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Pregnancy in the female athlete Part 1: antenatal

By ***Guy Pitchers[1], Kirsty Elliott-Sale[2], Marlize DeVivo[1], Thomas Donelon[1], Hayley Mills[1], Emma Brockwell[3]*** *and* ***Grainne Donnelly[4],***
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OVERVIEW

As female participation in sport and exercise continues to increase, there is a strong likelihood that a strength and conditioning (S&C) coach will work with a pregnant athlete. High profile athletes such as Serena Williams and Dame Jessica Ennis-Hill have shown recently that it is not uncommon for female athletes to become mothers during their careers, rather than after they have retired. However, historically pregnancy was perceived as time spent away from sport and being active was wrongly associated with a high, unreasonable risk to the unborn foetus. The challenge for the S&C coach working with pregnant athletes is navigating the wide range of global recommendations that are often aimed at active or inactive individuals, but not at elite athletes. It is fundamental that any coach working with pregnant athletes is knowledgeable about the physiological and anatomical changes that occur throughout the trimesters, the nutritional demands of pregnancy, and its effect on weight management in order to appropriately facilitate athlete and foetal health during the antenatal period. Therefore, the aim of this initial review is to summarise current literature and provide key insights that promote best practice for practitioners working with pregnant athletes. The use of 'women' throughout this paper will refer to the general population and 'sportswomen' to the athletic population. 'Antenatal' refers to a pregnant woman before childbirth and the term 'postnatal' means after childbirth, something which will be covered in part 2 of this review series.

Anatomical and physiological changes throughout pregnancy

The average pregnancy lasts 38 weeks after ovulation. The gestation period (carrying of embryo/foetus) is subdivided into three relatively equal trimesters. Throughout gestation, many changes occur within the body to maintain the biological homeostasis. Changes within the cardiovascular system are gradual: resting cardiac output can increase by 50%, resting heart rate by 15-20 bpm, stroke volume by 10% and blood volume by 45-50%.[2,23,25,48,49,50,58] As such, increases in heart rate, stroke volume and cardiac output should not be used as markers of training.[47] Blood plasma volume can increase by 10% as early as the seventh week;[45] these increases in blood plasma volume are required because of vascular dilations and to ensure that blood pressure does not decrease too much.[41]

Furthermore, changes in blood volume allow an increased supply of nutrients to, and remove waste products from, the uterus and placenta.[33] Rapid growth of the foetus in the third trimester poses the greatest risk of anaemia; however, practitioners should be mindful not to incorrectly diagnose anaemia due to changes to blood volume.[47]

Specific hormones mediate essential anatomical and physiological functions for the foetus and mother. The corpus luteum (mass of cells on the ovary) is the main source of pregnancy-specific hormones during the first six to eight weeks of gestation before the placenta takes over the role.[59] Oestrogen stimulates breast growth and growth of the ducts within the breasts; it also increases prostaglandin and oxytocin production, which assist during labour.[59] Cortisol and thyroid hormones also increase to meet metabolic demands during pregnancy.[26,59] Relaxin and progesterone have key roles in preparing the mother for giving birth and increasing the mobility of joints. As the foetus and mother grow in size and mass, likely postural changes include: increased lordosis, anterior tilt in the pelvis, flexion in cervical spine, and abduction and depression of the shoulder girdle.[56]

The respiratory system also adapts to ensure oxygen supply to the placenta. Lowering maternal partial pressure of carbon dioxide is required to facilitate the exchange of carbon dioxide (CO_2) from the foetus.[20,30] Progesterone mediates these changes as it decreases CO_2 threshold and increases minute volume.[20,30] Vital capacity is unaltered, but decreases are observed in lung capacity, residual volume and VO_2max.[2,37,47] The increasing size of the uterus will displace the diaphragm upwards and increased relaxin and progesterone in the second and third trimester will increase the muscular demand to compress the ribs during breathing.[47]

'Micronutrient deficiencies are common during pregnancy'

Nutrition and weight management

Contrary to the popular idiom 'eating for two', the nutritional requirements of pregnancy are not overly different from the non-pregnant state. The Institute of Medicine[29] prescribes energy intake based on each trimester, with no additional calories needed in the first trimester and an additional 340 kcal·d^{-1} and 452 kcal·d^{-1} needed for the second and third trimesters. Butte et al[17] further refined these recommendations on the basis of pre-pregnancy BMI; they suggested that underweight women should increase their daily energy intake (DEI) by 150, 200 and 300 kcal·d^{-1} during the first, second and third trimesters, normal weight women should increase their DEI by 0, 350 and 500 kcal·d^{-1} and obese women should increase their DEI by 0, 450 and 350 kcal·d^{-1}. Therefore, to avoid excessive gestational weight gain, pregnant women should limit themselves to within these ranges. Nutritional modulation has been shown to be an effective strategy for weight management during pregnancy (for a review on this topic, see Elliott-Sale et al[24]). Sportswomen who continue to exercise during pregnancy will need to further adjust their dietary intakes based on the type, intensity, frequency, and duration of the exercise performed. As such, Silva et al[54] recommend that, to maintain adequate energy availability during pregnancy, eating before (3-4 hours), during, and after physical activity is necessary.

Training times may need to be flexible, should sportswomen be experiencing morning sickness or hyperemesis gravidarum (extreme morning sickness), which typically occurs in the first trimester. Consumption of energy drinks is not recommended because of the high caffeine content.[35] In a team sport setting where it may be not possible to change the times of 'squad' or 'pitch-based' sessions, then having simple carbohydrates available and moving additional sessions (ie, gym) till later in the day or to another day are simple strategies that can be implemented to aid sportswomen.

In terms of dietary composition during pregnancy, 175 g·d^{-1} (usually 130 g·d^{-1}) of carbohydrate and 71 g·d^{-1} (usually 46 g·d^{-1}) of protein is typically recommended, while no change to the daily recommended intake of fat is required.[15,29] Micronutrient deficiencies are common during pregnancy, especially folate, iron and fibre intakes;[27] therefore, eating fruit and vegetables should be encouraged during pregnancy and may also help avoid excessive gestational weight gain.[14]

Preconception

Concerns, questions, and doubts are to be expected when a sportswoman is planning to become pregnant or becomes pregnant. Specific worries might include: (i) practical concerns such as availability of childcare and loss of income; (ii) sporting concerns such as adverse effects on performance; and (iii) medical concerns such as harm to foetal development. It has recently been noted that some sportswomen experienced a reduction or removal of funding or loss of sponsorship during pregnancy.[51] Prior to pregnancy, discussions and education may be required around hormonal contraceptive use, such as the implant, intrauterine devices and oral contraceptives.

Miscarriages sadly occur for a range of reasons, with chromosomal abnormalities being the most common cause. Should women or sportswomen be planning to conceive, Bø et al[10] could find only low to moderate evidence that strenuous exercise seven days post-ovulation can increase risk of miscarriage. Hjollund et al[28] researched the risk of physical strain in Danish women: participants were required to complete a questionnaire, which covered a range of health factors and included physical strain, average workday, standing and lifting loads. The women were instructed to stop their diary recordings once a pregnancy was diagnosed. The results showed that an adjusted risk ratio (RR) for miscarriage was higher in women who reported higher than average physical strain on days 6–9 after the estimated date of ovulation (RR 2.5, 95% CI 1.3 to 4.6). More evidence is required to ascertain if strenuous exercise in sportswomen has a miscarriage risk during implantation.

Exercising in the first trimester

Nausea, vomiting and retching often occur during the first trimester,[31,32] which is when sportswomen may experience a sudden drop in performance. It is important to reassure sportswomen that this is to be expected, and until these symptoms subside training volume and intensity should be revised. Despite research being limited, a coach should always put the health of sportswomen and foetus at the forefront and should any heavy lifting and high intensity exercise be warranted, they should seek guidance from a medical professional. Madsen et al[38] researched the exercise habits of 2,551 women who experienced a miscarriage (<22 weeks gestation); they found that when a woman exercised for more than seven hours a week there was an increased risk of miscarriage (hazard ratio - 3.7 (95% Cl 2.9-4.7)), particularly with high impact exercise (hazard ratio - 4.7 (95% Cl 3.3–5.3)). No association was seen between exercise and risk of miscarriage after 18 weeks of gestation. The results should, however, be interpreted with caution owing to potential bias arising from retrospective data collection.

Further advice for women and sportswomen during the antenatal period includes: avoiding hyperthermia, training at intensities >90% of their VO_2max and high altitude for low land individuals.[8,9] Exercises and activities to avoid throughout gestation include skydiving, scuba diving, contact sports and sports that involve an increased risk of falling such as ice skating.[8] Should a sportswoman and practitioner wish to continue with a sport that is not recommended, then clearance from a medical professional needs to be provided and reviewed regularly.

The current consensus is that the foetus' and mother's well-being during

light and moderate exercise is not compromised and it is recommended that women complete 150 minutes of moderate activity a week throughout pregnancy.[55] When a coach is assessing the intensity of a session with a woman or sportswoman, it would be best practice to use both a heart rate monitor and the talk test. When using the talk test, they should be able to maintain a conversation and the practitioner should reduce the intensity if this is not possible.[44] Regarding heart rate values, moderate intensity is considered 40-59% of heart rate reserve (HRR) and vigorous intensity 60-80% of HRR (see Table 1).[43,44] Caution is required, however, when using a heart rate monitor, due to changes in resting rates: more research into vigorous intensity heart rate ranges is required.[44,47]

Table 1: Heart rate ranges for low-risk pregnant women[44]

MATERNAL AGE	INTENSITY	HEART RATE RANGE (BPM)
<29 years	Light Moderate Vigorous	102-124 125-146 147-169
> 30 years	Light Moderate Vigorous	101-120 121-141 142-162

Limited research exists on weight training during pregnancy. The Valsalva manoeuvre (trapping air in the lungs to create increased pressure) is often used in normal strength training; however, due to rapid changes in blood pressure and reduction in placental blood flow, this is contraindicated.[47] Excessive strain (particularly in isometrics and eccentric exercises) should be avoided or modified to avoid the Valsalva manoeuvre. Schoenfeld[53] recommends the following advice for resistance training during pregnancy: three non-consecutive sessions a week that are total body, mostly single joint exercises; two minutes rest between sets; two-three sets per exercise, <70% 1RM and not to the point of failure.

Exercising during second and third trimester

Sportswomen can continue to train into their second and third trimester. It is recommended to gradually decrease both exercise time and intensity as pregnancy develops:[2] this should be an individualised and not a generalised approach. As the hormone relaxin increases and balance decreases[18,57] during pregnancy, it is fundamental to assess the risk of exercises. Movements such as change of direction or exercises that require high stabilisation and/or impact (ie, plyometrics and ballistic exercises) may have an increased risk due to changes in joint mobility, mass, and change in centre of mass. Within the second and third trimester, any sport, activity or environment that has the potential for contact should be avoided.[8]

Lower back pain and pelvic girdle pain are often symptoms reported in women during pregnancy.[16] Bø and Backe-Hansen[7] researched the prevalence of pelvic girdle pain and back pain in pregnant sportswomen and in an aged-matched pregnant woman. No significant differences were shown for pelvic girdle pain (33.3 vs 30.4%, p = 0.76) and lower back pain (18.5 vs 32.6%, p = 0.20). This suggests that all women might benefit from some form of exercise modification (ie, single arm row instead of bent over row) to ease or not aggravate symptoms during training.

Salvesen et al[52] stated that when sportswomen (23-29 weeks gestation) reach ≥90% maximal maternal heart rate, this could compromise foetal well-being. Although exercise changes uteroplacental blood flow, moderate intensity activity does not pose a health risk despite approximately 25% reduction in blood flow, as the blood supply in the placenta is maintained, but the uterine wall will see a decline in blood flow.[2] Bø et al[8] highlight the lack of research regarding above-moderate intensity training and suggest that particular attention should be given to monitoring foetal development in the second and third trimester. If you are unable to monitor foetal development, this type of activity is not advised regardless of the pre-gravid fitness of the mother.

Exercising in the supine position is associated with a reduced cardiac output and orthostatic hypotension. After the first trimester, symptoms such as light-headedness and nausea are most likely to occur after 28 weeks gestation as the uterus enlarges.[8] Exercises can be modified by putting sportswomen into a sitting/standing position or an incline to reduce the compression from the uterus. However, the research[3,4,44] has shown conflicting results on this and only very low quality evidence supports this concept. Table 2 provides a summary of sports, exercises, training methods and athlete considerations during the preconception and antenatal period. Although Table 2 includes a large body of research,[1,8,9,18,28,38,43,44,47,53,55,57] research specifically for antenatal sportswomen and practitioners is still emerging.

Pelvic floor

The pelvic floor muscles (PFM), along with ligament and fascia, offer structural support to the pelvic organs and continence mechanism. When they work optimally, they prevent pelvic organ prolapse (POP), urinary incontinence (UI) and/or anal incontinence (AI). Effective functionality of this support system is required to counteract the increases in intra-abdominal pressure and ground reaction forces that occur during physical activity. Women who exercise have stronger PFM,[11] but in other studies high impact sport has been shown to weaken the PFM compared to non-exercisers, due to the role the PFM have in counteracting impact and abdominal pressure.[6,13] Continent women who exercise the PFM during pregnancy are 62% less likely to experience UI in late pregnancy and 29% have a lower risk of UI 3-6 months postnatally.[46]

Pregnancy can weaken, lengthen, and overload the pelvic floor. Practitioners should not assume the sportswomen they work with are more capable in performing PFM contractions.[6] Ensuring it is the PFM which are contracted and not other muscle groups

Table 2: Summary of sport, exercise, training methods, modifications and monitoring during the antenatal period for low risk sportswomen

	SPORTS NOT RECOMMENDED	EXERCISES NOT RECOMMENDED	TRAINING METHODS NOT RECOMMENDED	ACTIVITY AND ATHLETE CONSIDERATIONS	RECOMMENDED MONITORING
Preconception	None	None	Increases in training load and intensity	None	Continue with current monitoring of load and intensity
First trimester	– Extreme sports: Scuba diving, skydiving etc – Contact sports: Boxing, rugby, ice hockey etc	- High force and high velocity plyometric exercises: Drop jumps, bounding etc	– Increases in training load and intensity – Altitude training >1,500m in non-acclimatised individuals – Saunas – Valsalva manoeuvre – Strength training >70% 1RM – Activities that result in HR values over 169 (<29 y/o) or 162 (>30 y/o) – Exercises that encourage isometric and/or eccentric actions: Wall sit, tempo training etc	Flexible approach to training time/duration/ intensity if morning sickness occurs	– HR – Talk test
Second trimester	– Extreme sports – Contact sports – Invasion sports: Football, basketball, hockey etc – Sports with a risk of falling: Equestrian, ice skating, hurdles etc	– Plyometric and ballistic exercises – Overhead pressing – Weightlifting and derivatives: power cleans, clean pulls, hang snatch etc – Laying prone or resistance machines where padding is in contact with stomach: Prone row, seated row, back extensions etc – Trunk exercises that include a large ROM and load through the abdomen: Sit-ups, landmine rotations, russian twists – Agility/change of direction exercises	– Increases in training load and intensity – Altitude training >1,500m in non-acclimatised individuals – Saunas – Valsalva manoeuvre – Strength training >70% 1RM – Activities that result in HR values over 169 (<29 y/o) or 162 (>30 y/o) – Exercises that encourage isometric and/or eccentric actions – Unstable surface training or training on an uneven surface – Strenuous stretching (ballistic, PNF) and alterations to certain poses/stretches in yoga and Pilates	– Additional back support – Incline or standing positions over supine – Minimise floor to standing transitions – Wider base of support in free weight exercises – Supportive bra use and encourage bra fit check – Maternity bump support/ belt during walking and running	– HR – Talk test – Monthly foetal assessment from doctor should the practitioner and athlete decide to participate in vigorous activities – Monthly use of readiness to exercise questionnaire
Third trimester	– Extreme sports – Contact sports – Invasion sports – Sports with a risk of falling – Competitive sports where exertions may reach vigorous levels	– Plyometric and ballistic exercises – Overhead pressing – Weightlifting and derivatives – Laying prone or resistance machines where padding is in contact with stomach – Trunk exercises that include a large ROM and load through the abdomen – Agility/change of direction exercises – Hip dominant exercises: RDL, hip thrust, deadlift etc	– Increases in training load and intensity – Altitude training >1,500m in non-acclimatised individuals – Saunas – Valsalva manoeuvre – Strength training >70% 1RM – Activities that result in HR values over 169 (<29 y/o) or 162 (>30 y/o) – Exercises that encourage isometric and/or eccentric actions – Unstable surface training or training on an uneven surface – Strenuous stretching (ballistic, PNF) and alterations to certain poses/stretches in yoga and Pilates	– Additional back support – Incline or standing positions over supine – Minimise floor to standing transitions – Wider base of support in free weight exercises – Supportive bra use and encourage bra fit check – Maternity bump support/ belt during walking and running	– HR – Talk test – Monthly foetal assessment from doctor should the practitioner and athlete decide to participate in vigorous activities – Monthly use of readiness to exercise questionnaire

may require assessment from the medical department. Sportswomen may wish to self-test by placing one hand on the perineum and when contracting feel it lifting away from the hand by 'squeezing and lifting' as opposed to 'squeezing and pushing'. Exercises focused on the PFM should be included in the antenatal programme. Bø et al[12] recommend 6-8 seconds of maximal pelvic floor contractions, repeated 8-12 times, three times a day, which can be progressed by increasing the duration. Practitioners need to be mindful that this does not coincide with an increase in intra-abdominal pressure (ie, holding breath and co-contractions of other musculature). If UI and/or AI incontinence, urinary and/or faecal urgency, heaviness/dragging in the pelvic area or pain with intercourse is reported, high impact exercises need to be suspended until symptoms are addressed. Overall, PFM training has no reported adverse effects and should be a primary prevention method for UI, POP, and AI, especially in high impact sports. Should an intervention be unsuccessful, referral to a specialist is essential, given the impact UI, POP and AI can have on health and well-being.

Diastasis recti

The linea alba is a meshwork of collagen fibres that maintain the abdominal muscles and have a normal width of up to 15mm-22mm in nulliparous women (women who have never given birth).[5] 'Diastasis recti' is the term for the thinning and widening of the linea alba[21] and its associated laxity of the anterior abdominal wall.[40] It is commonly diagnosed by inter-recti distance via finger-width palpation,[34] although no standardised diagnostic criteria currently exists. In the absence of definitive diagnostic criteria, the true prevalence of diastasis recti remains unknown. Some degree of separation towards the end of pregnancy is considered a normal adaptation for the abdominal wall to accommodate the growing uterus,[21] with the inter-recti distance considered normal up to 21-28mm in primiparous women (women on their first pregnancy).[42]

Recommendations for managing diastasis recti in pregnancy include encouraging tension-free diaphragmatic breathing patterns (ie, belly breathing and/or thoracic expansion breathing exercises), as well as reducing activities that cause unnecessary and repeated increases in intra-abdominal pressure, such as sit-ups and straining on the toilet.[22] An individualised approach to exercise prescription should be employed.[22] Signs include visible doming or invagination at the midline[22] and/or compensatory strategies such as excessive lumbar lordosis or gripping the outer abdominal muscles.[21] Exercise prescription should focus on achieving load transfer across the abdominal wall and progress to functional rehabilitation.[21,22,36] Pilates exercises that focus on targeting the pelvic floor and transverse abdominis, and which enable appropriate tension and load transfer across the abdominal wall should be used.[36] Once achieved, progression to exercises engaging the outer abdominal wall muscles, such as head-lifts, may be employed.[22]

Table 3: Relative and absolute contraindications[39]

ABSOLUTE CONTRAINDICATIONS	RELATIVE CONTRAINDICATIONS
Severe respiratory diseases (eg, chronic obstructive pulmonary disease, restrictive lung disease and cystic fibrosis)	Mild respiratory disorders
Severe acquired or congenital heart disease with exercise intolerance	Mild congenital or acquired heart disease
Uncontrolled or severe arrhythmia	Well-controlled type 1 diabetes
Placental abruption	Mild pre-eclampsia
Vasa previa	Preterm premature rupture of membranes
Uncontrolled type 1 diabetes	Placenta previa after 28 weeks
Intrauterine growth restriction	Untreated thyroid disease
Active preterm labour	Symptomatic, severe eating disorder
Severe pre-eclampsia	Multiple nutrient deficiencies and/or chronic undernutrition
Cervical insufficiency	Moderate-heavy smoking (>20 cigarettes per day) in the presence of co-morbidities

Contraindications during pregnancy

Sociocultural advice has often superseded research, and so it is important that sportswomen and all coaches are aware of contraindications: see Table 3 for absolute and relative contraindications. Expert opinions and limited empirical evidence had previously determined most contraindications, but recent guidelines now remove barriers to physical activity during pregnancy for women with certain medical conditions.[39] Sportswomen with absolute contraindications should be encouraged to continue daily living activities, whereas sportswomen with a relative contraindication should have a discussion with a health care professional and, where necessary, modifications can be made to their exercise programme rather than completely stopping it.[39] It is important to understand that sportswomen are unlikely to display any contraindications at the start of pregnancy, but this may change throughout the term. Sportswomen, coaches, and medical personnel should regularly consult with each other and have coherent procedures to deal with any contraindication.

There is currently no common practice within the UK for assessing readiness for exercise during the antenatal period. The Physical Activity Readiness Medical Examination for Pregnancy (PARmed-X)19 provides a simple guideline to evaluate the risk of exercise,

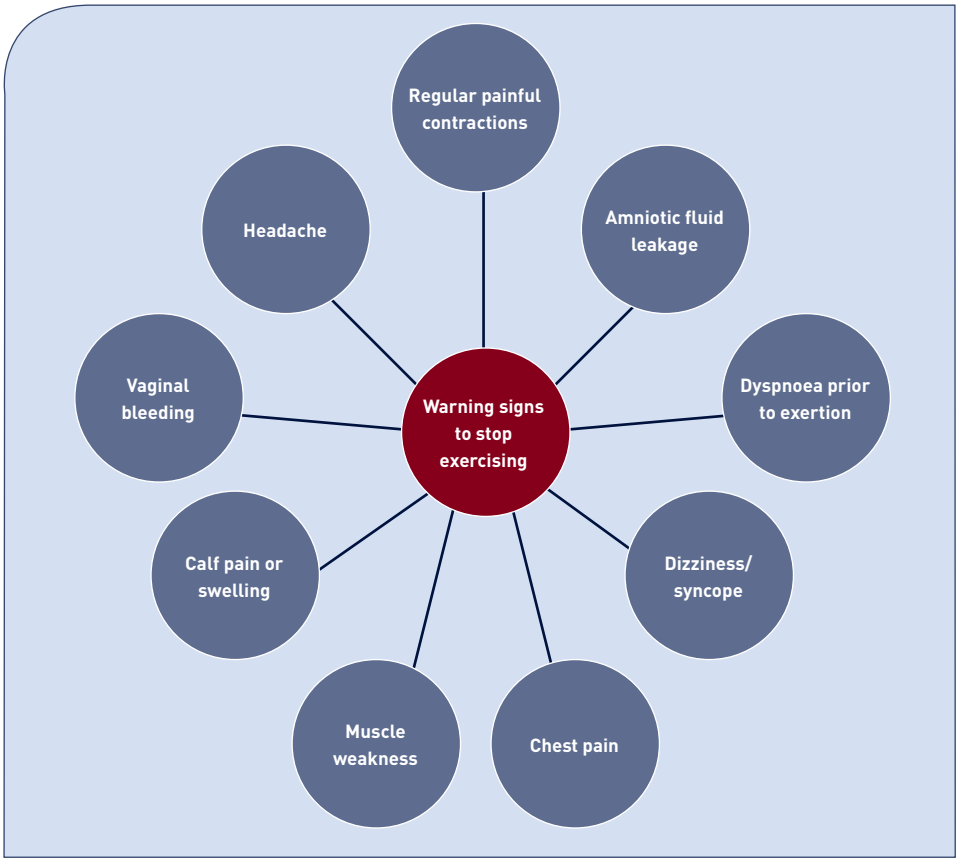

Figure 1. Warning signs to stop exercising[8]

requiring the individual to answer questions on general health status, status of current pregnancy, activity habits during the past month, and physical activity intensions. But it is important to note that the PARmed-X does not use the most current absolute and relative contraindications. It is recommended that practitioners use this questionnaire or develop their own as standard practice, but this should also be in conjunction with appointments and care provided from their doctor. The final consideration for the practitioner is when to stop exercise: Figure 1 provides warning signs for when to stop exercising.

Conclusion

It can be challenging for sportswomen and practitioners to successfully manage exercise during the antenatal period. This paper highlights that physical activity can be safely undertaken, providing that health, not performance, are at the forefront of any sports-based decision.

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References

1. Artal, R and O'Toole, M. Guidelines of the American College of Obstetricians and Gynecologists for exercise during pregnancy and the postpartum period. *British Journal of Sports Medicine*, 37 (1): 6-12. 2003.
2. Barakat, R, Lucia, A, and Ruiz, J. Exercise and pregnancy. In: *The Female Athlete*. M, Mountjoy, Eds. New Jersey: Wiley Blackwell, 2015. pp 9-19.
3. Barakat, R, Pelaez, M, Cordero, Y, Perales, M, Lopez, C, Coteron, J and Mottola, M F. Exercise during pregnancy protects against hypertension and macrosomia: randomized clinical trial. *American Journal of Obstetrics and Gynecology*, 214 (5): 649.e1-8. 2016.
4. Barakat, R, Perales, M, Cordero, Y, Bacchi, M and Mottola, M F. Influence of Land or Water Exercise in Pregnancy on Outcomes: A Cross-sectional Study. *Medicine and Science in Sports and Exercise*, 49 (7): 1397-1403. 2017.
5. Beer, G M, Schuster, A, Seifert, B, Manestar, M, Mihic–Probst, D and Weber, SA. The normal width of the linea alba in nulliparous women. *Clinical Anatomy*, 22 (6): 706-711. 2009.
6. Bø, K. Exercise and pelvic floor dysfunction in female elite athletes. In: *The Female Athlete*. M, Mountjoy, Eds. Blackwell: Wiley, 2015. pp. 76-85.
7. Bø, K and Backe-Hansen, K L. Do elite athletes experience low back, pelvic girdle and pelvic floor complaints during and after pregnancy? *Scandinavian Journal of Medicine & Science in Sports*, 17 (5): 480-487. 2007.
8. Bø, K, Artal, R, Barakat, R, Brown, W J, Davies, G A L, Dooley, M, Evenson, K R, Haakstad, L A H, Kayser, B, Kinnunen, T I, Larsen, K, Mottola, M F, Nygaard, I, van Poppel, M, Stuge, B and Khan, K M. Exercise and pregnancy in recreational and elite athletes: 2016/2017 evidence summary from the IOC expert group meeting, Lausanne. Part 5. Recommendations for health professionals and active women, *British Journal of Sports Medicine*, 52 (17): 1080-1085. 2018.
9. Bø, K, Artal, R, Barakat, R, Brown, W, Davies, G A L, Dooley, M, Evenson, K R, Haakstad, L A H, Henriksson-Larsen, K, Kayser, B, Kinnunen, T I, Mottola, M F, Nygaard, I, Poppel, M V, Stuge, B, and Khan, K M. 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. 2016.
10. Bø, K, Artal, R, Barakat, R, Brown, W, Dooley, M, Evenson, K R, Haakstad, L A H, Larsen,

References

K, Kayser, B, Kinnunen, T I, Mottola, M F, Nygaard, I, van Poppel, M, Stuge, B, and Davies, G A L. Exercise and pregnancy in recreational and elite athletes: 2016 evidence summary from the IOC expert group meeting, Lausanne. Part 2-the effect of exercise on the foetus, labour and birth. *British Journal of Sports Medicine*, 50 (21): 1297-1305. 2016.

11. Bø, K, Ellstrøm Engh, M, and Hilde, G. Regular exercisers have stronger pelvic floor muscles than nonregular exercisers at midpregnancy. *American Journal of Obstetrics and Gynecology*, 218 (4): 427.e1-e5. 2018.
12. Bø, K, Hagen, R H, Kvarstein, B, Jørgensen, J, Larsen, S, and Burgio, K L. Pelvic floor muscle exercise for the treatment of female stress urinary incontinence: III. Effects of two different degrees of pelvic floor muscle exercises. *Neurourology and Urodynamics*, 9 (5): 489-502. 1990.
13. Borin, Lílian Cristina Marques da Silva, Nunes, F R, and Guirro, Elaine Caldeira de Oliveira. Assessment of pelvic floor muscle pressure in female athletes. *The Journal of Injury, Function, and Rehabilitation*, 5 (3): 189-193. 2013.
14. Brantsæter, A L, Haugen, M, Myhre, R, Sengpiel, V, Englund-Ögge, L, Nilsen, R M, Borgen, I, Duarte-Salles, T, Papadopoulou, E, and Vejrup, K. Diet matters, particularly in pregnancy-results from MoBa studies of maternal diet and pregnancy outcomes. 2014.
15. Brown, S L. Nutrition requirements during pregnancy. In: *Essentials of life cycle nutrition*. J, Sharline, and S, Edelstein, Eds. Massachusetts, NE: Jones & Bartlett, 2011: pp. 1-24.
16. Bump, R C and Norton, P A. Epidemiology and natural history of pelvic floor dysfunction. *Obstetrics and Gynecology Clinics of North America*, 25 (4): 723-746. 1998.
17. Butte, N F, Wong, W W, Treuth, M S, Ellis, K J, and O'Brian Smith, E. Energy requirements during pregnancy based on total energy expenditure and energy deposition. *The American Journal of Clinical Nutrition*, 79 (6): 1078-1087. 2004.
18. Cakmak, B, Ribeiro, A P, and Inanir, A. Postural balance and the risk of falling during pregnancy. *The Journal of Maternal-Fetal & Neonatal Medicine: The Official Journal of the European Association of Perinatal Medicine, the Federation of Asia and Oceania Perinatal Societies, the International Society of Perinatal Obstetricians*, 29 (10): 1623-1625. 2016.
19. Canadian Society for Exercise Physiology. *PARmed-X FOR PREGNANCY Physical Activity Readiness Medical Examination*. 2015. Available at: http://www.csep.ca/cmfiles/publications/parq/parmed-xpreg.pdf
20. Carlin, A and Alfirevic, Z. Physiological changes of pregnancy and monitoring. *Best practice & research Clinical Obstetrics & Gynaecology*, 22 (5): 801-823. 2008.
21. Donnelly, G. Diastasis rectus abdominis – physiotherapy management. *Journal of Pelvic, Obstetric and Gynaecological Physiotherapy*, (124): 15–19. 2019.
22. Dufour, S, Bernard, S, Murray-Davis, B, and Graham, N. Establishing Expert-Based Recommendations for the Conservative Management of Pregnancy-Related Diastasis Rectus Abdominis: A Delphi Consensus Study. *Journal of Women's Health Physical Therapy*, 43 (2): 73–81. 2019.
23. Duvekot, J J, Cheriex, E C, Pieters, F A, Menheere, P P, and Peeters, L H. Early pregnancy changes in hemodynamics and volume homeostasis are consecutive adjustments triggered by a primary fall in systemic vascular tone. *American Journal of Obstetrics and Gynecology*, 169 (6): 1382-1392. 1993.
24. Elliott-Sale, K J, Graham, A, Hanley, S J, Blumenthal, S, and Sale, C. Modern dietary guidelines for healthy pregnancy; maximising maternal and foetal outcomes and limiting excessive gestational weight gain. *European Journal of Sport Science*, 19 (1): 62-70. 2019.
25. Gilson, G J, Samaan, S, Crawford, M H, Qualls, C R, and Curet, L B. Changes in hemodynamics, ventricular remodeling, and ventricular contractility during normal pregnancy: a longitudinal study', *Obstetrics and Gynecology*, 89 (6): 957-962. 1997.
26. Glinoer, D. The regulation of thyroid function during normal pregnancy: importance of the iodine nutrition status. *Best practice & research Clinical endocrinology & metabolism*, 18(2): 133-152. 2004.
27. Goletzke, J, Buyken, A E, Louie, J C, Moses, R G, and Brand-Miller, J C. Dietary micronutrient intake during pregnancy is a function of carbohydrate quality. *The American Journal of Clinical Nutrition*, 102 (3): 626-632. 2015.
28. Hjollund, N H I, Jensen, T K, Bonde, J P E, Henriksen, T B, Andersson, A, Kolstad, H A, Ernst, E, Giwercman, A, Skakkebæk, N E, and Olsen, J. Spontaneous Abortion and Physical Strain Around Implantation: A Follow-Up Study of First-Pregnancy Planners. *Epidemiology*, 11 (1): 18–23. 2000.
29. Institute of Medicine: DRI dietary reference intakes for energy, carbohydrates, fiber, fat, protein and amino acids (Macronutrients). Washington, DC: National Academy Press. 2002.
30. Jensen, D, Webb, K A, and Donnell, D E. Chemical and mechanical adaptations of the respiratory system at rest and during exercise in human pregnancy. *Applied Physiology, Nutrition, and Metabolism*, 32 (6): 1239-1250. 2007.
31. Jewell, D and Young, G. Interventions for nausea and vomiting in early pregnancy. *The Cochrane Database of Systematic Reviews*, (4). 2003.
32. Jewell, D. Nausea and vomiting in early pregnancy. *Clinical Evidence*, (7): 1277-1283. 2002.
33. Kawaguchi, J K and Pickering, R K. The pregnant athlete, part 1: anatomy and physiology of pregnancy. International *Journal of Athletic Therapy and Training*, 15 (2): 39-43. 2010.
34. Keeler, J, Albrecht, M, Eberhardt, L, Horn, L, Donnelly, C, and Lowe, D. Diastasis Recti Abdominis: A Survey of Women's Health Specialists for Current Physical Therapy Clinical Practice for Postpartum Women. *Journal of Women's Health Physical Therapy*, 36 (3): 131-142. 2012.
35. Koletzko, B, Bauer, C P, Bung, P, Cremer, M, Flothkötter, M, Hellmers, C, Kersting, M, Krawinkel, M, Przyrembel, H, and Rasenack, R. 'German national consensus recommendations on nutrition and lifestyle in pregnancy by the 'Healthy Start-Young Family Network'. *Annals of Nutrition and Metabolism*, 63 (4): 311-322. 2013.
36. Lee, D and Hodges, P W. Behavior of the Linea Alba During a Curl-up Task in Diastasis Rectus Abdominis: An Observational Study. *The Journal of Orthopaedic and Sports Physical Therapy*, 46 (7): 580-589. 2016.
37. LoMauro, A and Aliverti, A. Respiratory physiology of pregnancy: physiology masterclass. *Breathe*, 11 (4): 297-301. 2015.
38. Madsen, M, JÃ¸rgensen, T, Jensen, M L, Juhl, M, Olsen, J, Andersen, P K, and Nybo Andersen, A. Leisure time physical exercise during pregnancy and the risk of miscarriage: a study within the Danish National Birth Cohort. BJOG: *An International Journal of Obstetrics & Gynaecology*, 114 (11): 1419-1426. 2007.
39. Meah, V L, Davies, G A, and Davenport, M H. Time to revisit medical 'absolute' and 'relative' contraindications: systematic review of evidence of harm and a call to action. *British Journal of Sports Medicine*, doi: 10.1136. 2020.
40. Mommers, E H H, Ponten, J E H, Al Omar, A K, de Vries Reilingh, Tammo S, Bouvy, N D, and Nienhuijs, S W. The general surgeon's perspective of rectus diastasis. A systematic review of treatment options. *Surgical Endoscopy*, 31 (12): 4934-4949. 2017.

References

41. Moss, S J, van Oort, A F, and Schutz, Y. Physical Activity and Pregnancy. Ins: *Exercise and Human Reproduction*. D, Vaamonde, S S, du Plessis, and A, Agarwal, Eds. London: Springer. 2007: pp. 253-286.
42. Mota, P, Pascoal, A G, Carita, A I, and Bø, K. Normal width of the inter-recti distance in pregnant and postpartum primiparous women. *Musculoskeletal Science and Practice*, 35: 34-37. 2018.
43. Mottola, M F, Davenport, M H, Brun, C R, Inglis, S D, Charlesworth, S, and Sopper, M M. VO_2peak prediction and exercise prescription for pregnant women. *Medicine and Science in Sports and Exercise*, 38 (8): 1389-1395. 2006.
44. Mottola, M F, Davenport, M H, Ruchat, S, Davies, G A, Poitras, V J, Gray, C E, Garcia, A J, Barrowman, N, Adamo, K B, Duggan, M, Barakat, R, Chilibeck, P, Fleming, K, Forte, M, Korolnek, J, Nagpal, T, Slater, L G, Stirling, D, and Zehr, L. 2019 Canadian guideline for physical activity throughout pregnancy. *British Journal of Sports Medicine*, 52 (21): 1339-1346. 2018.
45. Maternal physiology and complications of multiple pregnancy. Proceedings; Elsevier, *Seminars in perinatology*. 2005. pp. 338.
46. Nygaard, I, Barber, M D, Burgio, K L, Kenton, K, Meikle, S, Schaffer, J, Spino, C, Whitehead, W E, Wu, J, Brody, D J, and Network, for the Pelvic Floor Disorders. Prevalence of Symptomatic Pelvic Floor Disorders in US Women, *JAMA*, 300 (11): 1311-1316. 2008.
47. Pickering, R. Pregnancy and the exercising female. In: *The Exercising Female: Science and its application*. J, Forsyth and C, Roberts, Eds. Abingdon: Routledge, 2019. 198-210.
48. Pivarnik, J M. Cardiovascular responses to aerobic exercise during pregnancy and postpartum. *Seminars in Perinatology*, 20 (4): 242-249. 1996.
49. Pivarnik, J M, Lee, W, Miller, J F, and Werch, J. Alterations in plasma volume and protein during cycle exercise throughout pregnancy. *Medicine and Science in Sports and Exercise*, 22 (6): 751-755. 1990.
50. Pivarnik, J M, Mauer, M B, Ayres, N A, Kirshon, B, Dildy, GA, and Cotton, D B. Effects of chronic exercise on blood volume expansion and hematologic indices during pregnancy. *Obstetrics and Gynecology*, 83 (2): 265-269. 1994.
51. Roberts, C and Kenetta, G. Motherhood as an athletic career transition. Women in Sport and Physical Activity Conference. Stoke-on-Trent, Staffordshire. 2018.
52. Salvesen, K Å, Hem, E, and Sundgot-Borgen, J. Fetal wellbeing may be compromised during strenuous exercise among pregnant elite athletes. *British Journal of Sports Medicine*, 46 (4): 279-283. 2012.
53. Schoenfeld, B. Resistance training during pregnancy: safe and effective program design. *Strength & Conditioning Journal*, 33 (5): 67-75. 2011.
54. Silva, M R, G, Doñate, B R, and Carballo, K N C. Nutritional Requirements for the Pregnant Exerciser and Athlete. In: *Exercise and Sporting Activity During Pregnancy*. R, Santos-Rocha, Eds. Champaign: Springer. 2019. pp 327-345.
55. Smith, R, Reid, H, Matthews, A, Calderwood, C, Knight, M, and Foster, C. Infographic: physical activity for pregnant women. *British Journal of Sports Medicine*, 52 (8): 532-533. 2018.
56. Soma-Pillay, P, Catherine, N, Tolppanen, H, Mebazaa, A, Tolppanen, H, and Mebazaa, A. Physiological changes in pregnancy. *Cardiovascular Journal of Africa*, 27 (2): 89-94. 2016.
57. Vladutiu, C J, Evenson, K R, and Marshall, S W. Physical activity and injuries during pregnancy. *Journal of Physical Activity & Health*, 7 (6): 761-769. 2010.
58. Wolfe, L A, Ohtake, P J, Mottola, M F and McGrath, M J. Physiological interactions between pregnancy and aerobic exercise. *Exercise and Sport Sciences Reviews*, 17: 295-351. 1989.
59. Wylie, L. *Essential anatomy and physiology in maternity care*. UK: Churchill Livingstone. 2007.

NEWS

UNIVERSITY & TRAINING PROVIDER PARTNERSHIP UPDATE

Over the last year, the UKSCA has begun to take on a wider role of supporting and positively influencing strength and conditioning education in the UK, outside of that which we deliver and offer directly to the membership. We have been working closely with a small number of institutions to pilot partnership opportunities and are now planning to roll these out in order to partner with more universities and training providers in the UK. Please contact janet@uksca.org.uk for more details.

In addition to the discounted student membership package, institution subscription and access to our vault of exercise videos to support teaching (see back cover for details), we have also been working on the following:

FILMING DAY:

We have committed to running six film shoot days a year to generate more video content for our university and training provider partners to use in their teaching. The exercises and scenarios produced have been driven by our partners – keeping the vault well-stocked with the materials they want and need. This latest shoot, at the end of November, has generated an additional 250 videos for the vault.

CAREERS EVENT:

In mid-December, we were pleased to be invited to support the University of Gloucestershire's 'Your Future Plan' event, held for students from their BSc (Hons) and MSc programmes in Strength and Conditioning. Run over MS Teams and supported by the academic staff from the university, their programme included an update on the UKSCA's latest developments, a roundtable interview with S&C Coaches from the Scottish Rugby Union, workshop tasks to help students develop their 'sales' skills as well as an informative session on the social media landscape in strength and conditioning. This day gave the students an opportunity to consider in more detail their career options, talk directly to and learn from employers, and help them to start to form a realistic picture of their future career options in strength and conditioning..

This is a concept we will be expanding on in the future to give more support to S&C students at the very start of their careers.