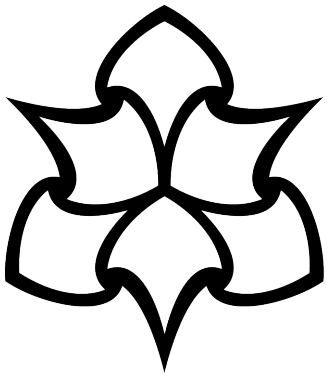

The Legacy of Pregnancy: Elite Athletes and Women in Arduous Occupations

Jackson T, Bostock EL, Hassan A, Greeves JP, Sale C, Elliott-Sale, KJ

ABSTRACT

Best-practice guidance and management of pregnant and postpartum elite athletes and women in arduous occupations is limited by the lack of high-quality evidence available within these populations. We have summarized the adaptations and implications of pregnancy and childbirth, proposed a novel integrative concept to address these changes, and made recommendations to progress research in this area.

INTRODUCTION

Motherhood has been considered incompatible with an athletic career; traditionally, sportswomen have been encouraged to end their careers to have children (1), although there are now increasing numbers of elite female athletes conceiving, giving birth, and successfully returning to sport (2). Similarly, there are many women employed in arduous occupations, such as servicewomen (11% of the UK Regular Forces are female (3)), police officers (31% of police officers in England and Wales are female (4)), firefighters (7% of all firefighters employed by Fire and Rescue Authorities England are female (5)), and manual laborers (15% of construction jobs are held by women (6)), who have returned to their physically demanding occupations after childbirth. Women in elite sport and arduous occupations must adapt training, competition, and occupational activities during and after pregnancy to minimize adverse effects on maternal and fetal health outcomes and reduce their risk of injury.Elite female athletes face many challenges when considering having a baby, planning a pregnancy within an Olympic/Paralympic cycle, time away from training and competition, profound pregnancy- and postpartum-related physiological and anatomical changes, and returning to previous levels of performance within a limited time frame (7). In 2016, the International Olympic Committee produced a five-part series providing expert opinion on these matters and highlights the need for more high-quality evidence investigating the impact of high-intensity exercise on pregnancy, childbirth, and the return to competitive sport in elite athletes (8–12). Subsequent evidence has shown that postpartum elite athletes are still unsatisfied with the training and exercise advice given to them (13), which may present practical challenges when rehabilitating in preparation for returning to sport.Since 2016, servicewomen have been fully integrated into all UK Armed Forces roles, including ground close combat, and are required to be physically and mentally fit and ready for intense physical training and deployment. Upon declaring pregnancy, servicewomen are medically downgraded, meaning they are not deployable for the duration of their pregnancy. UK servicewomen can return to physically and mentally demanding roles as early as 2 wk postpartum. As of October 1, 2020, 99% of servicewomen who went on maternity leave returned to work within 27 to 40 wk after giving birth (3). Recent data suggest that postpartum UK servicewomen are at greater risk of illness and injury in the year after giving birth compared with prepregnancy (14). The number of working days lost due to illness and injury per week was twofold higher postpartum than prepregnancy (14). Postnatal depression and gynecological disorders were the most common causes of workdays lost due to illness (14). Similarly, several studies have shown that U.S. military

servicewomen are returning to work unprepared for the demands of their role because of reduced physical fitness compared with prepregnancy, and with symptoms of depression and anxiety (15,16). Little is known about pregnancy and postpartum fitness in other arduous occupations, including police officers, firefighters, and manual laborers. The characteristics of these occupations require women to be able to perform physically strenuous activities, such as sustained heavy lifting and running. There is a dearth of evidence regarding the implications of pregnancy on the risk of injury and illness when returning to work, although physically strenuous jobs are a risk factor for pelvic floor dysfunction in the general female population (17). At 12 months postpartum, women with physically strenuous occupations experience more symptoms of pelvic organ prolapse (POP) compared with women who did not participate in heavy lifting and spent <50% of their day seated (18). Moreover, reduced abdominal muscle function (19) and incomplete recovery of the structural integrity of the linea alba observed after childbirth (20) (decreased strength (21,22), increased fatigability (22), and decreased steadiness of muscle contraction (22)) expose high-functioning postpartum women to increased injury risk, especially those who return to occupations that demand repetitive, sustained, or strenuous physical activity (19). Despite evidence to suggest that women in arduous occupations are at an increased risk of pelvic floor dysfunction and musculoskeletal injury postpartum, there are no data or guidelines on the most appropriate management of pregnant or postpartum women in arduous and manual occupations. The aim of this opinion article is to detail the changes that occur because of pregnancy, provide opinion on the current management of pregnancy in elite athletes and women employed in arduous occupations, propose a novel integrative concept to improve the legacy of pregnancy in these groups, and recommend future high-quality, impactful studies.

PREGNANCY AND POSTPARTUM ADAPTATIONS AND IMPLICATIONS

Pregnancy and childbirth cause unique physiological, musculoskeletal, and psychological adaptations that have potential implications for pregnancy and postpartum health, function, and physical activity (Table). Many of these adaptations resolve naturally after childbirth, as physiological homeostasis is restored, but some adaptations can persist and affect maternal health, posing significant challenge on physical activity participation. It is understood now that the effects of pregnancy and childbirth can extend beyond 12 months postpartum (130). The long-term health implications of returning to high-impact and intense physical activity too soon after childbirth are unknown (10).

TABLE

Adaptations and implications during pregnancy and after childbirth.

Full Size Table

	Pregnancy Adaptations				
	Trimester 1	**Trimester 2**	**Trimester 3**	**Pregnancy Implications**	**Postpartum Adaptations**
Hormonal					

TABLE

Adaptations and implications during pregnancy and after childbirth.

Full Size Table

	Pregnancy Adaptations			Pregnancy Implications	Postpartum Adaptations
	Trimester 1	**Trimester 2**	**Trimester 3**		
Human chorionic gonadotropin	↑ (23)	Peaks at 8–11 wk, then ↓ and levels off (23)		Stimulates the production of estrogen and progesterone within the ovary (23)	Appears to rapidly ↓ after delivery (24)
Relaxin	↑ to peak (23)	↓ (23)	Peaks again at delivery (23)	Plays a role in: ↑ cardiac output, renal blood flow, and arterial compliance ↑ joint laxity (25)	Appears to ↓ to nonpregnant values within the first week postpartum (26)
Progesterone	Gradual ↑ (23)			Maintains the uterus lining and supportive environment for the developing fetus (23)	Rapid ↓ after childbirth (27)
Estrogen	Gradual ↑ (23)			Plays a role in (23): • Maintaining uterus lining and regulating hormones essential for fetal growth • Preparing the body for breastfeeding • Enabling the uterus to respond to oxytocin in labor • ↑ venous capacitance	Rapid ↓ after childbirth (27)
Prolactin	↑ throughout and by term levels are ~10 to 20 times higher (23,28)			Preparation for lactation Progesterone blocks prolactin from exerting its effect on milk secretion (28)	Signals for milk glands to start milk production but ↓ as lactation is established (28)

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	Trimester 1	**Trimester 2**	**Trimester 3**		
Oxytocin	Gradual ↑ (23)		↑ in labor (23)	↑ length, strength, and frequency of contraction in labor Keeps uterine contraction going after birth to shrink the uterus	↓ (27) Released in response to breastfeeding (29)
Physiological					
Cardiovascular	Substantial, rapid, and progressive cardiovascular system changes from ~5th week gestation (30) which ensure blood supply to the fetus: • Gradual ↑ in resting cardiac output during trimesters 1 and 2, plateaus ~20 wk gestation, and remains elevated until term (~50% over nonpregnant values by 16–20 wk gestation) (31) • ↑ resting HR throughout pregnancy (~15 bpm ↑ by term) (32) • ↑ stroke volume (~10% end of trimester 1), plateaus ~20 wk (31) Mean arterial pressure ↓ up to mid-pregnancy (~10 mm HG ↓), during trimester 3 blood pressure gradually ↑ to prepregnancy levels (33) RPE scale does not strongly correlate with HR (34) Swelling (edema) is common, often in the legs, ankles, feet, and fingers			Gestational hypertension can lead to preeclampsia in severe cases If monitoring HR during exercise, RPE should not be used as the only measure of exercise intensity	Blood pressure often ↓ straight after delivery, then ↑ to peak by 3–6 d (33) Dramatic stroke volume ↑ after delivery, ↑ cardiac output and HR remaining elevated for 24 h after birth, returning to baseline by 12 wk (31,35) Other reports that changes gradually return toward baseline but remain different from prepregnancy 1 year after birth (32)

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	Trimester 1	**Trimester 2**	**Trimester 3**		
Respiratory	Elevation of the diaphragm and altered thoracic configuration (36,37) = ↓ expiratory reserve volume during 2nd half of pregnancy (8%–40% ↓ at term) = ↓ functional residual capacity (9.5%–25% at term) and ↑ inspiratory capacity to maintain constant total lung capacity (36,38,39) Sensitivity to carbon dioxide ↑ in early pregnancy (40) ↑ tidal volume + ↔ respiratory rate = ↑ minute ventilation during trimester 1 (up to 48% ↑), maintained through pregnancy (36–39,41) ↓ arterial carbon dioxide tension and ↑ arterial oxygen tension (38) Respiratory discomfort (dyspnea) often reported, trimester 3 (42)			Perception of respiratory effort and dyspnea ↓ during submaximal steady-state exercise (43)	↓ in intra-abdominal pressure allows ↑ expansion of diaphragm Respiratory changes during pregnancy return to prepregnancy levels within a few months (44)
Thermoregulation	Fetal temperature regulation is dependent upon maternal temperature, fetal metabolism, and uterine blood flow Enhanced thermoregulatory capacity as pregnancy progresses (45,46): • ↑ plasma volume • ↑ heat dissipation ↓ body temperature thresholds for sweating (46)			Moderate intensity exercise (~60%–70% V˙O2max) tolerated with no significant core temperature changes in most women (47) Hyperthermia should be avoided, especially in trimester 1 (48)	Transient chill or shivering is often experienced ~15 min after birth Transient maternal temperature ↑ (up to 38°C) can be experienced in the first 24 h after delivery (49)
Glucose metabolism	Maternal blood glucose = major energy substrate for fetoplacental unit = maternal metabolism adapts to supply adequate glucose (51) Hormonal events cause: • ↑ maternal blood glucose, ↑ maternal insulin levels and liver glucose release			GDM is glucose intolerance with onset or first recognition during pregnancy (58) and can result in adverse perinatal	Women with GDM have ↑ risk for developing diabetes (59,60)

TABLE

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	Pregnancy Adaptations			Pregnancy Implications	Postpartum Adaptations
	Trimester 1	**Trimester 2**	**Trimester 3**		
	(52) • ↓ liver glycogen storage (53) = ↑ insulin resistance in skeletal muscle (54) = ↓ maternal utilization of glucose in peripheral tissues = more maternal glucose for fetal use (55) Fetoplacental unit can use up to 30%–50% of maternal glucose pool in late gestation (56) ↑ maternal insulin levels in trimester 1 = ↑ stored maternal body fat (57)			outcomes Elite athletes and those regularly exercising at a high level are less likely to have the risk factors associated with GDM	
GWG	Recommended GWG (61):			GWG is an indicator for sufficient energy intake for fetal growth and development (61) Excessive or inadequate GWG can lead to adverse pregnancy outcomes (62–66) Intensive exercise during pregnancy could cause inadequate GWG and energy intake should be adjusted accordingly	0.5 to 4 kg average weight retention 1 year after pregnancy in the general population (67,68)
	Prepregnancy BMI ($kg \cdot m^{-2}$)	Total weight gain (kg)	Weekly weight gain range in trimesters 2 and 3 (kg)		
	<18.5	12.5–18.0	0.44–0.58		
	18.5–24.9	11.5–16.0	0.35–0.50		
	25.0–29.9	7.0–11.5	0.23–0.33		
Energy intake	Recommended additional calorie intake across trimesters (71):				Additional ~330 kcal d^{-1} in the first 6 months of lactation, if exclusively breastfeeding (72)
	Underweight: 150 kcal d^{-1}	200 kcal d^{-1}	300 kcal d^{-1}		

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	Pregnancy Adaptations			**Pregnancy Implications**	**Postpartum Adaptations**
	Trimester 1	**Trimester 2**	**Trimester 3**		
	Normal weight: 0 kcal d^{-1}	350 kcal d^{-1}	500 kcal d^{-1}		
	Overweight: 0 kcal d^{-1}	450 kcal d^{-1}	350 kcal d^{-1}		
Nutrition (73)	Growing fetus needs to receive sufficient energy in the form of glucose During trimesters 2 and 3, protein is deposited in maternal, fetal, and placental tissues, and therefore, the recommended protein intake is increased A gestational diet should contain essential fatty acids, choline, sterols, phospholipids, and triglycerides to support fetal growth (74)			Recommendations during pregnancy (75): Carbohydrate intake: 175 g d^{-1} Protein intake: 71 g d^{-1} Fat intake: does not change (~20%–35% of total calories)	Carbohydrate intake important to maintain milk supply to meet baby's nutritional needs Protein needs are ↑ for breastfeeding women Dietary fats are important for baby's growth and development
Bone and calcium	In some rare cases women develop osteoporosis during pregnancy In most cases bone lost during pregnancy is recovered after childbirth or after breastfeeding ends (76)			Ensuring adequate calcium intake is important, especially if energy expenditure is high through training	Women often lose 3–5% of their bone mass breastfeeding but this usually recovers within a few months after breastfeeding ends (76)
Fatigue	Fatigue (an overwhelming sustained sense of exhaustion and decreased capacity for physical and mental work (77)) is common in pregnancy (78), particularly in trimester 1 and again in trimester 3 Severe fatigue or fatigue that lasts the entire pregnancy			Lack of rest and recovery could ↑ symptoms of fatigue Important to rule out	General lack of energy, tiredness, and irregular sleep are common Severe postpartum fatigue may be a symptom of

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	Trimester 1	Trimester 2	Trimester 3		
	could be sign of a more serious condition, medical advice should be sought			hyperthyroidism or anemia	a significant medical or psychiatric illness (79,80)
Hyperemesis gravidarum	Nausea affects ~70% and vomiting ~60% of pregnant women (81) Symptoms usually begin between 4 and 7 wk gestation and disappear by 16 wk gestation (81,82) Excessive and persistent nausea and vomiting = hyperemesis gravidarum Reported incidence of 1 in 200 (82), often needs hospital treatment			Can result in: • Dehydration • Weight loss • Electrolyte imbalances • Low blood pressure when standing • Fetal growth restriction and prematurity in severe cases	None
Pelvic floor					
Anorectal	↑ progesterone levels relax smooth muscle including the digestive tract, slowing the digestion of food, may cause constipation (83)		Engagement of the fetus head in the pelvis ↑s pressure on the rectum anal sphincter descent (84)	Potential pathologies: • Fecal incontinence (85) • Defecation dysfunction including constipation (83)	Childbirth can result in: • Neuromuscular trauma (86) • Anal sphincter injury (87) • Perineal tears • Levator ani muscle Injury (88) • Pelvic floor muscle weakness (89)
Urinary	↑ bladder neck mobility and ↑ urethral mobility (90) ↑ pelvic floor distensibility (91) Uterine weight exerts pressure on and irritates the bladder (92) Reduced bladder volume from trimesters 1 to 3 (93)			Potential pathologies: • Urinary incontinence (94) • Nocturia (excessive urination at night) (95) • ↑ micturition	Childbirth can result in: • Perineal tears • Neuromuscular trauma (86) • ↑ bladder neck mobility (97) • ↑ levator hiatus distensibility (97) • Pelvic floor muscle

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Adaptations and implications during pregnancy and after childbirth.

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	Pregnancy Adaptations			Pregnancy Implications	Postpartum Adaptations
	Trimester 1	**Trimester 2**	**Trimester 3**		
				(urination) frequency (96)	weakness (89) Instrumental delivery can ↑ risk of developing pathologies (89)
POP	Downward movement of the anterior and posterior vaginal walls leads to descent of one or more of the pelvic organs. This is associated with: • ↑ straining associated with defecation dysfunction • ↑ peroneal body length and genital hiatus (components of the POP quantification assessment) (98)			Symptoms include vaginal: • Vaginal heaviness (99) • Vaginal dragging (99) POP can: • Be asymptomatic • Impact bladder (100) and bowel function (101) • Impact quality of life (102)	Childbirth can result in: • Perineal tears • Neuromuscular trauma • ↑ levator hiatus distensibility (97) • Levator ani muscle Injury • Pelvic floor muscle weakness (89) Instrumental delivery and episiotomy can ↑ risk: 50% of postpartum women have some degree of symptomatic or asymptomatic prolapse (103)
Sexual function	Reduced sexual function is often caused by or results in (104,105): • ↑ physical discomfort as the fetus grows • ↑ fear of injury to baby • Perceived lack of attractiveness and physical awkwardness • Dyspareunia (painful intercourse) • ↓ sexual desire and sexual arousal • Orgasmic disorders			Sexual dysfunction leads to (106): • ↓ quality of life • Dissatisfaction with others • Changes in sexual and marital relationships	Factors affecting sexual function (105,107): • Lactation • Vaginal lubrication • ↓ sexual arousal and desire • Postnatal depression (108) • Dyspareunia • Orgasmic disorders

TABLE

Adaptations and implications during pregnancy and after childbirth.

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	Pregnancy Adaptations			**Pregnancy Implications**	**Postpartum Adaptations**
	Trimester 1	**Trimester 2**	**Trimester 3**		
Musculoskeletal					
Pelvic girdle pain	Experienced by 1 in 5 pregnant women and can be caused by (109): • A history of falls or trauma to the pelvis and/or falls during pregnancy (110) • A history of lower back pain before pregnancy (110)			May reduce function and movement, with potential implications on: • Performance • Emotional well-being • Quality of life	Often resolved postpartum but can be persistent (111) Caesarean section ↑ risk of persistent pelvic girdle pain (112)
Postural balance	None	Shift in the center of gravity causes ↓ postural balance and ↑ risk of falls (114)		2 to 3 times more likely to be injured because of falls than nonpregnant women (114)	↓ postural stability is persistent 6–8 wk after delivery (115)
Rectus diastasis	Rectus diastasis +/− protrusion or hernia (occurs in 100% of women from 37 wk onward to varying degrees) as a result of (116): • ↑ mechanical stresses placed on the abdominal wall and displacement of the abdominal organs by the growing fetus • Thinning and widening of the linea alba			Reduced function of the abdominal wall, particularly rectus abdominus function (19,20,22)	Rectus diastasis +/− protrusion or hernia may naturally resolve after childbirth (117) (39% of women 6 months postpartum have a rectus diastasis of >2 cm (116))
Breast enlargement	Can result in pain and ↑ sensitivity			Pain and discomfort may affect training and performance	Breast enlargement with lactation

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	Pregnancy Adaptations				
	Trimester 1	**Trimester 2**	**Trimester 3**	**Pregnancy Implications**	**Postpartum Adaptations**
Gait biomechanics	None	Expanding uterus and breast enlargement: • Displaces the center of gravity • ↑ lumbar lordosis • ↑ anterior rotation of the pelvis on the femur Gait cycle changes: • ↓ length of gait cycle (120–123) • ↓ step length (120–123) • ↑ double support time (122,123) • ↑ width of step and stance (124)		Postural and biomechanical adaptations could impact performance specific tasks	Gait cycle changes early postpartum (123): • ↓ length of gait cycle • ↓ step length • ↑ double support time • ↑ width of step • ↑ width of stance
Psychological					
Depression	Symptoms: low mood, insomnia, feelings of irritability, sadness, guilt, and aversion to activity affecting thoughts, feelings, and well-being			↑ the risk of poorer birth outcomes including (125): • ↑ risk of preterm birth • Low birth weight • Preeclampsia • Intrauterine growth restriction	Postpartum depression = ↑ depressive symptoms from 0–12 months after birth (126)

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	Pregnancy Adaptations			Pregnancy Implications	Postpartum Adaptations
	Trimester 1	**Trimester 2**	**Trimester 3**		
Anxiety	1 in 3 women experience anxiety during pregnancy (129)			Associated depressive feelings ↑ risk of poor birth outcomes (125)	Anxiety can persist after childbirth and correlates with depressive symptoms (129)

BMI, body mass index; GDM, gestational diabetes; GWG, gestational weight gain; HR, heart rate; RPE, rating of perceived exertion.[Context Link]

In the absence of contraindications, exercise can be beneficial during pregnancy (131), including fewer newborn complications and improved maternal health outcomes (132). The American College of Obstetricians and Gynecologists committee proposed that the type and volume of training modality should be considered between trimesters because of the normal anatomical and physiological changes (Table) that occur (133). Observational studies have shown that both elite athletes and physically active controls reduced their training volume between the first, second, and third trimesters, and none participated in high-intensity training in the final trimester (13). Although elite athletes and women in arduous roles are more likely than the general population to be physically active throughout pregnancy, they still undergo significant anatomical and physiological changes. Emerging evidence suggests that physically demanding occupations (heavy lifting, prolonged standing, prolonged walking, and prolonged bending) during pregnancy are associated with increased risk of adverse pregnancy outcomes including preterm delivery, low birth weight, small for gestational weight, and preeclampsia (134). Furthermore, the changes that occur during pregnancy may affect exercise capacity (8); however, the full extent of these implications on exercise performance is not fully understood (for a review on the state of the art, see (135)). The time taken to recover from pregnancy and childbirth can vary, dependent on gestational complications, mode of delivery (vaginal, instrumental, or cesarean section), pelvic floor dysfunction, pain, and depression. After an uncomplicated pregnancy, it is possible for women to return to low-impact physical activity in less than 12 wk after childbirth (136), and elite athletes have returned to physical activity less than 6 wk postpartum (13,137,138). Women who return to high-impact physical activity in the early postpartum period risk becoming injured without adequate rehabilitation and recovery after childbirth (13,137,139,140).Twelve weeks or more are required for the musculoskeletal soft tissues to heal after an injury, which is accounted for by the time taken to progress through the defined stages of inflammation, proliferation, and remodeling (141). Recent self-published guidelines for returning to running after childbirth suggest that symptomatic women or asymptomatic women who are without the guidance of a health care professional may benefit from waiting until 12 wk postpartum to resume high-impact activities (142). Without adequate healing and rehabilitation of the pelvic floor (143) and abdominal muscles (19–22), women are at risk of

dysfunction, which may present with (symptomatic) or without (asymptomatic) physical symptoms. If asymptomatic, it is unknown whether pelvic floor dysfunction, such as POP, could worsen because of lack of detection and intervention and become a barrier to returning to physical activity, competition, or occupational performance. Moreover, it is important to understand that the degree to which symptoms relate to function can vary between individuals, and symptomatic women will be better placed to seek help to manage these symptoms.Women may return to work or training/competition prematurely after pregnancy because of external pressure regardless of physical health or symptoms. Elite athletes are forced to consider the timing of major sporting events including the Olympic/Paralympic cycle. Taking time away from sport to have a baby may impact on ranking, team selection, or qualification to major sporting events. In addition to considering qualification or selection, elite athletes face financial worries, because paid maternity leave is uncommon. Most sports do not offer financial protection for pregnant athletes, and often, funding is withheld. Women in arduous occupations also face financial pressures as maternity pay decreases over time; for example, UK servicewomen are entitled to 26 wk' full pay, 13 wk of additional maternity leave paid at the statutory pay rate, followed by 13 wk of unpaid leave. The reductions in paid maternity leave coincide with when UK servicewomen typically return to work after childbirth (3). Moreover, women in elite sport are faced with social and psychological challenges driven by cultural beliefs and traditions regarding their responsibility to prioritize their role as a new mother over their career as an athlete. Elite female athletes often strive to meet the expectation that they can “do it all” but may experience psychological distress when they do not feel they meet the expectation of being a mother and able to perform at the highest level (7).

CURRENT AND PROPOSED MANAGEMENT

There is a lack of evidence available to develop best-practice guidelines for the care of pregnant and postpartum elite athletes and women employed in arduous occupations. Consequently, beyond the standard care provided by the UK National Health Service (NHS), there are disparities in the guidance and care available. For uncomplicated pregnancies, standard NHS care provides a midwife and general practitioner-led model of care, and women are offered additional care provided by specialist teams, if problems are identified (144). The management of pregnant and postpartum elite athletes is guided by the experiences of support staff and any medical professionals that form part of the wider support team (***e.g.***, sports physiotherapists) rather than by scientific evidence or clinical guidelines. As such, there is no standardized approach to managing a pregnant/postpartum elite athlete, and organizational policies make little to no reference to the support of pregnant or nursing athletes at competitive events or even for day-to-day training. Women in arduous occupations are subject to unique organizational policies, for example, there are differences in the UK approach to returning women to physical training after childbirth between the Royal Air Force, Royal Navy, and the British Army. The British Army provides women with a graduated return to fitness program for 6–12 wk after their return to work, whereas the Royal Air Force and Royal Navy do not provide a specific phased return to physical activity, unless requested by the individual.Herein, we propose an approach that could be implemented to address inconsistencies in the management of pregnant and postpartum elite athletes and women in arduous occupations using a multidisciplinary team (MDT). An MDT approach has been successfully adopted in many sporting contexts including both team and individual sports. For instance, Dijkstra ***et al.***(145) describes an MDT and integrated approach to athlete health that underpinned the success of the UK track and field team at the London 2012 Olympic/Paralympic Games. An MDT approach (Fig. 1) provides a range of skills and expertise for holistic athlete health management and, consequently, achievement of performance goals. It also ensures specialist care is provided and the unique implications of pregnancy and childbirth are addressed (136). In this model, different members of an MDT are required at different stages

throughout an athlete's journey, for instance, coaches, physiotherapists, and nutritionists are required to adapt physical training, performance, and dietary needs for a pregnant athlete (Fig. 1), and the priority of care is adapted to an individual's needs and stages of pregnancy.

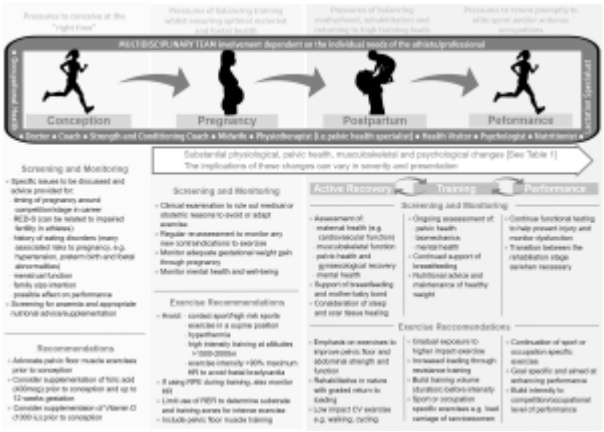

Figure 1

Novel integrative concept to return elite female athletes and women in arduous occupations to high-level performance after pregnancy. CV, cardiovascular; HR, heart rate; RED-S, relative energy deficiency in sport; RER, respiratory exchange ratio; RPE, rating of perceived exertion.Women in arduous occupations face similar physical and psychological demands as elite athletes, and on this basis also warrant an MDT approach to care. At present, UK servicewomen, policewomen, and firefighters access standard NHS care throughout pregnancy and after childbirth. Access to an MDT, such as specialist pelvic health physiotherapists, is not routine practice. Only in the presence of symptoms will they be able to access additional services. It is, therefore, vital that women, coaches, employers, and members of the wider MDT (Fig. 1) develop a sound understanding of the adaptations that occur during each trimester of pregnancy and after childbirth and how these changes may impact upon exercise physiology. Women also should be encouraged to evaluate their own risk for exercise participation during pregnancy, using tools such as the Canadian Society of Exercise Physiology “Get Active Questionnaire for Pregnancy” (146). Using a questionnaire such as this in combination with better awareness of pregnancy adaptations (Table), women and MDT are better placed to make informed decisions regarding training, performance, or occupational duties through pregnancy to avoid injury and complications and to facilitate postpartum recovery (Fig. 1).Contrary to traditional approaches and beliefs, it is possible to prevent common complications associated with pregnancy, such as urinary incontinence (144) and lower back pain (147). Often, women wait until after childbirth to address common complaints, meaning that they have become more established conditions and are harder to treat (148). Evidence suggests that if the intervention is intensive and early enough, pelvic floor muscle training throughout pregnancy in healthy women (with no prior pelvic floor dysfunction) may reduce the incidence of urinary incontinence and pelvic floor dysfunction in late pregnancy and the postpartum period (10,143,149). Adverse pregnancy outcomes, such as preterm birth, preeclampsia, and intrauterine growth restriction associated with physically demanding occupations, could be prevented through careful consideration of workplace guidance and strategies that reduce activities such as prolonged standing (>4 h), prolonged walking (>4 h), and heavy lifting (>100 $kg \cdot d^{-1}$) (134). The use of similar preventative approaches in elite athletes and women in arduous occupations may help limit pelvic floor dysfunction throughout pregnancy and after childbirth and reduce the risk of adverse pregnancy outcomes, although more research is needed to investigate preventative strategies within these cohorts.After an uncomplicated pregnancy, labor, and birth, individualized rehabilitation can start as early as the first

day after birth (142). Using a phased approach, such as the one proposed by Bø ***et al.*** (10), and updated by Deering ***et al.*** (136), elite athletes and women in arduous occupations should progress through three distinct postpartum phases: active recovery, training, and performance, under the supervision of an MDT (Fig. 1). The "active recovery" phase should support the transition into motherhood and address pregnancy-and birth-related concerns. To enhance continuity of care, a pelvic health physiotherapist should be employed throughout pregnancy to address the musculoskeletal complaints and pelvic floor dysfunctions identified in Table. The "training" phase should prioritize functional or sport-specific exercises in preparation for returning to competition. During the "performance" phase, the primary goal is to develop athletic performance that requires continuing communication between all members of the MDT involved. The transition between each phase is a dynamic process, whereby women can reenter phases dependent upon injury or after competition in an off-season. We suggest that a similar approach should be adopted by women in arduous occupations to ensure graded return to exercise including a progression from low- to high-impact exercise and an increase in training volume before intensity. The initial active recovery phase would not need to be altered; however, the training phase should place emphasis on occupation-specific exercise and functional tasks replicating occupational demands. The final phase should encourage occupational performance, enhancing maternal well-being and improving physical and psychological health on returning to work.The unique adaptations of pregnancy and childbirth pose a significant challenge to elite athletes and women in arduous occupations, requiring person-centered, MDT-based management. It is important to raise awareness of the changes that occur during pregnancy and the possible implications on health and performance in elite athletes and women in arduous occupations and to educate the MDT. Furthermore, preventative approaches during pregnancy aimed at improving maternal health after childbirth require further investigation within the context of elite sport and arduous occupations. Women in arduous occupations urgently need improved provision and accessibility to services to reduce injury and illness concerns upon returning to work. Overall, it should be emphasized that recovery after childbirth is not necessarily linear and women should be prepared to transition back and forth between training and performance phases.

FUTURE PERSPECTIVES

Major gaps in our understanding exist because of the lack of studies investigating pregnancy, postpartum, and return to exercise in elite athletes and arduous occupations. It is important to acknowledge the similarities between the populations discussed in this article and use this collaborative approach to broaden the evidence base. Bø ***et al.*** (11) outlined important research questions that still need answering to advance the care of elite female athletes (spanning fertility; medical conditions, physiological and anatomical changes, exercise testing, athletic training, and exercise interventions) and recommended investigating the impact of strenuous exercise and the prevalence and risk factors associated with pregnancy complications. With reference to the postpartum period, they called for research to consider athletic training and exercise, breastfeeding, physiological and anatomical changes, and medical conditions. In addition to these recommendations, we suggest several other considerations to progress research and, thus, the care of elite female athletes and women in arduous occupations.

- ***Point 1:*** A wider MDT should be used throughout pregnancy and after childbirth to maximize recovery. Seeking and reflecting upon qualitative data from elite female athletes who have previously trained and competed through and beyond pregnancy might help shape future MDT configurations as well as timelines of care.

- ***Point 2:*** Pelvic health physiotherapists are well placed to evaluate specific pregnancy-related and postpartum concerns and to implement preventative strategies during, and even before, pregnancy. Further research is required to (i) assess the effectiveness of pelvic health physiotherapy interventions, such as pelvic floor muscle training during pregnancy; (ii) establish whether these interventions are required in the absence of dysfunction to improve overall performance outcomes after childbirth; and (iii) investigate whether implementation of interventions in asymptomatic women improves long-term health outcomes. A 5- to 10-year follow-up of women after these interventions would provide useful information on the long-term effectiveness of such interventions.
- ***Point 3:*** Swift ***et al.*** () showed that "early pregnancy" is a period of significant and heterogeneous behavior change, which is prejudiced by women's lived experience and their perceptions of risk. As such, the time scale for pregnancy-based interventions needs to be established to maximize the advantages of an active pregnancy.
- ***Point 4:*** The most effective exercise-based interventions for the active recovery phase of postpartum care needs to be investigated. We need to establish whether a combination of pelvic floor, abdominal, and general strengthening and conditioning exercises is more effective than each component in isolation.
- ***Point 5:*** Six weeks postpartum is an arbitrary time point at which commencing exercise is often advised and many interventions start. For active women, where time to return to activity is often critical, research that investigates rehabilitation and exercise interventions from day 1 postpartum, rather than 6 wk, is needed. A similar approach is already adopted in the immediate postoperative period for many conditions.
- ***Point 6:*** Observational studies of the interventions used by active women throughout pregnancy and postpartum would provide useful retrospective data for analysis to establish the most effective methods used to return to performance and competition. Furthermore, a repository of this case study-type information that is made accessible to researchers and medical professionals would improve the current state of the art.
- ***Point 7:*** Continued surveillance of injuries and illness incurred in the first year after childbirth would provide useful information and direction for future intervention-based studies. Similarly, documentation of training, competition, and working days lost due to injury and illness during pregnancy and after childbirth may provide useful information of the significance of the injuries and illnesses experienced.
- ***Point 8:*** Research is needed to demonstrate the effectiveness of an MDT approach with a structured exercise program to return women in arduous occupations to postpartum occupational fitness. Such studies should include an active recovery phase followed by a gradual increase in loading through both resistance and endurance training. Research should explore rehabilitative postpartum interventions with a focus on long-term health outcomes of UK servicewomen and incidences of illness and injury after return to work.
- ***Point 9:*** Sociological implications of pregnancy and childbirth need to be assessed in active women. It is imperative that we improve our understanding of the impact of pregnancy and childbirth, including maternity pay, sponsorship, pressures to secure position on a team, and pressures to be fit and ready for major sporting events or deployment.

- ***Point 10:*** Anecdotally, there are more mothers in elite para-sport than able-bodied sport, perhaps due, in part, to the longevity of their careers. It would be pertinent to scrutinize how para-athletes deal with their synchronous roles as mothers and Paralympians.

Conclusion

More research is required to advance our knowledge, understanding, and quality of care of pregnant and postpartum elite athletes and women in arduous occupations. Such advancement will facilitate the safest and most timely return to employment.

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