



CHAMPIONING MOTHERHOOD: EXERCISE AND THE PREGNANT ATHLETE

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KEY POINTS

- The growing number of pregnant athletes demonstrates that pregnancy is not the end of an athletic career.
- Pregnancy is associated with significant adaptations and medical conditions of which all people working with pregnant athletes need to be aware.
- Maintaining participation in sport during pregnancy is encouraged but may require modification of activities.
- It is essential to manage risk to sport participation in pregnancy but also take a holistic view of maternal/fetal benefits.
- Athlete-centered decision making around sport participation during pregnancy in conjunction with the athletes' obstetric care team and coach/support staff is essential.

INTRODUCTION

"Happy retirement!" was a common refrain when athletes became pregnant in the not so distant past (Davenport et al., 2021). Until recently, it was assumed that pregnancy and motherhood meant athletes couldn't meet the demand of their sport – physically, mentally or just being able to devote the time. Those that have risen beyond the challenges and stereotypes have still faced hurdles. Yet the longstanding belief that athleticism ends with motherhood has been put to rest as athlete-mothers time and again prove otherwise. Sports' acceptance and support for athletes successfully competing while parenting has also changed and has been cemented by the inclusion of a nursery in the 2024 Paris Olympic and Paralympic village. The tide has turned.

As female athlete careers extend, many are reaching the pinnacle of their career at the same time as their peak fertility. Unfortunately, sport-specific recommendations remain scarce placing a heavy burden on athletes, coaches and healthcare providers to make decisions about play without strong guidance to support them. However, major advances are currently underway. This Sport Science Exchange (SSE) article explores the challenges, evidence and current understanding of how best to support pregnant athletes. This SSE article provides general principals and practical guidance for pregnant athletes, coaches and healthcare providers to support decision-making for those who wish to continue training and competing during pregnancy. To support pregnant athletes, it is critical to understand the body's adaptations to pregnancy, develop awareness of key pregnancy complications and tailor considerations for pregnant athletes continuing to train and/or compete in their sport. It is also essential to acknowledge that every pregnancy and athlete is highly unique. Having a flexible, adaptable plan developed by a multi-disciplinary team with the athlete voice at its center is essential to success.

PHYSIOLOGICAL ADAPTATIONS TO PREGNANCY

The nine short months of pregnancy is a period of rapid growth and adaptation to support the growing fetus. Beginning early in pregnancy,

estrogen, progesterone and placental hormones rise to support adaptations to virtually every organ system in the body. As pregnancy progresses, a mother's metabolism increases to support the growth of the fetus, placenta and maternal tissues such that the additional energy expenditure of pregnancy is the equivalent of running 30 marathons! While there are negligible changes in caloric needs during the first trimester, the second and third trimesters of pregnancy require an extra ~350 and ~500 calories per day above preconception values, respectively (Butte et al., 2004). Combined with athletic training, it is essential that athletes ensure adequate fueling and hydration to support pregnancy, training and recovery. The daily recommended intake of macronutrients, vitamins and minerals are substantially increased during pregnancy.

While achieving a high-quality diet that incorporates essential vitamins and minerals is key to support fetal development, it may be difficult to meet all nutritional needs through diet alone. The World Health Organization recommends routine iron and folic acid supplementation to support maternal and fetal health (Tuncalp et al., 2020). Folic acid supports normal fetal brain and spinal cord development, reducing the risk of neural tube defects (e.g., spina bifida and anencephaly). Female athletes commonly experience iron deficiency, and this may be compounded by pregnancy where one in four are affected (Holtzman & Ackerman, 2021; O'Brien & Ru, 2017). In addition to the known detrimental impacts on performance and recovery, iron deficiency in pregnancy is associated with preterm birth (< 37 weeks gestation) and low birthweight (< 2500g) (Burden et al., 2015; Rahmati et al., 2020; Young et al., 2019). Therefore, ensuring sufficient iron intake is crucial for pregnant female athletes. This can be achieved by incorporating iron-rich foods, like red meat and leafy greens, and by taking supplements if recommended by a healthcare provider.

Some of the most profound adaptations relevant to pregnant athletes occur within the cardiorespiratory systems. Heart rate starts to rise by the second trimester and increases by 15-20% by term. This means

that the interpretations of resting heart rate as a marker of aerobic (over) training needs to be adjusted, as do heart rate-based targets for exercise intensity (Mottola et al., 2018). Utilizing heart rate reserve to account for the progressive increase in resting heart rate, alongside perceived exertion is recommended to guide training intensity. In addition to elevated heart rates, maternal blood volume increases by 50% and is associated with a 30% (1.5 L) increase in cardiac output (Meah et al., 2016). As a result, the heart strengthens and grows during pregnancy, and this effect can persist into the postpartum period. In some cases, this may actually improve exercise capacity, particularly in aerobic sports.

Adequate hydration during pregnancy is essential to support increased blood volume, as well as amniotic fluid volume (the fluid surrounding the fetus within the amniotic sac) and fetal development. Pregnant women are typically recommended to increase fluid intake to 3.0 L/day (~300 mL/day over preconception needs) (Medicine, 2005). However, hydration requirements will be impacted by a wide variety of factors including volume of exercise, ambient temperature and vomiting (e.g., morning sickness). Although hydration needs vary widely between individuals, a reasonable proxy for hydration is the color of urine. Those with clearer urine have better hydration while those who produce dark yellow urine should be encouraged to drink more fluids throughout the day.

As the fetus grows, the diaphragm rises 3-4 cm to accommodate the increased size of the uterus. This results in a 20% decrease in functional residual capacity. Simultaneously, the stimulating effects of

sex hormones (i.e., progesterone) causes a significant rise in overall ventilation reaching as much as 50% over preconception levels. As a result, hyperventilation and breathlessness are a normal physiological change in pregnant women at rest, and these sensations can be exacerbated during exercise.

SCREENING FOR CONTRAINDICATIONS

While exercise is safe and beneficial during most pregnancies, there are key medical conditions or contraindications that can develop in a small number of pregnant women where exercise may not be recommended due to the potential for harm to either the mother or baby. The Get Active Questionnaire for Pregnancy (<https://csep.ca/2021/05/27/get-active-questionnaire-for-pregnancy/>) is a self-administered exercise pre-participation screening tool available in nine languages that is designed to identify whether consultation with a primary healthcare provider is required before beginning or continuing to exercise during pregnancy (Davenport et al., 2022). This questionnaire should be re-administered anytime health status changes throughout pregnancy.

Relative contraindications (see Table 1) are those where moderate-to-vigorous physical activity may continue normally, or with modification to the intensity, duration or modality of exercise. In contrast, in the presence of absolute contraindication, engaging in moderate-to-vigorous physical activity is not advised until the condition resolves, but activities of daily living may continue in consultation with an athlete's obstetric healthcare provider (Mottola et al., 2018).

Relative Contraindications	Absolute Contraindications
<ul style="list-style-type: none"> • Recurrent pregnancy loss. • Gestational hypertension. • A history of spontaneous preterm birth. • Mild/moderate cardiovascular or respiratory disease. • Symptomatic anemia. • Malnutrition. • Eating disorder. • Twin pregnancy after the 28th week. • Other significant medical conditions. 	<ul style="list-style-type: none"> • Ruptured membranes. • Premature labor. • Unexplained persistent vaginal bleeding. • Placenta previa after 28 weeks' gestation. • Pre-eclampsia. • Incompetent cervix. • Intrauterine growth restriction. • High-order multiple pregnancy (e.g., triplets). • Uncontrolled type I diabetes. • Uncontrolled hypertension. • Uncontrolled thyroid disease. • Other serious cardiovascular, respiratory or systemic disorders.
<p><i>Relative</i> contraindications are those where moderate-to-vigorous physical activity may continue normally, or with modification to the intensity, duration or modality of exercise. <i>Absolute</i> contraindications, engaging in moderate-to-vigorous physical activity, is not advised until the condition resolves, but activities of daily living may continue in consultation with an athlete's obstetric healthcare provider.</p>	

Table 1: Absolute and relative contraindications to physical activity during pregnancy (adapted from Mottola et al., 2019, with permission).

COMMON PREGNANCY COMPLICATIONS

The key concern for many athletes in early pregnancy is the risk of miscarriage. The fact is, ~1 in 4 women will experience a miscarriage. However, current evidence does not support a link between exercise and risk of having a miscarriage (Davenport et al., 2019). Nonetheless, a miscarriage can be a devastating and emotionally difficult experience, compounded by persistent misinformation and stigma regarding exercise during pregnancy. It is essential to have a supportive personal and sporting environment, with space to grieve and recover both physical and mental health.

We know 1 in 7 women experience depression during pregnancy, which if untreated increases the risk of preterm delivery and having a small baby. Conversely, we have shown that engaging in regular exercise reduces the risk of mild to moderate depression by 67% (Davenport et al., 2018). However, the intersection between sport, pregnancy and mental health is poorly understood and currently, there is no specific research on pregnant athletes. In the absence of specific evidence, it is practical to encourage athletes to remain connected to team-mates, coaches and staff, and remain involved in training at the discretion of the athlete to support both physical and mental health.

Changes in metabolism can predispose some women to develop a pregnancy-specific form of diabetes called gestational diabetes mellitus (GDM) (Feig et al., 2018). While continued participation in exercise reduces the risk of developing GDM by ~40% (Davenport et al., 2018) even highly active individuals may still develop this condition. Frequent glucose monitoring is recommended for those with GDM, and in cases where glucose cannot be managed by diet and exercise alone, insulin may be required. While the risk of low blood glucose levels and associated dizziness, weakness and pallor with exercise is very low in pregnancy, those who take insulin are at higher risk and are encouraged to ensure they eat prior to exercise to avoid hypoglycemia. They should adjust their insulin requirements in consultation with their healthcare provider if prone to low blood glucose.

During “healthy” pregnancies maternal blood pressure is maintained or decreases slightly mid-pregnancy due to peripheral vasodilation. However, up to 15% of pregnant individuals will develop hypertensive disorders during pregnancy (chronic hypertension, gestational hypertension and preeclampsia). Preeclampsia is a severe condition and is a leading cause of maternal/fetal mortality. Exercise has been recognized as a frontline-preventative therapy to reduce the risk of hypertension in pregnancy, reducing the risk by 41% (Davenport et al., 2018; Magee et al., 2022). Although gestational and chronic hypertension are no longer contraindications to exercise during pregnancy, close monitoring by health-care providers is recommended. Preeclampsia remains a contraindication to exercise during pregnancy, but athletes may stay engaged in activities of daily living in consultation with their obstetric care provider as bedrest is no longer recommended for this condition.

More than a third of pregnant women will experience anemia or iron deficiency during pregnancy (Stevens et al., 2013). In addition to

the characteristic fatigue and exercise intolerance, anemia has been associated with an increased risk of preterm birth and other issues. While dietary changes including iron-rich foods such as red meat or iron supplementation can help prevent anemia, athletes may be at higher risk for anemia prior to pregnancy and should be screened if excessive fatigue develops.

Stress urinary incontinence is the involuntary leakage of urine with activities such as jumping, coughing or sneezing. Nearly two-thirds of pregnant women experience urinary incontinence. Since this condition is also very common in athletes, it is likely more prevalent in pregnant athletes. Pregnant women are encouraged to speak to a pelvic health physiotherapist for both prevention and management of this and other related conditions, as pelvic floor muscle training can reduce both the severity and prevalence of this condition by ~50% (Davenport et al., 2018).

EXERCISE AND THE PREGNANT ATHLETE

Up until the 1980's, traditional thinking supported a reduction in physical activity due to the longstanding view that pregnancy was a fragile state and time to rest and relax. Pioneering research challenged this narrative with evidence to the contrary, underlying the first guidelines for exercise during pregnancy by the American College of Obstetricians and Gynaecologists in 1985. However, these revolutionary guidelines were conservative in their recommendations, suggesting the now infamous recommendation not to exceed a heart rate of 140 bpm. While there is now extensive literature supporting the safety and benefits of vigorous intensity training, even during the third trimester, this idea persists (Wowdzia et al., 2020).

The majority of current physical activity guidelines for pregnancy around the world encourage regular engagement in at least 150 min/week of moderate intensity aerobic and resistance exercise. In the general population, meeting these guidelines is associated with many health benefits (examples above) without increasing the risk of having a miscarriage, or baby born early or small. Yet, athletes regularly exceed this volume often on a daily basis. The health outcomes of pregnant athletes are less studied but existing research is supportive, demonstrating similar health benefits to less active counterparts (Beetham et al., 2019; Wowdzia et al., 2020).

Over recent years, many international organizations have stated their commitment to gender equity in sport including the International Olympic Committee's (IOC) goal for "promotion of women in sport at all levels and in all structures." However, in order to achieve this goal, strong policies and guidance are necessary to ensure that athletes, coaches and healthcare providers are able to make evidence-informed decisions about continued training during pregnancy. Although moderate exercise is safe and beneficial for the general obstetric population, much less is known when we push the boundaries of current guidelines regarding duration, intensity and volume of training during pregnancy. As a result, pregnant athletes often face negative criticism and societal stigma by colleagues, media and the public alike (McGannon et al., 2012). During

pregnancy, athlete training volume typically declines because of limited guidance on what is safe, contributing to fear and anxiety and lack of support to remaining in sport (Culvin & Bowes, 2021; Davenport et al., 2021). Indeed, several studies have demonstrated that sport and exercise participation declines in pregnant athletes due, at least in part, to a lack of research and policy in this area (Borodulin et al., 2008; Evenson et al., 2004).

In 2016/2017 the IOC produced a series of documents outlining the state of evidence to develop guidance for pregnant athletes (Bø et al., 2016). Given the paucity of studies in pregnant athletes at the time, the panel had limited ability to develop athlete-specific recommendations but provided general guidance following the principals of exercise prescription in the general obstetric population.

The IOC Panel recommended that women who continue to engage in elite sport and/or exercise substantially beyond general guidelines be closely monitored by their obstetric healthcare provider to monitor fetal growth and development, and the development of potential contraindications to exercise (Bø et al., 2016). Having an athlete-centred obstetric and sporting team to support both the clinical aspects of pregnancy, as well as sport-specific considerations is optimal but in all cases the athlete should play a prominent role in decision making (Jackson et al., 2022). Consistent and open communication is essential when laying out a plan for training, with clear, written, adaptable protocols to be flexible as the athlete's mental and physical health, as well as their desire to continue training, changes with the progression of pregnancy. Maintaining an open conversation between the pregnant woman, her coaches and medical providers is critical since the safety of high-level training during pregnancy has not been well-studied.

MANAGING RISK TO MAXIMIZE BENEFITS

As trailblazing mother-athletes gain visibility in both research literature and media, the global acceptance and encouragement of these athletes continues to grow. At the same time, new research is finally providing the evidence needed to inform recommendations. A recent systematic review of the literature examining the impact of elite-level sport immediately before pregnancy found evidence that elite athletes have reduced risk of pregnancy-related low-back pain and increased risk of excessive weight gain compared with active/sedentary controls (Wowdzia et al., 2020). Athlete, coaches and healthcare professionals alike need to balance the training demands of sport by identifying the risks versus benefits of physical (e.g., potential for adverse pregnancy outcomes vs. detraining), and psychological health (mental health impacts of training vs. detraining). The change in the balance of risk versus benefit may change frequently as pregnancy progresses, thus open communication with the athlete at the center of all decision making is essential (Figure 1).

The 2016/2017 IOC guideline recommends avoiding a number of activities that recreational and elite athletes would commonly encounter during their daily training (Bø et al., 2016). The recommendation to avoid exercise intensities above 90% of maximal effort was based on the findings of two studies that showed transient signs of fetal distress with progressive exercise to maximal effort lasting 20-30 min (Salvesen et al., 2011; Szymanski & Satin, 2012). However, a growing body of contemporary work has suggested that shorter bouts of high intensity exercise may be tolerated by mother and fetus. Recently, we demonstrated no adverse maternal or fetal responses to a session of high intensity interval training (HIIT) involving 10 x 1 min intervals > 90% heart rate max (Wowdzia et al., 2022; Wowdzia et al., 2023).



Figure 1: Supporting pregnant athletes to maintain sport participation.

These data also demonstrated similar glucose responses to both HIIT and more traditional moderate intensity continuous exercise, and the potential for an improvement in the duration of maternal sleep following exercise. These findings demonstrated an alternative for athletes to engage in high intensity exercise to maintain fitness, without adversely affecting the fetus. Further, a recent meta-analysis demonstrated no impact of engaging in vigorous intensity physical activity on maternal and fetal health outcomes during pregnancy (e.g., birthweight, low birth weight, maternal weight gain) (Beetham et al., 2019).

The IOC also recommended athletes focus on technique and safety during strength training (Bø et al., 2016). It is essential that proper technique is maintained, and athletes engaged in Olympic lifting and other bar work should be monitored to ensure the growing belly does not alter the bar path. Nonetheless, emerging evidence has argued for the continuation of resistance training (including heavy weightlifting). In a cross-sectional survey of 679 athletes engaged in resistance exercise > 80% 1 repetition maximum (RM) before and during pregnancy, the majority of respondents reported no pregnancy complications while continuing to engage in activities discouraged by many prenatal physical activity guidelines (Olympic lifting, Valsalva maneuver, supine exercise). Indeed, those who maintained pre-pregnancy resistance training until delivery had a 51% reduction in the odds of having pregnancy and delivery complications than those who reduced their training level prior to delivery (Prevett et al., 2023). Only two studies have examined the fetal responses to higher load resistance exercise during pregnancy. The first found no adverse effect of supine bench press (up to 50 lbs. or ~23 kg) on placental blood flow (Gould et al., 2021). The second examined the impact of back squat, supine bench press and deadlifts up to 90% 10 RM (~75% 1RM) with and without the Valsalva maneuver, and found both the mother and fetus well tolerated the load with no signs of fetal distress (Moolyk et al., 2023). These key data support the safety of high-intensity resistance training during pregnancy and are foundational for much needed additional work.

Athletes who participate in full contact sports (e.g., boxing) are recommended to avoid these activities during pregnancy (Bø et al., 2016), while training during the first trimester may continue in sports where some contact or risk of falling may occur (e.g., soccer, downhill skiing). Key concerns include the potential for direct trauma, and risk of placental abruption (separation of the placenta from the uterus). However, this recommendation is based on expert opinion only as there is no empirical evidence available. Nonetheless, although cessation of contact sport is recommended to reduce the risk to the fetus, it is essential that athletes continue with non-contact training with their team (with or without other modifications) for as long as the athlete is able and wishes to in order to support their mental and physical health.

Much like other areas of elite sport, there is limited evidence supporting a maximal duration of exercise during pregnancy. Key concerns of exercise exceeding 45-60 min include the potential for compromised blood flow to the baby, maternal hyperthermia harming the baby and long duration exercise sessions increasing the risk of premature

labor. However, a systematic review of acute and chronic exercise on low to vigorous intensity exercise found fetal heart rate did not show signs of distress, and umbilical and uterine blood flow (i.e., blood flow delivered to the fetus) was not compromised in testing lasting < 60 min (Skow et al., 2019). Similarly, under room temperature conditions maternal core temperature did not cross teratogenic (substance that interferes with fetal development) thresholds, even up to vigorous intensities (Ravanelli et al., 2018). While data on fetal health is absent for longer durations, case studies of a twin marathoner, skier, cyclist, ultramarathoner and others, as well numerous media representations of pregnant athletes training and competing for durations exceeding an hour provide reassuring data and demonstrate proof of concept, although not proof of safety. In the absence of empirical evidence, all athletes considering engaging in exercise sessions over an hour are encouraged to consult with their obstetric care provider, maintain adequate hydration and fueling during exercise, as well as reduce the risk of potential hyperthermia by training in cooler environments. Indeed, global physical activity guidelines caution against exercise in high heat and humidity due to theoretical risk of overheating and dehydration. Although the sole study of moderate intensity exercise under conditions of moderate heat and humidity (32 °C, 45% relative humidity) presented reassuring data on the ability to thermoregulate and maintain core temperature under these conditions, no data are currently available under warmer conditions or high intensity exercise. Therefore, caution and taking key precautions (described above) are recommended until research is available. Exercise at high altitude (< 2500 m) has also been cautioned for athletes born and living at lower altitudes until appropriate acclimatization has been achieved (Keyes & Sanders, 2023).

The anatomical changes of pregnancy include the growing belly and breasts, as well as alterations in the musculoskeletal system and may require alterations in sporting equipment and clothing. A high support bra that minimizes breast movement without being restrictive can help to reduce breast pain with exercise (White et al., 2015). As gestation increases and the belly grows, it is important that clothing and equipment around the abdomen are not overly restrictive to maintain comfort. Some athletes may also benefit from additional supports such as belly bands if higher impact activities become uncomfortable. It is not unusual for foot size to change during pregnancy and ensuring adequate fit is essential.

While traditionally it was believed that pregnancy was the end of an athletic career, there is growing support that for some pregnancy may enhance athletic performance. A systematic review of available evidence found that athletes who returned to the high-performance setting were able to meet or beat their pre-conception personal best performance, which has been supported by more recent cohort data (Darroch et al., 2023; Forstmann et al., 2022; Wowdzia et al., 2020). However, remaining in sport during and following pregnancy is critically facilitated by social and financial support from teammates, support staff and sporting organizations. There have been growing calls to action for national and international sport organizations to develop clear,

written policies to support pregnant athletes. Similarly, sport-specific guidance is urgently needed to support continued sport participation during pregnancy. The gestational period also provides essential time to develop goals and associated plans on “how” and “when” to return to sport postpartum (Donnelly et al., 2022). While validation efforts are ongoing, concerted, athlete-centered efforts between the research and sporting worlds are essential to support athletes and their potential.

PRACTICAL APPLICATIONS

- In the absence of contraindications, exercise is encouraged throughout pregnancy.
- Athletic training should be supported by open communication between the obstetric care provider and coach(s), with the athlete as the key voice in decision-making.
- Know the key reasons to stop exercise and consult a healthcare provider when there are signs of:
 - Persistent, excessive shortness of breath that does not resolve on rest
 - Severe chest pain
 - Regular and painful uterine contractions
 - Vaginal bleeding
 - Persistent loss of fluid from the vagina indicating rupture of membranes
 - Persistent dizziness or faintness that does not resolve on rest
- Understand key physiological changes in pregnancy to adapt training and monitoring, as well as key safety precautions (e.g., avoid activities with a high risk of contact or falling, exercise in excessive heat and humidity, etc.).
- Take a holistic view in training, recognizing the substantial physical, mental and societal changes occurring, including a transition in identity.
 - Recognize the impact of the athletes’ environment (social, financial supports), adequate recovery (sleep and fueling), mental and physical health on training.

SUMMARY

The meteoric rise in women’s sport combined with the unique physiological and biopsychosocial challenges of pregnancy underscores the critical need for dedicated research and support for pregnant athletes. Investing in more research will not only support the health and well-being of pregnant athletes but promote a more inclusive and equitable sporting environment.

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REFERENCES

- Beetham, K.S., Giles, C., Noetel, M., Clifton, V., Jones, J.C., & Naughton, G. (2019). The effects of vigorous intensity exercise in the third trimester of pregnancy: a systematic review and meta-analysis. *BMC Pregnancy Childbirth*, 19(1), 281.
- Bø, K., Artal, R., Barakat, R., Brown, W., Davies, G.A.L., Dooley, M., Evenson, K.R., Haakstad, L.A.H., Henriksen-Larsen, K., Kayser, B., Kinnunen, T.I., Mottola, M.F., Nygaard, I., van Poppel, M., Stuge, B., & Khan, K.M. (2016). Exercise and pregnancy in recreational and elite athletes: 2016 evidence summary from the IOC expert group meeting, Lausanne. Part 1—exercise in women planning pregnancy and those who are pregnant. *British Journal of Sports Medicine*, 50(10), 571-589.
- Borodulin K.M., Evenson K.R., Wen F, Herring A.H., Benson A.M. Physical activity patterns during pregnancy. *Med Sci Sports Exerc*. 2008 Nov;40(11):1901-8.
- Burden, R.J., Morton, K., Richards, T., Whyte, G.P., & Pedlar, C.R. (2015). Is iron treatment beneficial in, iron-deficient but non-anaemic (IDNA) endurance athletes? A systematic review and meta-analysis. *Br J Sports Med*, 49(21), 1389-1397.
- Butte, N.F., Wong, W.W., Treuth, M.S., Ellis, K.J., & O’Brian Smith, E. (2004). Energy requirements during pregnancy based on total energy expenditure and energy deposition. *Am J Clin Nutr*, 79(6), 1078-1087.
- Culvin, A., & Bowes, A. (2021). The incompatibility of motherhood and professional football in England. *Frontiers in Sport Active Living*, 3, 1-13.
- Darroch, F., Schneeberg, A., Brodie, R., Ferraro, Z.M., Wykes, D., Hira, S., Giles, A.R., Adamo, K.B., & Stellingwerff, T. (2023). Effect of Pregnancy in 42 Elite to World-Class Runners on Training and Performance Outcomes. *Med Sci Sports Exerc*, 55(1), 93-100.
- Davenport, M.H., Kathol, A.J., Mottola, M.F., Skow, R.J., Meah, V.L., Poitras, V.J., Jaramillo Garcia, A., Gray, C.E., Barrowman, N., Riske, L., Sobierajski, F., James, M., Nagpal, T., Marchand, A.A., Slater, L.G., Adamo, K.B., Davies, G.A., Barakat, R., & Ruchat, S.M. (2019). Prenatal exercise is not associated with fetal mortality: a systematic review and meta-analysis. *Br J Sports Med*, 53(2), 108-115.
- Davenport, M.H., McCurdy, A.P., Mottola, M.F., Skow, R.J., Meah, V.L., Poitras, V.J., Jaramillo Garcia, A., Gray, C.E., Barrowman, N., Riske, L., Sobierajski, F., James, M., Nagpal, T., Marchand, A.A., Nuspl, M., Slater, L.G., Barakat, R., Adamo, K.B., Davies, G.A., & Ruchat, S.M. (2018). Impact of prenatal exercise on both prenatal and postnatal anxiety and depressive symptoms: a systematic review and meta-analysis. *Br J Sports Med*, 52(21), 1376-1385.
- Davenport, M.H., N.A., Ray L, Thornton J, Khurana R, McHugh TLF. (2021). Pushing for change: A description of elite athletes’ experiences of pregnancy. *Br J Sports Med*.
- Davenport, M.H., Nagpal, T.S., Mottola, M.F., Skow, R.J., Riske, L., Poitras, V.J., Jaramillo Garcia, A., Gray, C.E., Barrowman, N., Meah, V.L., Sobierajski, F., James, M., Nuspl, M., Weeks, A., Marchand, A.A., Slater, L.G., Adamo, K.B., Davies, G.A., Barakat, R., & Ruchat, S.M. (2018). Prenatal exercise (including but not limited to pelvic floor muscle training) and urinary incontinence during and following pregnancy: a systematic review and meta-analysis. *Br J Sports Med*, 52(21), 1397-1404.
- Davenport, M.H., Neil-Sztramko, S.E., Lett, B., Duggan, M., Mottola, M.F., Ruchat, S.M., Adamo, K.B., Andrews, K., Artal, R., Beamish, N.F., Chari, R., Forte, M., Lane, K.N., May, L.E., Maclaren, K., & Zahavich, A. (2022). Development of the Get Active Questionnaire for Pregnancy: Breaking down barriers to prenatal exercise. *Appl Physiol Nutr Metab*.
- Davenport, M.H., Ruchat, S.M., Poitras, V.J., Jaramillo Garcia, A., Gray, C.E., Barrowman, N., Skow, R.J., Meah, V.L., Riske, L., Sobierajski, F., James, M., Kathol, A.J., Nuspl, M., Marchand, A.A., Nagpal, T.S., Slater, L.G., Weeks, A., Adamo, K.B., Davies, G.A., . . . Mottola, M.F. (2018). Prenatal exercise for the prevention of gestational diabetes mellitus and hypertensive disorders of pregnancy: a systematic review and meta-analysis. *Br J Sports Med*, 52(21), 1367-1375.
- Donnelly, G.M., Moore, I.S., Brockwell, E., Rankin, A., & Cooke, R. (2022). Reframing return-to-sport postpartum: the 6 Rs framework. *Br J Sports Med*, 56(5), 244-245.
- Evenson, K.R., Savitz, D.A., & Huston, S.L. (2004). Leisure-time physical activity among pregnant women in the US. *Paediatric and perinatal epidemiology*, 18(6), 400-407.
- Feig, D.S, Berger, H., Donovan, L., Godbout, A., Kader, T., Keely, E., et al. . (2018). Diabetes Canada 2018 Clinical Practice Guidelines for the Prevention and Management of Diabetes in Canada: Diabetes and Pregnancy. *Can J Diabetes*, 42, S1-S325.

- Forstmann, N., Meignié, A., Laroche Lambert, Q., Duncombe, S., Schaal, K., Maître, C., Toussaint, J.F., & Antero, J. (2022). Does maternity during sports career jeopardize future athletic success in elite marathon runners? *Eur J Sport Sci*, 1-21.
- Gould, S., Cawyer, C., Dell'Italia, L., Harper, L., McGwin, G., & Bamman, M. (2021). Resistance Training Does Not Decrease Placental Blood Flow During Valsalva Maneuver: A Novel Use of 3D Doppler Power Flow Ultrasonography. *Sports Health*, 13(5), 476-481.
- Holtzman, B., & Ackerman, K.E. (2021). Recommendations and Nutritional Considerations for Female Athletes: Health and Performance. *Sports Med*, 51(Suppl 1), 43-57.
- Jackson, T., Bostock, E.L., Hassan, A., Greeves, J.P., Sale, C., & Elliott-Sale, K.J. (2022). The Legacy of Pregnancy: Elite Athletes and Women in Arduous Occupations. *Exerc Sport Sci Rev*, 50(1), 14-24.
- Keyes, L.E., & Sanders, L. (2023). Pregnancy and Exercise in Mountain Travelers. *Curr Sports Med Rep*, 22(3), 78-81.
- Magee, L.A., Nicolaidis, K.H., & von Dadelszen, P. (2022). Preeclampsia. *N Engl J Med*, 386(19), 1817-1832.
- McGannon K.R., C.K., Schinke R.J., Schweinbenz A.N. (2012). (De)constructing Paula Radcliffe: Exploring media representations of elite running, pregnancy and motherhood through cultural sport psychology. *Psychology of Sport & Exercise*, 13, 820-829.
- Meah, V.L., Cockcroft, J.R., Backx, K., Shave, R., & Stohr, E.J. (2016). Cardiac output and related haemodynamics during pregnancy: a series of meta-analyses. *Heart*, 102(7), 518-526.
- Medicine, I.O. (2005). *Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate*. The National Academies Press.
- Moolyk A.W.M., Matenchu B., Bains G., Gervais M., Wowdzia J., Davenport M.H. (2023). Maternal and fetal responses to acute high-intensity resistance exercise during pregnancy. WCHRI Research Day.
- Mottola, M.F., Davenport, M.H., Ruchat, S.M., Davies, G.A., Poitras, V.J., Gray, C.E., Jaramillo Garcia, A., Barrowman, N., Adamo, K.B., Duggan, M., Barakat, R., Chillibeck, P., Fleming, K., Forte, M., Korolnek, J., Nagpal, T., Slater, L.G., Stirling, D., & Zehr, L. (2018). 2019 Canadian guideline for physical activity throughout pregnancy. *British Journal of Sports Medicine*, 52(21), 1339-1346.
- O'Brien, K.O., and Ru, Y. (2017). Iron status of North American pregnant women: an update on longitudinal data and gaps in knowledge from the United States and Canada. *Am J Clin Nutr*, 106(Suppl 6), 1647s-1654s.
- Prevett, C., Kimber, M.L., Forner, L., de Vivo, M., & Davenport, M.H. (2023). Impact of heavy resistance training on pregnancy and postpartum health outcomes. *Int Urogynecol J*, 34(2), 405-411.
- Rahmati, S., Azami, M., Badfar, G., Parizad, N., & Sayehmiri, K. (2020). The relationship between maternal anemia during pregnancy with preterm birth: a systematic review and meta-analysis. *J Matern Fetal Neonatal Med*, 33(15), 2679-2689.
- Ravanelli, N., Casasola, W., English, T., Edwards, K.M., & Jay, O. (2018). Heat stress and fetal risk. Environmental limits for exercise and passive heat stress during pregnancy: a systematic review with best evidence synthesis. *British Journal of Sports Medicine*, 53(13), 799-805.
- Salvesen, K.Å., Hem, E., & Sundgot-Borgen, J. (2011). Fetal wellbeing may be compromised during strenuous exercise among pregnant elite athletes. *British Journal of Sports Medicine*, 46(4), 279-283.
- Skow, R.J., Davenport, M.H., Mottola, M.F., Davies, G.A., Poitras, V.J., Gray, C.E., Jaramillo Garcia, A., Barrowman, N., Meah, V.L., Slater, L.G., Adamo, K.B., Barakat, R., & Ruchat, S.M. (2019). Effects of prenatal exercise on fetal heart rate, umbilical and uterine blood flow: a systematic review and meta-analysis. *Br J Sports Med*, 53(2), 124-133.
- Stevens, G.A., Finucane, M.M., De-Regil, L.M., Paciorek, C.J., Flaxman, S.R., Branca, F., Peña-Rosas, J. P., Bhutta, Z.A., & Ezzati, M. (2013). Global, regional, and national trends in haemoglobin concentration and prevalence of total and severe anaemia in children and pregnant and non-pregnant women for 1995-2011: a systematic analysis of population-representative data. *Lancet Glob Health*, 1(1), e16-25.
- Szymanski, L.M., & Satin, A.J. (2012). Exercise during pregnancy: fetal responses to current public health guidelines. *Obstet Gynecol*, 119(3), 603-610.
- Tuncalp, Ö., Rogers, L.M., Lawrie, T.A., Barreix, M., Peña-Rosas, J.P., Bucagu, M., Neilson, J., & Oladapo, O.T. (2020). WHO recommendations on antenatal nutrition: an update on multiple micronutrient supplements. *BMJ Glob Health*, 5(7).
- White, J., Mills, C., Ball, N., & Scurr, J. (2015). The effect of breast support and breast pain on upper-extremity kinematics during running: implications for females with large breasts. *J Sports Sci*, 33(19), 2043-2050.
- Wowdzia, J.B., Hazell, T.J., & Davenport, M.H. (2022). Glycemic response to acute high-intensity interval versus moderate-intensity continuous exercise during pregnancy. *Physiol Rep*, 10(18), e15454.
- Wowdzia, J.B., H.T., Vanden Berg, E.R., Labrecque, L., Brassard, P., Davenport, M.H. (2023). Maternal and fetal cardiovascular responses to acute high-intensity interval and moderate-intensity continuous training exercise during pregnancy: A randomised crossover trial. *Sports Medicine*.
- Wowdzia, J.B., McHugh T-L., Thornton, J., Sivak, A., Mottola, M.F., Davenport M.H. (2020). Elite Athletes and Pregnancy Outcomes: A Systematic Review and Meta-Analysis. *Med Sci Sports Exerc*.
- Young, M.F., Oaks, B.M., Tandon, S., Martorell, R., Dewey, K.G., Wendt, A.S. (2019). Maternal hemoglobin concentrations across pregnancy and maternal and child health: a systematic review and meta-analysis. *Ann N Y Acad Sci*, 1450(1), 47-68.