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Physical activity throughout pregnancy is key to preventing chronic disease

Taniya S. Nagpal
University of Ottawa

Michelle F. Mottola
Western University, mmottola@uwo.ca

REPRODUCTION
REVIEW

Physical activity throughout pregnancy is key to preventing chronic disease

Taniya S Nagpal[1,2] and Michelle F Mottola[3,4,5,6]

[1]*Faculty of Health Sciences, University of Ottawa, Ottawa, Canada,* [2]*The Society of Obstetricians and Gynaecologists of Canada, Ottawa, Canada,* [3]*Faculty of Health Sciences, University of Western Ontario, London, Canada,* [4]*R. Samuel McLaughlin Foundation-Exercise and Pregnancy Laboratory, University of Western Ontario, London, Canada,* [5]*Children's Health Research Institute, University of Western Ontario, London, Canada and* [6]*Schulich School of Medicine & Dentistry, University of Western Ontario, London, Canada*

Correspondence should be addressed to M F Mottola; Email: mmottola@uwo.ca

Abstract

According to The Developmental Origins of Health and Disease theory, the intrauterine environment of the developing fetus may impact later life physiology, including susceptibility to chronic disease conditions. Maternal exposures during pregnancy can affect the intrauterine environment and result in fetal programming for chronic diseases through changes in the structure or function of specific organs. Negative maternal exposures, such as poor nutrition intake, have been shown to increase the risk for later life chronic diseases. On the contrary, healthful behaviors, such as physical activity, may have a positive and protective effect against chronic disease risk. This narrative review summarizes literature to discuss the potential preventative role prenatal physical activity may have on prevalent chronic diseases: obesity, type 2 diabetes, and cardiovascular disease. We describe the natural physiological response to pregnancy that may increase the risk for complications and consequently later life disease for both mother and baby. We then present evidence highlighting the role prenatal exercise may have in preventing pregnancy complications and downstream chronic disease development, as well as proposing potential mechanisms that may explain the protective maternal and fetal physiological response to exercise. As the prevalence of these non-communicable diseases increase globally, intervening during pregnancy with an effective exercise intervention may be the key to preventing chronic disease risk in more than one generation.
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Introduction

The Developmental Origins of Health and Disease (DOHaD) theory proposes that the intrauterine environment of the developing embryo and fetus may have a major impact on later life physiology, including potential *in utero* programming for chronic disease risk (Barker 2007). Developmental plasticity suggests that a genotype gives rise to a range of physiological or morphological states in response to different environmental conditions sensed during development (Barker 2007, Gluckman *et al.* 2007). This plasticity may be reflected as fetal programming, which is a permanent or long-term change in the structure or function of a specific organ resulting from a stimulus or insult at critical periods of development and early life (Hales & Barker 2013).

The DOHaD theory is based on the link between maternal exposures during pregnancy, birth outcomes and later life chronic disease risk (Painter *et al.* 2005, Guarner-Lans *et al.* 2020). This is exemplified by the Dutch winter famine during 1944–1945 as medical records showed that women who experienced the famine early in gestation were more likely to have a small for gestational age (SGA) baby and a preterm delivery compared to women who were exposed to famine later in their second or third trimester or not exposed at all (Roseboom *et al.* 2000, Painter *et al.* 2005). Babies born preterm or SGA when examined longitudinally were at greater risk of developing cardiovascular disease and type 2 diabetes as adults, compared to babies that were born with an appropriate birthweight for gestational age at delivery (Roseboom *et al.* 2011).

The majority of the maternal exposure studies have focussed on the impact of nutrition on fetal development and chronic disease risk which consistently show that poor nutrition (inadequate or excessive intake) is associated with an increased risk for pregnancy complications (e.g. gestational hypertension, excessive or inadequate gestational weight gain, gestational diabetes) and later-life chronic diseases that can impact both the mother and developing fetus (e.g. cardiovascular disease, obesity, diabetes) (Roseboom *et al.* 2011, Hsu & Tain 2019). Physical activity during pregnancy has also been examined as a maternal exposure and has been associated with improved

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maternal outcomes, such as a decreased risk for excessive gestational weight gain (EGWG), gestational diabetes mellitus (GDM), and hypertensive disorders during pregnancy including preeclampsia (Davenport *et al.* 2018*b*, Ruchat *et al.* 2018). The purpose of this narrative review is to summarize the impact of exercise during pregnancy on the mother and the effects of fetal exposure to maternal exercise on later life chronic disease development, including obesity, type 2 diabetes and cardiovascular disease. We provide evidence that specifically highlights the potential for prenatal exercise as an effective preventative intervention for later life chronic disease development in both the mother and her fetus. In addition, we will summarize the *2019 Canadian Physical Activity throughout Pregnancy Guideline* (Mottola *et al.* 2018) and propose suggestions for future directions.

Prevention of obesity with exercise during pregnancy for mother and offspring

The prevalence of obesity globally has been an increasing trajectory for nearly two decades, with recent global statistics suggesting that 18% of men and 21% of women will have a BMI ≥30.0 kg/m^2 by 2025 (Collaboration 2016, Swinburn *et al.* 2019). Obesity is a chronic disease condition defined by excess adiposity, increasing the risk for other co-morbidities, including high blood pressure, mental health complications, and insulin resistance (Sharma & Kushner 2009). BMI has been criticized as a marker of measuring obesity, as BMI utilizes standard cut-offs based on height and weight and this does not assess body fatness and co-morbidities (Sharma & Kushner 2009). Although a BMI cut-off of ≥30.0 kg/m^2 should not be used as the sole criteria to diagnose obesity, it remains a commonly used and accessible population-level measurement approach (Gutin 2018). During pregnancy there is a natural increase in insulin resistance and adaptations are made by metabolic and cardiovascular systems to support fetal development; however, women with obesity may have higher baseline blood glucose values and blood pressure, thus increasing their risk for additional complications, such as GDM or preeclampsia (Barbour 2014).

Furthermore, obesity during pregnancy has been associated with an increased risk for EGWG (Suliga *et al.* 2018). Gaining excessively during pregnancy may result in higher fetal adiposity and thus infants are more likely to be born LGA (Geserick *et al.* 2018). LGA newborns may experience childhood and adult obesity (Geserick *et al.* 2018), thus potentially perpetuating a cycle of obesity that actually had its origin *in utero* (Ruchat & Mottola 2012). Higher fetal adiposity, as a result of EGWG, has been linked with greater adipocytes, and increased fat storage capability in the offspring (Abeysekera *et al.* 2016). Additionally, studies have shown that EGWG and maternal obesity are associated with decreased cord blood leptin methylation (Lesseur *et al.* 2013, Kadakia *et al.* 2017), which suggests that there may be *in utero* programming of appetite dysregulation, and when coupled with an increase in fat storage capacity, can predispose infants to later life obesity (Lesseur *et al.* 2013, Abeysekera *et al.* 2016).

One study found that 35% of LGA babies born from mothers who had a pre-pregnancy BMI of obese, also had obesity by age 11 (Boney *et al.* 2005). Individual patient data from over 100,000 women and children pairs showed that the risk for childhood obesity (ages 2–5 years) was 1.72 times higher among children of women who had gained excessively than appropriately during pregnancy (Voerman *et al.* 2019). In addition to delivering LGA newborns, which in itself has consequences for labor and birth, pregnant women who gain excessively are at risk for postpartum weight retention and this, in turn, can lead to later life obesity for the mother (Ruchat & Mottola 2012).

Infants born SGA who experience rapid weight gain or 'catch-up growth' in the first year of life are also at greater risk of developing obesity later in life (Singhal 2017). A proposed mechanism for obesity among infants born SGA is a potential mismatch between nutrient exposure during pregnancy and in the first year of life (Ezzahir *et al.* 2005). Due to poor placental nutrient transport or inadequate maternal nutrition intake, it is hypothesized that infants are more likely to be born SGA and *in utero* are programmed for a thrifty phenotype that upregulates fat storage (Hales & Barker 2001, Dulloo 2006). However once born, if nutrient availability increases, then the infant may continue to store fat and have high adiposity as a child and adult, and consequently develop obesity and obesity-related co-morbidities (Dulloo 2006). In fact, a recent systematic review and meta-analysis summarized longitudinal data from 17 studies and found that rapid catch-up growth up until age 2 was positively correlated with both percent body fat and BMI in the child at 6 years of age (Chen *et al.* 2020).

Exposure to exercise during pregnancy may be an effective intervention to prevent LGA and SGA babies, EGWG, postpartum weight retention in the mother and consequently, later life obesity for both mother and child. In a large sample of 962 pregnant women, a supervised light to moderate resistance and aerobic exercise program found that those women who exercised gained less weight than the inactive control group (Ruiz *et al.* 2013). Furthermore, high-quality evidence from a systematic review and meta-analysis (135 studies) suggested that prenatal exercise reduced the odds of delivering an infant born large by 39%, and did not increase the risk for SGA (Davenport *et al.* 2018*a*). Similarly, a systematic review and meta-analysis that included 84 studies found that exercise interventions delivered during pregnancy significantly reduced total gestational weight gain and postpartum weight retention in comparison to sedentary controls (Ruchat *et al.* 2018).

A recent animal study examined the multigenerational effect of physical activity in pregnant rats, and found that prenatal exercise reduced adiposity and glucose concentrations in offspring up to three generations later compared to rats that were sedentary throughout gestation (Martins Terra *et al.* 2020). Limited research has evaluated the effect of exercise during pregnancy on cord blood leptin levels and adipocytes in human models. One human study found that a healthy lifestyle intervention including physical activity and healthy eating during pregnancy, reduced leptin levels in female neonates compared to standard care (van Poppel *et al.* 2019). Furthermore, a follow-up study that included 1555 pregnant women with obesity found that prenatal exercise was associated with a decrease in infant adiposity at 6 months of age compared to the standard antenatal care group (Patel *et al.* 2017).Finally, contrary to the misconception that exercise will reduce maternal blood flow to the developing fetus, exercise during pregnancy improves endothelial functioning and increases vascular endothelial growth factors, and this, in turn, may be protective against SGA (Skow *et al.* 2017). Figure 1 summarizes the effect exercise during pregnancy may have on obesity prevention.

Prevention of type 2 diabetes with exercise during pregnancy for mother and offspring

According to the World Health Organization, 422 million individuals were affected by diabetes in the year 2014, with a rising incidence of early diagnosis of type 2 diabetes (https://www.who.int/news-room/fact-sheets/detail/diabetes; Accessed July 27 2020). Glucose intolerance that develops with first onset or recognition during pregnancy is defined as GDM (Plows *et al.* 2018). During a normal pregnancy, there is a cascade of hormonal events that create a pseudo-diabetic state of insulin resistance at the peripheral tissues with declining insulin sensitivity (Mottola & Artal 2016*b*). Since the fetus requires maternal blood glucose as a major source of energy for growth and development, these maternal adaptations occur to augment the maternal blood glucose supply (Plows *et al.* 2018). In order to maintain normal glucose regulation with the accompanying insulin resistance, the maternal pancreas and beta cells respond to the increasing insulin demand. Glucose intolerance may develop because of the inability of the maternal pancreatic beta cells to keep up with the insulin demand leading to hyperglycemia above normal values in the mother (Plows *et al.* 2018).

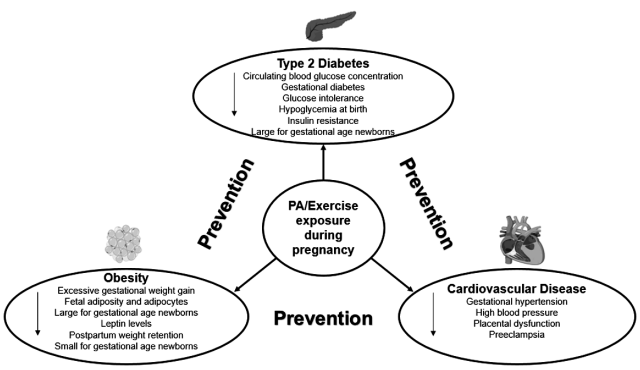

Figure 1 Summary of the role of exposure of exercise/physical activity during pregnancy on the prevention of obesity, type 2 diabetes and cardiovascular disease for both mom and baby. PA, physical activity.

Epidemiological evidence has shown that GDM increases the risk for the child to have type 2 diabetes later in life, including the potential for earlier diagnosis during childhood or adolescence (Sellers *et al.* 2016). The increased risk for type 2 diabetes for the child may be due to the fetal response *in utero* to the high glucose concentrations crossing the placenta, which includes increasing fetal pancreatic insulin beta cell secretion to counter the high glucose resulting in potential pancreatic dysfunction (Thompson *et al.* 2013). Furthermore, at birth, when the umbilical cord is cut, the high glucose supply from the mother is immediately stopped, while the fetal pancreas continues to secrete high insulin concentrations, thus creating a state of hypoglycemia in the newborn (Thompson *et al.* 2013). Moreover, women who develop uncontrolled GDM are also at risk of having type 2 diabetes post-delivery (Thompson *et al.* 2013).

Exposure of exercise during pregnancy may be an effective method to prevent GDM, and as a result, reduce the risk for type 2 diabetes for mother and child. A systematic review and meta-analysis, including 106 studies, found that prenatal exercise interventions reduced the risk for GDM by 25% compared to standard care (Davenport *et al.* 2018*b*). These results were supported by an additional meta-analysis that found exercise during pregnancy significantly reduced the relative risk for GDM compared to physical inactivity in women with an overweight or obese pre-pregnancy BMI (Du *et al.* 2019). Furthermore, a recent systematic review and meta-analysis found that lifestyle interventions incorporating exercise reduced fasting and postprandial blood glucose concentrations, improved glucose tolerance and delayed or prevented the initiation of insulin in women diagnosed with GDM (Allehdan *et al.* 2019).

Exercise is considered an adjunctive therapy for women diagnosed with GDM by medical societies (Hopkins & Artal 2013); and there may be many mechanistic explanations for why exercise during pregnancy can also be protective against the development of GDM. First, engaging in low-moderate activity has acute benefits, including reducing maternal blood glucose concentration (Mottola & Artal 2016*a*). Secondly, maternal exercise promotes appropriate gestational weight gain and this also has a protective effect against GDM, as EGWG increases blood glucose concentrations

that are associated with a dysregulation of adipokines that normally regulate insulin sensitivity (Mottola & Artal 2016*a*). Moreover, the fetal-insulin hypothesis suggests that exposure to high levels of glucose *in utero* will promote an over-production of fetal insulin, and this will stimulate growth causing an increased risk for LGA newborns, hypoglycemia at birth, and consequently a predisposition to developing type 2 diabetes later in life (Hattersley & Tooke 1999). Alternatively, exposure to exercise during pregnancy reduces maternal circulating blood glucose and maternal-fetal transmission of glucose, and therefore prenatal exercise may prevent the development of type 2 diabetes in the child by reducing the risk for GDM, LGA birthweight and hypoglycemia at birth (Fig. 1) (Mottola & Artal 2016*a*,*b*, Davenport *et al*. 2018*b*).

Prevention of cardiovascular disease with exercise during pregnancy for mother and offspring

Cardiovascular disease (CVD) is the leading cause of mortality due to non-communicable diseases globally and accounts for approximately 17 million deaths around the world annually (https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds); Accessed May 21, 2020). There are natural adaptations to the maternal cardiovascular system during pregnancy to increase blood flow to the placenta and promote fetal development (Ouzounian & Elkayam 2012). There is an increase in maternal blood volume, cardiac output and maternal heart rate (Ouzounian & Elkayam 2012). The increase in maternal blood volume and cardiac output are coupled with a decrease in arterial blood pressure and systemic vascular resistance, thus controlling blood pressure (Ouzounian & Elkayam 2012). However, these natural responses, and with potential co-morbidities such as elevated blood pressure prior to pregnancy or obesity, may increase the risk for cardiovascular complications, such as gestational hypertension and preeclampsia. Preeclampsia may be diagnosed after 20 weeks of gestation if the pregnant woman has persistent hypertension (blood pressure >140/90 mmHg) and proteinuria (24 h urinary protein level ≥ 0.3 g/day) (American College of Obstetrics and Gynecology 2002). Previous longitudinal studies have shown an increased risk for later life cardiovascular disease if there was exposure to high blood pressure or preeclampsia *in utero* (Lee & Tubby 2015).

As discussed earlier, babies born SGA from mothers that experienced famine in their first trimester had a greater incidence of adult CVD (Roseboom *et al*. 2011). Hattersley and Tooke (1999) hypothesized that this may be due to abnormal vascular development causing poor vasodilation and blood circulation. Research has also shown that the risk of CVD increases with accelerated growth in the early years of life by examining blood pressure in 346 men and women at age 22 and weight measurements at birth and at 10 years of age (Law *et al*. 2002). Results showed that babies who were born SGA and experienced accelerated growth between ages 1–5 had the highest blood pressure at 22 years of age (Law *et al*. 2002). Mothers who have hypertensive disorders during pregnancy may experience continued high blood pressure post-delivery and are at risk for CVD (Lee & Tubby 2015).

Prenatal exercise improves maternal blood pressure and reduces the risk for developing gestational hypertension and preeclampsia (Davenport *et al*. 2018*b*). A systematic review and meta-analysis reported that women who meet physical activity guidelines reduced the risk of developing gestational hypertension and preeclampsia by 38% (Davenport *et al*. 2018*b*). In addition, exposure to prenatal exercise has been shown to improve placental growth and vascularity, and thus promote effective nutrient transport for fetal development (Weissgerber *et al*. 2010). Studies have demonstrated that prenatal exercise increases placental villous tissue volume (Weissgerber *et al*. 2010). This would reduce the risk for fetal hypoxia, intrauterine growth restriction and fetal malnutrition, and therefore there would be an improvement in fetal organ development that may have a preventative effect on developing heart disease in later life (Weissgerber *et al*. 2010). Meeting prenatal activity guidelines has been shown to reduce inflammatory markers, including C-reactive protein, which is associated with a reduced risk of elevated blood pressure during pregnancy (Hawkins *et al*. 2015). In addition to reducing inflammatory markers, exposure to exercise during pregnancy improves endothelial functioning, such as increasing angiogenesis and vasodilation, which may explain the reduced risk for preeclampsia and improvement in blood flow and nutrient transport to the placenta (Dubé *et al*. 2017, Skow *et al*. 2017). Potential factors contributing to the preventative effects of maternal exercise on CVD risk are summarized in Fig. 1.

Summary

According to the DOHaD theory, the risk for prevalent non-communicable chronic diseases, including obesity, type 2 diabetes, and cardiovascular disease, may be programmed *in utero* based on maternal exposures during pregnancy (Barker 2007, Gluckman *et al*. 2007). Natural physiological responses to pregnancy include gestational weight gain, an increase in circulating maternal blood glucose, and cardiac output (Ouzounian & Elkayam 2012, Thompson *et al*. 2013, Suliga *et al*. 2018). Exceeding gestational weight gain recommendations has been positively correlated with LGA newborns and postpartum weight retention, and this increases the risk for later life obesity (Ruchat & Mottola 2012). In addition, EGWG may increase fetal adiposity and adipocytes, which increases fat storage. Infants born SGA, who experience rapid catch-up

growth in the first year of life, may also develop later life obesity and associated co-morbidities (Singhal 2017). Exposure to prenatal exercise reduces the risk for EGWG, postpartum weight retention in the mother and the risk of SGA, LGA and excessive fetal adiposity (Davenport *et al.* 2018*a*, Ruchat *et al.* 2018, van Poppel *et al.* 2019). Therefore engaging in moderate exercise during pregnancy can prevent later life obesity for mother and child.

Gestational diabetes and high maternal blood glucose results in an increase of glucose transported to the growing fetus which has detrimental effects on the development of the fetal pancreas and beta-cell functioning (Thompson *et al.* 2013). An increase in maternal blood glucose concentrations promotes fetal overgrowth leading to LGA newborns, macrosomia, and hypoglycemia at birth (Mottola & Artal 2016*b*). Prenatal physical activity reduces circulating maternal blood glucose, promotes appropriate fetal growth and development, and prevents GDM and thus reduces the risk for later life type 2 diabetes (Mottola & Artal 2016*b*).

Finally, the natural increase in maternal blood volume, cardiac output and heart rate coupled with co-morbidities, such as high blood pressure or obesity, increases the risk for gestational hypertension and preeclampsia (Skow *et al.* 2017). Newborns exposed to gestational hypertension or preeclampsia *in utero* are more likely to develop CVD in the future (Lee & Tubby 2015). However, engaging in prenatal physical activity improves maternal blood pressure, reduces inflammation, and prevents endothelial dysfunction, and therefore protects against hypertensive disorders during pregnancy (Skow *et al.* 2017). Figure 1 summarizes the preventative effects of prenatal physical activity on obesity, type 2 diabetes and cardiovascular disease discussed in this review.

Recommended prenatal exercise/physical activity guidelines

The *2019 Canadian Guideline for Physical Activity throughout Pregnancy* is an evidence-based guideline that has been informed by 12 systematic reviews and is endorsed by national and international health organizations (Mottola *et al.* 2018). In consensus with other international guidelines (Evenson *et al.* 2014, 2019), the Canadian guideline suggests that pregnant women without any contraindications to exercise are encouraged to be active throughout gestation (Mottola *et al.* 2018). Women should aim to achieve 150 min of moderate-intensity exercise every week, which can be accumulated by exercising for 30 min on most days of the week (Mottola *et al.* 2018). There are three ways to monitor intensity during pregnancy: (1) talk-test: individuals should be able to maintain a conversation but not sing; (2) using the Borg's Scale for Rating of Perceived Exertion: individuals should aim for a 12–14 (somewhat hard) on a 20-point scale; and (3) refer to heart rate cut-offs based on maternal age (Mottola *et al.* 2018).

Popular and safe physical activities during pregnancy, include walking, stationary cycling, swimming and aerobic prenatal group fitness classes (Mottola 2016). Women should also aim to include 2–3 days of resistance training, using lighter weights and more repetitions (Mottola 2016). Pelvic floor muscle training should also be performed daily, such as Kegel exercises, as this is an effective way to strengthen muscles that will prevent urinary incontinence and assist with labor and delivery (Mottola *et al.* 2018). Women should avoid exercises that have a high fall-risk (e.g. downhill skiing), contact sports (e.g. soccer) or may cause poor balance (e.g. ice skating) (Mottola 2016, Mottola *et al.* 2018). Furthermore, although there is limited evidence related to the effect of supine exercise during pregnancy, if women feel light headedness or nausea while lying flat on their back they should stop the activity and avoid this position (Mottola *et al.* 2018, 2019).

Women who were active prior to pregnancy can continue, making any necessary, modifications such as reducing the intensity or duration of the activity (Mottola 2016). Women who were sedentary prior to pregnancy are encouraged to start at the light-intensity physical activity for 15 min, and gradually progress as they become more comfortable (Mottola 2016). Irrespective of previous activity level, all women should consult with a health care provider before beginning an exercise program to ensure that it is safe to participate and discuss any necessary modifications (Mottola *et al.* 2018). A sample frequency, intensity, time and type (FITT) prescription is presented in Table 1.

Recommendations for future work

Recommendations for future work related to pregnancy and exercise/physical activity includes diversifying the population being studied and determining effective strategies to increase adherence to guidelines. Majority of the research that has evaluated the preventative effects of prenatal exercise on pregnancy complications and future chronic conditions has included healthy pregnant women, with singleton pregnancies, no chronic conditions, no use of substances, similar ethnic backgrounds (mostly Caucasian) and high education levels. In addition, all studies that have examined prenatal obesity and exercise, have used BMI as a marker of obesity instead of more appropriate measurement methods of obesity as a chronic condition, such as the Edmonton Obesity Staging System (EOSS) (Sharma & Kushner 2009). The EOSS evaluates metabolic markers, presence of co-morbidities, and psychosocial factors to appropriately diagnose obesity, and this has been shown to be a better predictor of a chronic condition vs the BMI cut-off of ≥30.0 kg/m^2 which may account

Table 1 Sample of frequency, intensity, time, type (FITT) aerobic exercise prescription for pregnant women.

For women who were sedentary prior to pregnancy, the goal is to achieve 150 min of light to moderate intensity activity per week	
Frequency	Start at 2–3 days per week, and gradually progress to 4–5 days per week. Consider including resistance training 1–2 days per week using light weights and increased repetitions for major muscle groups.
Intensity	Start at a light intensity, and gradually progress to a moderate intensity.
Time	Start at 15–20 min sessions, and gradually progress to 30 min sessions.
Type	Examples of activities: Walking, stationary cycling, swimming, supervised prenatal group fitness classes.
For women who were active prior to pregnancy, the goal is to achieve or maintain at least 150 min of moderate intensity activity per week	
Frequency	Aim for at least 4–5 days per week, increasing to 6–7 days is encouraged if appropriate. Consider including resistance training 2–3 days per week using similar or reduced weights as prior to pregnancy with increased repetitions using reduced weights for major muscle groups.
Intensity	Start at a similar or moderate intensity as before pregnancy, and lower the intensity as needed.
Time	Aim for at least 30-min sessions, and progress to 60 min (but may need to reduce frequency).
Type	Examples of activities: Jogging, brisk walking, stationary cycling, swimming, supervised prenatal group fitness classes

*In addition, yoga and gentle stretching may be added for additional benefits. Pelvic-floor muscle training may be performed daily to reduce the risk of urinary incontinence (Mottola *et al*. 2018).

for individuals who have an elevated BMI but are metabolically healthy (Richard *et al*. 2017). More research is needed to elucidate the potential protective effects of prenatal exercise on pregnancy complications for women who enter pregnancy at high risk, such as women who have type 2 diabetes, obesity or high blood pressure. In addition, we do not have exercise guidelines for women who may have twin or triplet pregnancies, and therefore we need randomized controlled trials that include this population group. Furthermore, as women may be active prior to pregnancy and engaging in higher intensity programs, future research should also further investigate the effects of high-intensity interval training during pregnancy on maternal and fetal outcomes.

Despite the known health benefits of prenatal physical activity, only 15% of pregnant women in North America report meeting guidelines (Huberty *et al*. 2016). Common barriers to physical activity include a lack of time, childcare and low self-efficacy to perform an exercise (Evenson *et al*. 2009). Future interventions should consider taking a patient-oriented approach to deliver exercise interventions to address and overcome individual barriers to behavior change. At the beginning of this review, we introduced the DOHaD theory, however, this theory can be extended and also include programming of behavioral mechanisms *in utero*, referred to as the Developmental Origins of Behavioral Health and Development (DOBHaD) (Van den Bergh 2011). The DOBHaD theory takes into account that maternal exposures during pregnancy also have an impact on fetal brain development and consequently future behaviors, such as mood and emotion regulation, knowledge processing, motivation and stress–response (Van den Bergh 2011). Therefore future interventions should include assessment of behavioral development of the newborn based on maternal exposures during pregnancy, including physical activity.

Conclusion

Exercise during pregnancy may be the key to reduce the prevalence of chronic conditions that currently have an increasing global trajectory including obesity, type 2 diabetes and cardiovascular disease. Encouraging women to lead an active lifestyle during pregnancy can reduce the risk for complications, promote appropriate fetal growth and improve overall health and well-being for mother and child. Future knowledge translation and implementation practices for increasing physical activity levels during pregnancy may include incorporating prescriptions or referrals for exercise during pregnancy into standard prenatal care practices to encourage all women to be physically active throughout gestation.

Declaration of interest

The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of this review.

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Author contribution statement

Both authors, T S N and M F M, contributed to the conception of this narrative review and the development of the manuscript.

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