Title: Research across the female lifecycle: Reframing the narrative for health and performance in athletic females and showcasing solutions to drive advancements in research and translation.

Authors: Kelly L. McNulty[1,2*], Bernadette C. Taim[1,3*], Jessica A. Freemas[1], Amal Hassan[1], Carly Lupton Brantner[1,4], Chimsom T. Oleka[1,5], Dawn Scott[1,6,7], Glyn Howatson[1,2,8], Isabel S. Moore[1,9], Kate K. Yung[1,10,11], Kirsty M. Hicks[1,2,6], Matthew Whalan[1,11,12,13], Ric Lovell[1,11], Sam R. Moore[1,14], Suzanna Russell[1,15], Abbie E. Smith-Ryan[1,14*], and Georgie Bruinvels[1,16*].

**Joint first and last authors*

Affiliations: [1]Kynisca Innovation Hub (KIH), Falls Church, VA 22042, United States of America; [2]Department of Sport, Exercise and Rehabilitation, Faculty of Health & Life Sciences, Northumbria University, Newcastle Upon Tyne, United Kingdom; [3]Sport, Health, and Exercise (SHE) Research Centre, Department of Sport & Health Sciences, Technological University of the Shannon, Athlone, Republic of Ireland; [4]Department of Biostatistics, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland 21205, United States of America; [5]Department of OBGYN, Division of Pediatric and Adolescent Gynecology, INOVA Fairfax Hospital, Falls Church, VA 22042, United States of America; [6]Performance, Medical & Innovation Department, Washington Spirit Soccer Club, Washington DC, United States of America; [7]School of Health Sciences, Western Sydney University, Australia; [8]Water Research Group, North West University, Potchefstroom, South Africa; [9]Cardiff School of Sport and Health Sciences, Cardiff Metropolitan University, Cardiff, United Kingdom; [10]Department of Orthopedics & Traumatology, The Chinese University of Hong Kong, Hong Kong, China; [11]Faculty of Science, Medicine and Health,

University of Wollongong, Wollongong, New South Wales, Australia; [12]La Trobe Sport and Exercise Medicine Research Centre, La Trobe University, Australia; [13]Football Australia, Sydney, Australia; [14]Applied Physiology Laboratory, Department of Exercise and Sport Science, University of North Carolina at Chapel Hill, Chapel Hill, NC, United States of America; [15]Sports Performance, Recovery, Injury and New Technologies Research Centre (SPRINT), Faculty of Health Sciences, Australian Catholic University, Brisbane, Queensland, Australia; [16]Institute of Sport, Exercise and Health (ISEH), Division of Surgery and Interventional Science, University College London, London, United Kingdom.

Corresponding author: Dr Georgie Bruinvels. Kynisca Innovation Hub (KIH), Falls Church, VA 22042, United States of America. *Email:* gbruinvels@kynisca.com

ORCID ID:

Kelly L. McNulty: 0000-0001-6176-7983

Bernadette C. Taim: 0000-0003-3565-1869

Jessica A. Freemas: 0000-0001-7044-9549

Amal Hassan: 0000-0003-4034-9074

Carly Lupton Brantner: 0000-0003-1067-3260

Chimsom T. Oleka: 0000-0002-5411-2345

Glyn Howatson: 0000-0001-8494-2043

Isabel S. Moore: 0000-0002-4746-3390

Kate K. Yung: 0000-0003-1906-4111

Kirsty M. Hicks: 0000-0002-5057-9191

Ric Lovell: 0000-0001-5859-0267

Sam R. Moore: 0000-0003-0639-3266

Suzanna Russell: 0000-0001-9146-756X

Abbie E. Smith-Ryan: 0000-0002-5405-304X

Georgie Bruinvels: 0000-0002-9352-7228

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Abstract

Over the last few decades there has been an unprecedented growth of females in sport and exercise; including an exponential rise in female participation, alongside an increased interest and investment in female sport. This success in many aspects underscores the demand for, and importance of, female-specific research to optimize health, participation and performance of athletic females. It has also brought awareness to the numerous inequities that exist between females and males. Indeed, the prevailing narrative within sport and exercise science focuses on the disparity of research in females compared to males, which has led to a lack of a critical mass of high-quality data on athletic females. While acknowledging the current gap and the need for

63 further higher-quality data, there is still a body of knowledge pertaining to athletic females
64 spanning back over a century. This existing literature, amidst its criticisms, offers a valuable
65 foundation to build upon for current translation and to inform future research. Thus, it is essential
66 to acknowledge, interpret, and apply prior learnings from previous work, while also considering
67 any limitations. This commentary proposes a reframing of the current narrative that there is an
68 absence of useful data in athletic females, to one that recognizes both the strides made and how
69 past findings can be integrated into practice today as well as inform future research directions. It
70 also addresses the opportunities that remain, and how a more comprehensive and pragmatic body
71 of knowledge can be developed and translated to better serve athletic females in the future.

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73 **The time is now**

74 In recent decades, the rise of female participation in sport and exercise has been prominent. At the
75 most elite level the number of females participating in the 2024 Paris Olympic Games is set to
76 achieve parity with males for the first time, representing a 3,789% increase since the last Games
77 held in Paris in 1924 (International Olympic Committee, 2024). In parallel, results from the recent
78 'Active Lives Adult Survey' of people across England show a year-on-year increase in the number
79 of recreationally active females (Sport England, 2023). The unprecedented increase in both elite
80 and recreational female participation in sport and exercise is aligned with an accelerated growth
81 in the interest and investment in female sport. For example, in the United Kingdom, the viewing
82 time per person for televised female sport surged by 131% in 2022 compared to the previous year
83 (Women in Sport Trust, 2022). Additionally, projections suggest that elite female sports, including
84 football, basketball, and tennis, are set to amass global matchday, broadcast, and commercial

revenues of $1.3 billion in the United States in 2024, marking a staggering increase of over 300% compared to three years prior (Deloitte, 2023).

The current momentum in female sport and exercise supports the increasing demand for, and importance of, female-specific data and its dissemination to optimize health, participation and athletic performance in females. However, the prevailing narrative in this area centers on the imbalance of sport and exercise science research between females and males (Cowley et al., 2021), as well as criticisms regarding the poor methodological quality of the data (Elliott-Sale et al., 2021). As a result, it is commonly cited that there is a limited and low-quality evidence base to support the individualized and integrated application of health and performance insights specific to athletic females in practice (Emmonds et al., 2019), including across the many different sub-areas, such as training adaptation, recovery, nutrition, injury and illness. Although further and higher-quality female-specific data are needed, and constructive criticism is essential for scientific development, this current narrative overshadows the positive developments in female-specific research and its application. Literature that has aimed to identify and investigate female sport and exercise-specific considerations dates to 1877 (Jacobi, 1877). This body of research is valuable to athletic females; with the potential to inform enhancements in health, participation and athletic performance, and should not be discarded. The key is to determine how findings from previous work can be interpreted and applied within their constraints, as well as built on and developed to inform future research. By doing so, it will ensure that the insights gained from previous and emerging research contribute meaningfully to the health, participation and performance of athletic females. Therefore, the aim of this commentary is twofold. Firstly, to highlight previous research in this area and how it can contribute to the current pursuit of optimizing health, participation and performance in athletic females, thereby reframing the narrative from a perceived lack of useable

data. Secondly, to continue building on this existing knowledge, by showcasing areas for further female-specific research and its translation, to drive advancements in athletic female health, participation and performance.

Scope of this commentary

This commentary focuses on cisgender females. While the health, participation and performance research discussed, and its application, might be relevant beyond cisgender females, future research is needed to specifically support individuals with variations of sex development, as well as those who are transgender or gender diverse. Furthermore, unless otherwise stated, the term 'athletic female' is used throughout this commentary to encompass females from all performance classification tiers (*i.e.,* recreationally active to world class; (McKay et al., 2022)), and across the female lifecycle (*i.e.,* from puberty to post-menopause).

Female-specific considerations in sport and exercise

Extensive research exists demonstrating fundamental sex differences (*e.g.,* anatomical, physiological, neurological etc.) which can subsequently influence athletic performance and physiological responses to exercise (Ansdell et al., 2020). One of the major differences between females and males pertains to reproductive endocrinology, whereby females experience a multitude of hormone milieus that change across the lifecycle from puberty to menopause (Table 1). Each female life stage is characterized by markedly different endogenous sex hormone concentrations of estrogen and progesterone (Davis & Hackney, 2017). Typically, these life stages encompass: cyclic fluctuations in sex hormone concentrations across the menstrual cycle starting from menarche; the potential for supra-physiological sex hormone concentrations during pregnancy and unique sex hormone changes during postpartum as well as with breastfeeding;

unpredictable fluctuations and gradual declines in sex hormone concentrations during perimenopause; and chronically low concentrations of sex hormones during post-menopausal years (Elliott-Sale et al., 2021). Although the primary function of these sex hormones is to support reproduction, the systemic effects of these hormones on biological tissues and systems containing the respective hormone receptor(s) are well-established (Wierman, 2007). As such, changes in these endogenous sex hormone concentrations across the female lifecycle might affect multiple aspects of health (*i.e.,* physical and/or psychological), participation, and performance outcomes in athletic females (Elliott-Sale et al., 2021). These reproductive hormonal profiles can be altered through exogenous hormones, such as hormonal contraception, hormonal replacement therapy, and in-vitro fertilization treatment (Elliott-Sale et al., 2021). Additionally, reproductive status can be further altered by menstrual cycle dysfunctions (*e.g.,* secondary amenorrhea), other gynecological and/or endocrinological disorders (*e.g.,* polycystic ovary syndrome and thyroid dysfunction) and disruptions in environmental and/or lifestyle factors (*e.g.,* energy availability and physical and/or psychological stress; Elliott-Sale et al., 2021). Beyond reproductive function, there are other female health domains that have been historically overlooked in sport and exercise, including but not limited to breast and pelvic floor health (Moore et al., 2023). Furthermore, other increasingly acknowledged critical considerations for overall health, participation and performance of athletic females should not be ignored; these include, technology and equipment specifically designed with athletic females in mind, the impact of possible influences of socio-cultural norms and gender, as well as the consideration of sponsorship requirements and subsequent potential gendered harm experienced by females regarding social media (Okholm Kryger et al., 2022; Parsons et al., 2021). It is well recognized that the diverse characteristics of the endogenous and exogenous hormonal milieus throughout the female lifecycle, alongside

153 unique considerations in other female health domains, necessitate female-specific exploration in
154 sport and exercise science research.
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Table 1. An overview of the different types of reproductive hormone profiles in females across the lifecycle.

Lifecycle stage:	**Childhood**	**Adolescence**		**Reproductive years**	**Menopausal years**	
Sub-stages:	*Pre-puberty*	*Peri-puberty*	*Puberty*	*Pre-menopause*	*Perimenopause*	*Post-menopause*
Definition	The time before peri-puberty starts (on average age 0 to 8 years)	The time when a child's body begins to undergo changes (i.e., maturation of the genital organs, development of secondary sex characteristics) as they transition into adulthood (on average age 9 to 12-13 years). The transitional time before menarche in girls	The onset of menarche (on average 12-13 years)	Menstrual cycle between 21 and 35 days or up to 45 days if within the first 5 years post-menarche (on average between the ages of 12-13 years to 50 years)	Transitional time before menopause (on average age 45-50 years). Menopause is the point in time when a female experiences 12 consecutive months of amenorrhea because of the cessation of normal ovarian function, and that is not because of any other medical condition	The time after menopause (on average 51 years+)
Examples of variation in reproductive status		1. Early puberty (i.e., when girls have signs of puberty before 8 years) 2. Delayed puberty (i.e., when girls have not started breast development by 13 years, or absence of menarche 3 years after breast development has begun.	1. Primary amenorrhea (i.e., no menarche by age 15 years when development of secondary sexual characteristics is evident)	1. Menstrual cycle irregularity (e.g., secondary amenorrhea [i.e., the absence of ≥3 consecutive periods in non-pregnant females with past menses], anovulation [i.e., cycle that has menstruation but no ovulation], luteal phase deficiency [i.e., cycles with less than 16 nmol·L−1 of progesterone], abnormal uterine bleeding – short cycle [i.e., cycle length <21 days], abnormal uterine bleeding – long cycle [i.e., cycle length >35 days]) and dysfunction (e.g., endometriosis, polycystic ovarian syndrome) 2. Hormonal contraceptive use (any type of contraceptive capable of altering the endogenous hormonal milieu e.g., combined forms: oral contraceptive pill, vaginal ring, contraceptive patch; single forms: progestin-only oral contraceptive pill, contraceptive injection, contraceptive implant and intrauterine system [IUS]) 3. Intrauterine device [IUD] use 4. Other exogenous hormone use (i.e., in-vitro fertilization treatment, hormone replacement therapy etc.) 5. Pregnancy (i.e., 40 weeks on average divided into three trimesters each lasting 12–14 weeks (first trimester = 0-13 weeks, second trimester = 14-27 weeks, third trimester = 27 weeks onwards)	1. Premature menopause (i.e., menopause before the age of 40 years) 2. Early menopause (i.e., menopause before the age of 45 years) 3. Surgical/medical menopause 4. Hormonal contraceptive use 5. Hormone replacement therapy use (starting at any point from the onset of irregular periods and menopausal symptoms. Any type of HRT capable of altering the endogenous hormonal milieu e.g., tablets, patches, gels, implants, vaginal creams, pessaries or rings; combined or estrogen only; cyclical or continuous)	

Lifecycle stage:	**Childhood**	**Adolescence**		**Reproductive years**				**Menopausal years**		
Sub-stages:	*Pre-puberty*	*Peri-puberty*	*Puberty*	*Pre-menopause*				*Perimenopause*	*Post-menopause*	
				6. Postpartum (i.e., the time up to 12 months following birth. If breastfeeding, there is the potential for lactational amenorrhea.						
Endogenous estrogen (E) and progesterone (P) concentrations	Minimal quantities of E/P	E/P begin to rise (in non-linear fashion) with increasing age (e.g., the initial increase in E has been noted 6-12 months prior to the onset of puberty)	E/P begin to fluctuate in a fairly predictable pattern. Potential for irregular fluctuations within 5 years post menarche	*Menstrual cycle*	*Hormonal contraceptive use*	*Pregnancy*	*Postpartum*	*Perimenopause*	*Post-menopause*	*Hormone replacement therapy use*
				Cyclic fluctuations in E/P (Supplementary File 1)	Suppressed E/P with presence of exogenous sex hormones. The suppression of endogenous sex hormones and presence of exogenous sex hormones varies depending on the type/brand of hormonal contraceptive used	Supra-physiological E/P (i.e., 35 times more E than the menstrual cycle and almost 7 times more P than the menstrual cycle; Supplementary File 2)	If not breastfeeding/ using hormonal contraception, then resumption of menstrual cycle. The typical timeframe for ovulation to return postpartum is between 6-12 weeks (Supplementary File 2)	Unpredictable fluctuations and gradual declines in E/P (Supplementary File 3)	Significantly reduced E/P (~80%) compared to pre-menopausal females (Supplementary File 3)	E/P replacement (depending on the type/brand used)

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Female-specific research often entails careful methodological considerations, and in recent years several methodological papers for including female participants in sport and exercise science research have been published (Elliott-Sale et al., 2021; Janse De Jonge et al., 2019; Sims & Heather, 2018). The intent of these papers is to provide researchers with recommendations for best practice methods (*e.g.,* noting regular bleeding and measures of ovulation and progesterone in menstrual cycle research) thereby improving the rigor and interpretation of female-specific sport and exercise science data. These methodological considerations frequently require additional resources and participant/researcher burden, but investigations in females should not be avoided solely based on these methodological factors. The inability to adopt all best practice guidelines should not preclude female-specific research (Noordhof et al., 2022), nor should it hinder the potential practical application of current findings to benefit athletic females. While acknowledging the role of rigorous methodological design within this area, it is important to highlight that study impact cannot be solely determined via the quality of the research methodology, as it is also essential to consider factors, such as the clinical relevance and practical applicability of the research to athletic females (Bishop, 2008; Bullock et al., 2023). Moreover, akin to the evidence pyramid, researchers, editors and reviewers should remain cognizant of the potential benefit and value of practical implications for athletic females that can arise from a diverse range of research activities, beyond those that might not strictly adhere to the most rigorous methodological criteria. Thus, adjusting the lens through which previous and future female-specific research is viewed might allow for meaningful real-world applications to be drawn. Moving forward, if relevant to the research question, it is important for all researchers to implement as many of the current best practice guidelines as possible when evaluating females, whilst being transparent in describing the sample and methodology used, the rationale which informed such decisions, any statistical

techniques that have been applied to account for design limitations, the setting in which the study was intended to impact, and a comprehensive explanation of the implications of any limitations (Burden et al., 2024). Such accountability and transparency will help guide the interpretation and application of findings for athletic females, while simultaneously enabling innovation and progression in the area. In addition to transparency, there is a demand for researchers to adapt and refine the current guidelines to develop a practical and inclusive blueprint for achieving 'better practice' standards in applied research, facilitating ecologically valid data collection. Further, there is a need for methodological guidance within female specific domains beyond the menstrual cycle (*e.g.,* hormonal contraceptive use, breast health), as well as statistical models to analyze the relevant data. That said, improving the quality of research in athletic females might not necessarily require additional time or resource-intensive procedures but call for researchers to introspect and question their habitual way of conducting research, such as the inclusion of accurately defined and consistent female-specific demographic data (*i.e.,* description of reproductive and/or breastfeeding status). Ultimately, conducting higher-quality female-specific research is critical for advancing our understanding of female physiology, to better support the health, participation, and performance of athletic females across the lifecycle; however, these standards should not impede the pursuit and use of research that holds practical applicability in real-world contexts, while recognizing any limitations.

The current sport and exercise science research landscape in athletic females

While acknowledging the need for further and higher-quality research in females, it is important to recognize and utilize the female-specific data that is currently available. Research in females in the context of sport and exercise has been a longstanding pursuit spanning at least 150 years (Jacobi, 1877) and is now considered a 'trending' or 'hot' topic in sport and exercise science

research. There has been an exponential growth in the pursuit of research investigating key topics, such as the influence of different sex hormone profiles on sport and exercise participation, the health of athletic females across the lifecycle and athletic performance (Table 2). Specifically, there has been greater advocacy for, and substantial evidence supporting, the health benefits of exercise amongst females during key life stages, such as puberty, pregnancy, postpartum, as well as perimenopause and post-menopause (Hayman et al., 2023; Tamariz-Ellemann et al., 2023; Warburton, 2006). While this is encouraging, research also highlights a significant challenge in effectively engaging and ensuring continued female participation in sport and exercise across these key life stages (Women in Sport, 2021). Furthermore, many experimental studies, narrative and systematic reviews, books/book chapters, and meta-analyses have contributed to understanding the effects of female physiology on performance outcomes. By acknowledging the strengths and limitations of scientific findings that currently exist, it is possible to leverage and translate these existing (and emerging) data effectively into tangible benefits, positively impacting the health, participation and performance of athletic females across the lifecycle.

225 **Table 2.** An overview of examples of research in athletic females across the female lifecycle.

<table>
<tr><td>Lifecycle stage:</td><td>Childhood</td><td>Adolescence</td><td colspan="4">Reproductive years</td><td colspan="3">Menopausal years</td></tr>
<tr><td>Sub-stages:</td><td rowspan="2">Pre-puberty</td><td rowspan="2">Puberty</td><td colspan="4">Pre-menopause</td><td>Perimenopause</td><td colspan="2">Post-menopause</td></tr>
<tr><td>Reproductive status:</td><td>Menstrual cycle</td><td>Hormonal contraceptive use</td><td>Pregnancy</td><td>Postpartum</td><td>Perimenopause</td><td>Post-menopause</td><td>Hormone replacement therapy use</td></tr>
<tr><td rowspan="3">Participation in sport and exercise: Examples of what we know so far</td><td rowspan="2">-Girls are more likely to have never played sports and less likely to be currently playing sports compared to boys throughout childhood (Women's Sport Foundation, 2020)</td><td rowspan="2">-Participation tends to decline throughout puberty in girls, with a larger drop-off in participation rates compared to boys (Women in Sport, 2019, 2022)
-Menstruation is frequently perceived as a barrier to participation in physical education or school sport activities, often due to fears of leaking and pain or discomfort (Youth Sport Trust, 2023)</td><td colspan="2">-Females are less likely than males to meet physical activity guidelines (World Health Organization, 2022)</td><td rowspan="2">-Fewer than 15% of women achieve the minimum recommendations for physical activity during pregnancy (Evenson & Wen, 2011)
-Pregnancy-related physical and psychosocial factors might lead women to cease exercise during pregnancy (Atkinson & Teychenne, 2019)</td><td rowspan="2">-Up to 26% of women might not return to exercise postpartum. Factors such as pelvic floor health, fear of exercising postpartum and pre-pregnancy exercise levels affect the likelihood of women returning to exercise postpartum (Moore et al., 2021)</td><td colspan="3" rowspan="2">-One third of women in the United Kingdom aged between 41 to 60 are not meeting the recommended guidelines of 150 minutes of exercise per week, including muscle strengthening exercises on two occasions (Women in Sport, 2021)</td></tr>
<tr><td>-Females who experience longer and heavier bleeding, along with fatigue and pain during menstruation, might avoid engaging in physical activity (Kolić et al., 2021)</td><td>-Athletic females who experience negative physical side effects related to hormonal contraceptive use may be unable to participate in or complete training (Oxfeldt et al., 2020)</td></tr>
<tr><td></td><td colspan="8">-Increase in female participation in sport and exercise across all lifecycle stages (Eime et al., 2021)</td></tr>
<tr><td></td><td></td><td colspan="8">-Breast-related considerations (e.g., breast movement, sports bra fit, breast pain) present as barriers to physical activity engagement in females (Scurr et al., 2016)
-Physical activity engagement tends to decrease in females as breast size increases (Coltman et al., 2019)</td></tr>
<tr><td>Health and athletic performance: Examples of what we know so far</td><td>-The differences in athletic performance between pre-pubertal females and males are minimal (Hunter et al., 2023)</td><td>-Performance and physiological responses to exercise begin to differ between males and females (Ansdell et al., 2020)</td><td>-Menstrual cycle disorders such as amenorrhea and oligomenorrhea are indicators of Relative Energy Deficiency in Sport (REDs)</td><td>-Use of the combined oral contraceptive pill might result in slightly inferior exercise performance compared to naturally</td><td>-Exercise can help to reduce pregnancy complications and optimise maternal and foetal health across their lifespans (Mottola et al., 2018)</td><td>-A maternity leave does not appear to negatively impact a female athlete's performance development, when age is taken into consideration</td><td>-Exercise can improve the quality of life in women with menopausal symptoms (Nguyen et al., 2020)</td><td>-Physical exercise reduces the risk of cardiovascular disease in post-menopausal women (Mendoza et al., 2016)</td><td></td></tr>
</table>

Lifecycle stage:	**Childhood**	**Adolescence**	**Reproductive years**				**Menopausal years**		
Sub-stages:	*Pre-puberty*	*Puberty*	*Pre-menopause*				*Perimenopause*	*Post-menopause*	
Reproductive status:			*Menstrual cycle*	*Hormonal contraceptive use*	*Pregnancy*	*Postpartum*	*Perimenopause*	*Post-menopause*	*Hormone replacement therapy use*
			(Mountjoy et al., 2023) -The estimated prevalence of low energy availability or REDs in athletic females range from 23% to 80% (Mountjoy et al., 2023) -Scientific advancements have been made in the prevention, assessment, and treatment of REDs for clinicians (e.g., validated REDs Clinical Assessment Tool-Version 2) (Mountjoy et al., 2023) -Between 16% and 60% of female athletes exhibit at least one component of the Female Athlete Triad (Gibbs et al., 2013) -Exercise performance might be reduced by a trivial amount during the early follicular phase	menstruating females (Elliott-Sale et al., 2020) -Exercise performance remains consistent across the combined oral contraceptive pill cycle (Elliott-Sale et al., 2020) -Combined oral contraceptive pill use has no effect on hypertrophy, power, and strength adaptations in response to resistance exercise (Nolan et al., 2024)	-Engaging in elite-level training and competition before and during pregnancy is not associated with an increased odds of adverse pregnancy outcomes although research is limited (Wowdzia et al., 2021) -Elite female athletes can perform the same volume of training in each trimester, but supplement high impact activities (e.g., running) with low impact activities (e.g., cross-training) to maintain training volume (Darroch et al., 2023)	(Forstmann et al., 2023)		-Physical exercise has a positive influence on bone health in post-menopausal women (Mendoza et al., 2016) -Physical exercise is a principal strategy for preventing and treating sarcopenia and its effects by increasing muscle mass and function in post-menopausal women (Mendoza et al., 2016) -Both aerobic exercise and strength exercises can partially or completely counteract the changes associated with metabolic syndrome in sedentary post-menopausal women	

Lifecycle stage:	**Childhood**	**Adolescence**	**Reproductive years**				**Menopausal years**		
Sub-stages:	*Pre-puberty*	*Puberty*	*Pre-menopause*				*Perimenopause*	*Post-menopause*	
Reproductive status:			*Menstrual cycle*	*Hormonal contraceptive use*	*Pregnancy*	*Postpartum*	*Perimenopause*	*Post-menopause*	*Hormone replacement therapy use*
			when compared with other phases (McNulty et al., 2020) -Resistance training conducted in the follicular phase might be superior to luteal phase-based training in terms of enhancing muscle strength and mass (Kissow et al., 2022) -Changes in sex hormones across the menstrual cycle might influence muscle damage responses post exercise (Romero-Parra et al., 2021) -Perceptual responses might vary across different phases of the menstrual cycle (Paludo et al., 2022) -Menstrual cycle symptoms are common in athletic females and are					(Mendoza et al., 2016) -Physical exercise is inversely related to the risk of dementia and improves the cognitive function of post-menopausal women (Mendoza et al., 2016)	

Lifecycle stage:	**Childhood**	**Adolescence**	**Reproductive years**				**Menopausal years**		
Sub-stages:	*Pre-puberty*	*Puberty*	*Pre-menopause*				*Perimenopause*	*Post-menopause*	
Reproductive status:			*Menstrual cycle*	*Hormonal contraceptive use*	*Pregnancy*	*Postpartum*	*Perimenopause*	*Post-menopause*	*Hormone replacement therapy use*
			associated with perceived negative effects on performance (Bruinvels et al., 2021) -An increase in menstrual cycle related symptom magnitude (frequency and severity) is associated with a perceived reduction in exercise performance and a longer recovery time post-training (McNulty et al. 2023). -Menstrual cycle disorders are commonplace among athletic females (Taim et al., 2023) -Exercise is effective in improving menstrual cycle physical and psychological symptoms (Yesildere Saglam & Orsal, 2020)						
		-Contact breast injuries frequently occur in female athletes, but reporting and treatment remains low (Bibby et al., 2024) -Well-fitting and supportive sports bras can reduce exercise-induced breast discomfort during physical activity. There are several guidelines and design features to ensure a properly fitted and supportive sports bra (McGhee & Steele, 2020)							

Lifecycle stage:	**Childhood**	**Adolescence**	**Reproductive years**				**Menopausal years**		
Sub-stages:	*Pre-puberty*	*Puberty*	*Pre-menopause*				*Perimenopause*	*Post-menopause*	
Reproductive status:			*Menstrual cycle*	*Hormonal contraceptive use*	*Pregnancy*	*Postpartum*	*Perimenopause*	*Post-menopause*	*Hormone replacement therapy use*
		-Stress urinary incontinence has been reported in a variety of sports and can interfere with training and compromise athletic performance (De Mattos Lourenco et al., 2018) -Sex differences exist in common sport injuries; for example, smaller calf girth, femoral adduction, and higher rates of loading are risk factors for injuries in female athletes (Lin et al., 2018).							

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Research opportunities across the female lifecycle

With the recent surge in data specific to females, it is crucial to capture and build on the current understanding and capitalize on the numerous opportunities that remain (Table 3). Notably, across the past century, researchers in this area have primarily pursued similar female physiology-related research questions largely focused on sex differences (*e.g.,* functional and/or structural) and clinical challenges, such as the female athlete triad (Otis et al., 1997), and subsequently, the syndrome of relative energy deficiency in sport (Mountjoy et al., 2023). The focus on these specific research questions has led to clusters of data that constitute most of the female-specific information available today. Additionally, instead of highlighting the strengths and capabilities of females across the lifecycle, external interpretation of this body of research has potentially fueled a narrative of fragility and vulnerability in female health and performance. Moreover, a prevalent theme in recent years has been the effects of endogenous sex hormones across the menstrual cycle on athletic performance. This performance-focused, menstrual cycle research has often been conducted in repetitive ways (*i.e.,* iterations of the same research design and methods) that might not always be reflective of real-world needs. For example, an overemphasis on a few pre-defined menstrual cycle phases (*i.e.,* early follicular, late follicular and mid-luteal phases) disregarding the day-to-day hormonal changes that females accommodate to perform optimally and consistently (Bruinvels et al., 2022). It is without a doubt that higher-controlled research has been instrumental in advancing our understanding of athletic females, but moving forward, the challenge for researchers in this area is to build upon these studies with the development of contextual and innovative research, whilst also applying a broader lens within these popular questions. For example, key questions could include understanding the intra- and inter-individual variability in menstrual cycle characteristics among athletic females, taking advantage of advancements in

technology (*e.g.,* 'FemTech'), to ascertain insight into the current heterogenic findings to date. In addition, intervention development to track and proactively manage menstrual cycle-related symptoms is needed. Furthermore, it is important that other key areas for female-specific research are represented, such as hormonal contraceptive use, pregnancy and postpartum, peri- and post-menopause, and implications on health, participation and performance outcomes. This could encompass various questions, including but not limited to, the effects of hormone replacement therapy on athletic performance, the prevalence and management of infertility among elite female athletes, and the investigation of illness and injury risk, by utilizing large data sets and optimal, standardized methods for recording and reporting epidemiological data (Moore et al., 2023), to inform better prevention and management.

260 **Table 3.** Examples of opportunities for future research in athletic females across the lifecycle.

Lifecycle stage	**Adolescence**	**Reproductive years**				**Menopausal years**		
Sub-stages:	*Puberty*	*Pre-menopause*				*Perimenopause*	*Post-menopause*	
Reproductive status:		*Menstrual cycle*	*Hormonal contraceptive use*	*Pregnancy*	*Postpartum*	*Perimenopause*	*Post-menopause*	*Hormone replacement therapy use*
	- Research prioritization, through the likes of Delphi studies to determine which research topics should be considered a priority across the female lifecycle - Creation of standardized, validated screening, monitoring and analysis tools for female health data collection - Creation of standardised, validated and effective education resources for athletic females and those who work with them							
Research opportunities* *Not an exhaustive list	- Timing of puberty in paediatric and adolescent athletes - Influence of puberty on performance ability, training responses and recovery - Menstrual cycle characteristics (inter/intra-cycle variability) in female adolescent athletes, within initial years of menarche (e.g., 5 years)	- The intra- and inter-individual variability in menstrual cycle characteristics - Aetiology of menstrual cycle-related symptoms - Strategies to manage menstrual cycle-related symptoms - Effects of the menstrual cycle and disorders on performance ability, training responses and recovery - Methods to identify menstrual cycle disorders - Rates of menstrual cycle disorders, such as endometriosis, polycystic ovary syndrome etc. in elite female athletes	- Influence of different types of hormonal contraception on health in the short- and long-term - Effects of different types of hormonal contraception (namely progestin-only forms) on performance ability, training responses and recovery - How different forms of hormonal contraception affect menstrual cycle characteristics - Aetiology of hormonal contraception side effects - Strategies to manage hormonal contraception side effects	- Exercise and nutritional guidelines during pregnancy across different athletic calibres - Influence of in vitro fertilisation on performance ability, training responses and recovery - Influence of sport and exercise on fertility - Infertility in elite female athletes	- Evidence-based policies to support postpartum return-to-sport - Influence of breast feeding on performance and health	- The influence of perimenopause and post-menopause on participation in sport, exercise and physical activity - The role of exercise and nutritional changes to manage menopausal symptoms and optimise health and well-being outcomes during perimenopause and beyond - Exploration of menopause specific exercise and nutrition recommendations - The influence of perimenopause and post-menopause (as well as hormone replacement therapy use) on performance ability, training responses and recovery		
	- Injury and illness surveillance, potential associations, prevention and return to performance across the female lifecycle (*i.e.,* different sex hormone profiles) - Influence of breast biomechanics on sport and exercise participation and performance - The integration of breast biomechanics data collection into routine biomechanical practice when assessing athletic female performance and injury risk							

	- The effects of different types of sports bras and correct fit on performance and health - Prevalence of breast injuries across sports and management strategies - Prevalence and prevention of pelvic floor dysfunction in athletic females - Effects of pelvic floor dysfunction on performance - Prevalence and prevention of vulva injury in elite athletes - The development of kit and equipment specific to athletic females

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In addition to the research opportunities highlighted in Table 2, it is also time to reframe the ways in which we conduct research in athletic females by working collectively to advance the field. Fundamentally, sport and exercise science research aims to guide practices to ultimately enhance health and performance (Bishop et al., 2006). However, it is crucial for researchers to recognize that only research findings which will be (*i.e.,* accepted by athletes, coaches, and practitioners) and can be (*i.e.,* feasible to implement) adopted within a practical setting can potentially impact health and performance (Bishop, 2008). To that end, collaborations between applied and mechanistic researchers in the laboratory or field, practitioners, science and medicine support teams, and athletic females themselves are essential for establishing interdisciplinary, translatable outcomes. These synergistic collaborations will not only ensure research-informed practice, but also allow athletic females and practitioners working in sporting environments to identify research priorities, advise on and/or co-design research to ensure practice-informed research (Haag, 1994). Currently, within sport and exercise science, there remains a disconnect between research and practice, resulting in research outputs that may not always contribute to practice (Fullagar et al., 2019; McLean et al., 2021; Owoeye et al., 2020). Utilizing an integrated approach between academics, practitioners, and athletic females will ensure that concurrent progress can be made in both theory and practice, allowing us to better understand and serve athletic females moving forward.

Translating research to practice through education

Research has shown an average lag of 17 years before research findings impact practice (Morris et al., 2011); athletic females cannot afford to wait until all the answers are present before research is utilized to inform and educate. It is well-established that athletic females lack knowledge in female-specific topics, such as menstrual health, breast health, pregnancy, and menopause (Davenport et al., 2023; Larsen et al., 2020; McGhee et al., 2010; O'Reilly et al., 2023). Yet, they

have expressed a desire to learn more (Brown et al., 2021; Scurr et al., 2016; Taim et al., 2024), highlighting the need to provide effective education on female-specific topics, as well as embedding female health considerations into common sport and exercise areas, such as sleep, nutrition, and recovery, which will empower females to understand their own physiology (Table 4). This could encompass a range of topics, such as educating young girls about changes during puberty to encourage continued participation in sport and exercise during this life stage, promoting the benefits of exercise during pregnancy and postpartum, as well as during perimenopause and post-menopause, and highlighting the importance of correct breast support during sport and exercise. Notably, it is imperative that educational priorities are not solely determined by the gaps identified through research, but also through iterative collaborations that incorporate the voices of athletic females across all life stages alongside other key stakeholders.

In today's digital landscape, multiple communication avenues for research dissemination, in addition to scientific publication, should be explored. Leveraging social media and presenting information through a variety of formats, including infographics, podcasts, and short form videos could increase impact and translation (Barton & Merolli, 2019). There is also a need to "think outside the box" and create new ways to disseminate research, perhaps through creating experiential learning opportunities. For instance, this could involve integrating with technology, such as wearable devices and mobile application experiences to share research-based, relevant and contextualized information when it is most pertinent to users. By engaging with athletic females in their own environments and tailoring research content based on personalized data, researchers are presented with an opportunity to enhance the effectiveness, reach, and impact of study findings. Similarly, given the amount of misinformation and dis-information in aspects of female sport and exercise science, it is important to ensure education is factual, research based, and that athletic

females, coaches, and practitioners are taught how to critically appraise and identify trustworthy information (McGawley et al., 2023). Finally, educational materials should also be curated in an understandable, relevant (*e.g.,* attention to cultural constructs, resource availability, and religious beliefs etc.), and age-appropriate manner.

It is important to recognize that the translation of evidence-based research into practice is contingent not only on its dissemination, but also on the knowledge, expertise and skills of practitioners to facilitate its implementation (Bishop, 2008). In sport and exercise, many barriers to communication about female health still exist, which are often driven by a lack of education and knowledge among athletic females and practitioners. For instance, research demonstrates that athletic females as well as coaches and practitioners working with athletic females lack understanding in female-specific domains (Von Rosen et al., 2022). Notably, at the 2020 Olympics, only 13% of coaches were women (International Olympic Committee, 2021), reflecting a global gender gap among high-performance sport coaches, and potentially sport in general, which could impede effective communication in these female-specific domains due to perceived gender barriers (Brown & Knight, 2022; Höök et al., 2021). Nonetheless, research indicates that coaches, regardless of gender, are keen to improve their knowledge (Clarke et al., 2021; Donnelly et al., 2024). This highlights a timely opportunity for researchers to work with key stakeholders to integrate relevant research findings into the curricula of sports science and coaching programs, as well as offering continuing education courses and certifications, focused on the latest research. By educating key stakeholders, such as multidisciplinary teams, it will be possible to empower recipients of this material to enhance the level and quality of support to optimize health and unlock performance potential in athletic females. Furthermore, ethical considerations pertaining to privacy, consent, and scope of practice should be prioritized to ensure the safeguarding of athletic

females (Howe, 2024). Ultimately, athletic females have accomplished incredible feats and continue to push the boundaries of human performance even though education is historically limited; imagine what could be achieved when females are informed and empowered by current and forthcoming knowledge regarding their physiology.

335 **Table 4.** Female-specific education topics for health and performance in athletic females across the life cycle.

Life cycle stage	**Adolescence**	**Reproductive years**				**Menopausal years**		
Sub-stages	*Puberty*	*Pre-menopause*				*Perimenopause*	*Post-menopause*	
Reproductive status		*Menstrual cycle*	*Hormonal contraceptive use*	*Pregnancy*	*Postpartum*	*Perimenopause*	*Post-menopause*	*Hormone replacement therapy use*
Female-specific education topics* **Not an exhaustive list.*	- Female reproductive anatomy - Basic menstrual health and hygiene - Types of menstrual products considering their participation in sport and physical activity - Psychological, and physical changes that may occur during puberty - The potential impact of physical and psychological changes on sports performance - Encouraging positive body image and self-esteem - How to communicate about menstrual cycle and/or other female health issues and seek support - Comprehensive education on being an athletic female, including topics such as nutrition, sleep, injury prevention, and movement patterns	- Physiology of the menstrual cycle, including hormonal changes - Menstrual health (*e.g.,* characteristics of a typical menstrual cycle, menstrual cycle disorders) - How to communicate about the menstrual cycle and when to seek medical help - Using the menstrual cycle as an indicator of health for athletic females - Management strategies for menstrual cycle-related symptoms - Menstrual cycle tracking, including the rationale, methods for tracking, and data interpretation. - Current research evidence on the effects of the menstrual cycle on sport domains (*e.g.,* performance, recovery, sleep, injury risk etc.) - Real-world stories from female	- Types of hormonal contraception and their mechanisms of action - Possible side effects of hormonal contraception and when to seek medical help - Hormonal contraceptive tracking including the rationale, methods for tracking, and data interpretation - Current research evidence on the effects of hormonal contraception use on sport domains (*e.g.,* performance, recovery, sleep, injury risk etc.) - Pros and cons of hormonal contraception as an athletic female	- Benefits of exercise during pregnancy (*e.g.,* reduction in maternal and foetal morbidity) - Exercise guidelines for athletic females - Sport-specific concerns during pregnancy - Contraindications to exercise during pregnancy - Importance of discussing with healthcare professional prior to engaging in sport and exercise - Physical changes during pregnancy - Metrics to track and monitor during pregnancy - Optimising nutrition for pregnancy in athletic females - Practical considerations surrounding kit and equipment during pregnancy - Pelvic floor health, including pelvic floor symptoms - Importance of pelvic floor muscle training for the prevention and	- Exercise guidelines for postpartum safe return to sport and physical activity (*e.g.,* gradual increases, muscle strengthening) - Sport-specific concerns for postpartum return-to-sport (*e.g.,* breastfeeding and contact sports) - Symptoms of pelvic floor and/or abdominal wall dysfunction - Mental health considerations - The psychosocial considerations of the mother-athlete transition - Pelvic floor health, including pelvic floor symptoms - Importance of pelvic floor muscle training for the prevention and management of pelvic floor dysfunction	- Physiology of the menopause transition - Signs and support for premature and early menopause as well as medical menopause - Perimenopause symptoms - Management strategies for menopausal symptoms - The benefits of exercise during perimenopause and current guidelines - Perimenopause menstrual cycle tracking, including the rationale, methods for tracking, and data interpretation. - Current research evidence on the effects of perimenopause on sport domains (*e.g.,* performance, recovery, sleep, injury risk etc.) - Optimising nutrition for health and performance during perimenopause - Pelvic floor health, including	- Health conditions post-menopause - Management strategies for health conditions post-menopause - The benefits of exercise during post-menopause and current guidelines - Current research evidence on the effects of post-menopause on sport domains (*e.g.,* performance, recovery, sleep, injury risk etc.) - Optimising nutrition for health and performance during post-menopause - Pelvic floor health, including pelvic floor symptoms and exercises	- Hormone replacement therapy benefits and risks, including sport-specific considerations - Current research evidence on the effects of hormone replacement therapy on sport domains (*e.g.,* performance, recovery, sleep, injury risk etc.)

		athletes about their menstrual cycle-related lived experiences		management of pelvic floor dysfunction		pelvic floor symptoms and exercises		
	- Importance and benefits of girls and women participating and remaining in sport and physical activity throughout the lifespan - Reframing the narrative to emphasise the capabilities of the female body, and advocating for support to help women and girls recognise this throughout all life stages, from puberty to menopause - Injury and illness risk factors, prevention and return to performance - Breast health, including breast anatomy and detecting signs of breast cancer - Sports bra types and fit, including how to choose bras for specific sport and physical activity - Implications of breast movement on sport performance and participation in physical activity - Breast injuries - Pelvic floor health, including pelvic floor symptoms - Incorporating pelvic floor muscle training into a female athlete's regular strengthening program, treating it similarly to other muscle groups and body regions							

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Conclusion

The exponential rise in female participation in sport and exercise, and the increasing interest and investment in female sport, emphasizes the need to consider female-specific factors in the pursuit of optimal health and performance. This commentary has presented a case that a body of actionable data in athletic females currently exists, which should be carefully interpreted and applied within its constraints, to optimize health, participation, and performance outcomes while also advancing future research. In addition, this commentary highlights that several opportunities for further female-specific exploration across the entire lifecycle exist, particularly research that meets real-world needs. There is a call for a more inclusive and integrated research paradigm, whereby expertise and experiences from athletic females, researchers, applied practitioners, science and medicine support teams, and other key stakeholders are combined to translate current research to optimize female health, participation and performance, as well as ensure further research directly addresses the requirements of the population it serves. As researchers there is a strong need to critically question routine practices and ask what should be done to better serve athletic females in the future. Furthermore, it is crucial to educate and empower athletic females to understand their physiology at every life stage. Importantly, this should be achieved by using a strengths-based approach, for example focusing on what athletic females can do, rather than what they cannot. As we stand on the brink of unprecedented growth in female sport and exercise, there is an enormous opportunity to advance research and its translation in a new and innovative manner, thereby paving the way to unlock the full potential of athletic females across the lifecycle.

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