternal obesity extend to both the mother and fetus, in the long as well as the short term, making interventions aimed at this population essential (140).

1.7. The role of physical activity in pregnancy

Physical activity has an important role to play in the prevention and management of disease, and is also of particular importance during pregnancy. A review by Gavard and Artal (161) concluded that regular PA during pregnancy reduces maternal and fetal morbidities, and results in long-term benefits for both the mother and the child. It is unsurprising then that healthy women are recommended to participate in 150 minutes of moderate PA per week (>=600 MET min/wk) in order to gain these health benefits (19, 21, 22).

Various studies have shown that regular PA plays a role in weight management during pregnancy, and reduces the likelihood of pre-eclampsia (162, 163). A case-control study by Marcoux et al. (164) showed that women participating in regular leisure time PA had a reduced risk of gestational hypertension (aRR:0.75; 95%CI:0.54,1.05) and preclampsia (aRR:0.67; 95%CI:0.46,0.96). Evidence to support this is somewhat conflicting. For example, a similar reduction in risk has been found by other authors (165, 166) and a recent review has highlighted the beneficial effect of PA in reducing the risk of pre-eclampsia (163), possibly via its role in weight management. Even so, a review by da Silva et al. (28) found little evidence for the protective effect of leisure time PA on preclampsia in both cohort (RR=0.93; 95%CI: 0.55,1.57) and trial studies (RR=0.88; 95%CI: 0.73,1.06) (28), and this lack of association was further supported by a Cochrane review (167).

Although the literature presents mixed reports on the role of PA in the development of GDM, it is generally accepted to assist in reducing the risk, especially when adherence to the PA intervention is high (168). In a recent systematic review of 6 randomised control trials, three trials showed a lower incidence of GDM between the exercise intervention and control groups, two trials showed a higher incidence whilst one trial showed no effect. The authors conclude with a relative risk ratio of 0.91 (95%CI: 0.57, 1.44) from the meta-analysis of these studies, suggesting no reduced risk of developing GDM with an exercise intervention (169). On the other hand, da Silva et al.(28) reported a protective effect in their recent meta-analysis of 11 experimental studies (RR=0.67, 95%CI: 0.49,0.92), although this effect does not seem to carry through as strongly in the cohort studies (RR=0.75, 95%CI: 0.55,1.01). Similarly, in their meta-analysis of 10 studies, Russo et al. (24) reported a slight protective effect (28% reduced risk) for PA interventions to reduce the risk of GDM. In addition to reducing the risk of developing GDM, Bung and Artal (170) also found that exercise has a critical role to play once GDM has been diagnosed, potentially resulting in avoiding insulin therapy. Similarly, a longitudinal study by van Poppel et al. (171) involving objective measurements of time spent in moderate-to-vigorous physical activity (MVPA) measured at 15, 24 and 32 weeks of gestation, found that MVPA during early pregnancy was associated with an improved insulin response at 32 weeks gestation. In addition, they found that women that reduced their MVPA during pregnancy had higher fasting insulin levels, reduced insulin sensitivity and higher triglycerides. According to Dempsey et al. (172) both pre-pregnancy PA, as well as during pregnancy, is associated with a

69% lower incidence of GDM. Therefore, the authors concluded that at-risk pregnant women should be encouraged to increase their PA levels for improved insulin and triglyceride responses later in pregnancy.

Although regular PA has been associated with favourable labour and delivery outcomes, research in this area remains inconsistent. Some studies have shown a reduction in Caesarean rate with regular PA (173, 174), whilst others have found no association (175). Similarly, certain studies demonstrate an association between increased PA and shorter labour time (176), while other studies show no association (175), warranting further research for these outcomes.

1.7.1. Physical Activity and gestational weight gain

Unsurprisingly, engaging in PA during pregnancy has been shown to reduce excessive GWG (25-27, 177), and therefore may provide a protective effect against the development of other adverse maternal health outcomes. Although the review of selected studies on the role of PA in GWG in Table 2 shows some conflicting results, the majority of studies (74%) show a beneficial (👍) effect of PA on GWG. According to a systematic review of 44 randomised controlled trials, interventions with components of diet, PA or both show a reduction of 1.42kg (95%CI:0.95,1.89kg) in GWG when compared to controls. The recent meta-analysis by da Silva and colleagues (28) found that exercise interventions resulted in 1.11kg less GWG when compared to controls (95%CI: -1.53, 10.69), whilst active women in the cohort studies had a 18% lower risk of EGWG (OR=0.82, 95%CI: 0.68, 0.99).

Likewise, active women in the studies below appeared to gain between 7.3-0.36kg less than their non-active counterparts, with an overall inverse association of between r=-0.26 and -0.61 between PA and GWG. In addition, PA appears to play an important role in reducing the risk of exceeding the IOM recommendations (145) for weight gain during pregnancy, with an odds ratio of between 0.43-0.76 for excessive GWG (Table 2).

Table 2 Summary of selected studies on maternal physical activity and gestational weight gain

Source	**Sample size**	**Study design: PA Intervention**	**Results**
Haakstad & Bø (2011) (178)	105	RCT: 60min aerobic and 60min strength training 2/wk for 12 weeks	👍 Exercise group gained less weight (11.0 vs 13.8kg; p<0.01) and fewer had EGWG (0% vs 38%).
Nascimento et al. (2011) (179)	82	RCT: Intervention did group exercises and received home exercise counselling vs routine prenatal care.	👍 Less of the intervention group had EGWG (47 vs 57%, p=0.43). No difference in GWG between the groups. Overweight women in the intervention group gained less weight compared to the control group(10.0kg vs 16.4kg, p=0.001)
Barakat et al. (2014) (180)	200	I: Exercise group had a conditioning programme ±60min; 3days/wk	👍 More women in the control group had EGWG (35.6% vs 21.2%, p=0.02) although the effect size was small (Phi value =0.16)
Jiang et al. (2012) (181)	862	O: Pedometer assessed in 2nd and 3rd trimester. Grouped into sedentary (<5000 steps/day), low active (5000-7500), somewhat active (7500-10 000) and active (>10 000).	👍 The “active” group had an odds ratio of 0.59 for EGWG, put on 1.45kg less than the “sedentary” group, and the OR for EGWG decreased with the increased level of physical activity (p < 0.05).
Hui et al. (2014) (182)	116	RCT: Weekly group exercise sessions (instructor-led aerobic, strength and stretch exercises), home exercises (video instruction) and dietary counselling	👍 The intervention group gained less weight (14.1kg vs 15.2kg; p=0.28), and had less women with EGWG compared to the control group (36 vs 48; p=0.008).
Ehrlich et al. (2016) (26)	1055	C: Self-reported physical activity after a GDM diagnosis	👍 Vigorous PA was associated with a decreased odds of EGWG compared to no participation (OR: 0.63, 95%CI: 0.40-0.99). A reduced odds of EGWG in women with a BMI>25kg/m2 (OR: 0.46, 95%CI: 0.27-0.79) was found in those participating in vigorous PA. More exercise led to decreasing odds of EGWG (p≤ 0.03). No associations were observed for moderate intensity exercise.
Kraschnweski et al. (2013) (183)	3006	O: Self-reported PA	👍 Being “active” (150 minutes of MVPA/week) was associated with 29% lower odds of EGWG (OR: 0.71, 95%CI: 0.57-0.88).
Chasan-Taber et al. (2014) (184)	1276	O: Self-reported (PPAQ)	☞ No significant associations between PA (type or intensity) and GWG (total weight gain, rate of weight gain and EGWG).

Ronnberg et al. 2015) (185)	374	RCT: Home exercise prescription and weight chart versus standard care	👍 The exercise intervention was associated with a lower proportion of women who had EGWG, but this was not significant (41.1% vs 50.0%, p=0.086). Mean GWG was 14.2kg for the intervention vs 15.3kg for standard care group (p=0.03).
Harris et al. (2015)(177)	856	O: Self-reported PA (exercise/sport) and exercise index calculated	👍 Exercising women were more likely to meet GWG recommendations (32.7 vs. 18.7%) and had lower odds of EGWG (adjOR: 0.43, 95%CI:0.24-0.78)
Cohen & Koski (2013) (186)	54	O: Self-reported (PPAQ) and pedometer	☞ Walking >5,000 steps/day was not significantly associated with GWG (β=1.4; p=0.8271)
Ebrahimi et al. (2015) (187)	308	O: Self-reported PA (short version IPAQ)	☞ Age (OR=1.08, 95% CI 1.02–1.15) and pre-pregnancy BMI (OR=1.51, 95% CI 1.18-1.35; p<0.001) was associated with GWG but not PA (OR=1.00, 95%CI: 0.99-1.00, p=0.19).
Sui et al. (2014) (188)	305	O: Self-reported PA (SQUASH)	☞ There was no significant difference in physical activity for women with different BMI or GWG.
Ruiz et al. (2013) (189)	962	RCT: Light-to-moderate aerobic and resistance exercises 3x/wk for 50-55 min	👍 Women in the intervention group gained less weight (mean difference was 1.04 kg; P<.001) and were less likely to have EGWG (OR0.63, 95%CI: 0.46-0.85). Treatment effects were more in normal than overweight women.
Ruifrok et al. (2014) (190)	111	O: Accelerometer measure of PA	☞ No significant associations were found between time spent in MVPA and GWG.
Montpetit et al. (2012) (191)	59	O: Self-report (PPAQ) and pedometer	👍 Steps/d were inversely correlated with GWG (r=–0.26;p=0.049); but METhrs/wk was not associated with GWG (r=0.04; p=0.768)
Stuebe et al. (2009) (192)	1388	C: Self-report PA (PASE)	👍 Significantly lower odds of EGWG with 30 minutes of mid-pregnancy walking (OR, 0.92, 95%CI: 0.83-1.01) and vigorous physical activity (OR, 0.76, 95%CI: 0.60-0.97) per day.
Choi et al. (2013) (193)	11 s	Systematic review	👍 On average, pregnant women in the intervention groups gained 0.91kg less (95% CI: −1.76, −0.06) compared with those in the usual care groups.
Streuling et al. (2011) (27)	12 s	Systematic review of RCTs: Increased PA levels only	👍 Meta-analysis showed a negative association between increased PA and GWG of -0.61 (95% CI: 1.17, p=0.06)
Gray et al (2000) (194)	219	I: Media campaign for exercise and diet (walking/exercise a component of the intervention)	☞ No difference in GWG between the intervention and control groups (12.0kg vs 13.2kg, p=0.29).

Polly et al. (2002) (195)	121	RCT: Educational material to increase PA	👍 Normal weight women in the intervention had less EGWG (33 vs 58%, p=0.05), but this was not found in overweight women.
Kinnunen et al. (2007) (196)	105	I: Diet and PA counselling	☞ The intervention did not prevent EGWG
Shirazian et al.(2010) (197)	41	I: Information on nutrition, exercise	👍 GWG was lower in the intervention group compared to controls (8.1±7.4 kg vs 15.4±7.5 kg, p=0.01).
Phelan et al. (2011) (198)	177	RCT: Fit for Delivery – behavioural intervention (education on nutrition and PA) vs standard care	👍 EGWG was lower in normal weight women in the intervention group vs standard care (40.2% vs 52%; p=0.003).
Vinter et al. (2011) (199)	360	I: Dietary counselling sessions, fitness centre membership, group exercise classes 1x/wk, pedometer, PA coaching	👍 The intervention group gained less weight (7.0kg vs 8.6kg, p=0.01) and less women in the intervention group had EGWG (35.4% vs 46.6%, p=0.058)
Renault et al. (2014) (200)	389	RCT: PA and diet, PA alone and control group. PA was advice and measured by pedometer	👍 GWG was lower in the intervention group vs control (8.6kg vs 10.9kg, p=0.042). PA reduced GWG by 1.38kg (p=0.04).
Sui et al. (2012) (201)	7 s	Systematic review of 6 RCTs and 1 quasi-RCT of supervised antenatal exercise classes	👍 Overall, exercise was associated with lower GWG (-0.36kg) when compared to standard care Supervised antenatal exercise intervention was associated with lower gestational weight gain (five trials, 216 participants, mean difference of −0.36kg, 95%CI: −0.64; −0.09kg) when compared with standard antenatal care.

EGWG: Excessive gestational weight gain; O: Observational; RCT: Randomised controlled trial; C: Cohort; I: Intervention ; s: studies

1.7.2. Physical Activity and fetal outcomes

The WHO (202) defines LBW as <2500g (Table 3) and premature birth as delivery <37 weeks gestation. Both LBW and preterm birth are strongly associated with fetal and infant mortality and morbidity (203).This is of particular importance in LMIC countries, which are disproportionally affected by these issues (compared to HIC countries) and the burden of disease that goes along with them. For example, the prevalence of LBW babies is said to be 11% in developing countries (204). In addition, preterm birth is consistently found to be more frequent among the socially disadvantaged (203). In sub-Saharan Africa, the prevalence of pre-term birth is 19.9% and LBW is 10.2% (205). In South Africa, LBW is the second leading cause of death for children under 5 years, accounting for 11.2% of deaths (206), and the pre-term birth rate is estimated at 17.5% (207).

Table 3 Birth weight classification (WHO)

Classification independent of gestational age	**Weight (g)**
Extremely low birth weight (ELBW)	<1000
Very low birth weight (VLBW)	<1500
Low birth weight (LBW)	<2500
Normal birth weight	>2500
Macrosomia	>4500
Classification specific for gestational age	
Small for gestational age (SGA)	Weight <10th percentile
Appropriate for gestational age (AGA)	Weight 10th-90th percentile
Large for gestational age (LGA)	Weight >90th percentile

As the physiology of the mother and fetus are so closely linked during pregnancy, the potential benefits of PA may also extend to the fetus. The effects of regular PA have been measured using various fetal outcomes, with birth weight being the most widely studied outcome (20). In a systematic review, Schlüssel et al. (20) reported that light to moderate PA during pregnancy reduces the risk of LBW and premature birth, whereas other studies showed no association between PA and birth weight (208). A review of articles (Table 4) shows the conflicting evidence available for the association between PA and fetal outcomes. Out of the 34 studies that assessed birth weight as an outcome (Table 4), 63% found no association whilst 26% found that PA may reduce birth weight in the offspring and the remainder found a protective effect. A positive outcome (👍) in Table 4 is indicated if the exercise intervention is associated with protection against LBW/Macrosomia or an increase in birth weight that is within the normal spectrum (2500-4499g).

Furthermore, 22 of these studies assessed the role of PA on gestational age, preterm delivery or miscarriage (Table 4). Five studies found that PA plays a protective role against preterm birth, whilst 3 studies found an increased risk for preterm deliveries. It appears that an increased risk of preterm birth depends upon the type of PA that is performed. In a randomised controlled trial, Barakat et al. (209) found no association between leisure time PA and gestational age, although a physically demanding job may increase the risk of premature birth (210). When measuring total PA, a systematic review by Takito et al. (211) showed that both excessive and insufficient PA, in relation to the recommended guidelines, may negatively impact on pregnancy outcomes. Most of the systematic reviews conducted on this outcome have concluded that there is insufficient evidence for the beneficial role of PA in birth weight and preterm delivery, but that it is generally accepted that PA is safe to perform during pregnancy (212-214).

Much of the conflicting evidence for both maternal and fetal outcomes may be due to the complexities involved in measuring physical activity. The challenges of measuring physical activity are well known. It is a multifaceted construct, involving behavioural, psychological and physiological principles, making it difficult to measure all of these aspects using one tool (215). Kelly et al. (215) have described the inconsistencies in PA and SB evidence as being related to the lack of consensus regarding validity and reliability of the tools used to measure these constructs. Physical activity encompasses many domains, dimensions and determinants and yet the tools used to measure PA are often only validated for one of these aspects (215, 216). For example, questionnaires may provide a content-valid measure of domains of physical activity whilst accelerometers provide a criterion-valid measure of the dimensions of PA (intensity, frequency, time).

Furthermore, the prenatal period brings with it even more complexities with regards to PA measurement. The physiological and biomechanical changes during pregnancy make the measurement of energy expenditure complicated (217). Whilst measuring domains of activity during the gestational period become important since certain activity (such as recreational or leisure physical activity) may be beneficial to health outcomes, whereby other activities (such as occupation/work activities) may be detrimental. Therefore, studies with a combination of both self-report and objective (accelerometry) measures of PA may be useful to cover some of the complexities of this behaviour.

Additionally, the methodological issue of a variety of study designs (from experimental to observational) used in the above literature also complicates the outcome evidence. There appears to be good evidence for the role of PA in maternal health outcomes when experimental study designs are used over cohort studies (28) however, this was only used in 44% of the GWG studies, and only 20% of the fetal outcomes studies, described above.

Table 4 Summary of selected studies on maternal physical activity and birth outcomes

Source	**n**	**Study design: PA Intervention**	**Results**
Thangaratinam et al. (2012) (218)	44 s	Systematic review of RCTs: Lifestyle interventions including diet, PA or both.	☞ No differences between the intervention and control groups for ***BW*** (-50g, 95%CI: 100-0)***, LGA*** (RR: 0.85, 95%CI: 0.66-1.09) ***or SGA*** (RR: 1.00, 95%CI: 0.78-1.28). Interventions with PA alone were associated with reduced ***BW*** (-60g, 95%CI:-120- 10).
Jukic et al. (2012) (219)	1647	O: Self-reported vigorous PA	👍 Vigorous recreational PA (vs none) was associated with longer gestation (HR=0.85, 95%CI: 0.70-1.05). Frequency of vigorous recreational PA (≥ 4 vs 0-1 sessions/wk) was associated with decreased odds of ***preterm birth*** (OR=0.08, 95%CI: 0.006-1.0). PA was not associated with ***BW***.
Takito & Benicio (2010) (220)	819	CC: Case control study (273 LBW babies and 546 controls)	👍 Light PA (>7hrs/day) was protective against ***LBW*** (OR=0.61, 95%CI: 0.39-0.94), with a dose response relationship (p=0.026). Homemaking activities were protective for ***LBW*** (p=0.013) and ***preterm birth*** (p=0.035). Walking for leisure was protective against ***preterm birth*** (OR=0.52, 95%CI: 0.29-0.95)
Badon, et al. (2016) (221)	3310	O: Self-reported leisure time PA	☞ No association between LTPA and ***BW***.
Price et al. (2012) (222)	62	RCT: moderate aerobic exercise, 45–60 min, 4days/wk	☞ No differences in ***BW*** between the intervention and control groups (3329g vs 3308g, p=0.87)
McCullough et al. (2015) (223)	1281	O: Self-report PA (PPAQ)	👎 Active women had lower ***BW*** babies compared to non-active ($\beta = -81.16$, p=0.05).
Tinloy et al. (2014) (224)	3006	O: Self-reported PA	☞ Regular PA (>150min/wk) was not associated with ***preterm birth***
Owe et al. (2012) (225)	61 098	O: Self-reported PA	👍 Active women had increased ***GA*** compared to inactive (39.51wks vs 39.34wks, p < 0.001). Exercising 3-5x/wk from during week 17 and week 30 provided a protective effect against preterm birth (aOR=0.82, 95%CI: 0.73-0.91 and aOR=0.74, 95%CI: 0.65-0.83).
Nascimento et al. (2012) (214)		Review paper	☞ No association with ***BW*** or ***preterm birth***.

Nascimento et al. (2011) (179)	82	RCT: Intervention did group exercises and received home exercise counselling vs routine prenatal care.	☞ No difference in ***BW*** between the study vs control group (3267.4g vs 3228.4g, p=0.79) or ***GA*** (38.5wks vs 38.5wks, p=0.49).
Szymanski & Satin (2012) (226)	45	O: Self-reported PA and treadmill fitness test	☞ No differences between active and inactive women for ***GA*** (39.7wks vs 39.6wks, p=0.10) or ***BW*** (3408 vs 33460g, p=0.10).
Oostdam et al. (2012) (227)	121	RCT: Normal care vs exercise training (aerobic and strength exercises)	☞ No difference between normal care and intervention for ***BW*** (3352g vs 3524g, p=0.14) or ***GA*** (39.4wks vs 39.6wks, p=0.58)
Oteng-Ntim et al. (2012) (228)	19 s	Systematic review of RCT and trials	☞ No association with ***BW or LGA***
Barakat et al. (2014) (180)	200	I: Exercise group had a conditioning programme ±60min; 3days/wk	☞ No differences in ***BW or GA***
Montpetit et al. (2012) (191)	59	Self-reported PA and pedometer	☞ Exercise index explained 18% of the variability in ***BW***.
de Oliveria et al. (2012) (229)	209	RCT: Walking at moderate intensity 3x/week, starting at 13 weeks (group A), 20 weeks (group B) and a control (group C)	☞ No differences between group A, B, C for ***BW*** (3279g, 3285g and 3378g, p=0.53) or ***LGA*** (5.5%, 6.6% and 12.2%, p=0.21) or ***SGA*** (7.4%, 6.6% and 7%, p=0.94)
Barakat et al. (2012) (230)	290	RCT: Exercise and control group	☞ No differences in ***BW or GA***
Perales et al. (2016) (213)	61	Systematic review of RCTs	☞ Insufficient evidence for effect on ***birth outcomes***
Kramer & McDonald (2006) (231)	10 s	Systematic review of controlled trials	👎 Some risk of ***preterm birth*** found in the exercise group, no differences in ***BW***
Juhl et al. (2008) (232)	87,232	O: Self-reported PA	👍 Reduced risk of ***preterm birth*** found in the exercise group (HR=0.82, 95%CI: 0.76-0.88)
Juhl et al. (2010) (233)	79,692	O: Self-reported PA	👍 Exercising women had smaller babies, but results not significant. Slight decreased risk of ***LGA*** (HR=0.93, 95%CI: 0.89-0.98) and ***SGA*** (HR=0.87, 95%CI: 0.83-0.92).
Sternfeld et al. (1995) (234)	388	O: Self-reported PA	☞ No differences in ***BW or GA***
Klebanoff et al. (1990) (235)	7101	O: Self report	👎 Prolonged standing (>8 hours per day) was associated with moderate risk of delivering ***preterm*** (aOR=1.31). PA (work and non-work related) was not associated with age-adjusted ***BW***
Jarrett & Spellacy (1983) (236)	67	O: Self-reported data on runners	☞ No association with number of miles run and ***BW or GA***
Horns et al. (1996) (237)	101	O: Self-reported PA	☞ Regular PA had no significant effect on neonatal ***BW***
Rabkin et al. (1990) (238)	1507	O: Self-reported PA during work and leisure time	☞ No association between PA (at work or home) and ***BW***.

			Women in full time employment had babies that weighed 49g less (95%CI: 1-97).
Barakat et al. (2009) (239)	160	RCT: Training group had light resistance and toning exercises (±40min 3-5x/wk)	☞ No significant difference was found between the exercise and control group for ***BW*** (3165g vs 3307g, p>0.1) and ***GA*** (39wks vs 39wks, p>0.1)
Rao et al. (2003) (240)	797	O: Self-reported (activity questionnaire developed by the authors)	👎 No association with preterm birth, but early and mid-gestation PA was associated with lower ***BW*** (p=0.05 and 0.02)
Clapp et al. (1990) (241)	132	O: Self-reported PA in aerobic dancers and runners versus control	👎 Reduced ***BW*** in exercise group versus the control (-310g).
Campbell & Mottola (2001) (242)		CC: Self-reported PA of >5x/wk	👎 Exercise was associated with lower ***BW*** (OR:4.61)
Hopkins et al. (2010) (243)	80	RCT: Home based stationary cycle intervention	👎 Reduced ***BW*** in exercise group vs control (-0.19g vs 0.23g, p=0.03)
Clapp et al. (2002) (244)	75	RCT: Increase or reduce exercise volume	👎 Reduced ***BW*** in the group that increased their exercise volume (3.39g vs 3.81g)
Clapp et al. (2000) (245)	46	RCT: Weight-bearing exercise or control	👍 Increased ***BW*** in exercise group (3.75g vs 3.49g)
Hatch et al. (1993) (246)	800	O: Self-reported PA	👍 Increased ***BW*** in active women (117g, 95%CI: 17-217g). Those who exercised at 2000kcal/wk had differences of 276g (95%CI: 54-497g).
Hegaard et al. (2007) (212)		Systematic review	☞ No association with ***BW or preterm delivery***
Hegaard et al. (2008) (247)	5749	O: Self-report on participating in sport during pregnancy	👍 Reduced risk of ***preterm*** delivery when playing >1 sport women (OR=0.76, 95%CI: 0.60-1.02) or participating in moderate to heavy LTPA (OR=0.34, 95%CI: 0.14-0.85)
Hegaard et al. (2010) (248)	4458	O: Self-report of sport and leisure time PA	☞ No difference in ***BW*** between sedentary (3539g), light (3576g) and MVPA (3580g) groups.
Bell (2002) (249)	99	P: Exercisers did >30 minutes of MVPA 3 times/week, vs controls. Measure by exercise diary.	☞ No difference in ***GA*** between controls and exercisers (39.96wks vs 39.48wks) ***or preterm delivery.*** Women doing >4x/wk gave birth to babies that weighed 315g less.
Bell & Palma (2008) (250)	117	P: Women advised to continue their exercise (>3 times/wk) and controls (women advised to reduce their exercise to <3 times/wk)	☞ No difference in ***BW*** between the exercise group and controls.
Alderman et al. (1998) (251)	291	O: Self-reported PA	👍 MVPA (>2hours/week) was associated with reduced risk of

			LGA (OR=0.3, 95%CI: 0.2-0.7) but not associated with ***SGA*** (OR=0.8, 95%CI: 0.3-2.3) ***or GA***
Evenson et al. (2002) (252)	1699	O: Self-reported PA	👍 Vigorous leisure PA in 1st and 2nd trimester was associated with a reduced risk of ***preterm delivery*** (OR=0.80, 95%CI: 0.48-1.35 and OR=0.52, 95%CI: 0.24-1.11)
Hatch et al. (1998) (253)	557	C: Self-reported PA postpartum	👍 Heavier exercise (>1000kcal/wk) reduced the risk of ***preterm delivery*** (aRR=0.11, 95%CI: 0.02-0.81), no association with low-to-moderate PA.
Madsen et al. (2007) (254)	92 671	O: Retrospective self-reported PA	👎 Increased ***risk of miscarriage*** with increased exercise (>7 hrs/wk. HR=3.7, 95%CI: 2.9-4.7), in particular high impact exercise, and >7 hours/week.
Misra et al. (1998) (255)	1247	O: Self-reported PA (questions adapted from National Longitudinal Survey of Youth Study)	👍 👎 Increased risk of ***preterm delivery*** with climbing stairs (>10x/day, OR=1.60, 95%CI: 1.05-2.46) and purposive walking (>4days/wk, OR=2.10, 95%CI: 1.38-3.20). However, LTPA had a protective effect (OR=0.51, 95%CI: 0.27-0.95). TV viewing had a U-shaped effect (<15hrs/wk: OR=2.09, 95%CI: 1.21-3.61 and >42hrs/wk: OR=3.05, 95%CI: 1.75-5.40).
Mudd et al. (2012) (256)	1014	O: Self-reported PA recall question	👍 Meeting LTPA guidelines was associated with reduced odds of ***LGA*** (aOR=0.30, 95%CI: 0.14-0.64).
Owe et al. (2009) (257)	36,869	O: Self-reported PA	👍 Regular exercise reduced the odds of giving birth to babies with ***BW*** above the 90th percentile by 23-28%.
Both et al. (2010) (258)	11,759	O: Self-report by postal questionnaire	☞ Sedentary lifestyle was associated with lower BW. No association between PA and GA. Increased odds of ***preterm delivery*** with repetitive, boring tasks (aOR=1.25, 95%CI: 1.04-1.50) and bending and stooping (aOR=0.73, 95%CI: 0.63-0.84).
Leiferman & Evenson (2003) (259)	9089	O: Self-reported survey data on LTPA	☞ LTPA reduced the risk of very low ***BW*** (OR=1.75, 95%CI: 1.50-2.04) but not ***LBW*** (OR=1.15, 95%CI: 0.99-1.34). No relationship with ***GA.***
Duncombe et al. (2006) (260)	148	O: Self-reported PA by postal questionnaire, women were grouped into active and inactive	☞ No difference in ***BW*** (3435g vs 3482g)

Vamos et al. (2015) (261)	1713	O: Self-report of long term PA	👍 Long term PA reduced the risk of ***preterm delivery*** (12.2% vs 18.7%) compared to inactive group (aOR=0.55, 95%CI: 0.33-0.91)
Perkins et al. (2007) (262)	51	O: PA assessed by accelerometer	👎 PA was inversely associated with ***BW*** (r=0.42, p<0.02), women in the highest quartile of PA gave birth to babies that were 608g lighter.

PA: physical activity; LTPA: Leisure time physical activity; O: Observational; RCT: Randomised controlled trial; C: Cohort; CC: Case control, I: Intervention ; s: studies; BW: birth weight, LGA: large for gestational age; SGA: Small for gestational age; GA: gestational age

1.8. Patterns of physical activity during pregnancy

Despite the benefits of regular PA during pregnancy (162), NHANES data from the US has shown that the majority of pregnant women are not sufficiently physically active, tend to do less PA than their non-pregnant counterparts, or reduce their PA during pregnancy (31). Epidemiological research suggests that 40-56% of pregnant women in the United States (US) participate in recreational activity during pregnancy, with the majority of PA coming from domestic responsibilities and childcare (31). Data from HICs such as the US, UK and Europe, estimate that 20-42% of pregnant women meet the recommended PA guidelines (≥150 minutes of MVPA per week) (18, 31, 263-269).

Since the developed and developing world experience diverse ways of life, it is well known that patterns of energy expenditure will differ (270), but very little is known about PA patterns during pregnancy in women from LMICs. A recent Brazilian study suggests that around 12.9% of pregnant women participate in leisure-time PA (271), indicating lower PA participation than their HIC counterparts. Data from Ethiopia has shown that PA levels in pregnant African women are lower than their non-pregnant counterparts (272). In South Africa there appears to be a paucity of PA data on pregnant women. Patterns of PA in non-pregnant South African women indicate that women are vulnerable to low levels of PA (35, 38, 86), spending most of their PA commuting, with very few women participating in leisure time PA (78).

Furthermore, the amount and intensity of PA appears to change during the course of pregnancy. Borodulin et al. (263) found that there seems to be a shift from household to care-giving and recreational activity during pregnancy. Likewise, studies have shown that the intensity of activity decreases, especially in the third trimester (273). Active women reduce their activity during pregnancy, giving way to a more sedentary leisure time, including watching television and reading (274). NHANES data on sedentary behaviour during pregnancy have shown that pregnant women in the US spend up to five hours per day watching television (31). According to a recent study by Coll et al. (34) the percentage of women participating in leisure time PA in a cohort of Brazilian women decreased from 11.3% before pregnancy to 2.3% during pregnancy and 0.19% postpartum. Similar studies have shown that PA levels decrease when falling pregnant (271, 275) and during the gestational period (33, 276). There appears to be a shift in active women to become considerably more inactive (264). Of concern is that data from the PIN3 study (263) shows that sedentary lifestyle habits from pregnancy continue into the postpartum period (277). Overall, although PA may have a beneficial effect on the health of mothers and their offspring, it appears to decline during pregnancy, especially in the leisure domain.

1.9. Factors influencing physical activity during pregnancy

Several maternal and socio-economic characteristics which influence PA levels have been identified. Socio-economic factors, such as a higher education level, social class and income, have all been associated with increased participation in PA during pregnancy (31, 34, 137, 269). Kramer et al. (203) suggested that women from the lowest socio-economic stratum are more likely to have physically demanding jobs or more housework responsibilities, and tend to engage in less leisure time PA, which may lead to adverse birth outcomes.

Parity has also been shown to be associated with PA levels amongst pregnant women (34, 269, 271). For example, Evenson et al. (137) reported that women who have three or more children are less likely to engage in leisure time PA compared to women with less than three children. Conversely, Liu et al. (278) found that multiparous women are more likely to engage in strenuous activity for at least three hours per week, when compared to nulliparous women. Other factors that have been shown to influence engagement in PA during pregnancy include maternal age and BMI (31).

In addition to understanding correlates and patterns of PA and sedentary behaviour, it is also essential to understand attitudes and perceptions towards PA in pregnancy. Despite the evidence that supports the benefits of PA during pregnancy, many pregnant women frequently report that they are unsure of the safety of exercising during pregnancy and thus reduce their PA after becoming pregnant (279). Other commonly reported barriers to PA among pregnant women include health related factors, tiredness and busyness, lack of social support, as well as pregnancy complications (280). Moreover, the physiological and biomechanical changes that occur with increasing gestation, may in themselves act as barriers to being active (281, 282). In addition, time and finances may play a role in the low levels of PA (283, 284), and issues of crime and safety may become pertinent in certain contexts (279, 284).

Few studies are available on the determinants and barriers to PA in the South African population, however qualitative findings in non-pregnant SA women have shown that barriers to PA include fear of losing weight (which may be associated with being HIV positive, or not culturally attractive), personal safety and lack of exercising in the past (285), as well as crime and lack of walking or cycling paths (78). In a recent study South African study, Muzigaba et al.(279) found that although pregnant women are interested in participating in PA during their pregnancy, many were unaware of what is safely recommended. In addition, the women reported a lack of information and advice from healthcare providers, which may explain their safety concerns for themselves and their unborn baby.

In fact, the role of the healthcare provider may be important in possible interventions aimed at reducing the low levels of PA during pregnancy. Pregnancy is unique time in life, since many women are seen on a regular basis for nine months by their health care providers. This may provide a window of opportunity for health care providers to provide education and counselling on a healthy lifestyle at a primary care level (286, 287). In fact, in the general population, brief counselling from a general practitioner has shown to be a cost effective and successful method of improving activity levels (286). Similarly, a Cochrane review found moderate effects for PA counselling on short- and medium term PA and cardiovascular fitness levels (287). In a previous South African study, we found that medical practitioners advise their non-pregnant patients on increasing PA levels, and believed that PA promotion was an important part of primary healthcare (288). Despite the high levels of awareness of the importance of PA in this and other studies (289), practice guidelines and adequate training for this type of counselling is warranted. The same is true for antenatal PA counselling, where Leiferman et al. (290) found that less than half of the healthcare providers giving PA education were aware of the recommended guidelines, and only 17% had received formal training. Mayosi et al. (52) have highlighted the need for upscaling of primary health care services to meet the expanding demand of NCDs and preventative medicine. However, the current curriculum for South African primary health care providers urgently requires training in behavioural counselling skills (291). Therefore, encouraging PA in women with an uncomplicated pregnancy should form an integral part of prenatal care but further research is needed in this area.

PROBLEM STATEMENT

Social disparity appears to dictate general health and health outcomes (292), and LMICs bear much of the burden of NCDs, placing immense pressure on our healthcare system (77, 293). More specifically, South African women appear to be susceptible to obesity and physical inactivity and therefore NCD risk (294). The WHO calls for surveillance and monitoring of disease risk factors, of which PA is one aspect (295).

Disease risk factors and health behaviours become even more important during pregnancy for two main reasons. Firstly, pregnancy is seen to be a “stress test” on the expectant mother’s physiological system and subsequent health status. Preventing health issues such as GDM and excessive GWG will have a long term impact on the health of women as they get older. Secondly, the theory of metabolic programming provides insight into the effect of health behaviours during pregnancy, which also has implications for long-term outcomes in the offspring. This provides sufficient evidence to view pregnancy as a “teachable moment” (4, 296) in which changing behaviours, reducing risk factors and improving health can have long lasting effects, not only for the mother, but for the next generation as well.

Women from LMICs may also be more susceptible to adverse pregnancy outcomes due to limited knowledge around pregnancy and health, including PA recommendations. Despite the wealth of evidence to encourage PA in the prevention and management of chronic disease, minimal research exists in the prenatal population, particularly in LMICs. Although the current evidence provides a broad idea of factors which may influence PA participation during pregnancy, it is necessary for more research to be done in the South African context in order to develop effective interventions. Understanding PA in a given population should include monitoring of PA levels, patterns and correlates (45, 297), as well as understanding the social constructs that define one's activity behaviours. In order to achieve a holistic view, assessing key role-players and stakeholder's views (such as healthcare providers) is crucial and allows for a more directive intervention approach. In addition, evidence examining the association between maternal PA and maternal health and birth outcomes is accumulating in HICs but is currently lacking in women living in a low to middle income urban setting. The possible adverse consequences of an inactive pregnant population in SA, could have long-standing effects on its strained healthcare system.

Overall Aim

The overall aim of this study is to understand maternal PA during pregnancy, and examine its influences on maternal and birth outcomes. This overall aim has been separated into five study components: 1) to provide a theoretical background of evidence examining the role of PA during the prenatal period; 2) to examine the attitudes, beliefs and perceived barriers to PA during pregnancy in black South African women; 3) to assess the knowledge, attitudes and beliefs of South African medical practitioners towards exercise during pregnancy; 4) to describe the patterns and correlates of self-reported PA levels during pregnancy in black South African women; and lastly 5) to objectively and longitudinally measure PA in pregnant women, and examine its association with maternal and birth outcomes.

Study Objectives

Study 1: The attitudes, beliefs and perceived barriers to physical activity during pregnancy.

1. To describe the attitudes and beliefs towards physical activity during pregnancy in a cohort of urban black SA women

Study 2: Attitudes, knowledge and beliefs of medical practitioners towards physical activity during pregnancy.

1. To assess the knowledge, attitudes and beliefs of South African medical practitioners towards exercise during pregnancy
2. To determine which practitioners are more likely to prescribe physical activity during pregnancy

Study 3: Patterns and correlates of self-reported physical activity levels during pregnancy in black women living in Soweto, South Africa.

1. To determine the patterns of self-reported physical activity, and sedentary behaviour, measured at two time-points during pregnancy in a cohort of urban black SA women
2. To describe the change in physical activity and sedentary behaviour during pregnancy, in a cohort of urban black SA women.
3. To determine the correlates of physical activity and change in physical activity during pregnancy in a cohort of urban black women

Study 4: Objectively measured physical activity and sedentary behaviour in pregnancy, and maternal and delivery outcomes in black SA women

1. To objectively measure physical activity levels and patterns in pregnant urban black SA women
2. To determine the association between objectively measured physical activity in the second and third trimester and its influence on maternal outcomes.
3. To determine the association between objectively measured physical activity second and third trimester and its influence on birth outcomes

Chapter Two

STUDY CONTEXT AND METHODS

"I am not African because I was born in Africa, but because Africa was born in me." Kwame Nkrumah

This chapter provides contextual background for the study's setting in Soweto (South Africa), its unique healthcare system, as well as study participants. Whilst the methods for each study are presented in the respective chapters, this section provides a background setting from which to interpret the study as whole. In addition, specific details regarding the choice of various PA measurement tools used is described.

2.1. Home sweet home: Soweto, South Africa

South Africa is a sub-Saharan African country, classified by the World Bank in 2013 as a middle income country, with a gross domestic product (GDP) of $350.1 billion and a total population of 54 million people (298). The 2011 census reported that 79.2% of South Africans were black, 8.9% coloured, 8.9% white, and 2.5% were Indian or Asian.

Soweto, an English abbreviation for South Western Township, is the largest metropolitan municipality in South Africa, covering a distance of approximately 200km^2 (299), with an estimated population of over 1,2 million people (300). It is a large urban area outside of Johannesburg, representing some of the poorest neighbourhoods in this area. It is a cluster of townships that are steeped in the history of the struggle against apartheid. The township originated for mainly black mine labourers (www.southafrica.info), which saw waves of migrant workers flooding to the area in search of employment.

"…is this conglomerate urban or rural? No electricity in the houses, a telephone an almost impossible luxury: is this a suburb or a strange kind of junk yard? The enormous backyard of the whole white city, where categories and functions lose their ordination and logic…" This abstract from Nadine Gordimer's *Burgers Daughter* (1979) provides a vivid description of an urban black township which is not so very different almost 35 years later.

Although there is an emerging middle class, the majority of inhabitants come from low income households, with statistics showing that many earn much less than in the wealthier suburbs of Johannesburg (299). The majority of Sowetans are black ethnic origin (see Figure 7 below) and although South Africa has eleven official languages, the main spoken languages of Soweto include English, Zulu, Sotho, Tswana, Venda and Tsonga.

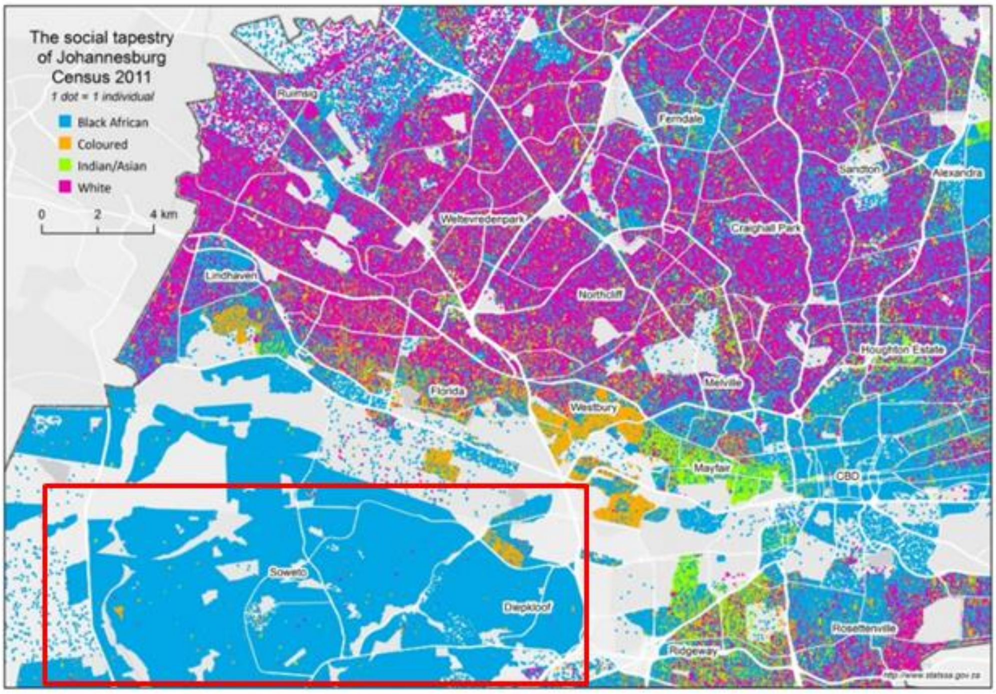

Figure 7 Ethnic distribution or "social tapestry" of Johannesburg, with Soweto indicated by the square outline (299).

Soweto is perhaps one of the clearest pictures of South Africa undergoing the nutrition transition. A rising middle class, combined with historically-related poverty, makes it a complex mix for social inequalities and health care issues. Despite the increase in income and quality of life since apartheid, citizenship in Soweto still carries issues of lack of access to basic services (such as electricity and water) and unemployment (301). Urbanisation (43.3% of South Africans live in urban areas) sees many communities living in informal housing resulting in a combination of poverty-related infectious diseases due to poor sanitation etc., violence and trauma, HIV/AIDs as well as lifestyle-associated NCDs (37). Consequently, South Africa is faced with issues of an existing communicable disease burden, poor sanitation as well as a rising NCD problem, in a heavily burdened and under resourced health care system (7).

The rise in risk factors for NCDs, and obesity in particular, has been described as a “time bomb” for urban, transitioning populations (302). Up until now, research in Soweto has focussed mainly on health risk screening and dietary intake, indicating a high prevalence of modifiable heart disease risk factors (303), and a vast increase in fast foods and high, energy-dense diet consumption (304-306). Physical activity research is sparse in this area, however recent data has reported an association between sedentary behaviour and adverse metabolic health in this population (86).

2.2. Study setting

This PhD thesis was nested within the larger Soweto First 1000 Days Study (S1000), which is a longitudinal pregnancy cohort study involving approximately 1000 pregnant women residing in Soweto. The study is being conducted at the Medical Research Council(MRC)/Wits Developmental Pathways for Health Research Unit (DPHRU), and is designed to measure pregnancy exposures, fetal development, delivery, and growth and development in the first two years of life (www.wits.ac.za/dphru).

DPHRU is based at the Chris Hani Baragwanath Hospital (CHBH), in Soweto, Johannesburg. The Soweto region has 13 primary health care clinics, 5 community health centres and 1 tertiary hospital, CHBH, or affectionately known as “Bara”. It is the world’s third largest hospital, and is a provisional government-run hospital that also serves as a teaching hospital for the University of the Witwatersrand. Antenatal care is offered at the 5 community health centres in the Soweto area and CHBH. Community health centres or clinics provide the first line of health care, and the place of initial antenatal care is determined by a woman's residential zone. Antenatal care, which consists of general screening as well as blood and urine testing, but no ultrasound measurements, is provided for low to intermediate risk women by nursing staff, community health care workers and a visiting medical officer (307). Basic antenatal care for low risk pregnant women will consist of four follow up visits, usually at 20, 26-28, 32-34 and 38 weeks gestation (307). CHBH is the only health care centre in Soweto that offers fetal ultrasounds. There are 396 beds in the Department of Obstetrics and Gynaecology in CHBH, which delivers approximately 17 000 babies and performs 4 160 caesarean sections per year (299). Although it is the only hospital serving the Soweto area, it is largely under-resourced with regards to infrastructure and medical supplies (308).

2.2.1. Study participant recruitment

Women were recruited for the study from the CHBH and the inclusion and exclusion criteria for the larger study are shown in Table 5 below:

Table 5 Inclusion and exclusion criteria for the S1000 study

Inclusion Criteria	Exclusion criteria
1) ≥ 18 years of age	1) Multiple pregnancies
2) < 14 weeks pregnant	2) Fetal abnormalities detected
3) Singleton pregnancies	3) Intellectually or physically disabled women
4) Women residing in Soweto	
5) Black South African females	
6) Must be able to give informed consent	

Recruitment from CHBH allowed for an accurate ultrasound-assessed gestational age, which would otherwise not have been possible through the antenatal clinics at the community health centres. Furthermore, recruitment from CHBH provides a larger and more diverse sample of pregnant women, and is convenient from a practical perspective as DPHRU's research site is based within the hospital grounds. Recruitment for participants for the studies in this thesis was carried out from August 2013 – August 2015, although the larger study continued until June 2016.

A flow diagram of the recruitment process, and attrition rates that determined the final sample size, is shown in Figure 8 below. The final sample size for study 3 was n=256, with participants having a complete data set at both time points. All participants from study 1 (n=15) and study 4 (n=130) overlapped into study 3.

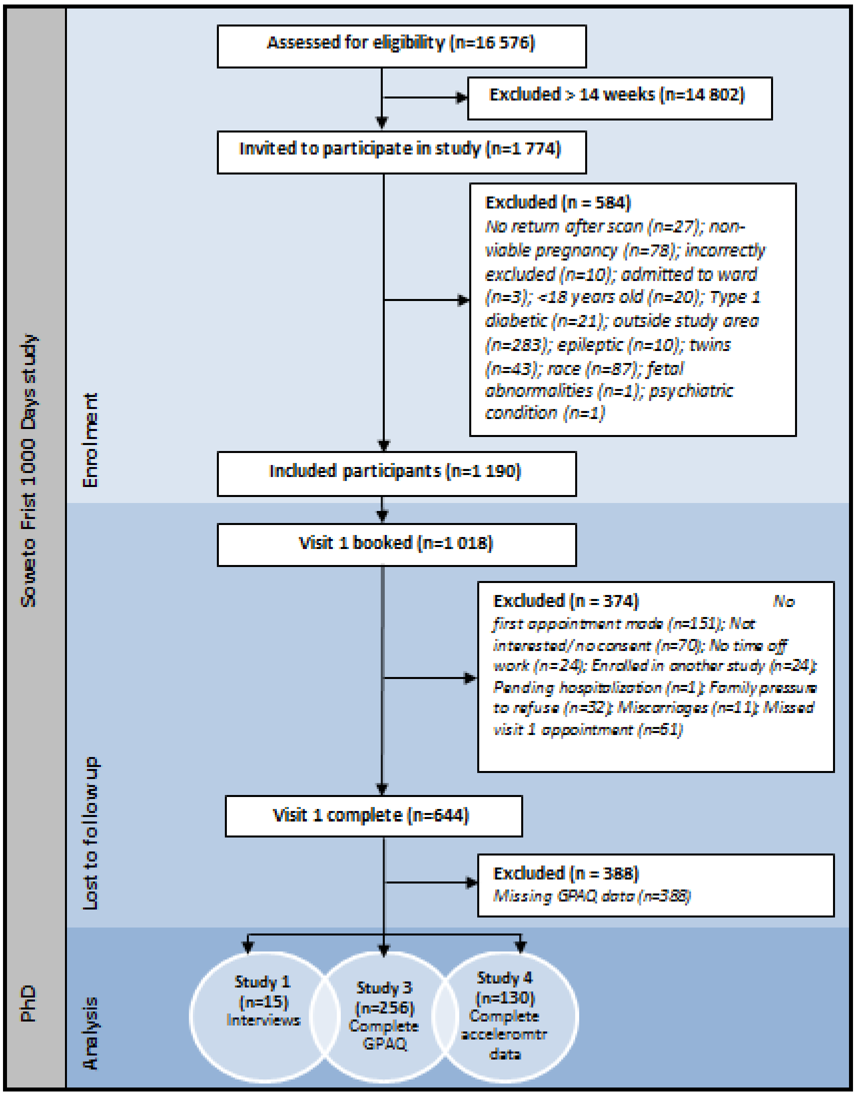

Figure 8 Flow diagram of participants through the study (309)

2.2.2. Data collection

Participants were seen at the DPHRU research unit seven times during the duration of the larger S1000 study (dependent upon delivery date), and various data was collected at each time point (Appendix A). For the sub-studies that formed part of this thesis, data was collected at visit 1 (<14 weeks), visit 2 (14-18 weeks), visit 5 (29-33 weeks) and delivery as per the data collection sheet (Appendix B). In addition, maternal weight was measured at each time point. Data was collected by trained research assistants, and PA data was collected by the researcher, with the assistance of trained research assistants. All questionnaires were interviewer-led in English, and any queries were clarified in the home language of the participant were possible. All participants were given the telephone number of the on-call research nurse, and the nurse was called when the participant went into labour. Trained research nurses collected delivery data within 48 hours of delivery, and clinic records were used when participants delivered at clinics outside of CHBH. All data was captured onto an online system called RedCap.

2.2.3. Measures of physical activity and sedentary behaviour

Surveillance studies of PA during pregnancy often rely on self-report assessments (31, 310). Various questionnaires exist and have been assessed for their validity during pregnancy (311, 312), with most assessing PA across the various domains including recreation/leisure, transport, housework and occupational domains. It is imperative to assess the domains of PA, as each domain may have a different effect on maternal and birth outcomes. For example, specifically recreational or leisure time PA has been associated with either positive (20), or no effects on birth outcomes (211), while occupational activities, such as lifting, bending, stooping or shift times, have been associated with negative effects on the maternal-fetal unit (258). In the South African context, it appears that occupational and commuting activities are the most significant contributors to PA (78), and this becomes essential to assess in this population.

The Global Physical Activity Questionnaire (GPAQ) (Appendix C) was developed by the WHO in order to produce a standardised tool for PA surveillance (270). It is especially relevant for developing countries, taking into account the diverse patterns of energy expenditure unique to these populations. It has been used extensively in South Africa (72, 313) and Africa (314), and has been validated in nine different LMICs (270). It has been shown to have moderate-to-good correlation coefficient with the International Physical Activity Questionnaire (IPAQ), r=0.54(270) and r=0.45-0.65 (315). The GPAQ has good-to-excellent test-retest reliability (0.67-0.81), and has poor-to-fair criterion validity when measured against pedometers, r=0.31 (270) and r=0.06-0.35 (315). The GPAQ has also been used during pregnancy (316, 317), and collects data in four domains of PA: 1) activity at work; 2) travel to and from places; 3) recreational activities and 4) time spent sitting/reclining. Self-report measures of PA remain the simplest, most cost effective manner of determining PA patterns in large population groups.

A self-report of common sedentary behaviours, such as sitting whilst at work, church or during recreational activity, was collected. A sedentary behaviour questionnaire (SBQ) (Appendix D) was administered to assess the time spent in common sedentary behaviours during the week and on weekends. Although this questionnaire has been used in previous cohort studies in the area (86), it has yet to be validated. However, it was developed and piloted for content/face validity prior to being used in the pregnant population, through the following steps (1) it was based on recent literature, (2) relevant experts in pregnancy as well as within the South African context were consulted and the questionnaire was adapted, (3) the domain/dimension was based on the literature, as well as on the theoretical framework of the GPAQ. A sensitivity analysis for the data processing was not conducted (215), with the aim to validate it for criterion validity and reliability in the future.

Although the doubly labelled water method remains the gold standard for measuring energy expenditure, it is not feasible in low resourced, large scale studies, or as a measure of habitual PA. Therefore, accelerometers have become an increasing popular objective method of measuring PA, and have also been used previously during pregnancy (32, 318). Accelerometers have been validated against the doubly labelled water method (319), and VO_2 laboratory (r=0.85-0.92) and field measurements (r=0.48-0.59) (320, 321).

To our knowledge, few studies have assessed objectively measured PA at more than one time point, and its effect on maternal and birth outcomes (322). The use of accelerometers to assess sedentary behaviour is relatively new, but is becoming increasingly popular (318, 323). Although accelerometers are possibly more accurate than questionnaires, it is not always the most feasible instrument, especially in epidemiological studies. Depending on the type of information needed (i.e. frequency, duration, type), a combination of self-reported and objective measures of PA is more likely to yield the best results (215).

2.2.4. Sample size calculation

Study 1: A sample matrix (324) was designed to include a sample size of 15 women; however, sample size was determined by saturation, whereby no new ideas or concepts emerge from the interviews.

Study 2: The sample of n=375 was calculated based on an estimated population of 15 375 general practitioners and gynaecologists currently practicing in South Africa (325), with a confidence interval of 5% and a confidence level of 95%.

Study 3: The sample size was based on an estimated 40% of the population meeting the current PA guidelines, or being classified as “active” (≥600 MET or 150 min of moderate PA, or 75 min of vigorous PA mins/wk), based previous research in this area (326). Based on this estimation, a sample size of n=209 was calculated, with a confidence level of 5% and a power of 0.05.

Study 4: The sample size of n=384 was calculated based on the estimated sample population of black women living in Soweto (327), with a confidence interval of 5% and a confidence level of 95%. The statistical package STATA 12.01 was used to calculate the sample sizes.

2.2.5. Ethical approval

All participants were provided with an information sheet for the sub-study (Appendix E) that was explained in their home language when necessary. Informed consent was provided for general data collection, as well as the in-depth interviews (as needed) (Appendix F). All identifying information was removed from the data collection sheets, and participant information was coded to maintain confidentiality. Ethical approval was granted for the larger S1000 study, “Investigating maternal factors associated with fetal growth and delivery outcomes” (M120524) (Appendix G), as well as for the PhD study, “Maternal physical activity: influence on maternal and delivery outcomes” (M130351) (Appendix H) and the “Factors Affecting Physical Activity Patterns in Pregnant Women” study (Chapter 2) (Appendix I) by the Human Research Ethics Committee (HREC) of the University of the Witwatersrand.

Chapter Three

“JUST BECAUSE YOU’RE PREGNANT, DOESN’T MEAN YOU’RE SICK!”

A QUALITATIVE STUDY OF BELIEFS REGARDING PHYSICAL ACTIVITY IN BLACK SOUTH AFRICAN WOMEN.[2]

“Life is not a problem to be solved, but a reality to be experienced” Soren Kierkegaard

[2] **Watson, E.D, Norris, S. A, Draper, C. E, Jones, R. A, van Poppel, M. N. M & Micklesfield, L.K.** (2016) “Just because you’re pregnant, doesn’t mean you’re sick!” A qualitative study of beliefs regarding physical activity in black South African women. *BMC Pregnancy and Childbirth,* 16:174. [**DOI**:10.1186/s12884-016-0963-3]

3.1. Introduction

Pregnancy is a unique time in a woman and her unborn childs' life course, and thus it is unsurprising that maternal health is a worldwide health priority (328). Although much of the focus of healthcare has been on reducing the direct causes of maternal morbidity, recent years have seen a shift towards addressing modifiable health risk factors, such as diet and PA. Indeed, pregnancy may be a critically receptive period to improve the health outcomes for both the mother and her unborn child (131, 134).

The benefits of an active pregnancy are well documented and studies have demonstrated a reduced risk of pre-eclampsia, GDM and gestational hypertension (162). Meeting the recommended >=150 minutes of moderate PA per week (19) during pregnancy may also lead to improved course of delivery and provide a protective effect against LBW and prematurity (25). Furthermore, it may play a crucial role in preventing maternal obesity, excessive GWG and infant obesity (131). This may be particularly important for women from LMICs, where low SES in a transitioning environment, has been reported as a risk factor for high prevalence of obesity, physical inactivity, impaired glucose intolerance and GDM (35, 36, 39, 329).

However, despite these recommendations, pregnant women have been shown to be less active than their non-pregnant counterparts, and tend to decrease their activity levels during pregnancy (330). Previous studies from Brazil indicate that pregnant women are susceptible to low levels of PA (271), despite their knowledge of the benefits (331). Pregnancy-specific psychological factors such as fear of miscarriage, and physical factors such as fatigue and increased stomach size, may contribute to a reduction in activity levels. These combined psychological and physiological factors may make pregnancy a vulnerable period for reducing PA levels and increasing sedentary behaviours (332).

Understanding the social, cognitive and behavioural factors that predict and describe PA participation becomes essential for understanding and intervening in this potentially vulnerable population group. To this end, the Theory of Planned Behaviour (TPB) is a useful approach for understanding, explaining and predicting PA behaviours (333, 334), including during pregnancy (335, 336). It involves three main domains, namely, behavioural beliefs/attitudes (the perceptions of the consequences of the behaviour), perceived behavioural control (PBC)/control beliefs (the perceived degree of control over performance of the behaviour) and subjective norms/normative beliefs (the social pressure, or perceptions of what significant others think about the behaviour) (335, 337). In order for researchers to plan interventions or change public health policy, the multidimensional determinants of PA participation need to be understood, and TPB provides a valuable framework in which to do this.

There is currently little research that has investigated South African women's beliefs or factors that influence their PA behaviours. Therefore, the aim of this study is to determine the beliefs of black South African women regarding PA during pregnancy, and therefore provide formative theory on which to design effective PA interventions during pregnancy.

3.2. Methods

3.2.1. Study sample

Pregnant (29-33 weeks gestation) participants were recruited from the MRC/Wits Developmental Pathways for Health Research Unit (DPHRU), based at Chris Hani Baragwaneth Hospital (CHBH), Soweto, South Africa. Soweto, an English abbreviation for South Western Township, is one of the largest urban areas in South Africa, with over one million inhabitants. Although the majority of its inhabitants come from low-income households, it also has a rising middle class and this, combined with historical apartheid-related poverty, makes it a complex mix for social inequalities and health care issues (www.soweto.co.za).

A purposive sampling approach was used to include a homogenous group of singleton, black pregnant women with non-complicated pregnancies in the third trimester (324). Third trimester was chosen in order for the women to provide a current and retrospective view of their activity levels during the majority of their gestational period. Women were purposively recruited from a public antenatal hospital, as this is a proxy for low to middle SES in South Africa. A sample matrix (324) was designed to include a sample size of 15 women; however, data saturation was reached after 13 interviews. The women attended the DPHRU for non-clinical, research purposes every 4-6 weeks during their pregnancy as part of a larger study (Soweto First 1000 Days study). Reporting of methods has been based on the Relevance, Appropriate, Transparency and Soundness (RATS) review guidelines to ensure rigour and quality (338, 339).

3.2.2. Theoretical framework

This study adopted a deductive logic approach (324) and was grounded in the Theory of Planned Behaviour (TPB) (334). Since this research was aimed at eliciting personal experiences and perceptions regarding the concepts of PA in its broader sense, an interpretative phenomenological analysis approach was adopted (324). Within the construct of PBC, the current study did not explicitly address the areas of self-efficacy or controllability. Instead, this was measured indirectly based on beliefs regarding the perceived ease or difficulty in participating in and performing a behaviour (e.g. I don't have the money to attend the gym) (334, 336, 337, 340). This belief based method of measuring PBC may have the advantage of providing underlying cognitive insights that would otherwise be missed if measured directly (334). The rationale, as described by Ajzen (334), is that the more resources and opportunities available, and the less or more manageable the barriers, the increased confidence to participate in the behaviour, and the higher the degree of perceived behavioural control exhibited (337). Furthermore, perceived control over the performance of a behaviour also involves various intrinsic and extrinsic factors that may serve to help or hinder the behaviour. Although it may be argued that self-efficacy is measured through intrinsic factors, and controllability through external factors, these concepts may reflect both beliefs and were therefore not treated as mutually exclusive in the current study (337). Since self-efficacy and controllability are also found to be closely related, both these constructs can be seen as influencers of an individual's perceived ability to control their behaviour (337).

3.2.3. Data collection

Semi-structured interviews were conducted between March and December 2014. All interviews were conducted in English, which is the language common to most inhabitants of Soweto. Each interview was conducted at the DPHRU by the researcher (EW), who did not have a clinical role in the participants' visits to DPHRU. Open-ended questions (Appendix J), with probes, were developed using the TPB theoretical framework, and informed by previous studies (280, 284, 341, 342). They were designed to facilitate breadth and depth of conversation and provide information-rich discussion (324). Although the concept of perceived behavioural control was not explicitly asked in the interview guide, questions related to factors that obstruct or facilitate participation in PA were used to elicit the participants' perception about their control over the achievement of the behaviour (341). The guide was reviewed for qualitative properties by an expert in the field of public health, and pilot tested prior to data collection. Each interview, which lasted between 45-80 minutes, was audio-recorded and notes on non-verbal actions were taken by the researcher.

Demographic and pregnancy medical history information was collected on all participants using an interview-administered questionnaire. Anthropometric data was measured by trained research nurses. Socioeconomic status was assessed using household inventory questions, assessing the ownership of nine household commodities (electricity, radio, television, refrigerator, cell phone, personal computer, bicycle, motorcycle/scooter, car). Furthermore, PA levels were measured using the GPAQ, a valid and reliable tool that measures PA in various domains, including work, travel and recreation (270). Participants were further classified as "active" (≥600 MET mins/wk) or "inactive" (<600 MET mins/wk). 600 MET mins/wk is the equivalent of reaching the recommended 150 min of moderate PA, 75 min of vigorous PA or a combination of the two (112, 270).

3.2.4. Data analysis

Recorded data were transcribed verbatim and reviewed by the researcher for accuracy. A formal thematic analysis process was undertaken, including familiarisation, construction of an initial framework within the TPB, indexing and sorting, reviewing, data summary, constructing categories and identifying links and patterns (324).

The following steps were taken to ensure the trustworthiness of the data. Firstly, the open-ended question discussion guide was based on previous literature as well as experts in qualitative and physical activity research, to ensure credibility of the data that emerged. In addition, multiple sources of data was used (such as the GPAQ as well as the interviews), to inform the data analysis. In order to ensure transferability of the research, the contextual background of the participants (Chapter 2) and the researcher (Preface) has been provided, as well as a detailed description of the methodological steps taken. Dependability and confirmability of the data was done by peer-review of the transcripts and coding framework (343, 344).

A data analysis software tool (ATLAS.ti 5.0) was used to organise the codes and themes into a structure for analysis. Major themes are represented according to frequency, and thematic saturation was reached by the thirteenth interview, whereby no new themes emerged. To ensure reliability of the coding framework the initial thematic coding was completed and left, and then done again one month later. In addition, a sample of three transcripts was peer-reviewed to agree on the coding framework.

3.3. Results

Participants (n=13) ranged in age from 19 to 41 years of age (Table 6). The average BMI was 30kg/m^2 (range: 19.6 – 39.0kg/m^2). Majority of the women (69%) were single, and 59% had only a secondary education level. Over half (54%) of the women were classified as inactive according to the GPAQ cut-off of less than 600 MET-minutes per week requirements (270).

Table 6 A summary of participant characteristics for Study 1 (n=13)

	Mean (range) / %
Age in years	28 (19 – 41)
Baseline (<14 weeks gestation) BMI (kg/m^2)	30 (19.6 – 39.0)
Marital status	
Single	69
Married	31
Education	
Secondary school	59
Professional/technical training	8
University	33
Employment	
Skilled manual labour	25
Unskilled manual labour	17
Clerical/administrative/student	33
Unemployed	25
HIV status	
Positive	33
Negative	67
Household inventory (/9)	
<6	17
6-7	83
>8	0
Paternal age in years	34 (23 – 44)
GPAQ physical activity status	
Active	46
Inactive	54

The qualitative findings of the study are presented according to the following typologies (i) behavioural beliefs and attitudes; (ii) perceived behavioural control (PBC) and (iii) subjective norms/normative beliefs. Common views and experiences of participants are presented as verbatim quotes, and described using the participant's age; BMI, gravida status (number of previous pregnancies) and PA status (according to the GPAQ).

3.3.1. Behavioural beliefs and attitudes

Although some women warned against the potential adverse effects of alcohol, drugs, stress and heavy work during pregnancy, the majority of participants were aware of the importance of adopting healthy behaviours during pregnancy including a healthy diet, exercise, and sufficient rest.

"A good diet. Exercise, but not excessive exercise. Good rest is also very important." (Age 28 years; BMI 30 kg/m^2; G2; Active)

All the women who participated in the interviews believed that PA was in some way beneficial. For most of the women, walking appeared to be the preferred form of PA. The most popular perceived benefits reported by participants included the belief that PA would help to prepare the body for labour, reduce labour time, and that the baby would also be prepared:

"*It helps relax the muscles so that when you give birth, the muscles are not tight, they're used to expanding, yes, that movement and even the baby is used to the movement and he won't be surprised…it prepares the body and the baby also." (Age 23 years; BMI 24.6 kg/m^2; G3; Active)*

One woman explained:

"I think for my own health…Apart from the birth, I think for myself, my own health, my heart, and I also feel the skin, I don't know, when I'm walking, I feel like my skin is breathing more. So I think it keeps it healthier, you know? The more it sweats and, I think it's good….It helps you relax as well. When you [walk], it is kind of therapeutic for me, I don't know." (Age 28 years; BMI 30 kg/m^2; G2; Active)

For many of the women, PA was defined as an activity of daily living, such as occupational and household tasks, and few described it as recreational. Throughout the interviews, many women presented the idea that being busy was synonymous with being active:

"*If you have a job, that job keeps you busy, you are always busy so the baby is busy too, but if you are always sleeping the baby will be sleeping too." (Age 27 years; BMI 32 kg/m^2; G3; Active)*

Another woman commented:

"Physical activity, I think, is just keeping active…when you're home walking around and not sitting too still. I have a baby so she keeps me very busy. If you have a child you don't have a problem with physical activity because you're always running after them." (Age 28 years; BMI 30 kg/m^2; G2; Active)

While participants reported on the benefits of PA, several women were also conscious of 'overdoing' it during pregnancy. Certain occupational, household and recreational tasks were described as too vigorous and were therefore perceived as unsafe. Many women revealed a general uncertainty, without always knowing why these activities were deemed unsafe. The perception as to whether a certain activity was safe or not, often originated from advice from family and friends, or listening to their own bodies:

"*I can talk about me…we used to go and fetch water at the tap, we must use the bucket and …when I pick it up, I can feel something inside me that is telling me that this thing is heavy just leave it, you know." (Age 24 years; BMI 30.6 kg/m^2; G2; Active)*

One woman commented:

"I don't know about swimming…you know you're working on all muscles of your body, so I don't know what impact that would have. Things like bending over, squatting... I always feel because it's very difficult… I think maybe it's hurting the baby." (Age 28 years; BMI 30 kg/m^2; G2; Active)

3.3.2. Perceived behavioural control beliefs

The women in the current study discussed various barriers, or obstacles, to participating in PA, which may influence the perceived control that women have over their PA behaviour, therefore reducing the time spent being physically active. The most frequently reported intrinsic barriers included tiredness, morning sickness, interrupted sleep and discomfort due to the size of the stomach. Participants appeared to display a reduced self-efficacy, and described the increasing difficulty in performing PA due to the pregnancy-associated physical changes. This was combined with a limited perceived control over their activity levels, where the unborn baby was described as determining the amount of PA done:

> *"You know, this person is heavy, that you're carrying….you get very tired. And being tired makes you sit down more, and you're not very... you can't do much." (Age 24 years; BMI 26.8 kg/m^2; G1; Active)*

Another participant commented:

> *"You're tired quicker when you're pregnant. I can tell when I can't take anymore, so I just stop when I feel like that's enough. Pregnancy is quite interesting, because you have those bouts of activity, you know, being extremely active and you do not know where it comes from and then the next minute you're, like, I don't want to do anything. I'm tired. So, it's quite interesting in that sense. It differs from woman to woman. It depends on how heavy your belly is." (Age 28 years; BMI 30 kg/m^2; G2; Active)*

On the other hand, one woman described her belief that these barriers are within her control, and was determined not to allow the pregnancy to affect her behaviour:

> "*They just say that this pregnancy it's too tiring…so if you let the pregnancy control you, you won't do anything in life truly. It does not mean that the baby just took over your body or your everything, you must exercise, you must eat well and do everything just the way that you are, you are not sick you are just pregnant." (Age 27 years; BMI 32 kg/m^2; G3; Active)*

Commonly reported extrinsic barriers included limited time or money available for PA. Prioritising their resources to meet their family's needs appeared to diminish the participants' perception of control towards being active:

> *"I don't have the time [to go to the gym]. When I'm coming to work I'm tired seriously. When you are off you are supposed to do the things at home so there is not time to go to gym." (Age 35 years; BMI 37.4 kg/m^2; G2; Active)*

Another woman commented:

"Some [people] do not have the money to buy healthy food. Yes it [gym] is expensive, and that money you can use for the child…to buy medication for that child or milk." (Age 32 years; BMI 32.2 kg/m^2; G3; Inactive)

Another extrinsic barrier noted by many women was the lack of information provided by healthcare professionals about PA during pregnancy. Many women reported receiving little information at the antenatal clinics, and information that was provided was often vague or non-specific. Some women mentioned that, within the healthcare system, education regarding communicable diseases was prioritised over providing information on the benefits of PA. Added to this, many women reported bad experiences at their antenatal clinics that prevented them from asking any PA-related questions:

"They [the nurses] are just teaching HIV and AIDS and that's it. There's no time to ask questions or anything, you know…" (Age 23 years; BMI 24.6 kg/m^2; G3; Active)

Another woman agreed:

"*No to be honest those people [the nurses] are mean and they're not helpful. I don't know, maybe they don't like pregnant women, we are making their lives difficult somehow. They don't seem to care that much so I wouldn't trust someone who doesn't care about you at all. No I'm very intimidated by them so I do not ask questions, I rather ask friends and family." (Age 20 years; BMI 29.4 kg/m^2; G1; Inactive)*

In fact, one woman articulated the importance of being provided with correct information to improve her perceived behavioural control, noting that with advice and education she would be more likely to be active:

"*I don't know, I'm just too lazy to do them [exercise], I don't know. Or maybe I don't know the importance of doing them." (Age 20 years; BMI 29.4 kg/m^2; G1; Inactive)*

Many women also discussed extrinsic and environmental influences that would assist them in becoming more active. They were particularly supportive of having community-based group exercise classes aimed at pregnant women. A supportive and safe environment appeared to be a motivator to become active, and may therefore improve their perceived behaviour control in this area. Many of the women felt that not only would these community facilities improve their PA behaviour, but that it would provide an opportunity to expand their social support network:

> *"Having antenatal classes in my neighbourhood, that would be awesome actually. Because they focus more on pregnant woman so I'll feel much safer. I know I can do anything that they tell me to do there; because I know it's not going to harm the baby. That would be great…I just want my baby to be safe." (Age 20 years; BMI 29.4 kg/m^2; G1; Inactive)*

> And another agreed:
> *"Pregnant ladies coming together, doing such [exercises], it would help a lot. If I had a group like that next to me, I would have been doing it…because that's where you get to know also the other experiences and what other ladies go through." (Age 24 years; BMI 26.8 kg/m^2; G1; Active)*

3.3.3. Subjective norms/normative beliefs

Healthcare providers were reported by some of the women as potential social influencers of their PA behaviours. However, since they provided very little education, healthcare workers were unlikely to provide any social pressure when it comes to participating in PA:

> *"If they [the gynaecologist] also gave us information on that, that would help – the exercise positions, show you that when you're pregnant you can do this, or in late pregnancy, you can't do this. They don't tell you…they never even mentioned to me to do exercise." (Age 28 years; BMI 30 kg/m^2; G2; Active)*

Due to this lack of information, many women turned to family, friends or the media for advice regarding pregnancy. However, in most cases, this advice encouraged women to reduce their activity levels during pregnancy, as a time to "take it easy". Furthermore, this advice to reduce activity levels was coupled with the fact that many women did not have family or friends that participated in, or talked about the importance of, PA:

> *"Just because you're pregnant it doesn't mean you're sick, you're not sick at all…go ahead and do what you normally would do, your daily routines as usual, keep them going until you can …You know, it's so easy to be spoiled. My family …they used to just spoil me, but no, don't do this, don't go down, don't pick it up, don't do this, you know? So you get spoiled easily, and it's easy for you to go, ah, I don't feel like doing this, and get so lazy…" (Age 24 years; BMI 26.8 kg/m^2; G1; Active)*

One woman described her friend's reactions to being active:

> *"Most of my friends are not physically active. If I even mention walking, they're like, 'Why would you …? "Only dogs walk" you know? I'm like, 'No, it's good for you!'They always want to drive, so yes. That's the experience that I've always had. I don't know if it's a South African thing, but most people just want to get into a car. My husband is, every time I say, let's go on a walk he says no. He doesn't feel a need. Whereas for me it is…kind of…a need." (Age 28 years; BMI 30 kg/m^2; G2; Active)*

Many of the participants mentioned cultural beliefs and practices during pregnancy that are passed down through the generations. Often the women noted that these beliefs and practices are followed without knowing the reasoning behind them. One woman described the beliefs passed on from her family:

> "*We have a lot of indigenous knowledge on pregnancy and, you know, as African people, you're taught that at a very young age. 'Do this, don't …" You know, some of them are silly, but…! Like, don't stand by the door, you know? Okay, some are just common knowledge, it's like common sense. Don't stand for too long. Maybe that's why they say don't stand at the door, but they have their own reasons, like superstitious reasons. You know, sometimes I remember things my mom used to tell me not to do this, from like a long time ago, but she never told me why! But I do it, every time. Even physical activity, some people will say, you don't sleep enough.*

Why are you walking? You know? Things like that. You should just let your husband drive you, things like that. "Why are you so busy? You have to rest." You know? "You're pregnant." (Age 28 years; BMI 30 kg/m^2; G2; Active)

There appeared to be conflicting ideas regarding activity during pregnancy. Whilst most women reported that their families were encouraging them to rest and take it easy, many women also reported on being warned of the dangers of too much rest. Many women alluded to the concept of being lazy during pregnancy, and believed this excessive rest was associated with adverse delivery outcomes:

"There's this myth that if you sleep a lot during the day the baby gets lazy, and when it's nearer to giving birth, the baby won't know when it's time…you might get issues with the baby still sitting and the baby doesn't want to come." (Age 24 years; BMI 26.8 kg/m^2; G1; Active)

3.4. Discussion

The purpose of this study was to qualitatively assess the beliefs, and elicit views and experiences, regarding PA during pregnancy in black South African women. In the current study, pregnant women described many positive beliefs about PA, which aligns with previous research (342, 345). Although some women mentioned walking as a preferred activity, many defined PA as activities of daily living. This is common in studies of women of low SES, who often consider exercise as synonymous with work, housework or childcare (329, 346). Indeed, despite their beliefs in the benefits of PA, the majority (54%) of women in this, and other studies (31, 330), remain inactive during the prenatal period.

The discord between favourable attitudes towards PA, and the actual behaviour, may be explained by the factors which influence pregnant women's' perception of control (347). Certain pregnancy-specific physical limitations appear to be a common intrinsic barrier to perceived volitional control of being active (281). Since all the women in the current study were in their third trimester, it is unsurprising that the issues of tiredness and size would become a barrier. Other research has reported similar physical limitations (329, 342) and Hausenblas et al. (332) propose that it is these psychological and biological consequences of pregnancy that may contribute to the declining PA levels during this period. Interestingly, there is much research to support the role of PA in reducing many of these pregnancy discomforts (348), although this was not mentioned by the women in the current study. It appears that these barriers influenced both the women's self-efficacy (it becomes harder to do the behaviour), and the controllability ('*I listen to the baby*'). It has become evident that this combination reduces many women's perceived behavioural control and their subsequent activity levels (341), whilst other women are determined not to let it hinder them ('*you are not sick you are just pregnant').*

These physical barriers were also combined with extrinsic obstacles such as lack of time, finances and adequate information, all of which are common in low socioeconomic pregnant women (283, 284). Indeed, with the majority of the women in the current study being single, and a quarter being unemployed, many of the women may not have the perceived social or financial support, to engage in PA outside of their daily routines (346). Therefore, strategies to support these women to gain a sense of control through education and counselling may be a possible method of empowering and motivating women to embark on an active lifestyle despite these perceived obstacles.

Group physical activity may provide a powerful motivator for changing behaviours and adopting a more active lifestyle during pregnancy. Kieffer et al. (329) suggested centre-based group exercises, delivered in the context of addressing safety and developing knowledge on lifestyle behaviours, for pregnant women. This appears to be one of the most commonly suggested interventions (342) and social networks, as well as group PA classes, was strongly supported in this study. Interventions such as this may be a cost effective way of increasing PA levels, as well as a platform for providing the much needed education and information that was described as a barrier for many of these women (286).

Healthcare providers are potentially valuable motivators for PA (281). However, the reported lack of accurate information, and perception of inadequate care, at the antenatal clinics diminished their influence toward improving PA levels. Although it may be argued that the limited healthcare resources are aimed at more eminent communicable diseases such as HIV, the overwhelming rise in non-communicable disease in South Africa warrants prioritisation within this area (52). In fact, within the current health transition that South Africa is undergoing, NCDs are estimated to exceed HIV/AIDS as a cause for mortality (52), emphasising the importance of addressing lifestyle issues at a primary health care level. Other studies have reported a similar lack of clear, understandable advice (349), which may further reduce self-efficacy and behaviour change (284, 350). On the other hand, our study supported the findings that increasing awareness could in fact be a facilitator for behaviour change, as women cited that they would more likely be active if they received information from their healthcare provider. A previous study by the author showed that as little as 19% of South African medical practitioners provided information regarding physical activity during the prenatal visit (351). Since pregnant women visit their healthcare provider on a regular basis, this may be an ideal opportunity to provide counselling and support that could improve PA levels (342).

This lack of guidance from health professionals prompted most women to turn to the media, or their family and friends, for advice, all of which are common sources of information during pregnancy (352, 353). A study by Clarke et al. (353) found that less than 20% of women's advice was received directly from healthcare professionals. Emotional support, and a sense of accountability towards being active, has been shown in previous studies to be interpersonal facilitators of physical activity (345). However, in the current study, many women did not have the social support network that encouraged physical activity. In fact, family advice seems to more likely discourage women from being active during pregnancy as many women, in this and previous studies, are told to "take it easy" (281, 353). Indeed, advice to not overexert oneself during pregnancy was also echoed in some of the reported cultural beliefs in the current study. However, other cultural beliefs warned of the adverse effects of being "too lazy" or resting excessively during pregnancy. Therefore, there appears to be a contradictory tension between the social norms of taking it easy, and too much rest. Without clear guidance from healthcare professionals, this will likely lead to confusion and uncertainty surrounding an active lifestyle.

The lack of social role models, coupled with the absence of adequate information, has been shown to be a predictor of decreased PA levels during pregnancy (346). Therefore, strategies to promote PA behaviours in these communities that include family and friends may have a more influential role than strategies directed at the pregnant women alone. Added to this, previous authors (331) have suggested a holistic approach to prenatal care to improve PA compliance. In a previous South African study, Muzigaba et al. (279) suggested using instructional resources such as posters, brochures and DVDs to promote healthy behaviours within the clinic setting. Added to provision of comprehensive education, we recommend incorporating physical education workers to provide exercise programmes, and social support within the community.

3.4.1. Limitations

This study reached saturation after 13 interviews, and therefore utilized a small, homogenous sample of urbanised black South African women, and may not be representative of other races, cultures or communities. Therefore, the findings from this study should be applied with caution to other contexts and sub-cultures. However, very little research has been done in black African women, and our study adds to the theory-based research upon which intervention protocols for pregnant women can be based.

Furthermore, the interviews were conducted in English, and although all women could speak English, there may have been a small percentage that could not have been able to fully express themselves. Despite these limitations, the current study provided rich data that reflects unique cultural beliefs and environmental context.

3.4.2. Conclusions

Since pregnancy is a crucial time for prevention of disease in both the mother and her offspring (131), it is essential that stakeholders prioritise this time for implementing PA interventions. The findings of this study highlight the need for proper PA education that is culturally sensitive, as well as social support for PA behaviour within this community.

Incorporating the immediate and wider social community into interventions may help to diminish perceived barriers whilst at the same time influencing key role players in the woman's support system. Designing interventions that are context and culturally specific, may promote PA behavioural change in not only the pregnant population, but at a community level as well.

Chapter Four

EXERCISE DURING PREGNANCY: KNOWLEDGE AND BELIEFS OF MEDICAL PRACTITIONERS IN SOUTH AFRICA: A SURVEY STUDY.[3]

"If we could give every individual the right amount of nourishment and exercise, not too little and not too much, we would have found the safest way to health." Hippocrates

[3] **Watson, E.D, Oddie, B. & Constantinou, D.** (2015) Exercise During Pregnancy: Knowledge And Beliefs Of Medical Practitioners In South Africa: A Survey Study. *BMC Pregnancy and Childbirth* 15(1): 245 [**DOI:** 10.1186/s12884-015-0690-1]

4.1. Background

The health benefits of an active pregnancy are well known. Several positive associations between regular activity and maternal outcomes have been clearly demonstrated. For example, an active pregnancy has shown an improvement in cardiovascular and metabolic function, and increased strength and bone density (354). Regular exercise appears to lower the risk of GDM, gestational hypertension, and preeclampsia (162). Evidence also exists for the role of exercise in preventing incontinence during pregnancy and in the postpartum period (21, 355). In addition, it has been shown to reduce excessive gestational weight gain (EGWG), which is an important predictor of numerous adverse maternal outcomes (354). Even more compelling is the recent evidence for fetal origin of adult disease. Maternal obesity may provide an early embryo environment that appears to have a major impact on the health of the offspring in adulthood (13). This is particularly important for South African women, where obesity is prevalent and has been found to be strongly associated with physical inactivity (35). In South Africa (SA), rates of obesity appear to be three times higher in women than in men (103), and 56.5% of the female population are overweight (35). Demographic surveys in SA have shown similar gender patterns for inactivity, where 63% of women are reportedly inactive compared to 48% of men (356). Although no data currently exists on the PA levels of South African women during pregnancy, literature suggests that women are particularly vulnerable to inactivity, and prescribing exercise during the prenatal period may provide a protective effect against these modifiable risk factors.

As the beneficial evidence for exercise during pregnancy mounts, the American College of Obstetricians and Gynaecologists (ACOG) guidelines have become less restrictive since initially released in 1985 (19). Unsurprisingly, pregnant women, in the absence of medical or obstetric complications, are encouraged to participate in moderate-intensity aerobic and low-intensity strengthening exercise. Some additional considerations may include restrictions to supine activities, or activities that may increase the risk of falling or contact (19, 21). Furthermore, exercise duration, frequency and intensity can be prescribed on an individual basis to avoid potential of hyperthermia (21). Although care needs to be taken when prescribing exercise, the benefits of being active during the prenatal period far outweigh the risks (21).

Primary health care providers are well placed to promote exercise to the pregnant population, and may have an important role to play in advising and educating women on healthy behaviours (286, 287). In fact, in the general population, brief counselling from a general practitioner has shown to be a cost effective and successful method of improving activity levels (286). Therefore, primary care prevention of disease may have a profound effect on, not only the prenatal population, but the health of future generations as well. Although encouraging exercise in women with an uncomplicated pregnancy should form an integral part of prenatal care, little is known about views of SA medical practitioners (MPs) on this subject. Therefore, the purpose of this study was to assess the knowledge, attitudes and beliefs of South African MPs towards exercise during pregnancy.

4.2. Methods

A cross sectional, descriptive survey study was conducted to determine exercise and pregnancy knowledge of MPs. Study participants were a convenience sample of 96 MPs, including general practitioners (GPs) (n=58), Obstetricians/Gynaecologists (n=33) and other Specialists (n=5). The 33-item questionnaire (Appendix K) was designed using published guidelines (357) and adapted from a previous study by Bauer et al.(358). The questionnaire consisted of 15 likert-type scale questions; 15 selected responses and 3 open-ended questions (see additional file 1). The questionnaire was piloted for content and construct validity, as well as technical functionality and usability. Questionnaires were distributed: (i) electronically via an emailed hyperlink to the online survey (http://www.surveymonkey.com); and (ii) manually via an appointment at medical practices. Questionnaires were distributed electronically to 958 Obstetricians/Gynaecologists and 562 General Practitioners located in all provinces in South Africa, whilst manual distribution included 100 Obstetricians/Gynaecologists offices within the central Gauteng area. This study used a closed survey recruitment process, whereby the contact details of the selected sample was sourced from the Health Professions Council of South Africa (HPCSA) website (http://www.hpcsa.co.za), or from the internet. In addition, the hyperlink to the survey was circulated by a medical directory service (MEDpages) to their selected distribution list. Medical practitioners not currently registered with the HPCSA were excluded from the study. In addition, due to time constraints and inaccessibility in public health care clinics, MPs working solely in the public sector were also excluded from the study.

For the reporting of the online survey methodology, the CHERRIES guideline has been followed (359). An introductory email, explaining the purpose of the study, length of the survey, data collection procedures and other important study details, was sent. Informed consent was provided through selecting the link to the questionnaire at the end of the email. The online survey was set up to include 3-7 items per page and 7 screens in total. All fields were set up as mandatory, which assisted in ensuring completeness of the survey, and respondents were able to go back and review any items at any stage in completion of the questionnaire. To maintain confidentiality, no personal identifying information was collected. The online system was set up in such a way that each participant was provided with a unique link to the webpage, and could therefore not participate in the survey more than once. An online survey completion rate of 0.89 was achieved. Ten participants filled in the questionnaire manually, whilst the remaining 86 participated using the online tool.

Participation was voluntary and no incentives for participating were provided. The Human Research Ethics Committee (HREC) of the University of the Witwatersrand approved the study (reference M130445).

Descriptive statistics and frequency tables were calculated for all questions. Chi-squared tests, or Fisher's exact test, were used to examine the differences in response by (1) age (<40 years or > 40 years); (2) focus of practice (obstetrics/gynaecology or general practice); and (3) years of practice (<15 years or >15 years). All statistical tests were done using Statistica version 11, and statistical significance was set at $p<0.05$.

4.3. Results

Demographic information for the sample is reported in Table 7. The majority of practitioners were Caucasian (55%, n=53) and female (64%, n=61), between the ages of 30-59 (73%). Thirty two participants had been in practice for over 20 years, and the main focus of practise was obstetrics/gynaecology (46%).

Table 7 Participant demographics for Study 2 (n=96)

Variable	**N (%)**
Occupation	
General practitioner	58 (60)
Obstetrician / Gynaecologist	33 (34)
Other Specialist	5 (5)
Gender	
Male	35 (36)
Female	61 (64)
Race	
Caucasian	53 (55)
African	21 (22)
Indian	19 (20)
Coloured	1 (1)
Asian	2 (2)
Age (years)	
<30	6 (6)
30-39	25 (26)
40-49	26 (27)
50-59	19 (20)

>60	20 (21)
Practise location	
Urban	82 (85)
Sub-urban	10 (10)
Rural	4 (4)
Years in practice	
1-5	18 (19)
6-10	15 (16)
11-15	15 (16)
16-20	16 (17)
>20	32 (33)
Main focus of practice	
Obstetrics / Gynaecology	44 (46)
Family Medicine	40 (42)
General practice	12 (13)

Key attitudinal statements of the respondents regarding exercise during pregnancy is shown in Table 8 and these were largely positive. For example, 98% of respondents believe that exercise is beneficial during pregnancy. The majority of responders (78%) believed that exercise promotion is an important component of prenatal care, and 74% felt that this advice influenced patient behaviour. Most MPs (94%) recommended that their patients participate in moderate exercise during pregnancy; however there appears to be a misalignment between the published recommendations and clinical practice. For example, 18% reported that previously sedentary women should not embark on an exercise programme during pregnancy, and 42% did not recommend a strength-training programme.

Table 8 Attitudes of practitioners to key questions

Statement	Numbers (%) of responders who indicated			
	Strongly agree	**Agree**	**Disagree**	**Strongly disagree**
Exercising during pregnancy is beneficial	64 (67)	30 (31)	2 (2)	0 (0)
Advising patients on exercise during pregnancy is not a major component of prenatal care	4 (4)	17 (18)	41(43)	34 (35)
Pregnant patients follow the advice given during their office visits	7 (7)	64 (67)	23 (24)	2 (2)
A sedentary woman, with an uncomplicated pregnancy, should not begin an exercise programme during pregnancy	6 (6)	11 (12)	58 (60)	21 (22)
Pregnant women who are chronic exercisers should be encouraged to continue an exercise programme throughout pregnancy	42 (44)	47 (49)	7 (7)	0 (0)
Pregnant women should not participate in a strength-training programme during pregnancy	12 (13)	28 (29)	47 (49)	9 (9)
During pregnancy, women should be recommended to exercise at a moderate intensity	31 (32)	59 (62)	6 (6)	0 (0)
Exercise during pregnancy increases the risk of low birth weight babies	4 (4)	7 (7)	48 (50)	37 (39)
The possible harmful effects of exercise on the fetus are minimal if not non-existent.	26 (27)	57 (59)	7 (7)	6 (6)

The perceived benefits of exercise during pregnancy are shown in Figure 9. The majority of practitioners believed in the benefits of exercise for weight management (71%) as well as cardiovascular (68%) and musculoskeletal (68%) health. Few were convinced of the effects of exercise on blood pressure response (44%) and pelvic floor strength (33%).

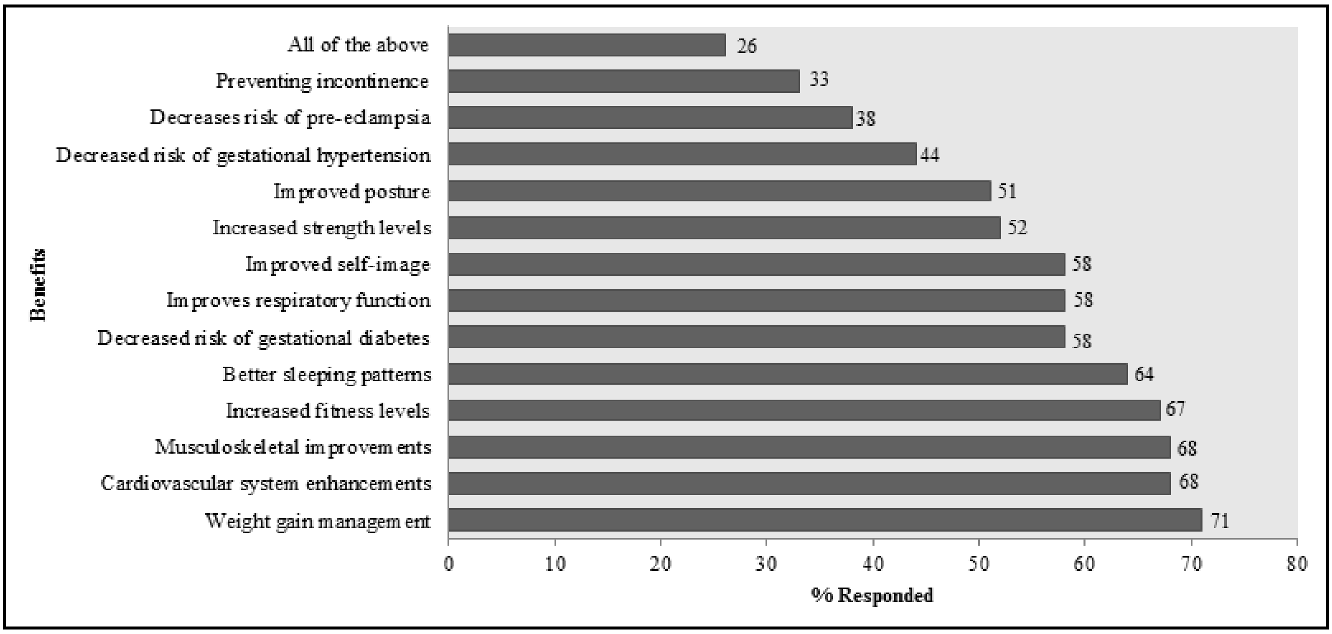

Figure 9 Benefits of exercise during pregnancy as indicated by respondents

Statements regarding exercise prescription knowledge and practises are shown in Table 9. Over half the respondents (56%) reported that patients enquired about exercise during a visit. Despite this demand from patients, few (19%) practitioners provide any written advice or informational pamphlets, and only 18% provide individualised exercise prescription. Furthermore, 69% do not routinely provide exercise restrictions and 15% believe that low intensity exercise is sufficient to gain health benefits. A large majority (83%) of the respondents were not familiar with the ACOG guidelines for exercise during pregnancy; however, an encouraging 71% of practitioners reported they would be interested in attending a continuous professional development (CPD) workshop on the subject. When assessing prenatal referral practices, approximately a quarter (24%) of the respondents reported that they did not refer their patients to other healthcare providers for exercise. In fact, 46% reported they were unaware of any exercise classes or trainers in their area. On the other hand, 39% reported that they would refer to a Biokineticist (Clinical Exercise Specialist), 26% to a personal trainer, and 21% to a Physiotherapist.

Table 9 Responses of participants to statements regarding exercise prescription during pregnancy

Statement	Numbers of responders % (n) (n=85)			
	Never	**Seldom**	**Often**	**Always**
Do your pregnant patients ask you questions about exercise during pregnancy?	7 (8)	31 (37)	44 (52)	3 (4)
Do you provide informational pamphlets on pregnancy and exercise to your patients?	43 (51)	26 (31)	13 (15)	3 (4)
Do you obtain exercise histories on your pregnant patients?	10 (12)	27 (32)	34 (40)	14 (17)
Do you give each pregnant patient an individualised exercise programme for her to follow?	39 (46)	28 (33)	15 (18)	3 (4)
	Very aware	**Aware**	**Vaguely aware**	**Unaware**
Are you aware of the 2002 ACOG guidelines for exercise during pregnancy	6 (5)	21 (18)	29 (25)	44 (37)
	Yes	**No**		
Would someone from your practice be interested in attending a workshop on pregnancy and exercise? (n=82)	71 (58)	29 (24)		
Do you routinely give exercise restrictions to your pregnant patients	31 (26)	69 (59)		
Are you aware of any exercise classes or trainers in your area? (n=82)	54 (44)	46 (38)		
	Low	**Moderate**	**Vigorous**	
What intensity would you recommend your patients exercise at? (n=82)	15 (12)	83 (68)	2 (2)	
	Biokineticist	**Personal trainer**	**Physiotherapist**	**Other**
Who do you refer your patients to for exercise prescription?	39 (33)	26 (22)	21 (18)	14 (12)

Approximately 72% of the younger respondents offered advice on exercise, and although this appeared to decrease with age (69% in >40 years), the difference was not significant ($p=0.730$). Practitioners whose practices focussed on obstetrics and gynaecology were more likely to be aware of the current guidelines than those in general practice ($p<0.001$). However, awareness of the guidelines did not have a statistically significant effect on beliefs regarding the benefits of exercise during pregnancy ($p=0.124$), nor on strength training ($p=0.117$) or intensity ($p=0.583$) recommendations. In addition, age ($p=0.374$) and years of practice ($p=0.248$) played no role in awareness of the ACOG guidelines.

4.4. Discussion

There is considerable evidence for the positive effects of exercise during a healthy pregnancy (354), and this belief appears to be strongly supported by MPs, in this, and other similar studies (288, 358). Exercise is a powerful tool to manage EGWG, and its associated complications (162), a view which is well supported in the current study. In addition, our study found that over half the respondents were knowledgeable on the role of exercise in improving cardiovascular fitness, strength, sleeping patterns and reducing the risk of GDM. However, the findings suggest that most practitioners were unaware of the benefits of exercise in preventing and treating incontinence. Women are encouraged to initiate pelvic floor exercises during pregnancy, and in the postpartum period, a concept that should be reinforced at a primary healthcare level (21, 355). Likewise, a recent systematic review suggests a reduced risk of preeclampsia with exercise (163), but few of the practitioners in this study were aware of this. Although the MPs in this study had a good knowledge of most of the benefits of exercise during pregnancy, awareness and education of its role in preventing incontinence and preeclampsia needs to be improved.

There appears to be a common disconnect between research and clinical knowledge on exercise during pregnancy. Other studies have highlighted the lack of healthcare provider's knowledge of ACOG guidelines (290, 358, 360). Similarly, the authors found that only a small portion of the practitioners in this study were aware of the ACOG guidelines. In fact, locally the South African Sports Medicine Association recently released its own position statement on prenatal exercise prescription (21), encouraging practitioners to advise on moderate exercise, inclusive of strength training, to all healthy pregnant patients. This statement, along with the ACOG guidelines, provides a clear outline for exercise prescription and applicable restrictions. However, the lack of awareness of the guidelines may explain why many of the practitioners in this study did not routinely provide restrictions, and many believed that one should not participate in strength-training during pregnancy. Furthermore, despite the health risks of being sedentary during pregnancy (21, 113), there is still a portion of practitioners that are reluctant to encourage previously sedentary patients to embark on an exercise programme during pregnancy. Nonetheless, when compared to their overseas counterparts, many more SA practitioners appear to encourage these pregnant women to start a new exercise programme (290, 360).

Studies have suggested that pregnancy may be viewed by clinicians as a high-risk state, in which even marginal fetal risk should be avoided, despite the potential benefit to the mother (349). In line with this, many practitioners in this study believed women should exercise at low intensities. This is consistent with a study by Evenson et al. (360), where most obstetricians were inclined to recommend mild over moderate exercise. Thus, there is a need for paradigm shift in how activity during pregnancy is viewed, as well as improved accuracy of the advice given. Healthcare providers should be reminded that in the absence of pathology or health risk to mother and/or fetus, pregnancy is a physiological state with benefits to be gained from exercise. There appears to be a great need for better dissemination of current guidelines and research to healthcare practitioners.

Encouragingly, the majority of the study participants indicated their willingness to attend a workshop on the subject. This interest in continued education has been echoed in other studies (358, 360), and can provide great potential for improving the occurrence and impact of physician advice, which can have an integral role to play in improving activity levels at a primary healthcare level. In fact, a study by Lewis and Lynch (361) found that physician training can double the amount of advice given. Therefore, training in the form of workshops may be warranted. This education and evidence-based medicine should be furthermore incorporated into the undergraduate medical degree curriculum.

Research has shown that healthcare providers can have a positive effect on their patient's attitudes towards exercise (162, 287). Indeed, gaining knowledge of the benefits of exercise may motivate pregnant women to become more active (354). Our study showed that over half the women asked their providers about exercise. Similarly, a study by de Jersey *et al.* (362) reported that women are interested in receiving education, but there appears to be a disparity between what they want and what is provided by their healthcare practitioners. Prenatal advice available to women is often overwhelming, and various healthcare providers should provide an accurate and standard message (362). Vague and conflicting information may explain why women tend to reduce their activity levels during pregnancy (277), making correct exercise prescription in the prenatal period all the more important.

4.4.1. Study strengths and limitations

Although similar studies have been done in other countries (290, 358, 360), this study is the first of its kind assessing South African healthcare providers beliefs and attitudes towards exercise prescription during pregnancy. The South African guideline for exercise during pregnancy is available (21), however such research is essential to determine if, and how, these public health messages are being provided at a primary care level. Furthermore, MPs may play a crucial role in implementation of interventions for this vulnerable population and therefore their attitudes towards exercise prescription, and delivery, provides useful formative research in the field. The study does, however, have certain limitations. Due to known low response rates from MPs, together with the convenience sampling design, these results may not be reflective of SA MPs as a whole. Additionally, as with similar studies (290), response bias may be a limitation due to non-randomisation of the sample, and the potential for selective bias (those who agreed to participate were interested in the topic). This bias may overestimate the results and further research should expand to reach a wider population, with more reliable sampling techniques. In addition, the exclusion of practitioners working in the public sector eliminates knowledge of practice that may affect the vast majority of the South African population. Lastly, a qualitative research design may provide useful insights into counselling barriers and facilitators, which will better inform future intervention strategies.

4.4.2. Conclusion and implications for practice

The SA medical profession appears to largely support the belief that exercise is beneficial during pregnancy, and believe that they have a role to play in exercise promotion on a primary care level, but lacked accurate specifics with regard to exercise prescription (mode, frequency, intensity and duration) and are not adequately promoting it to their patients. As research on prenatal exercise has increased in the past two decades, it has become imperative that innovative strategies are put in place to ensure the gap between research and clinical practise is bridged. There appears to be a great need for provision of clear, evidence-based information through continuous education activities that can be shared with patients.

Improving maternal health is a key directive of the WHO, and MPs can have major influence in promoting exercise, and changing health behaviours, in pregnant women.

Chapter Five

ARE SOUTH AFRICAN MOTHERS MOVING?

PATTERNS AND CORRELATES OF PHYSICAL ACTIVITY AND SEDENTARY BEHAVIOUR IN PREGNANT BLACK SOUTH AFRICAN WOMEN[4]

"Lack of activity destroys the good condition of every human being while movement and methodical physical exercise save it and preserve it"

Plato

[4] **Watson, E.D; van Poppel, M.N.M; Jones, R.A; Norris, S.A; Micklesfield, L.K.** Are South African mother's moving? Patterns and Correlates Of Physical Activity And Sedentary Behaviour In Pregnant Black South African Women *Journal of Physical Activity and Health (in press).*

5.1. Introduction

There is an ever-growing body of research to support the numerous health benefits of an active pregnancy, including a decreased risk of GDM (24), hypertension (163), and excessive GWG (28, 178). In addition, post-natal benefits of PA during pregnancy include reduced post-partum weight retention (178), and a decreased likelihood of an unfavourable weight gain trajectory after birth (363).

Therefore, current PA recommendations suggest that pregnant women should participate in 150 min of moderate intensity PA per week, or the metabolic equivalent (METs) of 600 MET minutes per week (MET mins/wk) (23). However, data suggests that only a minority of women meet these guidelines (31). In addition, overall PA levels, as well as duration and intensity, decline during pregnancy (18), and the type of activity is known to change during this period (277). There is a trend for active leisure time to be replaced by more sedentary pursuits (18), and according to the NHANES data, over 15% of pregnant women spend 5 hours or more a day watching television (31). Of concern is that even previously active women appear to be considerably more inactive during pregnancy (264), possibly due to the physiological changes that make certain activities uncomfortable or tiring, as well as the perceived psychological belief that sedentary activities may be safer (18).

Due to the health implications of changing behaviours during this period, surveillance of population-specific PA patterns becomes important. In addition, understanding factors which predict which women are more likely to be inactive, or reduce their PA levels, is essential for intervention planning. Previous studies have identified various sociodemographic, health and behavioural correlates and predictors of PA during pregnancy, although these findings are inconsistent (310). Zhang & Savitz (264) found that older, married, low socioeconomic, and overweight women are less likely to be active during pregnancy. Similarly, Jukic et al.(364)

found that white women with higher education levels were more likely to be active, whilst Evenson et al.(31) found no association between age or education and moderate to vigorous leisure time PA.

Therefore, it appears that correlates of PA may differ between populations, by gestational age, and by mode of PA in pregnant women (364). Low-to-middle income countries experience diverse patterns of PA when compared to high-income countries, and therefore may present with different and unique correlates and patterns of PA. South African women in particular, are at risk of being inactive and sedentary. Recent data from the SANHANES (2013) has reported that 46% of the population are not meeting current PA guidelines (365), with women being at higher risk of high levels of sedentary behaviour, as well as overweight and obesity (36). In addition, previous studies of patterns of energy expenditure in South African non-pregnant women have shown that most PA comes from occupation and commuting, with little time spent in recreational activities (35). South African pregnant women present a unique and potentially vulnerable population group, and investigating the pattern and correlates of PA during pregnancy is warranted. Therefore, the aim of this study is twofold: first to describe the current PA patterns of pregnant South African women, and second to determine the correlates of PA during the prenatal period.

5.2. Methods

This study was nested within a larger pregnancy study (Soweto First 1000 Days Cohort) in the Medical Research Council (MRC)/Wits Developmental Pathways for Health Research Unit (DPHRU), based at the Chris Hani Baragwanath Hospital (CHBH), in Soweto, Johannesburg. CHBH is a public hospital, providing antenatal care to women living in

Soweto, a large urban area of Johannesburg with the majority of inhabitants coming from low income households (299).

Singleton, pregnant women attending CHBH for antenatal care were recruited and data were collected at six time points: <14 wk; 14-18 wk; 19-23 wk; 24-28 wk; 29-33 wk and 34-38 wk. The GPAQ was collected at the second visit (14-18 wk gestation) and fifth visit (29-33 wk). Participants were informed of the study, provided with an information sheet and all participants signed a consent form for participation in the study. Participant information was coded to ensure confidentiality and anonymity. The sub-study was approved by the Human Research Ethics Committee of the University of the Witwatersrand (Clearance number M130351).

Anthropometric measurements: height (m) was measured using a stadiometer (Seca, Hamburg, Germany) and body weight (kg) was measured to the nearest 0.1 kg using a digital weighing scale (Seca, Hamburg, Germany). Body mass index was calculated as weight (kg) / height $(m)^2$ at baseline (<14 wk), and classified according to the World Health Organization's (WHO) category's for underweight (<18.5 kg/m^2), normal weight (≥18.5 – 24.9 kg/m^2), overweight (≥25-29.9 kg/m^2) and obese (≥30 kg/m^2). Socioeconomic status was assessed using household inventory questions, assessing the ownership of nine household commodities (electricity, radio, television, refrigerator, cell phone, personal computer, bicycle, motorcycle/scooter, car). In addition, household density was calculated by dividing the number of people living in the household by the number of rooms used for sleeping.

The GPAQ (270) is a validated measure used to quantify MVPA as Metabolic Equivalent (METs) minutes per week (MET mins/wk), at the second (14-18 weeks) and fifth visits (29-33 weeks). Time (min/wk) spent in each domain (work, travel and recreation) was calculated, as well as the total physical activity MET mins/wk, according to the WHO STEPwise method (http://www.who.int/chp/steps/resources/GPAQ_Analysis_Guide.pdf). METs are used to calculate volume of PA by weighting each type of activity with its energy requirements. Participants were further classified as "active" (≥600 MET mins/wk) or "inactive" (<600 MET mins/wk). 600 MET mins/wk is the equivalent of reaching the recommended 150 min of moderate intensity PA, 75 min of vigorous intensity PA or a combination of the two. Sitting time (mins/day) was determined from the last question of the GPAQ which asks: "How much time do you spend sitting/reclining on a typical day?" For further information on sedentary domains, a SBQ was included, assessing time spent sitting during work, transport, leisure (including television watching), and at church.

Normally distributed data are presented as mean ±SD and non-normally distributed data are presented as median (inter-quartile range). Non-normally distributed data were transformed (log for right skewed and squared for left skewed data) for analysis. For non-parametric data, or data that remained non-normally distributed after transformation, Mann-Whitney U tests were conducted to compare the active and inactive groups. For parametric data, independent t-tests were conducted for between group comparisons. Differences in PA levels between the two trimesters were analyzed using a paired t-test or Wilcoxon Sign Rank test, depending on the data distribution. Comparisons between those that decreased PA levels during pregnancy, those with no change and those that increased their PA levels, were completed using an ANOVA for continuous data and Chi-squared test for categorical data. Preliminary regressions assessed bivariate analyses between MVPA and individual (age, BMI, HIV status, parity, smoking, gestational illness) and socioeconomic (occupation, education, marital status, household inventory, household density) explanatory variables. If the bivariate regression was $p \leq 0.1$, the variable was included in the multiple regression analysis. Multivariate regression analyses were then completed to determine the most significant contributors to MVPA in the various domains. Statistical significance was set at 95% ($p < 0.05$).

5.3. Results

5.3.1. Participant characteristics

Baseline data (≤14 wk gestation) was collected on 332 participants between June 2013 and May 2015. Between the second (14-18 wk gestation) and third trimester (29-33 wk gestation), 16 participants were lost to follow up, 33 had missing data or missed their 29-33 wk appointment, 23 had a miscarriage or premature delivery and 4 participants withdrew from the study, leaving 256 participants with PA data at both time points (Figure 10). The average days between baseline and 29-33 weeks gestation were 145 days.

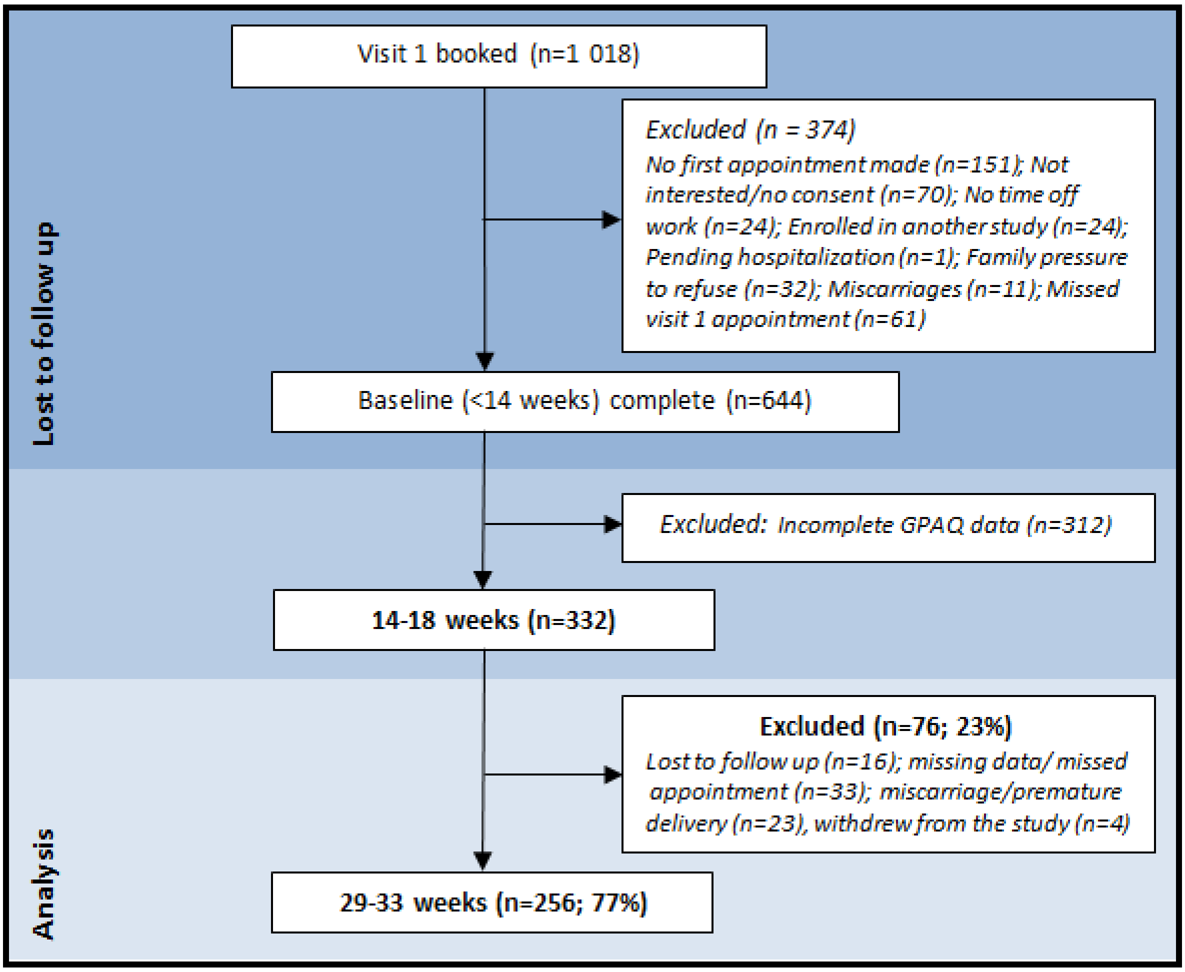

Figure 10 Attrition of participants through the study

Compared to the sample with data at both time points (n=256), there were no differences in those lost to follow up, with respect to age (p=0.78), baseline BMI (p=0.67) and PA at 14-18 weeks (p=0.17). Individual, demographic and socioeconomic characteristics of the participants measured at baseline (<14 weeks), are presented in Table 10.

Table 10 Study 3 participant anthropometric, demographic and socioeconomic characteristics at baseline (<14 wk), n=332

Characteristic	**Mean ±SD or n(%)**
Age (years)	29.5 ±5.8
Weight (kg)	73.8 ±18.0
Body mass index (kg/m^2)	29.3 ±7.1
Weight gain at 38 wk gestation (kg)	9.1 ±5.0
Body Mass Index	
Underweight	11 (3.3)
Normal range	96 (28.9)
Overweight	86 (25.9)
Obese	139 (41.9)
***Marital* status**	
Married/Cohabiting	129 (38.9)
Single	201 (60.9)
Education	
No school attended	1 (0.3)
Primary school	12 (3.6)
Secondary school	224 (67.5)
Professional/technical/university	93 (28.0)
Occupation	
Manual work	83 (25.0)
Non manual work	83 (25.0)
Unemployed/other	162 (48.8)
Smoking/chewed tobacco during this pregnancy	
No	296 (89.2)
Yes	36 (10.8)
Drank alcohol during this pregnancy	
No	289 (87.0)
Yes	43 (13.0)
HIV/AIDS	
No	254 (76.5)
Yes	78 (23.5)
Parity	
None	102 (30.7)
1 to 2	205 (61.7)
3 to 4	24 (7.2)
Household inventory	
Low (1-3)	19 (5.7)

Medium (4-6)	251 (75.6)
High (7-9)	60 (18.1)

5.3.2. Physical activity levels

Cross sectional data analysis (n=332) showed that during the second trimester (14-18 weeks), 168 (50.6%) women were classified as active. Longitudinal data analysis (where PA data was available for both time points, n=256), showed that 132 (52%) of the women were active, and this decreased to 111 (43.4%) in the third trimester (29-33 wk). For both active and inactive women, the majority of total MVPA time was spent walking for transport (second trimester: 80.1±35.4%; third trimester: 80.4±36.1). Physical activity at work (second trimester: 14.0±30.2%; third trimester: 10.8±26.6%) and in recreational activities (second trimester: 2.0±10.6%; third trimester: 2.6±14.5) contributed little to the total time spent in MVPA. No significant differences were found between the active and inactive women for age, weight at each time point, or GWG (data not shown).

Median (interquartile range) total MVPA declined significantly (p=0.01) from the second to the third trimester, as did time spent walking for transport (p=0.01), as shown in Table 11.

Table 11. Change in Physical activity behaviour patterns and sitting time from the second to third trimester

	2nd trimester	**3rd trimester**	p-value
Physical activity domains (GPAQ)	Median (IQR)	Median (IQR)	
Total moderate-vigorous physical activity (MET mins/week)	600 (260-1310)	480 (200-1080)	***0.01***
Total work (moderate-vigorous physical activity) (mins/week)	0 (0-0)	0 (0-0)	0.06
Total transport (moderate-vigorous physical activity) (mins/week)	120 (60-210)	90 (45-210)	***0.01***
Total recreation (moderate-vigorous physical activity) (mins/week)	0 (0-0)	0 (0-0)	0.69
Sitting time (min/day)	330 (180-480)	300 (180-480)	0.14

There were no differences in work, recreation or sitting time between the two trimesters. Of the 132 women that were active in the second trimester, 66 (50%) became inactive in the third trimester. Of the 124 that were inactive in the second trimester, 79 remained inactive and 45 women became active in the third trimester, and this change was significantly associated with time (X^2=4.89; p=0.03).

No significant differences were found in age (p=0.33), baseline BMI (p=0.35), weight gain at 33 weeks (p=0.49), education (p=0.46), marital status (p=0.64) and household inventory (p=0.71), between women who decreased time spent in PA (reduction in total MET min/week; n=137), to those who did not change their PA levels (no change in total MET min/week; n=20), and those who increased their time spent in PA (increase in total MET min/week; n=99).

5.3.3. Sedentary behaviour

Sedentary behaviour (sitting time min/day) did not change significantly between the second and third trimester (p=0.14). The majority of sedentary time was spent watching TV (43% of total sedentary time), and this pattern continued throughout pregnancy. In the second trimester, the inactive women spent significantly more time watching TV (p<0.001) and resting during the day (p=0.04) than the active women (Table 12). In the third trimester, no statistically significant differences were found between the active and inactive women in any of the different sedentary domains.

5.3.4. Correlates of physical activity

Multivariate linear regression models showed that being married was positively associated with PA for work in the third trimester (p=0.04), when adjusting for occupation, BMI, parity and SES. Walking for transport was inversely associated being married in both the second (p=0.03) and third trimester (p=0.01), and in the second trimester it was positively associated with being overweight (p=0.02) and inversely associated with owning a car (p=0.05). Recreational PA was positively associated with car ownership in both trimesters (p=0.02; p=0.01), and in the third trimester it was positively associated with whether the woman had had children or not (p=0.03). The regression models explained little of the determinants for PA in the second (3-5%) and third trimester (4-7%) for work, transport and recreational PA (Table 13 and 14).

Table 12 Comparison of sedentary behaviour patterns between active and inactive women

	2nd trimester			**3rd trimester**		
	Active (n=168)	***Inactive (n=164)***	***p-value***	***Active (n=111)***	***Inactive (n=145)***	***p-value***
Overall sedentary behaviour (GPAQ)						
Sitting/reclining (mins/day)	300 (165-480)	360 (240-540)	***0.01***	300 (120-420)	360 (240-480)	***0.01***
Sedentary behaviour domains						
Work (mins/day)	75 (0-300)	0 (0-300)	0.14	0(0-180)	0 (0-120)	0.87
Watching TV (mins/day)	180 (120-240)	240 (120-300)	***<0.01***	180(120-240)	180(120-300)	0.39
Computer (mins/day)	0 (0-0)	0 (0-0)	0.31	0(0-0)	0 (0-0)	0.48
Travel (mins/day)	40 (25-60)	42.5 (16.25-60)	0.68	45 (30-60)	30 (0-60)	0.58
Socialising (mins/day)	45 (15-60)	30 (10-60)	0.08	30(20-90)	30(15-90)	0.59
Recreational activities (mins/day)	45 (0-120)	30 (0-120)	0.99	60(0-120)	60(10-120)	0.30
Resting during the day (mins/day)	30 (0-120)	60 (0-120)	***0.04***	52.5 (0-120)	60(0-120)	0.31
Church (mins/day)	0 (0-0)	0 (0-0)	0.28	0(0-0)	0(0-0)	0.51

Table 13 Multivariate correlates of physical activity (mins/wk) per domain in the second trimester

	Work Adj R^2 = 0.018; p=0.08		Transport Adj R^2 = 0.030;p=0.02		Recreation Adj R^2 = 0.012; p=0.11	
	β (95% CI)	p-value	B (95% CI)	p-value	β (95% CI)	p-value
Marital status						
Unmarried	Reference		Reference			
Married	0.10 (-0.03 – 0.44)	0.08	-0.12 (-0.31 - -0.02)	***0.03***		
Occupation						
Manual			Reference			
Non-manual			-0.07 (-0.32 – 0.09)	0.28		
Unemployed/other			-0.09 (-0.30 – 0.06)	0.18		
BMI Category						
Underweight	-0.07 (-1.04 – 0.26)	0.24	0.04 (-0.27 – 0.55)	0.50	-0.07 (-0.51 – 0.13)	0.25
Normal	Reference		Reference		Reference	
Overweight	0.01 (-0.31 – 0.30)	0.97	0.16 (0.05 – 0.43)	***0.02***	0.01 (-0.13 – 0.17)	0.83
Obese	0.05 (-0.16 – 0.38)	0.42	0.12 (-0.02 – 0.33)	0.08	-0.10 (-0.24 -0.03)	0.13
Previous births						
No	Reference					
Yes	0.06 (-0.11 – 0.39)	0.27				
Sedentary promoters						
Car (no)			Reference		Reference	
Car (yes)			-0.11 (-0.31 - -0.00)	***0.05***	0.16 (0.02 – 0.32)	***0.02***
TV (no)	Reference					
TV (yes)	0.13 (-0.03 – 1.22)	0.06				
Household inventory	-0.02 (-0.13 – 0.91)	0.754			-0.11 (-0.102 – 0.010)	0.11

β = Standardised coefficient; CI = confidence interval

Table 14 Multivariate correlates of physical activity (mins/wk) per domain in the third trimester

	Work Adj R^2 = 0.019; p=0.09		**Transport** Adj R^2 = 0.044; p<0.01		**Recreation** Adj R^2 = 0.038; p<0.01	
	β (95% CI)	p-value	β (95% CI)	p-value	β (95% CI)	p-value
Marital status						
Unmarried	Reference		Reference			
Married	0.13 (0.01 – 0.47)	***0.04***	-0.17 (-0.42 - -0.07)	***0.01***		
Occupation						
Manual	Reference		Reference			
Non-manual	0.10 (-0.11 – 0.53)	0.19	0.01 (-0.23 – 0.25)	0.95		
Unemployed/other	0.12 (-0.06 – 0.48)	0.12	-0.12 (-0.37 – 0.03)	0.10		
Smoking						
No			Reference			
Yes			0.09 (-0.07 -0.50)	0.14		
Previous births						
No						
Yes					0.14 (0.02 – 0.25)	***0.03***
Sedentary promoters						
Car (no)			Reference		Reference	
Car (yes)			-0.05 (-0.31 – 0.15)	0.50	0.17 (0.04 – 0.27)	***0.01***
TV (no)	Reference					
TV (yes/no)	0.05 (-0.43 – 0.90)	0.48				
Household inventory	0.07 (-0.06 – 0.17)	0.33	-0.03 (-0.12 – 0.07)	0.59		

β = Standardised coefficient; CI = confidence interval

5.4. Discussion

This is one of the first studies to identify patterns and correlates of PA during pregnancy in black South African women. Half of the women in this study were classified as being active in the second trimester, however significantly fewer women participated in PA in the third trimester, and total PA decreased significantly as the pregnancy progressed. The greatest contribution to total MVPA was from walking for transport, which made up 80% of the total MVPA. Furthermore, women spent an average of 5 hours a day sitting throughout their pregnancy. Marital status and car ownership were found to be inversely associated with walking for transport, and car ownership was positively associated with recreational activity.

Internationally, 22-42% of pregnant women meet the recommended PA guidelines (≥150 minutes of MVPA per week) (18, 31, 263). This study showed a significantly higher prevalence (50.6%) of women participating in sufficient PA, which may be explained by the fact that many of these studies are largely from high income countries (HICs) and have assessed only leisure time PA (18). In the current study, only 2% of total PA time was spent in recreational activities, and the small amount of recreational PA reported in this, and other South African studies (35), highlights the pattern of PA unique to LMICs. It is likely that these women have few resources (50% were unemployed) and social support (60.5% were single) available to be recreationally active. Additionally, environmental influences, such as a lack of facilities and opportunities for pregnant women to participate in exercise, may have contributed towards the low recreational PA levels in these communities (279). Low participation in recreational PA has been further explained by Kruger et al. (35) from a traditional South African viewpoint, whereby PA is used purposively, to perform a task, and not necessarily for fun.

Nonetheless, the role of walking for transport and its effect on health outcomes should not be underestimated (366). Recent data from the Norwegian Fit For Delivery study has reported that it may be an effective means of reducing excessive GWG during pregnancy (367). However, within the South African context, although these levels may be acceptable now, it is likely that time spent walking for transport will be noticeably reduced in the near future due to populations undergoing an epidemiological and nutrition transition (365). Developments in transport infrastructure, such as the new bus rapid transit (BRT) system in Soweto, and other areas of South Africa, may result in a reduction in time spent walking for transport in the near future. This predicted change will increase the need for recreational facilities that are accessible to low income groups, in order to maintain or improve PA levels, particularly among pregnant women.

A significant decline in overall PA from the second to the third trimester was reported in this study. Likewise, data from the US NHANES (1999-2006), using objectively measured PA, showed a significant reduction in MVPA from the second to the third trimester (318). Zhang & Savitz (264) and others (265), have also reported a reduction in PA over the gestational period. The changes in PA levels are of concern, as a decline in PA during pregnancy has been shown to persist into the postpartum period and beyond (265), resulting in an increase in physical inactivity in the female population (which has already been shown to be high in South Africa). The decline in PA associated with pregnancy has been associated with postpartum weight retention (265) and may have consequences for maternal and fetal cardiovascular health in the long term.

This study makes a unique contribution, in that it is one of the few studies investigating correlates of PA in a longitudinal study of pregnant women from a LMIC. In HICs a higher

SES, Caucasian race, lower parity and pre-pregnancy PA have been shown to be associated with higher PA levels during pregnancy (364). In a study of 4 471 pregnant women in Brazil, Domingues et al. (271) found that leisure time PA was low and positively associated with schooling, income, being employed and parity. Similarly, in the same cohort, Coll et al. (34) found significant declines in leisure time PA from pre-pregnancy to pregnancy, and that leisure time PA was associated with higher income and education as well as lower parity. However, correlations of overall PA still remain largely unknown in LMICs. This study found that being married was associated with less walking for transport in both trimesters, and increased occupational PA in the third trimester. It may be assumed that a dual income household, or the opportunity to lift-share with a spouse, may result in less active transport for married women in this sample. Unsurprisingly, car ownership was associated with reduced active travel. These results are similar to those reported by Gradidge et al. (86), who reported on correlates of PA among middle-aged women from the same geographical area. In their study, reduced PA levels were associated with owning a TV or a car, and owning a car was associated with increased recreational PA. Having a car may provide easier access to surrounding exercise facilities, or may be an indicator of a higher SES, which means more resources available to be recreationally active. The current study also found that being overweight at baseline was positively associated with walking for transport. Similarly, a study of pregnant Latina women also found that pre-pregnancy BMI was related to increase in walking in early pregnancy (310). It is possible that this association may result from biased over-reporting of walking in overweight pregnant women (264) or that walking for transport is not always a choice in a LMIC setting, but rather a necessary function of daily living.(35)

As has been reported from other South African studies (365), our study in black South African women showed a high prevalence of overweight and obesity. In HIC studies, mean

BMI in early pregnancy has been shown to be much lower (22.9-23.4 kg/m^2) (263), and our study demonstrated a 40% higher prevalence of overweight/obesity during pregnancy when compared to US studies (277). However, prevalence of overweight/obesity appears to be associated with SES, as Chasen-Taber et al. (310) found a high rate of 49.1% in pregnant Latina women. Maternal obesity in sub-Saharan Africa is associated with adverse neo-natal outcomes (368) and overnutrition has implications for future generations. According to Whitaker et al. (369), women with a BMI of ≥30 kg/m^2 in the first trimester more than doubled the risk of obesity in their offspring's first 4 years of life. Therefore, the perinatal period has been identified as a critical time to intervene in the prevention of obesity and related diseases (131), before it becomes a major health problem for the mother and future generations. The low and declining levels of PA in this population highlight the need for interventions to promote and improve PA in pregnant women.

This longitudinal study has a number of strengths. Firstly, a holistic picture of PA during pregnancy has been captured, and the various domains of PA including work, transport and recreational PA have been reported. Secondly, few studies have assessed the change in PA levels over time during pregnancy, despite the fact that declining levels of PA may have negative health consequences both during gestation and in the postpartum. Thirdly, there is a dearth of large cohort studies of PA during pregnancy in a low-to-middle income setting. Studies such as this are especially important in these settings, since LMICs are particularly vulnerable to growing rates of overweight, obesity and its associated health issues. However, the data presented in this paper must be considered in light of the following limitations. The sample was relatively homogenous with respect to SES, ethnicity and educational levels. For example, previous studies have reported differences between race groups and SES (31), however this study assessed only black women and those attending a government hospital (a proxy for low SES in this population). Furthermore, the GPAQ is a self-report measure of PA, and self-report questionnaires have a number of well-known limitations (370). Although the GPAQ has been validated in South African non-pregnant populations, and provided domain-specific PA data, an objective measure of PA would have been useful. However, resources in LMICs are limited to measurements that can be done cost effectively and on a large scale (270).

5.4.1. Conclusion

This study is the first of its kind to assess PA levels and changes, and its correlates in a large, population-based prospective study in African pregnant women from a LMIC – a vulnerable population group where more research is needed. In conclusion, half the women in this study were active during pregnancy with some decline in PA levels by late pregnancy. In a population where the majority of women are either overweight or obese at the start of pregnancy, being active may be a key factor in mitigating some of the health risks associated with a high BMI. Clearly, we need to understand the moderating role of PA during pregnancy, and how to ensure more women remain active during pregnancy.

Chapter Six

THE INFLUENCE OF OBJECTIVELY MEASURED PHYSICAL ACTIVITY DURING PREGNANCY ON MATERNAL AND BIRTH OUTCOMES IN BLACK SOUTH AFRICAN WOMEN[5]

"The life of a mother is the life of a child: You are two blossoms on a single branch." Karen Mazezen Miller

[5] **Watson, E.D; Brage, S; White, T; Westgate, K; Norris, S.A; van Poppel, M.N.M; Micklesfield, L.K.** The Influence Of Objectively Measured Physical Activity During Pregnancy On Maternal And Birth Outcomes In Black South African Women *Submitted to Maternal and Child Health Journal*

6.1. Introduction

Current research supports the recommendation for regular PA during pregnancy. In the absence of obstetric complications, pregnant women are recommended to continue, or engage in, 150 minutes of moderate intensity PA per week (19). Physical inactivity is an important modifiable risk factor for adverse maternal and fetal outcomes during pregnancy. For example, maternal PA has been shown to reduce EGWG (25), which is an important predictor of adverse maternal outcomes such as GDM (146), preeclampsia and caesarean delivery (147). Furthermore, excessive weight gain during the pregnancy appears to have an adverse effect on maternal health risk and cardiovascular outcomes later in life. In the ALSPAC cohort, Fraser et al. (154) found women with a high GWG had a three times greater risk of being overweight, and had a higher BMI and blood pressure 16 years postpartum.

In addition, maternal overnutrition during pregnancy may expose the fetus to a sub-optimal intrauterine environment, resulting in an increased risk of macrosomia and obesity in the offspring through influencing appetite and metabolism (13). In a recent research review, Nelson et al. (371) reported that neonatal fat mass is associated with both maternal obesity and glucose concentration. Therefore, physical activity interventions during pregnancy may have the opportunity to break the obesity cycle in current and future generations (372). Since the physiology of the mother and fetus are so closely linked, maternal PA may also provide health benefits for the fetus. In a systematic review, Schlüssel et al. (20) reported that light to moderate PA during pregnancy reduces the risk of LBW and premature birth. This has been further substantiated by Takito et al. (220) who reported the protective effects of moderate PA against LBW and preterm birth. However, other studies show no association between PA and birth weight (208). Concerning preterm birth, it may be that the risk depends on the type of PA that is performed. In a randomised controlled trial, Barakat et al. (209) found no association between leisure PA and gestational age, although a physically demanding job may increase the risk of premature birth (210). The role of physical activity in fetal growth also remains uncertain. Clapp and Capeless (241) found that offspring of women that exercised regularly had lower Ponderal indexes but larger head circumferences. Another study by the same author found that women who increased or maintained their physical activity levels gave birth to offspring that were leaner as measured by Ponderal index, but with no differences in head circumference and Apgar score (244). Kramer et al. (203) suggested that women from the lowest socio-economic stratum are more likely to have physically demanding jobs or housework, as well as reduced participation in leisure time activity. This may lead to adverse birth outcomes, such as preterm birth and intrauterine growth restriction. Although women from LMICs have a diverse way of life and PA pattern, the contribution of PA to maternal and birth outcomes has not been well explored in these populations.

Physical activity is a complex phenomenon, and accurate measurement remains a challenge. Accurate PA measurement is also critical to determine associations between exposure and outcomes, and it is exactly this issue that often causes such variations in findings between studies. A consistent limitation in most population studies is the use of questionnaire-based methods of measuring PA during pregnancy. It is possible that these self-report measures have resulted in conflicting evidence for the effect of PA on preterm birth (203, 252, 373) and birthweight (233, 262). PA-related energy expenditure is most accurately measured through doubly-labelled water combined with indirect calorimetry of resting metabolic rate; however, these objective techniques are either prohibitively expensive, or are not feasible for assessing PA in a free-living environment in large scale studies (374). For this reason, body-worn accelerometers have become increasingly popular, as a useful method for measuring PA in population studies, and in a range of settings, including during pregnancy (375). Several studies have used accelerometers to validate questionnaires (312) or assess levels and patterns of activity during pregnancy (318). Only a few studies have examined the association between objectively assessed PA and birth outcomes (262, 322), and none have been done in black South African women. Therefore, the aim of the current study is to describe the change in objectively measured PA during pregnancy, as well as examine the association between PA and various maternal (gestational weight) and birth outcomes (gestational age, birth weight) as well as fetal growth and development (Apgar score, Ponderal index) in black South African women from a low-to-middle-income country.

6.2. Methods

6.2.1. Study sample

This observational study was nested within a larger pregnancy study (Soweto 1000 Days study) in the MRC/Wits Developmental Pathways for Health Research Unit, based at the Chris Hani Baragwanath Hospital, in Soweto, South Africa. Soweto, an English abbreviation for South Western Township, is a large urban area of Johannesburg with the majority of inhabitants coming from low income households. Data collection for the larger study included six time points: <14 weeks; 14-18 weeks; 19-23 weeks; 24-28 weeks; 29-33 weeks and 34-38 weeks. Women with a singleton pregnancy, attending the hospital for antenatal care, were recruited into the sub-study between May 2014 and August 2015. Participants were informed of the study, provided with an information sheet and all participants signed a consent form prior to participation in the study. The sub-study was approved by the Human

Research Ethics Committee of the University of the Witwatersrand (Clearance number M130351).

6.2.2. *Demographics and anthropometrics*

All demographic and anthropometric data were collected by experienced and trained research assistants/nurses. Demographic and socioeconomic information was gathered using an interviewer-led questionnaire. Socioeconomic status was assessed using household inventory questions assessing the ownership of nine household commodities (electricity, radio, television, refrigerator, cell phone, personal computer, bicycle, motorcycle/scooter, car). In addition, household density was calculated as the number of people living in the household divided by the number of rooms used for sleeping. All demographic, socioeconomic and behavioural data were collected at the baseline visit (<14 weeks gestation).

6.2.3. *Physical activity*

Physical activity was measured using a hip-worn triaxial accelerometer (ActiGraph GT3X+, ActiGraph, Pensacola, FL), at two time points during pregnancy (14-18 weeks and 29-33 weeks gestation). The device was initialized to record at a sample rate of 30Hz, for seven consecutive days, in order to include both week and weekend days. Participants were instructed to remove the device when washing or bathing, and during sleep. Non-wear time was defined as periods lasting 3 hours or longer where the standard deviation of acceleration in each axis remained below 5mg (375). All data from midnight to 6am were excluded, regardless of being classified as the device being worn. A day was considered valid if it contained at least 7 hours of wear time, and a minimum of 3 valid days (either week end or week day or a combination) of wear time was required for a record to be included in this analysis. Acceleration was calibrated to local gravity (376) and expressed in gravity-based acceleration units (mg), following which a measure of overall PA volume was derived from the acceleration data using the metric Euclidean Norm Minus One (ENMO) statistic (375, 377), which is the vector magnitude of acceleration in all three axes, and subtracting the value of gravity $(x^2 + y^2 + z^2)^{½} - 1$, with any negative values rounded up to zero. The use of ENMO for interpreting and estimating PA is well supported (375, 377) and has been used in other studies (378).

6.2.4. Maternal outcomes

Anthropometric measurements: height (cm) was measured using a stadiometer (SECA, Hamburg, Germany), and body weight (kg) was measured to the nearest 0.1 kg using a digital weighing scale (SECA, Hamburg, Germany). Body mass index (BMI) was calculated at baseline (<14 weeks) as weight (kg) / height $(m)^2$, and classified according to the World Health Organization's categories for underweight (<18.5 kg/m^2), normal weight (≥18.5 – 24.9 kg/m^2), overweight (≥25-29.9 kg/m^2) and obese (≥30 kg/m^2) (379). Gestational weight change was calculated as the difference between weight at baseline (<14 weeks) and weight at the 29-33 week visit.

6.2.5. Delivery outcomes

Gestational age (in weeks) was accurately determined by using ultrasound measurements taken by research sonographers at the baseline visit. Trained research nurses collected birth outcomes and neonatal anthropometric data (birth weight, length, and head circumference) within 48 hours of delivery. Missing data was back-filled with information from hospital delivery records. Ponderal index was calculated as birth weight (g) / height $(cm)^3$. Apgar score taken at 5 minutes was collected from hospital delivery records at the time of birth (380).

6.2.6. *Statistical analysis*

Descriptive data is presented as mean ±standard deviation (SD) for parametric data and n(%) for non-parametric data. Imputation was used for missing PA values in the third trimester (29-33 weeks), using linear regression of PA in 3^{rd} trimester on PA in 2^{nd} trimester. The PA 3rd trimester variable used in the models is a consolidated variable containing both measured and imputed data, and a separate variable indicating measurement status (measured/imputed) was used as confounding variable in the multiple linear regression models.

Non-normally distributed data (PA at 14-18 weeks, PA at 29-33 weeks, BMI, Ponderal Index) was log-transformed prior to analysis. Since PA data remained non-normally distributed after log transformation, a Wilcoxon Signed Rank test was performed to compare PA measures between the two time points. Multiple linear regression analyses were performed to determine the variables associated with maternal outcomes, namely weight (at 29-33 weeks) and weight gain (from <14 weeks to the 29-33 weeks' time point), as well as neonatal outcomes (gestational age, birth weight, Ponderal index, Apgar score). Full statistical analyses are presented in Appendix L. Furthermore, for logistic regression analysis, gestational age and birth weight were dichotomized into premature (<37 weeks gestation) or full term (≥37 weeks gestation), and low birth weight (<2500g) or normal birth weight (≥2500g). For the latter analysis, macrosomic babies (>4000g) were removed from the analysis (n=2). Analyses were done using Stata (Version 11; StataCorp LP), and statistical significance was set at $p \leq 0.05$.

6.3. Results

Maternal demographic, anthropometric and behavioural characteristics, as well as maternal and birth outcomes, of the 150 women who participated in the study, are presented in Table 15. There was a high prevalence of overweight (40.8%) and obesity (28.5%) at baseline (<14 weeks gestation), and 28.4% of the women reported to be HIV positive. The majority of women had completed secondary schooling (70.5%) and owned 5-7 items on the household inventory (77.7%). In this sample, 5.1% of the women had a miscarriage after their 14-18 week visit, and there were 4 neonatal deaths (3.4%).

Among the participating 150 women, 80% had valid activity data at 14-18 weeks (n=120), and 55% had valid activity data at 29-33 weeks (n=90). At 14-18 weeks, reasons for exclusion included insufficient wear time (n=24), devices missing/not returned (n=4) and other missing data (n=2). At 29-33 weeks, 16 women were excluded due to insufficient wear time, 16 women had delivered prior to their 29-33 week visit, 4 women had miscarriages, 2 women were admitted to hospital for gestational complications, and 22 women were lost to follow up (Figure 11).

There were no differences in age (p=0.97) or second trimester PA (p=0.67) between those who were lost to follow up and those who remained in the study; however the group lost to follow up had a higher BMI (p=0.02).

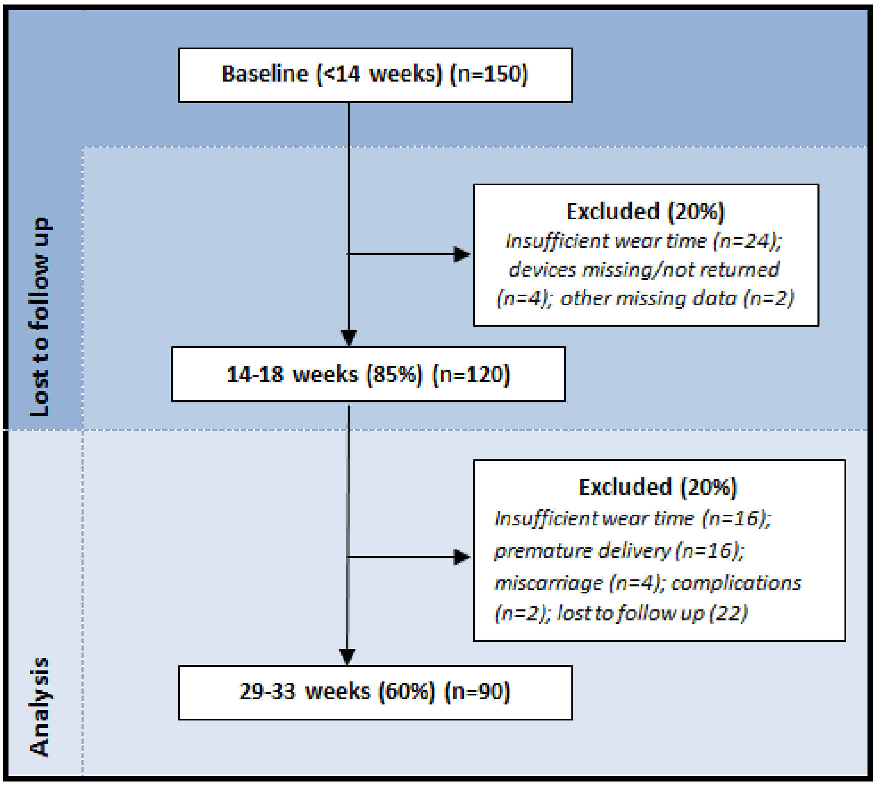

Figure 11 Attrition of participants through the study

The accelerometer was worn for a mean of 6.4±0.9 days at 14-18 weeks and 6.0±1.2 days at 29-33 weeks for those included in the final analysis. No significant difference was found in wear time between the two trimesters (p=0.99). There was a significant mean decline in overall volume of PA from the second to the third trimester (12.8±4.1 vs. 9.7±3.6mg, p<0.01) (Table 15).

Table 15 Demographics, physical activity, maternal and birth outcome characteristics of the participants in Study 4 (n=130)

Demographics	**n**	**Mean ±SD or median (IQR) or n (%)**
Age (years)	130	30.4 ±5.8
Height (cm)	130	158.8 ±5.9
Baseline weight (kg) <14 weeks	130	69.9 ±14.2
BMI (kg/m^2) <14 weeks	130	27.7 ±5.2
BMI Classification	130	

Underweight		2 (1.5)
Normal weight		38 (29.2)
Overweight		53 (40.8)
Obese Class I		37 (28.5)
Physical activity levels		
Physical activity (mg) 14-18 weeks	120	12.8 ±4.1
Physical activity (mg) 29-33 weeks	90	9.7 ±3.6[a]
Change in physical activity	81	-3.1 ±4.5
Maternal outcomes		
Weight (kg) 29-33 weeks	108	76.4 ±13.8
Weight gain (kg) 29-33 weeks	108	7.5 ±4.5
Birth outcomes		
Gestational age (wks)	126	36.2 ±4.6
Gestational age classification	121	
Premature (<37 weeks)		50 (41.3)
Term (≥37 weeks)		71 (58.7)
Newborn weight (g)	120	2876.1 ±647.0
Newborn weight classification	120	
Low birth weight (<2500g)		30 (25.0)
Normal (>2500g)		88 (73.3)
Macrosomia (>4500g)		2 (1.7)
Newborn weight classification	118	
Small for gestational age (<10th percentile)		16 (13.6)
Appropriate for gestational age (10th-90th percentile)		96 (81.4)
Large for gestational age (>90th percentile)		6 (5.1)
Newborn length (cm)	119	47.2±5.1
Newborn head circumference (cm)	119	34.3±2.8
Ponderal index (g/cm^3)	119	2.8 ±0.8
Apgar score (5 minutes)	118	9.7±0.7
Pregnancy outcome	129	
Live born		100 (77.5)
Live born, with complications/diagnosed condition		17 (13.2)
Antepartum death		6 (4.7)
Neonatal death		6 (4.7)
Sociodemographic (<14 weeks)		
Marital Status	127	
Single		73 (57.5)
Married/Cohabiting		54 (42.5)
Level of Education	129	
Completed primary school		5 (3.9)
Completed secondary school		91 (70.5)
Completed tertiary education		33 (25.6)
Employment Status	130	
Manual work		32 (24.8)
Non-manual work		29 (22.5)
Unemployed		33 (25.6)
Other		34 (26.4)
Household Inventory	130	
Low (<5)		7 (5.4)
Medium (5-7)		101 (77.7)
High (>7)		22 (16.9)
Behavioural (<14 weeks)		
Smoking or chewing tobacco/ betelnut?	128	
Yes		12 (9.4)

No	116 (90.6)

[a]*p<0.01 for PA 14-18 weeks vs. 29-33 weeks (mg, gravity-based acceleration)*

6.3.1. Determinants of maternal PA

The initial statistical modelling was informed, in part, by the conceptual model as previously described (Figure 2). Issues such as lifestyle behaviours and physical health became apparent, as well as the role of the social environment. Since the prevalence of overweight/obesity (69.3%) and HIV (28.4%) were relatively high in this sample, an initial analysis was completed to determine the relationship between these variables and PA, in order to inform the final statistical models, and gain some understanding of the interactions between these variables. Multiple regression analysis (adjusted for age, parity, education and SES) showed that there was an inverse association between early pregnancy BMI (<14 weeks) and PA at 14-18 weeks (β=-0.31, 95%CI:-0.55; -0.07; p=0.01) but no association with PA at 29-33 weeks (β=-0.01, 95%CI:-0.34; 0.31; p=0.93). Early pregnancy BMI was not associated with a change in PA between the two trimesters (β =0.06; 95%CI: -0.34; 0.47; p=0.75). In addition, no associations were found between HIV status and PA at either time point, however HIV status was associated with a change in PA, after adjusting for age, education, parity and household inventory (β =2.31; 95%CI: 0.46; 4.17; p=0.01).

6.3.2. Maternal outcomes

There was no association between PA at either time point and absolute weight at 29-33 weeks, after adjusting for early pregnancy BMI, age, parity, education, smoking and days from baseline to 29-33 weeks in a multiple regression analysis (Table 16). Similarly, PA at 14-18 weeks was not associated with weight change at 29-33 weeks, however, PA at 29-33 weeks was inversely associated with weight change at 29-33 weeks (β= -0.24; 95%CI= -0.49;

-0.00; $p=0.05$). A change in PA was also inversely associated with weight change at 29-33 weeks ($\beta= -0.36$; 95%CI= -0.62;-0.10; $p=0.01$).

Table 16 Multiple linear regression analysis for the association between maternal physical activity and maternal outcomes

Exposure variable	**Outcome variable**							
	Unadjusted model				Adjusted model			
	β (95% CI)	**SE**	**p- value**	**Adj R^2**	**β (95% CI)**	**SE**	**p- value**	**Adj R^2**
	Weight (<14 weeks)							
PA 2nd trimester	-15.04 (-22.72; -7.36)	3.87	***0.00***	0.10	-14.44 (-22.28; -6.60)[a]	3.95	***0.00***	0.13
	Weight (29-33 weeks)							
PA 2nd trimester	-12.77 (-21.0; -4.53)	4.14	***0.01***	0.07	-2.29 (-6.94; 2.34)[b]	2.33	0.32	0.75
PA 3rd trimester	-0.45 (-1.28; 0.36)	0.41	0.27	0.01	-0.28 (-0.72; 0.16)[c]	0.22	0.20	0.76
Change in PA	-0.19 (-0.40; 0.02)	0.10	0.08	0.01	-0.33 (-0.80; 0.13)[d]	0.23	0.15	0.78
	Weight change (from <14 weeks to 29-33 weeks)							
PA 2nd trimester	1.03 (-1.69; 3.77)	1.37	0.45	-0.01	1.26 (-1.27; 3.81)[b]	1.28	0.32	0.17
PA 3rd trimester	-0.14 (-0.41; 0.12)	0.13	0.29	0.01	-0.24 (-0.49; -0.00)[c]	0.12	***0.05***	0.21
Change in PA	-0.19 (-0.40; 0.2)	0.10	0.08	0.02	-0.36 (-0.62; -0.10)[d]	0.12	***0.01***	0.19

a Adjusted for age, parity, education, HIV status and smoking

b Adjusted for BMI (<14wks), age, parity, education, smoking, HIV status, days from baseline to 29-34wks

c Adjusted for BMI (<14wks), age, parity, education, smoking, HIV status, days from baseline to 29-33wks, imputed PA data

d Adjusted for BMI (<14wks), age, parity, education, smoking, PA (19-23wks), HIV status, days from baseline to 29-33wks

6.3.3. Birth outcomes

None of the PA variables contributed significantly to explain birth outcomes including gestational age, birth weight, Ponderal Index and Apgar score (Table 17). No associations were found between PA and neonatal head circumference (14-18 weeks: β=0.02, 95%CI:-0.07; 0.02, p=0.33; 29-33 weeks: β=-0.00, 95%CI: -0.00; 0.00, p=0.23, change in PA: β=-0.00, 95%CI: -0.00; 0.00, p=0.74), or neonatal length at birth (14-18 weeks: β=0.99, 95%CI:-1.54; 3.53, p=0.43; 29-33 weeks: β=-0.04, 95%CI: -0.19; 0.29, p=0.68, change in PA: β=-0.15, 95%CI: -0.42; 0.11, p=0.25). Logistic regression models (adjusted for age, BMI, smoking, education, and HIV status) showed no association between PA at 14-18 weeks and likelihood of giving birth to a full term baby (≥37 weeks) (OR: 1.52, 95%CI: 0.33; 6.86, p=0.58) as well as PA at 29-33 weeks (OR: 1.08, 95%CI: 0.92; 1.27, p=0.30). No significant associations were found between PA at either trimester and delivering a normal weight baby (≥2500g) (PA 14-18 weeks: OR: 1.55, 95%CI: 0.15; 15.35, p=0.70; PA 29-33 weeks: OR:0.90, 95%CI:0.71; 1.14, p=0.40), adjusted for age, BMI, smoking, education, gestational age and HIV status

Table 17 Multiple linear regression analysis for the association between maternal physical activity and birth outcomes

Exposure variable	**Outcome variable**							
	Unadjusted model				Adjusted model			
	β (95% CI)	**SE**	**p- value**	**Adj R^2**	**β (95% CI)**	**SE**	**p- value**	**Adj R^2**
	Gestational age (weeks)							
PA 2nd trimester	1.36 (-1.31; 4.05)	1.35	0.31	0.01	0.87 (-1.61; 4.12)[a]	1.44	0.38	-0.01
PA 3rd trimester	0.07 (-0.19; 0.35)	0.13	0.57	-0.01	0.09 (-0.14; 0.15)[b]	0.13	0.57	0.08
Change in PA	-0.10 (-0.26; 0.05)	0.08	0.20	0.01	0.08 (-0.12; 0.30)[c]	0.10	0.40	0.02
	Birth weight (g)[b]							
PA 2nd trimester	37.96 (-362.81; 438.73)	202.18	0.85	-0.01	99.57 (-193.99; 393.13)[d]	147.91	0.50	0.54
PA 3rd trimester	-2.48 (-41.53; 36.56)	19.71	0.90	-0.01	-7.87 (-35.84; 20.10)[e]	14.10	0.57	0.55
Change in PA	-19.82 (-47.48; 7.83)	13.88	0.16	0.01	-16.62 (-47.97; 14.75)[f]	15.71	0.29	0.33
	Ponderal index (g/cm^3)[b]							
PA 2nd trimester	-0.07 (-0.20; 0.05)	0.06	0.25	0.01	-0.04 (-0.17; 0.08)[d]	0.06	0.51	0.16
PA 3rd trimester	-0.00 (-0.02; 0.00)	0.00	0.12	0.01	-0.00 (-0.02; 0.00)[e]	0.00	0.22	0.14
Change in PA	-0.00(-0.01; 0.00)	0.00	0.63	-0.01	-0.00 (-0.02; 0.00)[f]	0.00	0.32	0.20
	Apgar Score[b]							
PA 2nd trimester	0.26 (-0.16; 0.70)	0.22	0.22	0.01	0.00 (-0.02; 0.02)[d]	0.01	0.97	0.17
PA 3rd trimester	0.00 (-0.03; 0.04)	0.02	0.80	-0.01	-0.00 (-0.02; 0.03)[e]	0.01	0.82	0.17
Change in PA	-0.01 (-0.03; 0.00)	0.01	0.19	0.01	-0.00 (-0.03; 0.02)[f]	0.01	0.90	-0.03

a Adjusted for maternal age, BMI (<14wks), smoking, education and HIV status

b Adjusted for maternal age, BMI (<14wks), smoking, education, HIV status and imputed data

c Adjusted for maternal age, BMI (<14wks), smoking, education, HIV status and PA(14-18 weeks)

d Adjusted for maternal age, BMI (<14wks), education, HIV status, smoking and gestational age

e Adjusted for maternal age, BMI (<14wks), education, HIV status, smoking, gestational age and imputed data

f Adjusted for maternal age, BMI (<14wks), education, HIV status, smoking, gestational age and PA(14-18 weeks)

6.4. Discussion

The purpose of this study was to describe the change in PA during pregnancy, and examine the association between objectively measured PA and pregnancy outcomes in black South African women, and has several unique findings. To our knowledge, it is the first longitudinal study to objectively measure free-living PA in black South African women during pregnancy. Incorporation of the objective measurement of biomechanical signals (raw accelerometry) has several advantages over the use of questionnaires and self-reported PA previously used (272), such as the avoidance of recall bias. Furthermore, few studies have assessed the effects of total PA on foetal growth and development (20), and this study collected PA data at two time points during pregnancy, allowing for a longitudinal analysis of PA behaviour change and its effects on maternal and birth outcomes. The main findings of this study indicate that there are significant reductions in PA during the gestational period. Furthermore, PA in the third trimester may play a role in weight management, with insufficient evidence to suggest an effect on fetal growth or development.

Previous studies examining the change in PA during pregnancy have reported conflicting results as well as methodological variations, with the use of both self-report and accelerometry to measure PA (381). Although some studies using self-report (278) and accelerometry (382, 383) have reported no change in PA during pregnancy, the evidence is accumulating for declining levels of PA during pregnancy. Evenson and Wen (318) reported significantly lower levels of moderate PA in the third trimester when compared to the first two trimesters. Similarly, Rousham et al. (32) found a significant decline in total PA measured by accelerometry at 38 weeks when compared to 16 and 25 weeks gestation. The current study found a significant reduction in total PA from the second to the third trimester, and provides supportive evidence for the decline in PA levels during pregnancy that has been found in other studies (272, 276, 384-387). However, many of these studies assessed changes specifically in moderate-vigorous PA during pregnancy (137, 318, 388). In a study of 140 obese pregnant women, Hayes et al. (276) found a reduction in moderate-vigorous PA at 35-36 weeks gestation, but no change in total PA. In contrast, our study found a reduction in total volume of PA, which is supported by the findings of Di Fabio et al. (389) who attributed this decline in PA to shifts from MVPA to light PA combined with an increase in sedentary behaviours during pregnancy. Encouragingly, there is evidence for the benefits of total PA, not exclusively moderate-vigorous PA, during pregnancy to reduce GWG (186) and increase insulin sensitivity (276, 390).

Societies undergoing the nutritional transition are demonstrating significant shifts in diet and PA patterns (59), and measures of SES such as income and higher education, have been associated with adopting these new patterns (63). Although all the women in the current study were recruited from a public hospital (a proxy for low to middle SES in South Africa), 25.6% had tertiary education and 16.9% had more than 7 household commodities, indicating that this particular sub-sample may be on the higher end of Soweto’s socioeconomic scale. In South Africa, urbanized individuals with higher educational levels have been found to consume energy-dense diets that are high in fat (391), and this may be supported by our study’s overweight and obesity prevalence (68%) during early pregnancy, that was 25% higher than other reports in black South African pregnant women (142). Of concern is that obese pregnant women face twice the risk of birth complications (392) and GDM (142), as well as postpartum maternal weight retention (146). Furthermore, an obese pregnant population has consequences for future generations, as an increased maternal body weight has been associated with large-for-gestational-age infants (146). Maternal overnutrition, as well as EGWG, have both been associated with adverse pregnancy outcomes, such as impaired glucose tolerance (393, 394), gestational hypertension and GDM (393). Guidelines for the recommended ranges of GWG is provided by the Institute of Medicine (IOM), however, a study by Chasen-Taber et al.(395) found that overweight women are more likely to gain weight above these recommendations. Furthermore, the applicability of the guidelines to obese women remains controversial (396). In a study of over 120 000 obese women, Kiel et al.(396) found a reduction in risk of perinatal outcomes with 4-11kg of GWG in Obese Class I women and 0-4kg for Obese Class II-III. This data suggests that minimal or no weight gain, or weight gain below the IOM recommendations in obese women may result in favourable outcomes, depending on the obesity class. Our study showed an inverse relationship between PA at 29-33 weeks and gestational weight change, providing evidence for the effectiveness of total PA during pregnancy in controlling GWG. Although some studies have shown little differences in GWG between active and inactive women (162, 397, 398), a meta-analysis of 12 randomised controlled trials showed that exercise was associated with a reduced relative risk (RR=-0.61) of GWG (27). A recent systematic review of both RCT and cohort studies found that leisure time PA was associated with lower GWG (28). Indeed, Clapp and Little (399) found that women who continued to exercise during pregnancy reduced their rate of weight gain by 3kg compared to the non-exercising group, and PA has been identified as a key behavioural determinant of GWG control (400).

Despite 30 years of research on this topic, the influence of PA on fetal growth and development is inconclusive. Some research has shown no effect of PA on gestational age (208, 258), whilst others have found an inverse association (272). A recent study assessing the effects of long term PA found that active women have lower rates of preterm birth (261). The association between PA and birth weight follows a similar, conflicting pattern. Some studies have reported a decrease in birth weight with increasing levels of PA (401). In comparison, a systematic review by Schlüssel et al. (20) reported 10 studies that showed no increase in risk of LBW for pregnant women participating in leisure time PA. Indeed, Vamos et al (261) found that the association between PA and birth weight is diminished when adjusting for sociodemographic and other confounders. The population in this study had unique co-founding factors such as high BMI levels at baseline and high HIV rates, which may dominate PA in their influence on birth outcomes, explaining the lack of evidence for an association between total PA and birth outcomes in this population.

Many previous studies have looked exclusively at moderate-vigorous PA and not total volume of PA, making comparisons between our population and other studies difficult. Our study did not analyse intensity and type of PA, and these may have some influence on maternal and birth outcomes (20). However, total volume of PA is emerging as an independent and influential factor in pregnancy outcomes (390), and using objective measures for assessing this is valuable when examining a dose-response relationship. Further research should include well-designed randomised controlled studies to determine the effect of PA on maternal and birth outcomes in this unique population (402). Limited resources in our study setting did not allow for objective PA monitoring on a large scale, as has been done in other countries (318), therefore the small sample size limited the number of confounding variables that we were able to include in the models.

In summary, this is the first study of its kind to objectively assess PA longitudinally over the gestational period and its influence on maternal and birth outcomes in black South African women. Total volume of PA significantly decreased from the second to the third trimester and this study highlights the need for future efforts to be directed at increasing, or maintaining, total volume of PA. In addition, total PA in the third trimester, as well as a reduction in PA, was associated with less GWG. We therefore support the evidence that "every little movement counts" (373) and future recommendations should encourage any PA in this population. Lastly, our study did not provide sufficient evidence for an association between PA and birth outcomes. Thus, this study supports the conclusion that PA is beneficial for maternal outcomes, whilst posing no adverse risk to the growing fetus (402). In a population where the majority of pregnant women are overweight and obese, PA interventions are needed to control GWG and minimise the potential effects of obesity on future generations.

Chapter Seven

DISCUSSION AND CONCLUSION

"We could go a long way to achieving that remarkable improvement by giving more people the life chances currently enjoyed by the few." Marmot Review, 2010

Overview

Chapter one provided a theoretical view of the role of PA in reducing NCDs risk, particularly within LMICs and then more specifically PA during pregnancy. From a review of the literature it is clear that: NCDs are a burden in LMICs, and black African women living in urban areas are particularly vulnerable to a high prevalence of both overweight/obesity and physical inactivity. Pregnancy is potentially a high risk period that may exacerbate these levels of overweight/obesity, and lead to even lower PA levels. However, it may also present a unique window of opportunity to change lifestyle behaviours and promote PA. Physical activity interventions during this period may have the added benefit of improving health in both the short and long term for the mother and the baby, as well as future generations.

Two main themes emerged from the findings of this thesis, that of the uniqueness and complexity of PA behaviour during pregnancy in South African women as well as the role of PA in maternal health. The findings from each of the studies have been discussed separately in chapters three through to six, and are summarised in Table 18 below.

This chapter will consolidate the findings of each of these chapters to provide an overview of the main findings of the thesis. Thereafter the recommendations for future interventions are presented and the strengths, limitations and future research avenues are discussed. And lastly, key take home messages conclude the chapter.

Table 18 Summary of the findings of each study

Objectives	Main findings
Chapter 3: *To assess the attitudes, beliefs and perceived barriers to physical activity during pregnancy*	Although the majority of women believed that physical activity was beneficial, this did not appear to translate into behaviour. Reported reasons for this included pregnancy-related discomforts, lack of time and money, and insufficient physical activity related education, all of which can contribute to a reduced perceived control to become active. Opportunities to participate in group exercise classes were a commonly reported facilitator for becoming active. In addition, influential role players, such as family, friends and healthcare providers, as well as cultural beliefs, reportedly provided the women with vague, conflicting and often discouraging advice about physical activity during pregnancy.
Chapter 4: *To assess the attitudes, knowledge and beliefs of medical practitioners towards physical activity during pregnancy.*	The majority of practitioners (98%) believe that exercise during pregnancy is beneficial, and were knowledgeable about most of the expected benefits. Seventy-eight percent believed that providing exercise advice is an important part of prenatal care, however only 19% provided information pamphlets and few (24%) referred their patients to exercise specialists. A large majority (83%) were unaware of the current ACOG recommended physical activity guidelines for pregnancy. Although age and years of practice played no role in this awareness, practitioners who focussed on obstetrics and gynaecology were more likely to be aware of the current physical activity guidelines, compared to those in general practice.
Chapter 5: *To assess the patterns and correlates of self-reported physical activity levels during pregnancy in black women living in Soweto, South Africa.*	In the first trimester (<14 weeks) 68% of the sample was overweight or obese. Fifty-one percent of the women were physically active in the second trimester, and this decreased to 43% in the third trimester. There was a significant decrease in MVPA between the second and third trimester (600 vs. 480 MET mins/wk; p=0.01). The majority of physical activity time was spent in walking for transport (80%), and less than 2% in recreational activities. In both trimesters, married women were less likely to walk for transport (2^{nd} trimester: β=-0.12, 95%CI: -0.31,-0.02 and 3^{rd} trimester: β=-0.17, 95%CI: -0.42, -0.07), and those that owned a car were more likely to participate in leisure time physical activity (2^{nd} trimester: β=0.16, 95%CI: 0.02,0.32 and 3^{rd} trimester: β=0.17, 95%CI: 0.04, 0.27) but were less likely to walk for transport in the 2^{nd} trimester (β=-0.11, 95%CI:-0.31, -0.00) The women spent an average of five hours per day sitting.
Chapter 6: *To objectively measure physical activity and sedentary behaviour in pregnancy, and assess its influence on maternal and delivery outcomes in black SA women*	As was shown in the self-report measure in Chapter 5, there was also a significant decline in objectively measured physical activity from the second to the third trimester (12.8±4.1mg vs. 9.7±3.6mg, p=<0.01). Physical activity in the third trimester, and change in physical activity during pregnancy, were both inversely associated with gestational weight change at 29-33 weeks (β= -0.24; 95%CI: -0.49; -0.00; p=0.05 and β=-0.36, 95%CI: -0.62, -0.10 respectively). No significant associations were found between physical activity and birth outcomes.

7.1. The complexity of physical activity during pregnancy

7.1.1. Get moving moms! Physical activity levels

This study provides a greater understanding of PA during pregnancy in a LMIC setting, by assessing longitudinal PA levels (both self-reported and objectively), as well as understanding pregnant women's beliefs and experiences of PA. Furthermore, this thesis included beliefs and attitudes of South African healthcare providers as potential role players for prescribing PA during pregnancy. Then, the influence of these PA patterns during pregnancy on maternal and birth outcomes was determined.

The results of this study currently provide the only published longitudinal data available on patterns and changes in PA during pregnancy in black South African women. When examining the PA patterns in urban black non-pregnant women in South Africa, only one third of the population are sufficiently active (>600METmin/week) (356). Our study showed that 51% of pregnant women were sufficiently active (>600METmin/week) in the second trimester, and this declined to 43% in the third trimester. This is similar to findings by Zhang & Savitz (264), who reported a 13% decrease in PA levels from 55% to 42% during pregnancy in women from the US. When compared to other studies in HICs, the number of women meeting the prenatal PA guidelines was higher in this study (43-51% vs 22-42%) (18, 31, 263, 264, 277). This may be due to the nature of the GPAQ questionnaire, which encompasses various domains of PA (occupation, travel, transport and recreational), whilst much of the HIC research has only focused on leisure time PA. In fact, a systematic review by Poudevigne & O'Connor reported that 28 out of 31 studies focussed on leisure time PA only (18). Previous US studies have reported as many as 65% of pregnant women participate in recreational PA (137). In their study of 1482 US pregnant women, Borodulin et al. (263) reported that leisure time PA accounted for most (30%) of the total MET h/wk of energy expenditure. In comparison, the majority of PA in this study came from walking for transport (80.1% and 80.4% in the second and third trimester, respectively) and very little from leisure time PA (2% and 2.6% in the two trimesters respectively). This provides further evidence for the diverse patterns of PA in LMICs which has been found in previous studies of South African women (35). It is likely that availability of resources, as well as both financial and social support, may hinder the ability of the women in the current study to be recreationally active. Many of the women in this study were single (60.5%) and unemployed (50%), leaving little financial and social aid to support leisure time PA, which may be considered a luxury. Furthermore, some women provided qualitative insight into the lack of recreational activities available for specifically pregnant women *"Pregnant ladies coming together, doing such [exercises], it would help a lot. If I had a group like that next to me, I would have been doing it…"(BMI 26.8 kg/m2; Active)*. Regardless of the higher overall PA levels reported in this study compared to HIC studies, a 50% prevalence of sufficient PA during pregnancy is of concern, as it is possibly not enough for a healthy nation of mothers-to-be.

7.1.2. Walking is man's best medicine[6]

This study has shown that walking for transport appears to be the most common form of PA during pregnancy, similar to other studies in non-pregnant SA women (86, 403). Internationally, walking has been identified as a popular form of PA in most studies involving pregnant women (33, 264, 277, 404, 405). In our sample, 80% of total PA was walking for transport. Whether this type of PA is through choice or as a means of commuting as a consequence of their SES, is still to be ascertained, however in our qualitative study walking was reported as the preferred type of PA and women described it as being "*therapeutic*", believing it was useful to prepare the body for labour and delivery. It is

[6] Hippocrates

important to consider that factors (such as the built environment) associated with walking for transport and walking for exercise may be very different from each other, and possibly require further investigation in this population (406).

This study, and other researchers, has examined the links between social variables and behaviour. However, emerging research has started to assess the causal pathways between physical environmental variables and behaviour (407, 408). In HICs walking to work has been associated with environmental factors such as walking routes, aesthetics and convenience (408). In the South African, and the Sowetan context, walking for transport may originate out of necessity. Many of the streets do not have pavements, and are not aesthetically pleasing, which leads to the conclusion previously stated by Kruger et al. (78) that walking PA is a means to an end in this population group. This was further supported by the social beliefs of friends as described by some of the pregnant women in chapter three: "*only dogs walk!*" and "*Why are you walking?"* Since much of the walking in these populations occurs within the context of neglected infrastructure, the health effects may be somewhat contradictory unless the gaps within the built environment are also addressed (409).

However, the benefits of active travel should not be underestimated. There is preliminary evidence for its effects on health outcomes, in particular the prevention of T2DM and obesity (366, 410, 411). In addition, it is an easy behaviour to adopt and fits in with activities of daily living, thereby facilitating adherence (412, 413). As many of the women in this study described a lack of time to do structured PA during pregnancy ("*you are supposed to do things at home so there is no time to go to the gym*"), walking for transport may be a perfect behaviour to promote from a public health perspective.

Little is known about the correlates and determinants of PA during pregnancy in South African women. The various interactions of individual, environmental and social factors in determining PA levels are well known (45, 297). Socioeconomic status appears to play a significant role in PA levels in both LMICs (297, 414, 415) as well as during pregnancy (264, 385, 404). The findings of this study support the theory that not only does SES play a role in determining PA levels, it also determines the type and domains of PA participation. We have shown in chapter five that being married was inversely associated with less time spent walking for transport. This is supported by qualitative quotes in chapter three showing the social pressure from a spouse to take it easy and reduce PA levels during pregnancy, particularly with regards to active transport ("*…they always want to drive…every time I say let's go for a walk he [husband] says no*" and "*...you should just let your husband drive you"*). Being married may also be a proxy for a higher SES, whereby two possible household incomes translate into a reduced need to have to walk for transport. In addition, this study contributes to previous research on the role of sedentary promoting assets (car and TV ownership) in reducing PA levels (86, 415). In a recent study of five countries, car ownership was associated with between 10-24 minutes less MVPA per day (415). On the other hand, our study found car ownership (a sedentary promoting asset and an indicator of a higher SES) (409) was positively associated with leisure time PA, suggesting that SES is a significant correlate of different PA domains, as has been shown repeatedly in other SA studies (86, 403).

7.1.3. Keep moving moms! Changes in maternal physical activity levels

This thesis, in agreement with previous studies (34, 263, 271, 275, 330), reported a decrease in time spent in PA during pregnancy, measured with both self-report and accelerometry.

Chapter three provides a useful insight into why these changes may occur. Women appear to have reduced perceived behavioural control over their ability to be active, due to the physiological changes that occur during pregnancy ("*This person is heavy…that you are carrying*") as well as other associated discomforts such as fatigue and nausea. Unsurprisingly, this decline in PA levels and the reasons behind it are similar worldwide (416, 417).

Although pregnancy-related discomforts are often cited as a reason for reducing PA levels, there is a wealth of evidence for the beneficial role of PA in easing these discomforts (418, 419). This inverse relationship between PA and pregnancy-related physical discomfort appears to be even greater in the third trimester (419). Research also suggests a link between reduced discomfort and increased self-esteem (418, 419), which could perhaps explain the observations found in these studies. It is likely that being active during pregnancy assists not only in bearing the physical load associated with a growing belly, but also assists in improving women's mood and self-efficacy. In fact, Gaston & Prapavessis (420) found that active mothers had significantly less depression, anger, tension, anxiety and fatigue than their sedentary counterparts. It is worth educating women on the fact that being active may assist in providing greater mobility, an increase in their ability to do activities of daily living, and greater vitality during pregnancy (421). Therefore, strategies to overcome barriers to PA, which may result in maintaining or increasing PA levels during pregnancy, are encouraged.

7.1.4. The state of our mothers

Although research has shown that South African women are particularly vulnerable to high rates of overweight and obesity (35, 103, 285), a 68% prevalence (<14 weeks) in this population of expectant mothers was surprising, since women of child-bearing age are expected to weigh less than the general population. It may be a function of the nutrition transition in this population, as overweight and obesity has been previously associated with SES and a transitioning environment in LMICs (422, 423). The participants in Chapter six of this thesis were found to be on the upper end of the SES scale for this area. Additional, the findings suggest that higher education levels are positively associated with GWG (as seen in the full statistical models in Appendix L). Therefore, the rising middle class in Soweto may be particularly at risk for overweight and obesity, as well as gestational weight gain during pregnancy. Maternal overweight and obesity has been linked to offspring all-cause mortality, premature death (424) and long-term childhood obesity (425, 426). Furthermore, maternal health outcomes such as GDM, gestational hypertension and preeclampsia all increase with increasing BMI (425). However, the findings of this study showed that women gained less weight at 29-33 weeks with increasing amount of PA during the third trimester (95%CI= -0.49; -0.00), and that changing PA levels would also inversely affect their weight change (95%CI= -0.62;-0.10). This study provides initial evidence that initiating and maintaining PA during pregnancy may be the required strategy or intervention to help control GWG. It presents a case for urgent intervention to prevent the cycle of obesity, not only for maternal health issues, but for the long-term health of the child as well.

It is evident from this, and other studies, that PA has an important role to play in maternal health, however there is more uncertainty regarding its role in birth outcomes. The literature presents a conflicting and generally inconclusive picture for the influence of PA on birth outcomes (Table 4). This thesis (chapter six) did not find sufficient evidence for an association between PA levels and the birth outcomes that were measured including length of gestation and birth weight. As with most of the current guidelines and recommendations, one can conclude with some confidence that PA should be recommended for maternal health benefits, and is not unsafe for the growth and development of the fetus (373, 402). Despite the lack of association between PA and birth outcomes in this study, and confirmed by others, it is still an essential part of a healthy lifestyle.

7.2. Baby steps: Recommendations for interventions

Overweight and obesity, coupled with its associated diseases, is one of the biggest global health problems, yet it is often the most neglected (49). The bottom line is that the associated financial burden far outweighs the cost of simple, effective interventions and, if assessed in terms of human life, is invaluable (102). Many prevention strategies and interventions have been proposed to stem the tide of NCDs. Perhaps the first step, as proposed by the WHO Global Action Plan, should be to increase the ***surveillance and monitoring*** of NCD risk factors (11). This should include physical inactivity as well as overweight and obesity during pregnancy. The findings of this thesis are the first of its kind to assess PA levels as well as BMI (two major risk factors for NCDs) in South African pregnant women. Further research and surveillance needs to be done encompassing other population groups (for example rural women or urban women of a different SES) as these findings may not be generalizable to other South African women. Unfortunately, just as there are disparities in health outcomes, there are also disparities in research and funding, with most health research funding being spent in HICs, despite the burden of disease that exists in LMIC (427, 428). Indeed, one of Gostin's four key steps in the global governance of NCDs is to ensure sustainable funding to allow LMICs to tackle the burden of NCDs (429). Therefore, funding sources should allocate resources in LMICs for not only surveillance of NCDs, but to assist in developing preventative interventions.

One of the WHO's "best buys" for the prevention and control of NCDs is public awareness and promotion of PA (430). A "best buy" is a pragmatic concept that encompasses not only cost effectiveness (when an intervention generates an extra year of healthy life for a cost that falls below the average annual income per person), but also interventions that are feasible and can be appropriately incorporated into LMICs facing constraints on the local health care system (431).

South Africa's Chief Director for NCDs noted in 2014 that a "re-engineering of the primary health care system is at the top of the health agenda" (432). This study proposes solutions for some of the gaps within the current antenatal primary health care system. One possible strategy to improve PA levels during pregnancy is to improve education, counselling and PA promotion at a primary healthcare level. In chapter four of this thesis, we found that the majority of healthcare providers believed in the benefits of PA during pregnancy, and many are supportive of their role in PA promotion. However, as with previous studies, there was a lack of knowledge of the PA guidelines and recommendations during pregnancy, resulting in only a few women getting clear, understandable and structured advice (281, 290, 349, 358, 360). One of the possible reasons for the decline in PA levels (as found in chapter 5 and 6) is that many women do not receive the relevant information (33) and remain confused or unsure of the safety of being active during their pregnancy (433).

Therefore, a crucial step would be to ***educate the health care providers*** on strategies for PA promotion and counselling, in the general public and during pregnancy. Women frequently visit their healthcare provider during pregnancy, and therefore the healthcare provider is well-placed to provide this essential service (286, 287, 342). This should be part of a healthcare policy change by the government in the prioritizing of prevention of disease over treatment (287). Indeed, this study, in alignment with others (362), demonstrates that women appear to want advice from their healthcare provider ("*if they [the gynaecologist] also gave us* *information, that would help…*”). The provision of PA guidance from a healthcare provider has been found to be positively associated with higher PA levels during pregnancy (33). It seems women receiving such PA advice will likely be motivated to become more active (349), as best described by one of the study participants: “*…maybe I don’t know the importance of doing them [exercises].*” Such a statement is profoundly insightful into the potential that education and knowledge has to empower women to become active during pregnancy.

Realistically, there are unique challenges that face the public healthcare system in South Africa, as described by de Jager & Van Belle (434): *“South Africa’s public healthcare system is under-resourced, ill managed and it is struggling with an amalgam of social and poverty related diseases*.” In this environment, adding PA counselling to a physician’s work load may be unrealistic and optimistic. However, one solution is to take a holistic approach to ***PA counselling and promotion*** in this sector. For example, many of the women attending public health clinics and hospitals will only see a nurse or midwife, and these health care providers ought to be educated on their role in promoting PA. Furthermore, South Africa’s healthcare system includes a Biokineticist (Clinical Exercise Specialist) who up until now, operates solely in the private health care sector. The Biokineticist, using exercise and PA as the primary modality for treatment, should begin to play an integral role in the public health care sector (435). It is hypothesised that providing Biokinetics posts within the public health sector would go far in helping South Africa reach its Strategic Plan for the prevention and control of NCDs. This strategic plan includes a reduction in overweight and obesity by 10% and an increase in the amount of people being sufficiently active by 10%, by 2020 (436). Since pregnancy is a crucial time to address issues of overweight and obesity, as well as physical inactivity, it may be an effective time to intervene in order to reach these goals.

In addition, much of the promotion and education regarding PA during pregnancy can be done through posters, leaflets, websites, media campaigns and use of technology. Tanha et al. (437) found that providing the ACOG PA guidelines to pregnant women increased their PA levels and reduced their anxiety. One such strategy for education is Mobile Health (mHealth) – the use of mobile phones and devices to provider healthcare related services (438). This has been shown to have potential impact in delivering services, especially in low-income groups (434). Examples of such programmes include *Text4baby* programme in the US, which has shown some promising results for the delivery of text messages, based on behavioural theory, that would help to assist new moms to improve their health behaviours (439, 440). In South Africa, programmes such as HEDUAfrica (www.hedu-africa.org), where education is delivered through interactive multimedia and storytelling, may be a unique and cost-effective method for provision of information. It is uncertain whether mHealth initiatives will in fact have an impact on improving PA levels during pregnancy (441), but it certainly warrants further investigation.

Furthermore, campaigns such as Active Australia or Agita São Paulo (Get São Paulo moving) have shown that mass media has a role to play in improving public health awareness and education regarding PA (442-444). In South Africa, the initial movement of Vuka South Africa – Move for Health seemed to be promising (445) but its reach and relevance to pregnant women is not apparent. Public health campaigns aimed at maternal PA need to be specific to the needs, safety and recommendations associated with being physically active during this period (19, 21). Furthermore, formative development and evaluation of such campaigns are often ignored (446) and whilst they appear to have an initial impact (444), their sustainability is often neglected.

The aim of any intervention needs to be clear: from a behavioural perspective, women need to be encouraged to build a behavioural plan that is sustainable and becomes habitual (447). We have shown that women believe in the benefits of physical activity during pregnancy, but that these beliefs do not always appear to translate into behaviour. Beliefs are theorised to be the basis for forming an intention to engage in a specific behaviour, such as physical activity (334, 448). This has been the source of much debate in behavioural change literature. It has been suggested that adding planning, maintenance, self-efficacy and action control strategies can help to bridge the "intention-behaviour" gap (449). In particular, research highlights the importance of action planning in converting intention into behaviour (450). Identifying psychological factors linked to physical activity behaviour, as was done in chapter three, is essential for highlighting which of these factors should be the target for interventions (450) From a PA perspective, this would mean that PA becomes a part of daily activities of living, and does not have to compete with other family and work demands. Hagger & Chatzisarantis (450) have built a model that incorporates the nonconscious implicit process of behavioural change and minimises the deliberative planned action used in previous models. One of the main issues with behavioural change, specifically in PA behaviour, is that many people have intentions to engage in the behaviour, but fail to carry out their intentions. To overcome this intention-action gap, researchers have proposed an action-control model, whereby people form a plan to act (450, 451).

Behaviour change techniques and models should also be used to develop the method and content of information delivery (choice of technology, content of website, leaflets, posters) as well as intervention planning. By providing an understanding of PA behaviours and beliefs of a particular community, this study was able to start the initial process of identifying key factors that correlate with PA levels to form a base to guide interventions unique to this population. Effective and repeatable interventions aimed at changing behaviour needs to be based on science, good theory and reliable technology (452). Communication content should be aimed at salient beliefs within each construct (attitude, subjective norms, perceived behavioural control) for the specific population at which the intervention is aimed. It should involve the promotion of facilitating factors (e.g. exercise is good for you and your baby) as well as dispel barriers (e.g. exercise does not harm your baby). The next step, according to Hagger & Chatzisarantis (450), is to develop an “if-then” plan where a PA behaviour can be linked to an event or situation (e.g. if my baby kicks, I will get up and do something active). Furthermore, although more research is needed to ascertain the effectiveness, there is some evidence for the use of priming manipulation of implicit attitudes and motives. For example, this could be a poster with only a picture that would prime a positive attitude or motive (e.g. a picture of an exercising pregnant mom having fun with friends) (450).

Disease prevention prioritisation demands the ***engagement of multiple sectors*** such as government, industry, academia and society. Since this, and other studies, show that the majority of South Africans participate in walking for transport, involvement in urban planning seems inevitable. Investment and alteration of the built environment, to include pavements, attractive playgrounds/parks, and bicycle lanes should encourage healthy activities (429). Access to green spaces has been shown to have beneficial effects on both physical and psychological health (453), and could provide opportunities for pregnant and post-partum women to embark on recreational walking and other physical activities. Much of the development in the built environment in South Africa, and in Soweto in particular, is geared towards improving passive public transport networks (such as the Rapid Bus Transport system recently introduced to Soweto). Transportation and planning policy that is geared towards promoting active travel is warranted now more than ever in South Africa to negate the effects of urbanisation on the health of the nation (454). Furthermore, there has been much in the literature on fiscal and regulatory measures for nutritional information and unhealthy food content (102, 455). One such example is the compelling case for taxing sugar-sweetened beverages in order to reduce consumption and therefore risk of obesity and associated diseases (456, 457). In South Africa, such measures have been estimated to reduce energy intake by 36kJ per day and decrease obesity rates by 3.8% (95%CI: 0.6%-7.1%) (458) and is said to be implemented by April 2017 (www.mg.co.za: 24 Feb 2016). Both of these issues – policy and fiscal measures - should be extended to active transport, since urban planning strategies that promote active transport can dually assist with both physical health (366) and climate change (459) – two major issues currently affecting our society.

Furthermore, strategies need to be developed that create environments in which individuals, families and communities are collectively empowered to change their behaviours (7, 49). To this end, ***community based intervention programmes*** have been shown to be successful in various LMICs (101). However, a major emphasis should be placed on the ***importance of culture*** in constructing beliefs regarding health and illness, and therefore its role as an integral part of a comprehensive package pf primary prevention (50, 57). The PEN3 model (Figure 10) provides a cultural lens through which health education programmes and health issues can be addressed (50, 460). This model makes culture the central issue when addressing issues of health behaviour, beliefs and outcomes. It has three domains, namely (i) cultural identity (this is where the intervention may happen, for example at an individual, family or community level); (ii) relationships and expectations (includes resources and facilities that can act as facilitators or barriers, and societal perceptions of health and care) and (iii) cultural empowerment (cultural beliefs and practices are identified and only the harmful ones are addressed) (460).

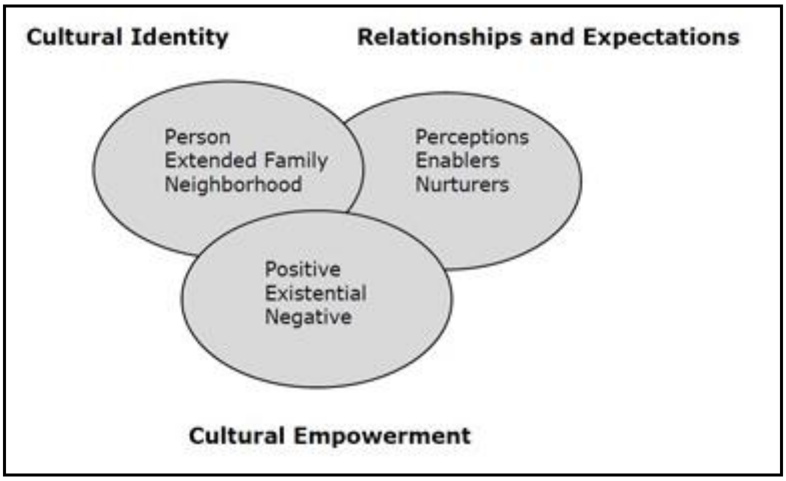

Figure 12 PEN3 Model and the importance of culture in intervention development (50)

Since culture shapes health behaviours, it is essential that interventions are culturally sensitive to a particular target group (57, 103). Chapter three of this study highlighted the role of indigenous knowledge in health behaviours during pregnancy which should be considered when designing interventions. In addition, the role of the traditional healer in African healthcare should not be ignored, and perhaps needs to be included in the educational interventions aimed at healthcare providers (57). Likewise, effective interventions need to include the socio-cultural context, and from the findings in chapter three, it can be argued that family and community support is essential for behaviour change. Women in this, and other studies (279), support the need for community-based exercise classes ("*pregnant ladies coming together doing such [exercises], it would help a lot*"). A re-structuring of primary health care that involves provision of such services through non-physician healthcare workers (and for example a Biokineticist or trained healthcare worker) is therefore warranted (6). Such interventions that involve non-physician healthcare workers, coupled with family and self-care could be the backbone of a cost-effective, life-course approach to changing behaviours and reducing the burden of disease in SA (427, 461). "*Where to begin will depend on the scientific capacity to deliver, national priorities and the funds available. The important point is to make a start somewhere.*" (427).

7.3. Strengths, limitations and future studies

This is the first study of its kinds to assess prenatal PA in an African population from both a qualitative and quantitative perspective, starting at understanding the barriers and facilitators of PA during pregnancy, looking at the role of healthcare providers, and then assessing the levels and patterns of PA and their role in determining maternal and birth outcomes. Maternal PA was measured in women attending CHBH and was part of the larger S1000 study. Soweto is specifically a unique low-to-middle income, urban environment within a large metropolis area. Therefore, population groups from smaller cities, high income areas or rural towns may present with different findings. Furthermore, women attending CHBH represent only a portion of pregnant women in Soweto, as the majority will attend a clinic close to their home. However, recruitment through the CHBH antenatal unit provided many advantages, such as accurate birth outcome data and regular follow up visits, which would have otherwise been lost with recruiting from nearby clinics. Thus, follow up studies should be done in other geographical areas, assessing PA in various socioeconomic levels.

It is well known that the mechanisms underlying being physically active are complex and multifaceted (45, 297). Understanding the correlates associated with PA is essential to inform interventions, but little has been done in LMICs (297). Chapter five of this thesis found few correlates of PA, specifically total MVPA, when compared to similar studies from HICs (31, 263, 330). This may be due in part to the relative homogeneity of our sample. For example, attending a government hospital is a potential proxy for SES, indicating that most women would have been within a low-to-middle income SES bracket. Furthermore, differences in PA (404) and overweight/obesity levels (462) have been found between different ethnic groups, but our study only included black women, making these comparisons impossible. Therefore, further studies should assess prenatal PA in a wide population range in order to specify which sub-groups need to be targeted for interventions. Indeed, this study showed a very high prevalence of overweight and obesity, as well as low and declining levels of PA in pregnant women living in Soweto, which provides initial evidence that this is an important group of women at which to target interventions.

This initial conceptual model underestimated the role of walking for transport in the PA profiles of this population group and thus has subsequently been updated to include the role of the built environment as a factor for influencing PA, and is presented in Figure 11. The role of the built environment in influencing human behaviour has become a popular subject in addressing PA levels (463). It may present issues of socioeconomic disparity (464) and be moderated by crime and safety concerns (465) and should therefore be taken into consideration when planning interventions during pregnancy in South Africa.

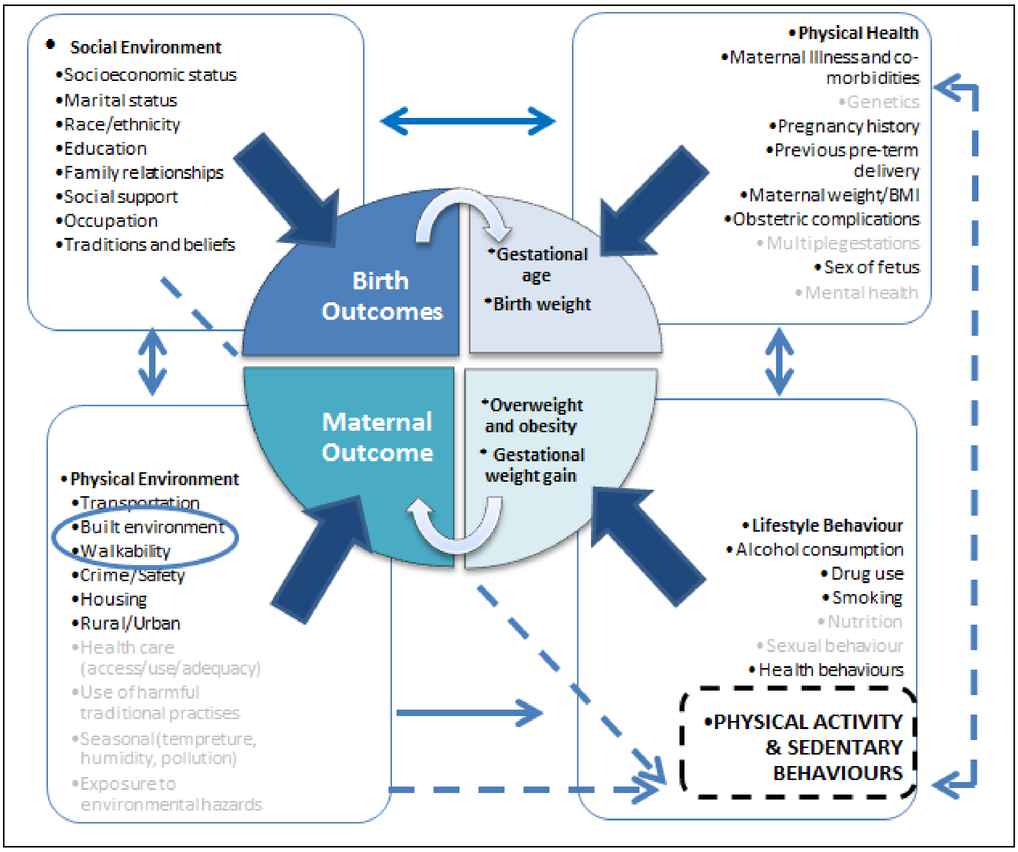

Figure 13. An updated conceptual model to include the built environment

As with many previous studies, this research focussed on social and individual factors and their associations with PA behaviour. However, these findings support the need for understanding environmental correlates in transport and leisure time PA, which is especially applicable to LMICs (297, 403). As a result, the conceptual model has been updated to include a multilevel model that should be used in future studies within this population group, in order to inform contextually tailored interventions (297).

In addition, an accurate and reliable measure of PA and sedentary behaviour remains a challenge in public health research (466, 467). Surveillance studies of PA during pregnancy often rely on self-report assessments. It is imperative to assess PA in each domain, since in the South African context, it appears that commuting activities contribute largely to the type of PA and energy expended (78). To this end, this study used the GPAQ questionnaire, and although it has been used extensively in Africa, it has not yet been validated in pregnant women in South Africa, and carries with it limitations that are common to all self-reported PA measures.

Objective measures of PA, such as the use of accelerometers, are generally considered to be better than questionnaires since they are free of random and systematic errors (468). However, each method has its own unique set of limitations (469). Matthews et al. (468) outlines several main weaknesses in accelerometry, namely the limited value in detecting activity that has a low ambulatory component or upper body work, or that is done in water (e.g. swimming). Secondly, unless used with an activity diary, the specific location or type of activity is not measured, and hence recent studies have started to use GPS tracking or video surveillance to further understand the context within which PA takes place (470, 471). Furthermore, data processing of the monitor outputs can be done in a variety of ways, and needs to be strictly quality controlled. Questions still exist regarding the use of PA monitors in the pregnant population. It is yet to be determined which site is best to place the monitor (e.g. wrist or hip) and due to the physiological changes that women undergo during pregnancy these issues become particularly challenging. Furthermore, cut points for accelerometer data processing are based on non-pregnant populations and an accurate method for this analysis in the pregnant population has yet to be established. Therefore, in order to avoid this methodological issue, the analysis in Chapter six of this study incorporated total PA rather than using non-specific cut points.

In addition, a further gold-standard would be to introduce individual calibration procedures into the data analysis based on individual fitness levels (472). However, in research such as this, with over 100 participants in a low-income setting, a study of that scale would not be feasible. With new technical advances in accelerometer sensors, researchers now have the benefit of access to the raw acceleration signal data, rather than the manufacturer-specific "counts" data (473). To this end, this study used the unique measure of ENMO to account for gravity within the acceleration output and to provide an accurate as possible measure of raw acceleration (375, 377). Therefore, within the limits of accelerometer measures, this study attempted to use the most precise measure of acceleration available. This processing method is relatively new, and limited work has been done in the pregnant population, making this a particularly unique study. Troiano et al. (473) warn researchers of the distinction between self-report and accelerometer measures of PA, and the dangers of using these interchangeably. Although they may be expressed in the same metrics, conceptually they are measuring a different phenomenon (473). A notable strength of the current study is that both accelerometry and self-report PA measures were collected and this complementary data set helps to provide a greater understanding of PA in this population. Furthermore, not only did this study present findings on the construct of PA, but we also provided a background understanding of this construct through the qualitative interviews, based within a social theory of behaviour, thus providing a unique glimpse into new aspects of prenatal PA.

7.4. Key take home messages

I. Pregnancy presents a vulnerable time for low and declining physical activity levels in black South African women.

II. Pregnant women believe in the beneficial effects of physical activity, but should be educated and empowered in order to translate their salient beliefs into behavioural change inclusive of embarking on, and maintaining, an active lifestyle.

III. The majority of physical activity during pregnancy in this population originates from walking for transport, and interventions to increase leisure time physical activity are warranted.

IV. An active pregnancy may play a role in reducing weight gain during pregnancy in this population of black South African women, who are at-risk for overweight and obesity, whilst posing no adverse effects on birth outcomes.

V. Future interventions should involve a holistic antenatal healthcare model aimed at promoting healthy behaviours and educating healthcare providers. This should involve key stakeholders, such as communities, government, universities and health care providers, to ensure a sustainable future in the prevention of disease.

"Science makes no sense if it does not help to change the world"

Hallal et al. (3)

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Appendix A: S1000 Data collection outline

Contact	• Participant is recruited from CHBH antenatal clinic • Make an appointment for her to come through to DPHRU
Visit 1 **<14 weeks**	• Pregnancy test - if positive continue • Discuss study with her • Give her a **Fetal Growth Study Information Sheet** • Get her to sign the **Fetal Growth Study Consent Sheet** • Give her a **Fetal Growth Study DNA Information Sheet** • Get her to sign a **Fetal Growth Study DNA Consent Sheet** • Complete a **Contact Sheet** • Send her for a **Dating Scan- USD** • Complete **BAS** and **MSE** • Complete **page 2** of the **Pregnancy and Delivery** form **(DEV)**- SES questions • Complete **Visit 1 Lab Sheet** • Complete **SSS** • Nurse to give participant her contact details • Make a follow-up appointment for 5 weeks' time/ for when she is 14-18 weeks pregnant • Give her a refreshment & R50 transport money
Visit 2 **14-18 weeks**	• Complete **PFU** • Complete **UFU** and **UMS** • Complete **GPAQ** and **SBQ** • Complete **FFQ** • Complete **Visit 2 Lab Sheet** • Complete **BAS** and **MSE (if not completed previously)** • Send her for a Scan- **USD (if not completed previously)** • Complete **Visit 1 Lab Sheet (if not completed previously)** • Nurse to give participant her contact details (if not given previously) • Make a follow-up appointment for 5 weeks' time/ for when she is 19-23 weeks pregnant • Give her a refreshment & R50 transport money
Visit 3 **19-23 weeks**	• Complete **PFU** • Complete **UFU** and **UMS** • Complete **Visit 3 Lab Sheet** • Complete **BAS** and **MSE (if not completed previously)** • Send her for a Scan- **USD (if not completed previously)** • Complete **Visit 1 Lab Sheet (if not completed before)** • Nurse to give participant her contact details (if not given previously) • Make a follow-up appointment for 5 weeks' time/ for when she is 24-28 weeks pregnant • Remind her to fast overnight (from 10pm; can have water) for her next appointment • Give her a refreshment & R50 transport money
Visit 4 **24- 28 weeks**	• Begin with OGTT • Complete **GLUQ** • Complete **PFU** • Complete **SSS** • Complete **UFU** and **UMS** • Complete **Visit 4 Lab Sheet** • Complete **BAS** and **MSE (if not completed previously)** • Send her for a Scan- **USD (if not completed previously)**

	• Complete **Visit 1 Lab Sheet (if not completed before)** • Nurse to give participant her contact details (if not given previously) • Make a follow-up appointment for 5 weeks' time/ for when she is 29-33 weeks pregnant • Give her a refreshment & R50 transport money
Visit 5 **29-33 weeks**	• Complete **PFU** • Complete **UFU** and **UMS** • Complete **GPAQ** and **SBQ** • Complete **Visit 5 Lab Sheet** • Complete **BAS** and **MSE (if not completed previously)** • Send her for a Scan- **USD (if not completed previously)** • Complete **Visit 1 Lab Sheet (if not completed previously)** • Nurse to give participant her contact details (if not given previously) • Give instructions for delivery • Make a follow-up appointment for 5 weeks' time/ for when she is 34-38 weeks pregnant • Instructions to be given around delivery
Visit 6 **34-38 weeks**	• Complete **PFU** • Complete **UFU** and **UMS** • Complete **Visit 6 Lab Sheet** • Complete **BAS** and **MSE (if not completed previously)** • Send her for a Scan- **USD (if not completed previously)** • Complete **Visit 1 Lab Sheet (if not completed previously)** • Nurse to give participant her contact details (if not given previously) • Make a follow-up appointment for 5 weeks' time/ for when she is 39-42 weeks pregnant (tell her she should come to that appointment if she is still pregnant) • Instructions to be given around delivery
Visit 7 **39-42 weeks**	• Complete **PFU** • Complete **UFU** and **UMS** • Complete **Visit 7 Lab Sheet** • Complete **BAS** and **MSE (if not completed previously)** • Send her for a Scan- **USD (if not completed previously)** • Complete **Visit 1 Lab Sheet (if not completed previously)** • Nurse to give participant her contact details (if not given previously) • Instructions to be given around delivery
Delivery	• Complete **DEV**

Appendix B: PhD study data collection sheet

Study Number		**Date**	

Please answer all yes/no questions by placing a "x" in the corresponding box

Section 1: Demographic, socio-economic and nutritional characteristics

1. Age: (years) ☐☐ yrs
2. Maternal height: (cm) ☐☐☐.☐ cm
3. 1st trimester or pre-pregnancy weight: (kg) ☐☐☐.☐ kg

During this pregnancy:

4. Has she smoked? yes / no — If yes, how many cigarettes/cigars per day? ☐☐
5. Has she sniffed/chewed tobacco? yes / no — If yes, how many times per day? ☐☐
6. Has she chewed betelnut? yes / no — If yes, how many nuts per day? ☐☐
7. On average, how many units of alcohol per week has she had? ☐☐
   (1 unit = small glass (125ml) of wine or one bottle/can (330ml) of beer; see table)
8. Has she used any of the following recreational drugs? (cross all that apply; see table)

Heroin ☐	Amphetamines ☐	Benzodiazepines ☐
Methadone ☐	Hallucinogens ☐	Inhalants/Solvents ☐
Crack/Cocaine ☐	Cannabis ☐	Other recreational drugs ☐

9. Has she been involved in any of the following high-risk occupations or activities? (cross all that apply; see table)
   - Frequent exposure to chemical/toxic substances ☐
   - Frequent physically demanding work ☐
   - Frequent high-risk sports/vigorous exercise ☐
10. Has she followed any of the following special diets? (cross all that apply; see table)

Vegetarian with no animal products ☐	Gluten-free ☐
Weight loss programme ☐	Malabsorption treatment ☐

11. Marital status: (cross one box only)

Single ☐	Widowed ☐
Married/Cohabiting ☐	Separated/Divorced ☐

12. Total number of years of formal education: ☐☐
13. Highest level of education attended: (cross one box only)

No school attended ☐	Primary ☐	Professional/technical training ☐
	Secondary ☐	University ☐

14. Which of the following best describes her occupational status? (cross one box only)

Housework ☐	Skilled manual work ☐	Managerial/professional/technical ☐
Student ☐	Unskilled manual work ☐	Clerical support, service or sales ☐
Other ☐		

15. *Please answer all parts (A to I) of Question 15 to help provide an indication of the woman's economic situation.*

A. Does the woman's household have or own any of the following:

Electricity	yes / no	Cell phone	yes / no	Bicycle	yes / no
Radio	yes / no	Personal computer	yes / no	Motorcycle/Scooter	yes / no
Television	yes / no	Farm animals	yes / no	Car/Truck/Tractor	yes / no
Refrigerator	yes / no	Agricultural land	yes / no		

B. Number of people living in the woman's household: ☐☐

C. Number of rooms used for sleeping in the woman's household: ☐☐

D. Main fuel used for cooking in the woman's household: (cross one box only)

Electricity ☐	Kerosene ☐	Animal dung ☐
Liquid propane gas (LPG) ☐	Charcoal ☐	Other ☐
Natural gas ☐	Wood ☐	No cooking ☐
Biogas ☐	Straw/shrubs/grass ☐	

E. Main source of drinking water in the woman's household: (cross one box only, unless selecting 'Bottled water' - see below)

Bottled water *(if so, please also cross the box corresponding to the main source for cooking/washing)* ☐

Piped water into dwelling ☐	Tanker truck/Cart with small tank ☐
Piped water into yard/plot ☐	Unprotected dug well ☐
Protected dug well ☐	Unprotected spring ☐
Protected spring ☐	Surface water ☐
Rainwater ☐	Other ☐
Public tap/standpipe ☐	

F. Type of toilet facility in the woman's household: (cross one box only)

Flush to piped sewer system ☐	Ventilated improved pit (VIP) latrine ☐
Flush to septic tank ☐	No facility or bush or field ☐
Traditional pit toilet ☐	Other ☐

G. Is the toilet facility shared with other households? yes / no

H. Main flooring material in the woman's household: (cross one box only)

Earth/sand/mud ☐	Vinyl/linoleum ☐	Carpet ☐
Wood planks ☐	Ceramic tiles ☐	Other ☐
Parquet or finished wood ☐	Cement ☐	

I. Main wall material in the woman's household: (cross one box only)

No walls ☐	Mud and cement ☐	Bare brick or cement block ☐
Plastic/cardboard ☐	Corrugated iron/zinc ☐	Plaster/finished ☐
Mud ☐	Prefab ☐	Other ☐

Section 2: Medical History

Before this pregnancy, was she diagnosed with, or treated for, any of the following conditions?

16. Diabetes — yes / no
17. Thyroid disease — yes / no
18. Other endocrinological condition — yes / no
19. Any type of malignancy/cancer (including leukaemia or lymphoma) — yes / no
20. Cardiac disease — yes / no
21. Epilepsy — yes / no
22. Mental illness e.g. Clinical depression — yes / no
23. Hypertension/chronic hypertension with treatment — yes / no
24. A chronic respiratory disease (including chronic asthma) — yes / no
25. Proteinuria, kidney disease or chronic renal disease — yes / no
26. Crohn's disease, coeliac disease, ulcerative colitis or any severe malabsorption condition — yes / no
27. Lupus erythematosus — yes / no
28. HIV or AIDS — yes / no
29. Hepatitis B or C — yes / no
30. Malaria - *within past 5 years* — yes / no
31. Tuberculosis — yes / no
32. Thalassaemia — yes / no
33. Sickle-cell anaemia — yes / no
34. Thrombophilia — yes / no
35. Glucose-6-phosphate dehydrogenase deficiency — yes / no
36. Any congenital abnormality or genetic disease — yes / no
37. Any other clinically relevant condition — yes / no

Section 3: Gynaecological History

38. Did she have regular (24-32 day) menstrual cycles in the 3 months prior to this pregnancy? — yes / no
39. What is the average length of her menstrual cycle? ☐☐ days
40. Had she used hormonal contraceptives or been breastfeeding in the 2 months prior to this pregnancy? — yes / no
41. Is the first day of the last menstrual period (LMP) known? — yes / no
42. If yes, date: D D M M Y Y
43. Was she certain of the date of her LMP? — yes / no

Section 4: Obstetric History

44. Number of previous pregnancies, excluding this pregnancy *(if 0, skip to Question 57)* : ☐☐
45. Date of last delivery, miscarriage or termination: D D M M Y Y
46. Has she ever had a molar pregnancy or choriocarcinoma? — yes / no
47. Has she ever had an extrauterine or ectopic pregnancy? — yes / no
48. Number of previous miscarriages: ☐☐
49. Number of previous terminations: ☐☐
50. Number of previous births *(if 0, skip to Question 57)* : ☐☐
51. Birthweight of the immediately previous newborn: ☐☐☐☐ g
52. Gestational age at birth of the immediately previous newborn: ☐☐ weeks ☐ days
53. Have ANY of her other babies weighed less than 2500g? — yes / no
54. Have ANY of her other babies been born preterm (<37^{+0} weeks' gestation)? — yes / no
55. Has she had ANY previous stillbirths? — yes / no
56. Has she had ANY previous neonatal deaths? — yes / no

Section 5: Vaccination History

Has she been vaccinated against the following medical conditions?

Influenza: 57. Before this pregnancy: yes / no — 58. During this pregnancy: yes / no

Tetanus: 59. Before this pregnancy: yes / no — 60. During this pregnancy: yes / no

Section 6: Clinical Conditions

During this pregnancy was she diagnosed with, or treated for, any of the following conditions?

61. Diabetes, thyroid disease or any other endocrinological condition — yes / no
62. Any type of malignancy/cancer (including leukaemia or lymphoma) — yes / no
63. Cardiac disease — yes / no
64. Epilepsy — yes / no
65. Mental illness e.g. Clinical depression — yes / no
66. Symptomatic malaria — yes / no
67. Symptomatic malaria with parasite count — yes / no
68. Respiratory disease (including asthma) — yes / no
69. Pyelonephritis or kidney disease — yes / no
70. Lower urinary tract infection requiring antibiotic treatment — yes / no
71. Respiratory tract infection requiring antibiotic/antiviral treatment — yes / no
72. Any other infection requiring antibiotic/ antiviral treatment — yes / no
73. Group B streptococcus carrier — yes / no
74. Positive syphilis test — yes / no
75. HIV or AIDS — yes / no
76. Any genital tract or sexually transmitted infection — yes / no
77. Cholestasis — yes / no
78. Any other medical/surgical condition requiring treatment/referral — yes / no
79. Any accident or maternal trauma requiring hospital admission or referral to a higher level of care — yes / no

Section 7: Pregnancy-related complications

During this pregnancy was she diagnosed with, or treated for, any of the following conditions?

80. Severe vomiting requiring hospitalisation — yes / no
81. Gestational diabetes — yes / no
82. Vaginal bleeding before 15 weeks — yes / no
83. Vaginal bleeding at 15-27 weeks — yes / no
84. Vaginal bleeding after 27 weeks — yes / no
85. Pregnancy-induced hypertension (BP>140/90, no proteinuria) — yes / no
86. Preeclampsia (BP>140/90 and proteinuria) — yes / no
87. Severe preeclampsia/Eclampsia/ HELLP syndrome — yes / no
88. Rhesus disease or anti-Kell antibodies — yes / no
89. Preterm labour — yes / no
90. Fetal anaemia — yes / no
91. Fetal distress (abnormal fetal heart rate [FHR] or biophysical profile [BPP]) — yes / no
92. Suspected impaired fetal growth — yes / no
93. Oligohydramnios — yes / no
94. Polyhydramnios — yes / no
95. A condition requiring amniocentesis or fetal blood sampling (FBS) — yes / no
96. Abruptio placentae — yes / no
97. Clinical chorioamnionitis — yes / no
98. Other pregnancy-related infection — yes / no
99. Other pregnancy-related condition — yes / no

	<15 weeks	15-27 weeks	>27 weeks
100. Lowest haemoglobin level:	__ __ . __ g/dl	__ __ . __ g/dl	__ __ . __ g/dl
OR Lowest haematocrit:	__ __ . __ %	__ __ . __ %	__ __ . __ %

Section 9: Delivery

130. Onset of labour: (cross one box only) Spontaneous ☐ Induced ☐ No labour ☐

131. Prelabour premature rupture of membranes (PPROM)? yes no

132. Place of delivery: (cross one box only) Home ☐ Health facility ☐

133. Mode of delivery: (cross one box only) Vaginal spontaneous ☐ Vaginal assisted (e.g. forceps, vacuum) ☐ Caesarean section ☐ Assisted breech or breech extraction ☐

If labour was induced or a Caesarean section performed, please cross all that apply:

134. Vaginal bleeding yes no
135. Placenta praevia yes no
136. Fetal death yes no
137. Pregnancy-induced hypertension (BP>140/90, no proteinuria) yes no
138. Preeclampsia (BP>140/90 and proteinuria) yes no
139. Severe preeclampsia/Eclampsia/ HELLP syndrome yes no
140. Breech presentation yes no
141. Fetal distress (abnormal fetal heart rate [FHR] or biophysical profile [BPP]) yes no
142. Reduced fetal movement yes no
143. Failure to progress yes no
144. Cephalo-pelvic disproportion yes no
145. PPROM yes no
146. Uterine rupture yes no
147. Abruptio placentae yes no
148. Worsening of a pre-existing clinical condition yes no
149. Suspected intrauterine growth restriction (IUGR) yes no
150. Post term (>42^{+0} weeks gestation) yes no
151. Rhesus disease or anti-Kell antibodies yes no
152. Intrahepatic cholestasis of pregnancy yes no
153. HIV or AIDS yes no
154. Any genital tract or sexually transmitted infection yes no
155. Any infection requiring antibiotic/antiviral treatment yes no
156. Any accident/maternal trauma yes no
157. Pregnancy termination yes no
158. Previous Caesarean section yes no
159. Maternal request yes no
160. Any other maternal reason yes no
161. Any other fetal reason yes no

Section 10: Newborn outcomes and care

162. Date of delivery: D D M M Y Y

163. Time of delivery: H H : M M (24-hour clock)

164. Gestational age at birth based on the best obstetric estimate: ☐☐ weeks ☐ days

165. Fetal presentation at delivery: (cross one box only) Cephalic ☐ Breech ☐ Other ☐

166. Newborn status at birth: (cross one box only) Alive ☐ Intrapartum death ☐ Antepartum death ☐

167. Newborn sex: Male ☐ Female ☐

168. Apgar score at 5 minutes: ☐☐

169. Was the newborn admitted to intensive care or any special care unit? yes no

170. If yes, total amount of days spent in intensive care or special care unit: (if less than 24 hours please enter 1 day) ☐☐☐ days

Was the newborn diagnosed with, or treated for, any of the following conditions before hospital discharge?

171. Respiratory distress syndrome yes no
172. Transient tachypnea of the newborn yes no
173. Apnea of prematurity yes no
174. Bronchopulmonary dysplasia yes no
175. Pneumothorax yes no
176. Meconium aspiration with respiratory distress yes no
177. No oral feeds for more than 24 hours yes no
178. Retinopathy of prematurity yes no
179. Hypoxic-ischaemic encephalopathy yes no
180. Hyperbilirubinaemia yes no
181. TORCH or any other intrauterine infection yes no
182. HIV yes no
183. Neonatal sepsis yes no
184. Fetal infection yes no
185. Fetal inflammatory response syndrome yes no
186. Seizures yes no
187. Necrotising enterocolitis, Bell's staging stage 2 or greater yes no
188. Meningitis yes no
189. Hypoglycaemia yes no
190. Anaemia (requiring transfusion) yes no
191. Hypotension (requiring inotropic treatment or steroids) yes no
192. Intraventricular haemorrhage grade 2 or greater, periventricular haemorrhage or leukomalacia yes no
193. Polycythaemia yes no
194. Patent ductus arteriosus (requiring pharmacological treatment or surgery) yes no
195. Any other serious condition yes no
196. Congenital abnormality (complete a **Neonatal Abnormality Form**) yes no

Section 11: Newborn Anthropometry (taken no longer than 48hrs after birth)

197. Date of measurement: D D M M Y Y

First set of anthropometric measurements		Repeat measurements (if required)	Repeat measurements (if required)
198. Weight:	g	g	g
199. Length:	. cm	. cm	. cm
200. Head circumference:	. cm	. cm	. cm

Second set of anthropometric measurements		Repeat measurements (if required)	Repeat measurements (if required)
201. Weight:	g	g	g
202. Length:	. cm	. cm	. cm
203. Head circumference:	. cm	. cm	. cm

Section 12: Newborn outcomes

204. Newborn status at hospital discharge: (cross one box only)

- Alive ☐
- Alive but referred to another centre for growth and development ☐
- Alive but referred to a higher level of care ☐
- Dead ☐

205. Date of neonatal hospital discharge or date of death:

Section 13: Maternal Outcomes

207. Was the mother admitted to intensive care or any special care unit after delivery? yes no

208. If yes, total number of days: (if less than 24 hours, please enter as 1 day)

209. Maternal status at hospital discharge: (cross one box only)

Alive

Alive but referred to a higher level of care

Dead

Name of Researcher/Midwife			
Signature		Researcher Code	
	Anthropometrist-1 Code		Anthropometrist-2 Code

Appendix C: Global Physical Activity Questionnaire

Physical Activity			
Next I am going to ask you about the time you spend doing different types of physical activity in a typical week. Please answer these questions even if you do not consider yourself to be a physically active person. Think first about the time you spend doing work. Think of work as the things that you have to do such as paid or unpaid work, study/training, household chores, harvesting food/crops, fishing or hunting for food, seeking employment. *[Insert other examples if needed].* In answering the following questions 'vigorous-intensity activities' are activities that require hard physical effort and cause large increases in breathing or heart rate, 'moderate-intensity activities' are activities that require moderate physical effort and cause small increases in breathing or heart rate.			
Questions		**Response**	**Code**
Activity at work			
1	Does your work involve vigorous-intensity activity that causes large increases in breathing or heart rate like *[carrying or lifting heavy loads, digging or construction work*] for at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P 4*	P1
2	In a typical week, on how many days do you do vigorous-intensity activities as part of your work?	Number of days └─┘	P2
3	How much time do you spend doing vigorous-intensity activities at work on a typical day?	Hours : minutes └─┴─┘ : └─┴─┘ hrs mins	P3 (a-b)
4	Does your work involve moderate-intensity activity that causes small increases in breathing or heart rate such as brisk walking *[or carrying light loads*] for at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P 7*	P4
5	In a typical week, on how many days do you do moderate-intensity activities as part of your work?	Number of days └─┘	P5
6	How much time do you spend doing moderate-intensity activities at work on a typical day?	Hours : minutes └─┴─┘ : └─┴─┘ hrs mins	P6 (a-b)
Travel to and from places			
The next questions exclude the physical activities at work that you have already mentioned. Now I would like to ask you about the usual way you travel to and from places. For example to work, for shopping, to market, to place of worship. [insert other examples if needed]			
7	Do you walk or use a bicycle (*pedal cycle*) for at least 10 minutes continuously to get to and from places?	Yes 1 No 2 *If No, go to P 10*	P7
8	In a typical week, on how many days do you walk or bicycle for at least 10 minutes continuously to get to and from places?	Number of days └─┘	P8
9	How much time do you spend walking or bicycling for travel on a typical day?	Hours : minutes └─┴─┘ : └─┴─┘ hrs mins	P9 (a-b)
Recreational activities			
The next questions exclude the work and transport activities that you have already mentioned. Now I would like to ask you about sports, fitness and recreational activities (leisure), [insert relevant terms].			
10	Do you do any vigorous-intensity sports, fitness or recreational (*leisure*) activities that cause large increases in breathing or heart rate like [*running or football,]* for at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P 13*	P10
11	In a typical week, on how many days do you do vigorous-intensity sports, fitness or recreational (*leisure*) activities?	Number of days └─┘	P11
12	How much time do you spend doing vigorous-intensity sports, fitness or recreational activities on a typical day?	Hours : minutes └─┴─┘ : └─┴─┘ hrs mins	P12 (a-b)

Physical Activity (recreational activities) contd.			
Questions		**Response**	**Code**
13	Do you do any moderate-intensity sports, fitness or recreational *(leisure)* activities that causes a small increase in breathing or heart rate such as brisk walking,(*cycling, swimming, volleyball*)for at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P16*	P13
14	In a typical week, on how many days do you do moderate-intensity sports, fitness or recreational (*leisure*) activities?	Number of days └─┘	P14
15	How much time do you spend doing moderate-intensity sports, fitness or recreational (*leisure*) activities on a typical day?	Hours : minutes └─┴─┘ : └─┴─┘ hrs mins	P15 (a-b)
Sedentary behaviour			
The following question is about sitting or reclining at work, at home, getting to and from places, or with friends including time spent [sitting at a desk, sitting with friends, travelling in car, bus, train, reading, playing cards or watching television], but do not include time spent sleeping. *[INSERT EXAMPLES] (USE SHOWCARD)*			
16	How much time do you usually spend sitting or reclining on a typical day?	Hours : minutes └─┴─┘ : └─┴─┘ hrs min s	P16 (a-b)

Appendix D: Sedentary Behaviour Questionnaire

SEDENTARY BEHAVIOUR QUESTIONNAIRE **SUBJECT CODE: __________Date: ________________**

Interviewer: *Please ask the respondent the following questions which relates to the time they spend sitting during various activities.*
*Ask them to think about a **usual day** or a normal day for each of the questions.*
All answers are per day.

We are very interested in the amount of time people spend sitting. I am going to ask you a few questions about your sitting behavior. These questions all refer to a usual day, and please answer in hours and minutes per day.

	Question	Week day (hours: minutes)	Week end day (hours: minutes)
1a.	How much time do you spend sitting while you are at work? (per day)	Hrs: Min:	Hrs: Min:
1b.	How many days per week do you work? __________ days		
1c.	Do you work on the week-end? (Please circle answer) Yes No		
2.	How much time do you spend sitting while watching TV per day?	Hrs: Min:	Hrs: Min:
3.	How much time do you spend sitting while using the computer per day, excluding your normal working hours	Hrs: Min:	Hrs: Min:
4.	How much time do you spend sitting while travelling from place to place (e.g. in car, bus, train)	Hrs: Min:	Hrs: Min:
5.	How much time do you spend sitting while eating and socialising and relaxing on a week day (Monday – Friday)?	Hrs: Min:	Hrs: Min:

6.	How much time do you spend sitting while reading and/or listening to the radio?	Hrs: Min:	Hrs: Min:
7.	How much time do you spend sitting while at church?	Hrs: Min:	Hrs: Min:
8. Sleep The following question relates to the amount of time you spend sleeping.			
8.1	<u>Weekday</u> a. What time do you go to bed? b. What time do you wake up?		
8.2	<u>Weekend</u> a. What time do you go to bed? b. What time do you wake up?		

Appendix E: Information sheet for the PhD study

Good day, my name is Estelle Watson. I am a Registered Biokineticist and Lecturer at Wits University. I am undertaking this research as part of my PhD degree. I would like to invite you to consider participating in my research study, entitled “Maternal Physical Activity: influence on maternal and delivery outcomes”. Before you decide to take part, it is important for you to understand why the research is being done and what it will involve. The information leaflet is to help you decide if you would like to participate. Please take time to read the following information carefully and discuss it with others if you wish. Please ask questions if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part. Thank you for reading this.

Study title: Maternal Physical Activity: Influence on maternal and delivery outcomes.

Invitation paragraph

It is well known that participating in regular physical activity leads to many health benefits. For example, it is helpful for preventing and treating diseases such as cardiovascular disease and diabetes, and is an essential tool in maintaining a healthy body weight. There are also health benefits for pregnant women. If you have an uncomplicated pregnancy, moderate exercise may help to reduce the risk of conditions such as gestational (pregnancy-related) diabetes, and pre-eclampsia. It can help to prevent excessive weight gain during pregnancy. It may also provide a protective effect against giving birth prematurely or having a LBW baby. Being physically active during pregnancy may also reduce the risk of obesity in your child in the future. The risks and benefits, however, depend upon the type and amount of physical activity that is done.

Where will the research be conducted?

All interventions will be undertaken at the Wits/MRC Developmental Pathways for Health Research Unit (DPHRU) at Chris Hani Baragwaneth Hospital in Soweto. Estelle will be assisted by trained and experienced research assistants and midwives.

What is the purpose of the research?

The aim of this study is to assess the relationship between physical activity levels and sedentary behaviour in pregnancy outcomes in urban black South African women. The research will help to identify which aspects of physical activity are good for the mom and baby, and which aspects carry risks. It will also provide an idea of the current physical activity levels in women, and whether pregnant women are meeting the recommended guidelines for physical activity. We will also examine the beliefs and attitudes that may prevent women from participating in exercise. The results of the study will help to guide medical interventions.

Patient selection

We are inviting all pregnant women in the Birth to Twenty cohort to participate in the study.

Do I have to take part?

Your participation is voluntary. We would like you to consent to participate in this study as we believe that you can make an important contribution to the research. If you decide to take part you are still free to withdraw at any time. Your withdrawal will not affect your access to other medical care.

What would I be asked to do if I took part?

If you are happy to participate in the research we will ask you to read this information sheet and sign the consent form. You will then be asked to come in for assessments at three points (during each trimester) during your pregnancy. At each visit, we will ask you to fill out a questionnaire, and we will weigh you on a scale. When you give birth, we will note down which mode of delivery was used (vaginal birth or caesarean section), as well as document how long you were in labour. We will measure how long you were pregnant for, and will measure your baby's weight and length when he/she is born.

You may also be asked to wear an Actigraph during the second trimester of your pregnancy. This is a small, light instrument that you will wear for 7 days. After 7 days, a research assistant will come and fetch the device from your home. It is non-invasive and there are no risks, to yourself or your baby, when wearing the device.

You may also be asked to take part in a small discussion group. The group will consist of 6-10 pregnant women, who will be asked various questions regarding their pregnancy and physical activity levels. These discussion groups will help us understand your feelings and thoughts regarding your pregnancy and physical exercise. Our discussions will be audio or video taped to help me capture your insights in your own words. Therefore, your information and feelings shared may not be anonymous; however the tapes will only be heard by only me for the purposes of this study, and will be kept in the strictest confidence. Direct quotes from you may be used in a published paper, however, your name and other identifying information will be kept anonymous.

Risks or side effects

There are no side effects for taking part in this study. You may experience some discomfort, should you wear the Actigraph, but there is no risk to you or your baby.

Benefits

There are no direct benefits to participating in this research project.

What happens to the data collected?

All information you provide to us will be kept confidential. Only members of the research team will have access to it. Information gained during the research will be used as part of a larger sample, and will remain anonymous. The outcomes of the research will be available in one or more of the following sources: scientific papers in peer reviewed academic journals, presentations at a regional conference, local seminars.

Ethical approval

This clinical study protocol has been submitted to the University of the Witwatersrand, Human Research Ethics Committee (HREC) and written approval has been granted by that committee. For further information regarding this, contact the HREC chairman Professor Peter Cleaton-Jones on 011 717 2635 or email peter.cleaton-jones@wits.ac.za

Doctor notification

Please indicate below, whether you want me to notify your personal doctor or your specialist of your participation in this study:

- ○ **YES**, I want you to inform my personal doctor / specialist of my participation in this study.

- ○ **NO**, I do not want you to inform my personal doctor / specialist of my participation in this study.

- ○ **I do not have** a personal doctor / specialist

Who to contact?

If you have any questions, you may ask them now or later, even after the study has started. If you wish to ask any questions, you may contact the following person

Estelle Watson

(tel) 011 717 3227   (fax) 011 717 3379 (Email) estelle.watson@wits.ac.za

Did the participant raise any questions? O**YES /** O **NO**   **If YES** – What where they:

Appendix F: Informed Consent

- I hereby confirm that I have been informed by the researcher, Estelle Watson about the nature, conduct, benefits and risks of clinical study called ***"Maternal Physical Activity: Influence on maternal and delivery outcomes"***
- I have also received, read and understood the above written information (Participant Information Leaflet and Informed Consent) regarding the clinical study.
- I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerised system by Estelle Watson or on their behalf.
- I may, at any stage, without prejudice, withdraw my consent and participation in the study.
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.

PARTICIPANT:

Printed Name *Signature / Mark or Thumbprint* *Date and Time*

I, Estelle Watson, herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

RESEARCHER:

Printed Name *Signature* *Date and Time*

TRANSLATOR/OTHER PERSON EXPLAINING INFORMED CONSENT (DESIGNATION):

Printed Name *Signature* *Date and Time*

WITNESS (If applicable):

Printed Name *Signature* *Date and Time*

CONSENT TO RECORD IN-DEPTH INTERVIEWS

I have read or understood the project information sheet, and I understand that it is up to me whether or not the interview is audio or video recorded. It will not affect in any way how the interviewer treats me if I do not want the interview to be recorded.

I understand that if the interview is recoded that the tape will be destroyed six years after the interview.

I understand that I can ask the person interviewing me to stop recording, and to stop the interview altogether, at anytime.

I understand that the information that I give will be treated in the strictest confidence and that my name will not be used when the interviews are typed up.

◯ Yes, I give my permission for the interview to be recorded

◯ No, I do not give my permission for the interview to be recorded

PARTICIPANT

Printed Name	*Signature / Mark or Thumbprint*	*Date and Time*

RESEARCH ASSISTANT:

Printed Name	*Signature*	*Date and Time*

Appendix G: Ethical clearance for the larger S1000 study

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG
Division of the Deputy Registrar (Research)

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
R14/49 Professor Shane Norris

CLEARANCE CERTIFICATE	M120524
PROJECT	Foetal Growth Study: Investigating Maternal Factors Associated with Foetal Growth and Delivery Outcomes
INVESTIGATORS	Professor Shane Norris.
DEPARTMENT	Developmental Pathways Research Unit
DATE CONSIDERED	25/05/2012
DECISION OF THE COMMITTEE*	Approved unconditionally

Unless otherwise specified this ethical clearance is valid for 5 years and may be renewed upon application.

DATE 14/07/2013 CHAIRPERSON ....
(Professor PE Cleaton-Jones)

*Guidelines for written 'informed consent' attached where applicable
cc: Supervisor :

DECLARATION OF INVESTIGATOR(S)
To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University.
I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to a completion of a yearly progress report.**

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES...

Appendix H: Ethical clearance for the Maternal Physical Activity study

R14/49 Mrs Estelle Watson et al

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M130351

NAME:
(Principal Investigator) Mrs Estelle Watson et al

DEPARTMENT: Developmental Pathways Research Unit
CH Baragwanath Acadmic Hospital

PROJECT TITLE: Maternal Physical Activity: Influence on Maternal and Delivery Outcomes

DATE CONSIDERED: 05/04/2013

DECISION: Approved unconditionally

CONDITIONS:

SUPERVISOR: Lisa Micklesfield

APPROVED BY:

Professor PE Cleaton-Jones, Chairperson, HREC (Medical)

DATE OF APPROVAL: 120/05/2013

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Secretary in Room 10004, 10th floor, Senate House, University.

I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report.**

Principal Investigator Signature Date 25/05/2013

Appendix I: Ethical clearance for the Factors affect Physical Activity Patterns study

M130445

R14/49 Ms B Oddie/N Eekhout

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M130445

NAME:
(Principal Investigator) Ms B Oddie/N Eekhout

DEPARTMENT: Centre for Exercise Science & Sports Medicine
Medical School

PROJECT TITLE: Factors Affecting Physical Activity Patterns in Pregnant Women in the Central Gauteng Area

DATE CONSIDERED: 26/04/2013

DECISION: Approved unconditionally

CONDITIONS:

SUPERVISOR: Ms Estelle Watson

APPROVED BY: Professor PE Cleaton-Jones, Chairperson, HREC (Medical)

DATE OF APPROVAL: 21/06/2013

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Secretary in Room 10004, 10th floor, Senate House, University.
I/we fully understand the conditions under which I am/we are authorized to carry out the above mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report**

Principal Investigator Signature   Date

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix J: Open ended question discussion guide

Qualitative Discussion Guide

1. What do you think is important for a healthy pregnancy?
2. What do you understand by the term "physical activity"? Think about all the ways women can be physically active. Name a few.
   a. What kinds of things do you do to be physically active?
   b. What is the difference between "exercise" and "physical activity"?
3. How important is it to you to be physically active while you are pregnant?
4. What do you think about being physically active during pregnancy?
   a. How do you think it might hurt your pregnancy?
   b. How do you think it might help your pregnancy?
5. Has anyone given you advice /talked to you about being physically active while you are pregnant?
   a. Who gave you this advice?
   b. What was the advice? What have you heard?
   c. Was the advice helpful to you? (why/why not)
   d. Did you follow the advice (why/why not)
6. List the individuals/groups who were most important to you when you thought about being physically active during pregnancy
7. Tell me in what ways your physical activity at work or home has changed since you became pregnant. Has it increased or decreased? Explain. Probe reasons for change.
8. Think about being physically active. What kinds of things have you not been able to do because of pregnancy?
9. Are there things in your life that make it hard for you to be physically active? Tell me more about that.
10. Are there things in your life that make it easier for you to be physically active?
11. Would you like to change how physically active you are since you have been pregnant? How would you change this? What kind of changes would you make?

(Weir et al 2010; Krans & Chang, 2012; Evenson et al 2009; Downs & Hausenblaus, 2004)

Appendix K: Knowledge, attitudes and beliefs questionnaire for healthcare providers

Please tick the response that most closely fits your demographics. If the choices given do not fit your situation, please feel free to write in one that does.

1. What is your current occupation?

☐G.P. ☐ Obstetrician ☐ Gynaecologist ☐ Specialist Other ____________

2. Where is your practice located?

☐ Urban ☐ Sub-urban area Other____________

3. How many years have you been practicing?

☐ 1-5 ☐ 6-10 ☐ 11-15 ☐16-20 ☐>20

4. What is the main focus or specialty of your practice?

☐ Obstetrics ☐Gynaecology ☐ Family medicine Other____________

5. What is your gender?

☐ Male ☐ Female

6. What is your race?

☐ Caucasian ☐African ☐Asian ☐Indian ☐Coloured Other____________

7. What races make up 20% or more of your patient population? (Please tick all that apply.)

☐Caucasian ☐African ☐Asian ☐Indian ☐Coloured Other____________

8. What is your age?

☐<30 ☐30-39 ☐ 40-49 ☐ 50-59 ☐>60

9. What percent of your practice involves obstetrics?

☐ 100% ☐75% ☐50% ☐25% Other____________

Please tick the response that most closely fits your feelings toward the statement given. If examples are requested, please write all those that you feel apply in the space provided.

10. Exercising during pregnancy is beneficial.

☐ Strongly agree ☐ Agree ☐ Disagree ☐ Strongly disagree

11. Advising patients on exercise during pregnancy is not a major component of prenatal care.

☐ Strongly agree ☐ Agree ☐ Disagree ☐ Strongly disagree

12. If exercise is discussed by you or your staff, it does not include individualized recommendations.

☐ Strongly agree ☐ Agree ☐ Disagree ☐ Strongly disagree

13. Pregnant patients follow the advice given during their office visits.

☐ Strongly agree ☐ Agree ☐ Disagree ☐ Strongly disagree

14. A sedentary woman, with an uncomplicated pregnancy, should not begin an exercise program during pregnancy.

☐ Strongly agree ☐ Agree ☐ Disagree ☐ Strongly disagree

15. Pregnant women who are chronic exercisers should be encouraged to continue an exercise program throughout pregnancy.

☐ Strongly agree ☐ Agree ☐ Disagree ☐ Strongly disagree

16. Pregnant women should not participate in a strength-training program during pregnancy.

☐ Strongly agree ☐ Agree ☐ Disagree ☐ Strongly disagree

17. What do you feel are the main benefits of exercising during pregnancy?

- ☐ Decreased risk of gestational diabetes
- ☐ Decreases risk of pre-eclampsia
- ☐ Decreased risk of gestational hypertension
- ☐ Cardiovascular system enhancements
- ☐ Musculoskeletal improvements
- ☐ Endocrine system changes
- ☐ Improves respiratory function
- ☐ Weight gain management
- ☐ Postural changes
- ☐ Increased fitness levels
- ☐ Increased strength levels
- ☐ Improved self-image
- ☐ Better sleeping patterns
- ☐ Increased viability of the placenta
- ☐ Increased amniotic fluid
- ☐ Preventing incontinence

18. During pregnancy, woman should be recommended to exercise at moderate intensity.

☐ Strongly agree ☐ Agree ☐ Disagree ☐ Strongly disagree

19. Exercising during pregnancy increases the risk of low birth weight babies.

☐ Strongly agree ☐ Agree ☐ Disagree ☐ Strongly disagree

20. The possible harmful effects of exercise on the fetus are minimal if not nonexistent.

☐ Strongly agree ☐ Agree ☐ Disagree ☐ Strongly disagree

Please tick the answer that most clearly represents what you do in your practice. When yes and no choices are given, if you answer yes, please continue and answer the lettered questions related to the initial question. If you answer no, please continue on to the next numbered question. If examples are requested, please write all that you feel apply in the space provided.

21. Does your office give advice to your pregnant patients about pregnancy and exercise?

☐ Yes ☐ No

If no, please skip to question 22.

a. If yes, who in your office gives this advice?

☐ Yourself ☐Nurse Other____________

b. If yes, at what stage in pregnancy would this occur? (Tick all that apply.)

☐ Initial visit ☐1st trimester ☐2nd trimester ☐3rd trimester ☐Postpartum

c. How long would a typical exercise advice session take?

☐ 5-10 minutes ☐11-20 minutes ☐21-30 minutes ☐>30 minutes

22. Do your pregnant patients ask you questions about exercising during pregnancy?

☐ Never ☐ Seldom ☐ Often ☐ Always

23. Do you provide informational pamphlets on pregnancy and exercise to your patients?

☐ Never ☐ Seldom ☐ Often ☐ Always

24. Do you obtain exercise histories on your pregnant patients?

☐ Never ☐ Seldom ☐ Often ☐ Always

25. Do you give each pregnant patient an individualized exercise program for her to follow?

☐ Never ☐ Seldom ☐ Often ☐ Always

26. Are you aware of the 2002 ACOG guidelines for pregnancy and exercise?

☐Very aware ☐Aware ☐Vaguely aware ☐Unaware

27. Do you routinely give exercise restrictions to your pregnant patients?

☐ Yes ☐ No

If no, please skip to question 28.

a. If yes, please list some of the examples below:

____

28. Who do you refer your pregnant patients to for exercise recommendations?

☐ Personal trainer ☐Biokinetics ☐Physiotherapist Other ____________

29. Do you recommend your patients exercise during pregnancy?

☐ Yes ☐ No

If no, please skip to question 29.

a. If yes, what types of exercise do you recommend for your patients? (Please circle all that apply; feel free to add others.)

☐ Walking ☐Running ☐Swimming ☐Cycling ☐Aerobics

Other____

____

30. Do you recommend your patients avoid certain types of exercise?

☐ Yes ☐ No

If no, please skip to question 30.

a. If yes, please write examples in the space below:

____

____

31. Are you aware of any exercise classes or trainers in your area that could benefit your patients?

☐ Yes ☐ No

If no, please skip to question 31.

a. If yes, do you recommend your patients go to any of these opportunities?

☐ Never ☐ Seldom ☐ Often ☐ Always

32. Would you or someone from your practice be interested in attending a workshop on pregnancy and exercise if offered?

☐ Yes ☐ No

a. If no, please explain in space below:

____

____

33. What intensity would you recommend your patients exercise at?

☐ Low ☐ Moderate ☐ Vigorous

Appendix L: Full statistical models for maternal and birth outcomes

i. Physical activity (2nd trimester) and weight (<14 weeks): adjusted and unadjusted model

```
      Source |       SS       df       MS              Number of obs =     120
-------------+------------------------------           F(  1,   118) =   15.04
       Model |  2794.89733     1  2794.89733           Prob > F      =  0.0002
    Residual |  21927.2547   118  185.824192           R-squared     =  0.1131
-------------+------------------------------           Adj R-squared =  0.1055
       Total |   24722.152   119  207.749176           Root MSE      =  13.632

------------------------------------------------------------------------------
                  Weight_1 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. In
> terval]
---------------------------+--------------------------------------------------
lnPA2ndtrimesterENMOmeanday |  -15.04179   3.878535    -3.88   0.000    -22.72234   -7
> .361235
                     _cons |   107.5629   9.783141    10.99   0.000     88.18965    1
> 26.9362
------------------------------------------------------------------------------
```

```
      Source |       SS       df       MS              Number of obs =     114
-------------+------------------------------           F(  7,   106) =    3.49
       Model |  4471.94784     7  638.849691           Prob > F      =  0.0021
    Residual |  19403.4223   106  183.051154           R-squared     =  0.1873
-------------+------------------------------           Adj R-squared =  0.1336
       Total |  23875.3702   113  211.286462           Root MSE      =   13.53

------------------------------------------------------------------------------
                  Weight_1 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. In
> terval]
---------------------------+--------------------------------------------------
lnPA2ndtrimesterENMOmeanday |  -14.44582   3.953474    -3.65   0.000    -22.28397   -6
> .607675
                       Age |    .485075   .2471088     1.96   0.052    -.0048423    .
> 9749923
              Parity_CODED |   1.471896   3.225183     0.46   0.649    -4.922343    7
> .866135
       Proffessional_CODED |   6.170378   6.752351     0.91   0.363    -7.216814    1
> 9.55757
           Secondary_CODED |   5.414896   6.401395     0.85   0.400    -7.276491    1
> 8.10628
                    HIVAIDS |  -4.337388   2.972217    -1.46   0.147     -10.2301
> 1.55532
     smokingtobaccobetelnut |  -3.748089   4.345348    -0.86   0.390    -12.36316    4
> .866985
                     _cons |   86.31727   14.92711     5.78   0.000     56.72283    1
> 15.9117
------------------------------------------------------------------------------
```

ii. Physical activity (2nd trimester) and weight (29-33 weeks): adjusted and unadjusted model

```
      Source |       SS       df       MS              Number of obs =      99
-------------+------------------------------           F(  1,    97) =    9.48
       Model |  1708.19857     1  1708.19857           Prob > F      =  0.0027
    Residual |   17478.715    97  180.192938           R-squared     =  0.0890
-------------+------------------------------           Adj R-squared =  0.0796
       Total |  19186.9135    98  195.784832           Root MSE      =  13.424

------------------------------------------------------------------------------
              Weight_5 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. In
> terval]
-----------------------+------------------------------------------------------
lnPA2ndtrimesterENMOmeanday |   -12.7744   4.148971    -3.08   0.003    -21.00896    -4
> .539846
                 _cons |    108.193   10.40755    10.40   0.000     87.53687     1
> 28.8491
------------------------------------------------------------------------------
```

```
      Source |       SS       df       MS              Number of obs =      95
-------------+------------------------------           F(  9,    85) =   34.02
       Model |  14673.9697     9  1630.44108           Prob > F      =  0.0000
    Residual |  4073.36252    85   47.921912           R-squared     =  0.7827
-------------+------------------------------           Adj R-squared =  0.7597
       Total |  18747.3322    94  199.439704           Root MSE      =  6.9226

------------------------------------------------------------------------------
              Weight_5 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. In
> terval]
-----------------------+------------------------------------------------------
lnPA2ndtrimesterENMOmeanday |  -2.299958   2.334342    -0.99   0.327    -6.941256
> 2.34134
                 lnBMI |   61.18662   4.106458    14.90   0.000     53.02188     6
> 9.35136
                   Age |   .1238661   .1466352     0.84   0.401     -.167684     .
> 4154163
          Parity_CODED |  -4.014066    1.83469    -2.19   0.031    -7.661921    -.
> 3662111
   Proffessional_CODED |   10.19936   3.501761     2.91   0.005     3.236926
> 17.1618
      Secondary_CODED |    8.86199   3.361655     2.64   0.010     2.178119     1
> 5.54586
               HIVAIDS |   -4.47388   1.764634    -2.54   0.013    -7.982446    -.
> 9653147
   DaysfromBaseline_V5 |  -.0005927   .0366326    -0.02   0.987    -.0734281     .
> 0722427
smokingtobaccobetelnut |   3.631634   2.620367     1.39   0.169    -1.578358     8
> .841625
                 _cons |  -128.1676   17.53373    -7.31   0.000    -163.0293    -9
> 3.30582
------------------------------------------------------------------------------
```

iii. Physical activity (3rd trimester) and weight (29-33 weeks): adjusted and unadjusted model

```
      Source |       SS       df       MS              Number of obs =     106
-------------+------------------------------           F(  1,   104) =    1.23
       Model |  231.703757     1  231.703757           Prob > F      =  0.2708
    Residual |  19662.0706   104  189.058371           R-squared     =  0.0116
-------------+------------------------------           Adj R-squared =  0.0021
       Total |  19893.7743   105  189.464518           Root MSE      =   13.75

------------------------------------------------------------------------------
              Weight_5 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. In
> terval]
-----------------------+------------------------------------------------------
PA3rdtrimester_consolidated |  -.4587473   .4143859    -1.11   0.271     -1.28049     .
> 3629955
                 _cons |   80.65909   4.261324    18.93   0.000     72.20873     8
> 9.10946
------------------------------------------------------------------------------
```

Source	SS	df	MS
Model	15277.7386	10	1527.77386
Residual	4162.34932	91	45.7401024
Total	19440.0879	101	192.476118

Number of obs =	102
F(10, 91) =	33.40
Prob > F =	0.0000
R-squared =	0.7859
Adj R-squared =	0.7624
Root MSE =	6.7631

Weight_5	Coef.	Std. Err.	t	P>|t|	[95% Conf.	In > terval]
PA3rdtrimester_consolidated	-.2822306	.2229802	-1.27	0.209	-.7251533	. > 1606921
lnBMI	64.54143	3.900194	16.55	0.000	56.79417	7 > 2.28868
Age	.0419314	.1341686	0.31	0.755	-.2245781	. > 3084409
Parity_CODED	-3.529283	1.695727	-2.08	0.040	-6.897636	-. > 1609293
Proffessional_CODED	10.90205	3.383703	3.22	0.002	4.180741	1 > 7.62336
Secondary_CODED	8.89046	3.245436	2.74	0.007	2.443799	1 > 5.33712
Imputeddata_1	-3.137604	1.760402	-1.78	0.078	-6.634425	. > 3592176
HIVAIDS	-3.762853	1.690104	-2.23	0.028	-7.120037	-. > 4056687
DaysfromBaseline_V5	.0144323	.0356607	0.40	0.687	-.0564033	. > 0852679
smokingtobaccobetelnut	4.507512	2.546061	1.77	0.080	-.5499258	9 > .564951
_cons	-142.3854	14.19379	-10.03	0.000	-170.5796	-1 > 14.1912

iv. Change in physical activity and weight (29-33 weeks): adjusted and unadjusted model

Source	SS	df	MS
Model	316.624056	1	316.624056
Residual	15691.7694	76	206.47065
Total	16008.3935	77	207.901214

Number of obs =	78
F(1, 76) =	1.53
Prob > F =	0.2194
R-squared =	0.0198
Adj R-squared =	0.0069
Root MSE =	14.369

Weight_5	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ChangeinPA	.4509471	.3641521	1.24	0.219	-.2743247	1.176219
_cons	77.31703	1.955732	39.53	0.000	73.42185	81.21221

Source	SS	df	MS
Model	12706.9913	10	1270.69913
Residual	2870.8706	64	44.8573531
Total	15577.8619	74	210.511647

Number of obs	= 75
F(10, 64)	= 28.33
Prob > F	= 0.0000
R-squared	= 0.8157
Adj R-squared	= 0.7869
Root MSE	= 6.6976

Weight_5	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
ChangeinPA	-.3358081	.234039	-1.43	0.156	-.8033547	.1317384
lnBMI	65.18347	4.387017	14.86	0.000	56.4194	73.94755
Age	.0347729	.1564695	0.22	0.825	-.2778108	.3473566
Parity_CODED	-2.273436	1.900956	-1.20	0.236	-6.071033	1.524161
Proffessional_CODED	12.20782	3.533481	3.45	0.001	5.148878	19.26676
Secondary_CODED	8.918596	3.341599	2.67	0.010	2.242985	15.59421
lnPA2ndtrimesterENMOmeanday	-5.785984	3.634657	-1.59	0.116	-13.04704	1.475078
HIVAIDS	-3.485827	2.035397	-1.71	0.092	-7.552	.5803466
DaysfromBaseline_V5	.01661	.0414405	0.40	0.690	-.0661768	.0993969
smokingtobaccobetelnut	5.829196	2.942716	1.98	0.052	-.0495555	11.70795
_cons	-134.8356	19.73465	-6.83	0.000	-174.2601	-95.4111

v. Physical activity (2nd trimester) and weight change (<14 weeks to 29-33 weeks): adjusted and unadjusted model

Source	SS	df	MS
Model	11.3042228	1	11.3042228
Residual	1929.68871	97	19.893698
Total	1940.99293	98	19.8060503

Number of obs	= 99
F(1, 97)	= 0.57
Prob > F	= 0.4528
R-squared	= 0.0058
Adj R-squared	= -0.0044
Root MSE	= 4.4602

Weightgain34weekskg	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
lnPA2ndtrimesterENMOmeanday	1.039183	1.378571	0.75	0.453	-1.6969	3.775265
_cons	5.102109	3.4581	1.48	0.143	-1.761262	11.96548

Source	SS	df	MS
Model	417.407594	9	46.3786215
Residual	1225.07072	85	14.4125967
Total	1642.47832	94	17.4731736

Number of obs	=	95
F(9, 85)	=	3.22
Prob > F	=	0.0021
R-squared	=	0.2541
Adj R-squared	=	0.1752
Root MSE	=	3.7964

Weightgain34weekskg	Coef.	Std. Err.	t	P>|t|	[95% Conf. In > terval]	
lnPA2ndtrimesterENMOmeanday	1.268172	1.280173	0.99	0.325	-1.277155	3 > .813498
lnBMI	-2.558855	2.252016	-1.14	0.259	-7.036466	1 > .918756
Age	-.1137472	.080416	-1.41	0.161	-.2736357	. > 0461413
Parity_CODED	-1.644144	1.006159	-1.63	0.106	-3.644658	. > 3563706
Proffessional_CODED	3.971489	1.920395	2.07	0.042	.1532296	7 > .789749
Secondary_CODED	3.995276	1.84356	2.17	0.033	.3297851	7 > .660767
HIVAIDS	-2.070339	.9677401	-2.14	0.035	-3.994466	-. > 1462125
DaysfromBaseline_V5	.0022573	.0200896	0.11	0.911	-.0376862	. > 0422009
smokingtobaccobetelnut	.8709864	1.437031	0.61	0.546	-1.986216	3 > .728189
_cons	13.69825	9.615641	1.42	0.158	-5.42022	3 > 2.81672

vi. Physical activity (3rd trimester) and weight change (<14 weeks to 29-33 weeks): adjusted and unadjusted model

Source	SS	df	MS
Model	23.1493922	1	23.1493922
Residual	2115.66051	104	20.3428896
Total	2138.80991	105	20.3696181

Number of obs	=	106
F(1, 104)	=	1.14
Prob > F	=	0.2886
R-squared	=	0.0108
Adj R-squared	=	0.0013
Root MSE	=	4.5103

Weightgain34weekskg	Coef.	Std. Err.	t	P>|t|	[95% Conf. In > terval]	
PA3rdtrimester_consolidated	-.1450029	.1359294	-1.07	0.289	-.414556	. > 1245501
_cons	8.916954	1.397825	6.38	0.000	6.145014	1 > 1.68889

Source	SS	df	MS
Model	533.254374	10	53.3254374
Residual	1302.49239	91	14.3131032
Total	1835.74676	101	18.1757105

Number of obs	=	102
F(10, 91)	=	3.73
Prob > F	=	0.0003
R-squared	=	0.2905
Adj R-squared	=	0.2125
Root MSE	=	3.7833

Weightgain34weekskg	Coef.	Std. Err.	t	P>|t|	[95% Conf.	In > terval]
PA3rdtrimester_consolidated	-.2466941	.1247339	-1.98	0.051	-.4944627	. > 0010745
lnBMI	-2.121393	2.181748	-0.97	0.333	-6.455167	2 > .212381
Age	-.1909453	.0750532	-2.54	0.013	-.3400294	-. > 0418613
Parity_CODED	-1.427026	.9485807	-1.50	0.136	-3.311265	. > 4572131
Proffessional_CODED	3.500457	1.892825	1.85	0.068	-.2594085	7 > .260322
Secondary_CODED	2.891864	1.81548	1.59	0.115	-.7143636	6 > .498092
Imputeddata_1	-1.053986	.9847592	-1.07	0.287	-3.010089	. > 9021178
HIVAIDS	-1.825905	.9454352	-1.93	0.057	-3.703896	. > 0520858
DaysfromBaseline_V5	.0157551	.0199484	0.79	0.432	-.02387	. > 0553801
smokingtobaccobetelnut	.9944972	1.424253	0.70	0.487	-1.834607	3 > .823601
_cons	18.88855	7.93993	2.38	0.019	3.116856	3 > 4.66025

vii. Change in physical activity and weight change (<14 weeks to 29-33 weeks): adjusted and unadjusted model

Source	SS	df	MS
Model	57.1821276	1	57.1821276
Residual	1374.51633	76	18.0857412
Total	1431.69846	77	18.5934865

Number of obs	=	78
F(1, 76)	=	3.16
Prob > F	=	0.0794
R-squared	=	0.0399
Adj R-squared	=	0.0273
Root MSE	=	4.2527

Wei~4weekskg	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ChangeinPA	-.191639	.1077759	-1.78	0.079	-.4062933	.0230154
_cons	7.351938	.5788264	12.70	0.000	6.199105	8.50477

Source	SS	df	MS
Model	377.662339	10	37.7662339
Residual	861.764328	64	13.4650676
Total	1239.42667	74	16.749009

Number of obs	=	75
F(10, 64)	=	2.80
Prob > F	=	0.0061
R-squared	=	0.3047
Adj R-squared	=	0.1961
Root MSE	=	3.6695

Weightgain34weekskg	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
ChangeinPA	-.3645669	.1282259	-2.84	0.006	-.6207275	-.1084063
lnBMI	.2025222	2.40357	0.08	0.933	-4.599161	5.004205
Age	-.1474196	.0857269	-1.72	0.090	-.3186787	.0238396
Parity_CODED	-1.18492	1.041501	-1.14	0.259	-3.265557	.8957166
Proffessional_CODED	5.138146	1.935933	2.65	0.010	1.270676	9.005616
Secondary_CODED	4.302477	1.830804	2.35	0.022	.6450259	7.959927
lnPA2ndtrimesterENMOmeanday	-1.093798	1.991365	-0.55	0.585	-5.072007	2.88441
HIVAIDS	-1.372428	1.115158	-1.23	0.223	-3.600213	.8553576
DaysfromBaseline_V5	.0261242	.0227045	1.15	0.254	-.0192333	.0714816
smokingtobaccobetelnut	1.728111	1.612263	1.07	0.288	-1.492754	4.948976
_cons	6.187962	10.81227	0.57	0.569	-15.41203	27.78796

viii. Physical activity (2nd trimester) and gestational age (weeks): unadjusted and adjusted model

Source	SS	df	MS
Model	23.0916201	1	23.0916201
Residual	2605.18035	115	22.6537421
Total	2628.27197	116	22.6575169

Number of obs	=	117
F(1, 115)	=	1.02
Prob > F	=	0.3148
R-squared	=	0.0088
Adj R-squared	=	0.0002
Root MSE	=	4.7596

Gestationalageatbirthwksday	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
lnPA2ndtrimesterENMOmeanday	1.369246	1.356201	1.01	0.315	-1.317128	4.055619
_cons	32.62247	3.421176	9.54	0.000	25.84578	39.39916

Source	SS	df	MS
Model	141.021357	7	20.1459082
Residual	2378.63227	105	22.6536407
Total	2519.65363	112	22.4969074

Number of obs	=	113
F(7, 105)	=	0.89
Prob > F	=	0.5178
R-squared	=	0.0560
Adj R-squared	=	-0.0070
Root MSE	=	4.7596

Gestationalageatbirthwksday > terval]	Coef.	Std. Err.	t	P>|t|	[95% Conf. In
lnPA2ndtrimesterENMOmeanday > .125869	1.254659	1.448047	0.87	0.388	-1.616551 4
Age > 1364079	-.0291481	.0834954	-0.35	0.728	-.1947041 .
lnBMI > .469285	.5119487	2.50015	0.20	0.838	-4.445388 5
Secondary_CODED > .312381	-2.126554	2.238703	-0.95	0.344	-6.56549 2
Proffessional_CODED > .365169	-2.362715	2.38443	-0.99	0.324	-7.090599 2
smokingtobaccobetelnut > .947182	.9006645	1.536461	0.59	0.559	-2.145853 3
HIVAIDS > 0479985	-2.009432	1.037631	-1.94	0.055	-4.066862 .
_cons > 4.86514	34.71391	10.16294	3.42	0.001	14.56267 5

ix. Physical activity (3rd trimester) and gestational age (weeks): unadjusted and adjusted model

Source	SS	df	MS
Model	6.86184242	1	6.86184242
Residual	2685.91048	123	21.8366705
Total	2692.77232	124	21.7159058

Number of obs	=	125
F(1, 123)	=	0.31
Prob > F	=	0.5761
R-squared	=	0.0025
Adj R-squared	=	-0.0056
Root MSE	=	4.673

Gestationalageatbirthwksday > terval]	Coef.	Std. Err.	t	P>|t|	[95% Conf. In
PA3rdtrimester_consolidated > 3539936	.0781246	.1393673	0.56	0.576	-.1977443 .
_cons > 8.20197	35.38675	1.422235	24.88	0.000	32.57152 3

Source	SS	df	MS			
Model	385.804211	8	48.2255264	Number of obs	=	121
Residual	2196.44025	112	19.6110737	F(8, 112)	=	2.46
				Prob > F	=	0.0172
				R-squared	=	0.1494
				Adj R-squared	=	0.0886
Total	2582.24446	120	21.5187039	Root MSE	=	4.4284

Gestationalageatbirthwksday > terval]	Coef.	Std. Err.	t	P>|t|	[95% Conf. In
PA3rdtrimester_consolidated > 3738301	.0987472	.1388345	0.71	0.478	-.1763356 .
Age > 1551139	.0067261	.0748915	0.09	0.929	-.1416618 .
lnBMI > .751819	2.252469	2.270826	0.99	0.323	-2.24688 6
Secondary_CODED > .220454	-.9355421	2.097535	-0.45	0.656	-5.091539 3
Proffessional_CODED > .327321	-1.03694	2.202646	-0.47	0.639	-5.401201 3
Imputeddata_1 > 1.70356	-3.569105	.941542	-3.79	0.000	-5.434649 -
smokingtobaccobetelnut > .901995	1.081004	1.423757	0.76	0.449	-1.739987 3
HIVAIDS > 7848241	-1.084613	.9435065	-1.15	0.253	-2.95405 .
_cons > 5.30044	29.78066	7.83285	3.80	0.000	14.26087 4

x. Change in physical activity and gestational age (weeks): unadjusted and adjusted model

Source	SS	df	MS			
Model	17.5340055	1	17.5340055	Number of obs	=	79
Residual	806.679665	77	10.4763593	F(1, 77)	=	1.67
				Prob > F	=	0.1996
				R-squared	=	0.0213
				Adj R-squared	=	0.0086
Total	824.213671	78	10.5668419	Root MSE	=	3.2367

Gestationa~y	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ChangeinPA	-.1039572	.0803562	-1.29	0.200	-.2639668	.0560524
_cons	36.93056	.4430228	83.36	0.000	36.04838	37.81273

Source	SS	df	MS
Model	113.067109	8	14.1333887
Residual	703.525839	69	10.1960267
Total	816.592949	77	10.6051032

Number of obs	=	78
F(8, 69)	=	1.39
Prob > F	=	0.2181
R-squared	=	0.1385
Adj R-squared	=	0.0386
Root MSE	=	3.1931

Gestationalageatbirthwksday > terval]	Coef.	Std. Err.	t	P>|t|	[95% Conf. In
ChangeinPA > 3161851	.1008391	.1079459	0.93	0.353	-.114507 .
Age > 1832528	.044629	.0694875	0.64	0.523	-.0939947 .
lnBMI > .853278	.8807865	1.991278	0.44	0.660	-3.091705 4
Secondary_CODED > .173242	.0766996	1.552194	0.05	0.961	-3.019842 3
Proffessional_CODED > 2.57659	-.795111	1.690122	-0.47	0.640	-4.166812
lnPA2ndtrimesterENMOmeanday > .103901	4.742782	1.684817	2.82	0.006	1.381663 8
smokingtobaccobetelnut > .242487	.6406455	1.304217	0.49	0.625	-1.961196 3
HIVAIDS > 9844316	-.8680018	.9285634	-0.93	0.353	-2.720435 .
_cons > 38.7228	21.67445	8.545772	2.54	0.013	4.626098

xi. Physical activity (2^{nd} trimester) and newborn weight (g): unadjusted and adjusted model

Source	SS	df	MS
Model	15129.0167	1	15129.0167
Residual	46351500.7	108	429180.562
Total	46366629.7	109	425381.924

Number of obs	=	110
F(1, 108)	=	0.04
Prob > F	=	0.8514
R-squared	=	0.0003
Adj R-squared	=	-0.0089
Root MSE	=	655.12

Newbornweightg > terval]	Coef.	Std. Err.	t	P>|t|	[95% Conf. In
lnPA2ndtrimesterENMOmeanday > 38.7338	37.96134	202.1884	0.19	0.851	-362.8111 4
_cons > 789.826	2777.927	510.4994	5.44	0.000	1766.029 3

```
      Source |       SS       df       MS              Number of obs =     106
-------------+------------------------------           F(  8,    97) =   16.54
       Model |  26111863.3     8  3263982.91           Prob > F      =  0.0000
    Residual |  19146104.1    97  197382.516           R-squared     =  0.5770
-------------+------------------------------           Adj R-squared =  0.5421
       Total |  45257967.4   105  431028.261           Root MSE      =  444.28

------------------------------------------------------------------------------
  -------
            Newbornweightg |      Coef.   Std. Err.      t    P>|t|     [95% Conf. In
> terval]
-----------------------------+------------------------------------------------
  -------
lnPA2ndtrimesterENMOmeanday |   99.57184   147.9111     0.67   0.502    -193.9907    3
> 93.1344
                        Age |  -7.227487   8.121459    -0.89   0.376    -23.34634    8
> .891361
                      lnBMI |   260.7658   242.5096     1.08   0.285    -220.5485    7
> 42.0802
     smokingtobaccobetelnut |  -83.18896   144.1973    -0.58   0.565    -369.3807    2
> 03.0028
             Secondary_CODED |   228.4735   210.9863     1.08   0.282     -190.276    6
> 47.2229
          Proffessional_CODED |   310.8783   225.5264     1.38   0.171    -136.7293    7
> 58.4858
Gestationalageatbirthwksday |   153.2313   14.24687    10.76   0.000     124.9552    1
> 81.5074
                     HIVAIDS |  -160.4493   102.8364    -1.56   0.122    -364.5511    4
> 3.65254
                       _cons |  -3863.071     1150.4    -3.36   0.001    -6146.296   -1
> 579.845
------------------------------------------------------------------------------
```

xii. Physical activity (3rd trimester) and newborn weight (g): unadjusted and adjusted model

```
      Source |       SS       df       MS              Number of obs =     118
-------------+------------------------------           F(  1,   116) =    0.02
       Model |  6797.89792     1  6797.89792           Prob > F      =  0.8999
    Residual |  49573721.5   116  427359.668           R-squared     =  0.0001
-------------+------------------------------           Adj R-squared = -0.0085
       Total |  49580519.4   117  423765.123           Root MSE      =  653.73

------------------------------------------------------------------------------
  -------
            Newbornweightg |      Coef.   Std. Err.      t    P>|t|     [95% Conf. In
> terval]
-----------------------------+------------------------------------------------
  -------
PA3rdtrimester_consolidated |  -2.486751   19.71704    -0.13   0.900    -41.53883    3
> 6.56533
                       _cons |   2899.845   202.3839    14.33   0.000     2498.998    3
> 300.692
------------------------------------------------------------------------------
```

Source	SS	df	MS
Model	28474881.9	9	3163875.76
Residual	19992558.2	104	192236.137
Total	48467440.1	113	428915.399

Number of obs	= 114
F(9, 104)	= 16.46
Prob > F	= 0.0000
R-squared	= 0.5875
Adj R-squared	= 0.5518
Root MSE	= 438.45

Newbornweightg	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
PA3rdtrimester_consolidated	-7.871576	14.10628	-0.56	0.578	-35.84487	20.10171
Age	-4.526656	7.725295	-0.59	0.559	-19.84621	10.79289
lnBMI	294.8244	232.9054	1.27	0.208	-167.0357	756.6845
smokingtobaccobetelnut	-58.77198	141.8575	-0.41	0.680	-340.0807	222.5367
Secondary_CODED	228.3954	208.1238	1.10	0.275	-184.3218	641.1126
Proffessional_CODED	361.4196	219.7452	1.64	0.103	-74.34333	797.1824
Gestationalageatbirthwksday	149.2947	13.99693	10.67	0.000	121.5382	177.0511
Imputeddata_1	-183.1055	100.5194	-1.82	0.071	-382.4393	16.22819
HIVAIDS	-142.545	97.67681	-1.46	0.147	-336.2418	51.15175
_cons	-3559.682	931.9933	-3.82	0.000	-5407.86	-1711.505

xiii. Change in physical activity and newborn weight (g): unadjusted and adjusted model

Source	SS	df	MS
Model	596939.079	1	596939.079
Residual	22256809.8	76	292852.76
Total	22853748.9	77	296801.933

Number of obs	= 78
F(1, 76)	= 2.04
Prob > F	= 0.1575
R-squared	= 0.0261
Adj R-squared	= 0.0133
Root MSE	= 541.16

Newbornwei~g	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ChangeinPA	-19.82598	13.88655	-1.43	0.157	-47.48343	7.831477
_cons	2937.459	74.67996	39.33	0.000	2788.721	3086.197

Source	SS	df	MS
Model	9294009.81	9	1032667.76
Residual	13086319.1	66	198277.563
Total	22380328.9	75	298404.386

Number of obs	= 76
F(9, 66)	= 5.21
Prob > F	= 0.0000
R-squared	= 0.4153
Adj R-squared	= 0.3355
Root MSE	= 445.28

Newbornweightg	Coef.	Std. Err.	t	P>|t|	[95% Conf.	In
> terval]						
ChangeinPA	-16.61264	15.71011	-1.06	0.294	-47.97888	
> 14.7536						
Age	-8.267466	9.783521	-0.85	0.401	-27.8009	1
> 1.26597						
lnBMI	541.9321	286.4477	1.89	0.063	-29.97928	1
> 113.843						
smokingtobaccobetelnut	-74.53532	182.3051	-0.41	0.684	-438.5191	2
> 89.4485						
Secondary_CODED	307.2242	218.3854	1.41	0.164	-128.7963	7
> 43.2447						
Proffessional_CODED	396.0416	238.5707	1.66	0.102	-80.28025	8
> 72.3634						
Gestationalageatbirthwksday	118.0424	20.13768	5.86	0.000	77.83627	1
> 58.2486						
lnPA2ndtrimesterENMOmeanday	151.1876	262.1999	0.58	0.566	-372.3114	6
> 74.6866						
HIVAIDS	-57.60267	130.5441	-0.44	0.660	-318.2423	
> 203.037						
_cons	-3667.439	1506.106	-2.44	0.018	-6674.478	-6
> 60.4009						

xiv. Physical activity (2nd trimester) and Ponderal index (g/cm³): unadjusted and adjusted model

Source	SS	df	MS
Model	.060095313	1	.060095313
Residual	4.82893389	107	.045130223
Total	4.88902921	108	.045268789

Number of obs	=	109
F(1, 107)	=	1.33
Prob > F	=	0.2511
R-squared	=	0.0123
Adj R-squared	=	0.0031
Root MSE	=	.21244

lnPonderalIndex	Coef.	Std. Err.	t	P>|t|	[95% Conf.	In
> terval]						
lnPA2ndtrimesterENMOmeanday	-.0760205	.0658786	-1.15	0.251	-.2066171	.
> 0545761						
_cons	1.195749	.1661457	7.20	0.000	.8663845	1
> .525113						

Source	SS	df	MS
Model	1.13919745	8	.142399682
Residual	3.7341999	96	.038897916
Total	4.87339735	104	.04685959

Number of obs	=	105
F(8, 96)	=	3.66
Prob > F	=	0.0009
R-squared	=	0.2338
Adj R-squared	=	0.1699
Root MSE	=	.19723

lnPonderalIndex	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
lnPA2ndtrimesterENMOmeanday	-.0435679	.0659556	-0.66	0.510	-.1744888	.087353
Age	-.0021968	.0036176	-0.61	0.545	-.0093776	.0049841
lnBMI	.2565414	.107981	2.38	0.019	.0422007	.4708821
smokingtobaccobetelnut	.0493365	.064154	0.77	0.444	-.0780082	.1766811
Secondary_CODED	-.1960092	.0937197	-2.09	0.039	-.3820414	-.009977
Proffessional_CODED	-.2470094	.1001171	-2.47	0.015	-.4457403	-.0482785
Gestationalageatbirthwksday	-.0211095	.0066404	-3.18	0.002	-.0342905	-.0079285
HIVAIDS	-.1344466	.0459136	-2.93	0.004	-.2255845	-.0433088
_cons	1.343246	.5164213	2.60	0.011	.3181579	2.368334

xv. Physical activity (3rd trimester) and Ponderal index (g/cm³): unadjusted and adjusted model

Source	SS	df	MS
Model	.09913099	1	.09913099
Residual	4.88083322	115	.042442028
Total	4.97996421	116	.042930726

Number of obs = 117
F(1, 115) = 2.34
Prob > F = 0.1292
R-squared = 0.0199
Adj R-squared = 0.0114
Root MSE = .20601

lnPonderalIndex	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
PA3rdtrimester_consolidated	-.0095003	.0062163	-1.53	0.129	-.0218135	.0028129
_cons	1.099004	.0637789	17.23	0.000	.9726704	1.225338

Source	SS	df	MS
Model	1.06955222	9	.118839135
Residual	3.89475011	103	.037813108
Total	4.96430233	112	.044324128

Number of obs	=	113
F(9, 103)	=	3.14
Prob > F	=	0.0022
R-squared	=	0.2154
Adj R-squared	=	0.1469
Root MSE	=	.19446

lnPonderalIndex	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
PA3rdtrimester_consolidated	-.0076226	.0062662	-1.22	0.227	-.0200502	.004805
Age	-.0012398	.0034378	-0.36	0.719	-.0080578	.0055783
lnBMI	.2840628	.1040384	2.73	0.007	.0777271	.4903984
smokingtobaccobetelnut	.0473236	.0630947	0.75	0.455	-.0778098	.1724571
Secondary_CODED	-.1928948	.0923107	-2.09	0.039	-.3759713	-.0098183
Proffessional_CODED	-.2212152	.097474	-2.27	0.025	-.414532	-.0278985
Gestationalageatbirthwksday	-.0174524	.0064586	-2.70	0.008	-.0302614	-.0046433
Imputeddata_1	.0028774	.0448439	0.06	0.949	-.0860598	.0918147
HIVAIDS	-.1113629	.0434776	-2.56	0.012	-.1975906	-.0251353
_cons	1.042592	.4240565	2.46	0.016	.2015759	1.883608

xvi. **Change in physical activity and Ponderal index (g/cm^3): unadjusted and adjusted model**

Source	SS	df	MS
Model	.00964794	1	.00964794
Residual	3.15396414	76	.041499528
Total	3.16361208	77	.041085871

Number of obs	=	78
F(1, 76)	=	0.23
Prob > F	=	0.6311
R-squared	=	0.0030
Adj R-squared	=	-0.0101
Root MSE	=	.20371

lnPonderal~x	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ChangeinPA	-.0025205	.0052275	-0.48	0.631	-.0129319	.0078909
_cons	.9874177	.0281126	35.12	0.000	.9314266	1.043409

```
      Source |       SS       df       MS              Number of obs =      76
-------------+------------------------------           F(  9,    66) =    3.09
       Model |  .935127467     9  .103903052           Prob > F      =  0.0038
    Residual |  2.22155694    66  .033659954           R-squared     =  0.2962
-------------+------------------------------           Adj R-squared =  0.2003
       Total |   3.1566844    75  .042089125           Root MSE      =  .18347

------------------------------------------------------------------------------
    ____________
              lnPonderalIndex |      Coef.   Std. Err.      t    P>|t|     [95% Conf. In
> terval]
------------------------------------------------------------------------------
    ____________
                   ChangeinPA |  -.0064584   .0064729    -1.00   0.322    -.019382     .
> 0064652
                          Age |   .0016183    .004031     0.40   0.689   -.0064299     .
> 0096665
                        lnBMI |   .3532041   .1180226     2.99   0.004    .1175643     .
> 5888439
          smokingtobaccobetelnut |   .0976876   .0751136     1.30   0.198   -.0522815     .
> 2476568
               Secondary_CODED |  -.1757055   .0899795    -1.95   0.055   -.3553554     .
> 0039444
           Proffessional_CODED |  -.2158039   .0982963    -2.20   0.032   -.4120587     -
> .019549
Gestationalageatbirthwksday |  -.0178093   .0082972    -2.15   0.036   -.0343751    -.
> 0012435
lnPA2ndtrimesterENMOmeanday |  -.0899294    .108032    -0.83   0.408   -.3056222     .
> 1257635
                      HIVAIDS |  -.1108108    .053787    -2.06   0.043      -.2182    -.
> 0034216
                        _cons |   .8529962   .6205483     1.37   0.174   -.3859685     2
> .091961
------------------------------------------------------------------------------
```

xvii. Physical activity (2nd trimester) and Apgar score: unadjusted and adjusted model

```
      Source |       SS       df       MS              Number of obs =     108
-------------+------------------------------           F(  1,   106) =    1.50
       Model |  .748763914     1  .748763914           Prob > F      =  0.2234
    Residual |  52.9086435   106  .499138146           R-squared     =  0.0140
-------------+------------------------------           Adj R-squared =  0.0047
       Total |  53.6574074   107  .501471097           Root MSE      =   .7065

------------------------------------------------------------------------------
    ____________
             Apgarscoreat5min |      Coef.   Std. Err.      t    P>|t|     [95% Conf. In
> terval]
------------------------------------------------------------------------------
    ____________
lnPA2ndtrimesterENMOmeanday |     .26971   .2202089     1.22   0.223   -.1668757     .
> 7062956
                        _cons |    8.99981   .5561957    16.18   0.000    7.897098     1
> 0.10252
------------------------------------------------------------------------------
```

Source	SS	df	MS
Model	6.26386729	8	.782983411
Residual	21.1730259	94	.225244957
Total	27.4368932	102	.268989149

Number of obs	=	103
F(8, 94)	=	3.48
Prob > F	=	0.0015
R-squared	=	0.2283
Adj R-squared	=	0.1626
Root MSE	=	.4746

Apgarscoreat5min	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnPA2ndtrimesterENMOmeanday	.1827447	.158829	1.15	0.253	-.1326139	.4981033
Age	-.0003936	.0087349	-0.05	0.964	-.0177369	.0169498
lnBMI	-.3082018	.2642701	-1.17	0.246	-.8329163	.2165126
smokingtobaccobetelnut	-.3586635	.1637995	-2.19	0.031	-.6838913	-.0334357
Secondary_CODED	.0131497	.2255294	0.06	0.954	-.4346443	.4609436
Proffessional_CODED	-.0523276	.2422862	-0.22	0.829	-.5333925	.4287374
Gestationalageatbirthwksday	.0545234	.0163939	3.33	0.001	.0219728	.0870739
HIVAIDS	-.2253027	.1109105	-2.03	0.045	-.4455182	-.0050873
_cons	8.390455	1.248297	6.72	0.000	5.911933	10.86898

xviii. Physical activity (3rd trimester) and Apgar score: unadjusted and adjusted model

Source	SS	df	MS
Model	.029987962	1	.029987962
Residual	54.4096672	114	.477277783
Total	54.4396552	115	.473388306

Number of obs	=	116
F(1, 114)	=	0.06
Prob > F	=	0.8025
R-squared	=	0.0006
Adj R-squared	=	-0.0082
Root MSE	=	.69085

Apgarscoreat5min	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
PA3rdtrimester_consolidated	.0052555	.0209666	0.25	0.803	-.0362792	.0467902
_cons	9.646703	.2155154	44.76	0.000	9.219768	10.07364

Source	SS	df	MS
Model	6.66101028	9	.740112253
Residual	21.2488996	101	.210385145
Total	27.9099099	110	.253726454

Number of obs	=	111
F(9, 101)	=	3.52
Prob > F	=	0.0008
R-squared	=	0.2387
Adj R-squared	=	0.1708
Root MSE	=	.45868

Apgarscoreat5min	Coef.	Std. Err.	t	P>|t|	[95% Conf.	In
> terval]						
PA3rdtrimester_consolidated	.000483	.014809	0.03	0.974	-.0288941	.
> 0298601						
Age	.0011413	.0081315	0.14	0.889	-.0149894	
> .017272						
lnBMI	-.2796637	.2527277	-1.11	0.271	-.7810075	.
> 2216801						
smokingtobaccobetelnut	-.3532093	.1583177	-2.23	0.028	-.6672691	-.
> 0391496						
Secondary_CODED	.0380467	.2177958	0.17	0.862	-.3940015	.
> 4700949						
Proffessional_CODED	-.010238	.231332	-0.04	0.965	-.4691384	.
> 4486625						
Gestationalageatbirthwksday	.0490458	.0156644	3.13	0.002	.0179718	.
> 0801198						
Imputeddata_1	-.1955811	.1075199	-1.82	0.072	-.4088717	.
> 0177095						
HIVAIDS	-.1813542	.1027292	-1.77	0.081	-.3851413	
> .022433						
_cons	8.933482	1.008271	8.86	0.000	6.933343	1
> 0.93362						

xix. Change in physical activity and Apgar score: unadjusted and adjusted model

Source	SS	df	MS
Model	.289419657	1	.289419657
Residual	12.4868961	74	.16874184
Total	12.7763158	75	.170350877

Number of obs	=	76
F(1, 74)	=	1.72
Prob > F	=	0.1944
R-squared	=	0.0227
Adj R-squared	=	0.0094
Root MSE	=	.41078

Apgarscor~in	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ChangeinPA	-.0138476	.0105736	-1.31	0.194	-.0349158	.0072207
_cons	9.78578	.0575043	170.17	0.000	9.6712	9.900359

Source	SS	df	MS
Model	1.07291078	9	.119212309
Residual	10.9811433	64	.171580364
Total	12.0540541	73	.165124028

Number of obs	=	74
F(9, 64)	=	0.69
Prob > F	=	0.7110
R-squared	=	0.0890
Adj R-squared	=	-0.0391
Root MSE	=	.41422

Apgarscoreat5min	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
ChangeinPA	-.0017711	.0146552	-0.12	0.904	-.0310482	.027506
Age	-.0000787	.0091504	-0.01	0.993	-.0183587	.0182013
lnBMI	.0561843	.2764052	0.20	0.840	-.4959986	.6083671
smokingtobaccobetelnut	-.0356998	.1861186	-0.19	0.848	-.4075145	.3361149
Secondary_CODED	.0957792	.2031813	0.47	0.639	-.3101221	.5016805
Proffessional_CODED	-.0285516	.2240528	-0.13	0.899	-.4761486	.4190453
Gestationalageatbirthwksday	.0114149	.0195295	0.58	0.561	-.0275999	.0504296
lnPA2ndtrimesterENMOmeanday	.2454534	.2448474	1.00	0.320	-.2436855	.7345924
HIVAIDS	-.2013074	.1218908	-1.65	0.104	-.4448123	.0421975
_cons	8.589669	1.406222	6.11	0.000	5.780418	11.39892

Appendix M: Turn it in receipt and report

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