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National Strength and Conditioning Association Position Statement on Strength and Conditioning of Female Athletes. Part I: Lifespan, Injury, and Health Considerations

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Abstract

Dabbs, NC, Binkley, H, Bott, C, Fragala, MS, Herda, A, Moeskops, S, Moore, EWG, Smith-Ryan, A, and Triplett, NT. National Strength and Conditioning Association position statement on strength and conditioning of female athletes. Part I: Lifespan, injury, and health considerations. *J Strength Cond Res* 40(8): 875–894, 2026—Throughout an athlete's lifespan, there are several contributing factors that can affect performance. Sex-specific physiological differences occur between male and female athletes that may result in different needs throughout the stages of an athlete's development and through maturation, where special consideration may be needed for specific health aspects and common injuries in female athletes. A greater understanding of the developmental stages of female athletes, including their unique biological differences in health and risk of injury, is warranted among strength and conditioning professionals to provide comprehensive training programs for female athletes. The purpose of this position statement is to help strength and conditioning practitioners understand current evidence and recommendations for female athletes throughout their lifespan, the female-specific injuries that may occur, and the health considerations that may enhance overall female athlete health and well-being. Therefore, Position Statement Part I is separated into 3 sections: (a) lifespan development, (b) injury considerations, and (c) health considerations.

Key Words: women, sports, girls, performance, player, training

Introduction

Since the publication of the original position statement in 1989, the participation of in sport has risen alongside uneven global political, social, and cultural advances for . The National Strength and Conditioning Association (NSCA), based in the United States, is significantly influenced by the country's athletic and sociopolitical environment. Therefore, the civil rights law, Title IX (signed in 1972 and implemented in 1975), left an indelible mark by prohibiting sex-based discrimination in education programs, including sports activities, that receive federal government funding (223). In context, the first NSCA Position Statement on "Strength Training for Female Athletes" was published less than 15 years after Title IX implementation. At that time, there had yet to be a generation of born who had benefited from Title IX across their entire athletic career.

Over 50 years since Title IX implementation, there is now a larger subject pool for research as the number of participating in high school and collegiate sports within the United States has risen more than 1,000% and 600%, respectively (223). Women's participation in sport has grown worldwide, with organized soccer alone experiencing an increase of nearly 25% in female and girl subjects from 2019 to 2023 (234). This participation has not occurred with similar growth of women employed as head coaches, strength and conditioning coaches, or sport administrators (223). However, while women's participation in sport has increased, similar improvements have not occurred in the representation of women as head coaches, strength and conditioning coaches, or sport administrators (158). The number of women serving as head coaches declined by 40% following the passage of Title IX (Acosta and Carpenter, 1990) and has yet to rebound; in soccer worldwide, women comprised only 5% of coaches and 9% of referees in 2023 (234). In the United Kingdom in 2017, it was reported that women only make up 6–7% of strength and conditioning coaches and 17% of sport coaches (140).

When moving from the field to research, examination of publications indicates a recent increase in topics related to research on female athletes (165). However, research with female subjects within exercise science, sports science, and sports medicine remains limited, with far greater amounts of research examining or isolating male subjects (50,179,218). Authors have highlighted the fact that the quantity of high-quality research on female subjects is lacking and even more scarce when further delimiting the population studied to female athletes (68,87).

The purpose of this update to the original position statement is to *provide a more comprehensive series of recommendations related to practices in strength and conditioning when training*

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Operation Terms

The following definitions are provided to establish context of the current evidence that was evaluated for this position statement.

- Athlete: participates in an official sports competition and engages in regular technical and tactical training for that competition (136).
- Sex: "a multidimensional construct based on a cluster of anatomical and physiological traits that include external genitalia, secondary sex characteristics, gonads, chromosomes, and hormones" (14). Classifications of sex are typically male, female, or intersex (also referred to as differences in sex development (DSD) and typically defined at birth).
- Gender: "a multidimensional construct that links gender identity (e.g., female, woman, girl), which is a core element of a person's individual identity; gender expression (e.g., feminine), which is how a person signals their gender to others through their behavior and appearance (such as hair style and clothing); and cultural expectations about social status, characteristics, and behavior that are associated with sex traits" (14).
- Subject Classification Framework: Classification of individual subjects in studies featuring exercise/training and/or sport performance outcomes. Tier 2 athletes regularly train about 3 times per week and train with a purpose to compete. Research conducted on female athletes, tier 2 and above, has been utilized whenever possible, thus guiding the scope of this position statement (135).

Scope of Position Statement Part I

Since the original 1989 NSCA Position Statement on female athletes (13), there has been increased discussion on the intersectional effects of gender (i.e., *women and girls, men and boys)* and sex (i.e., *female, males [adj]*). However, many publications use sex and gender terms interchangeably or without detailed descriptions of the population or athlete caliber. This position statement is divided into 2 parts: Part I—Lifespan development, injury, and health considerations for female athletes; Part II—Training adaptations and program design for female athletes. These position statements considered the gendered social and sporting environments for women and girls. In the introduction, which broadly describes these gendered experiences, the terms "women and girls" will be used. Subsequently, the term "female athletes" will be used, referring to cisgender (female assigned at birth) athletes.

It is important to note that these position statements on female athletes must assume that sex and gender effects are at least partially intertwined (155,250). This means that when researchers measure proposed sex differences that could influence strength and conditioning practice, these measurements may not be separated from gendered influence by cultural and social restrictions placed early in female youth sports (155,250). This is particularly true in studies with poor reporting, experimental design, and statistical methods. For example, lack of consideration of the population (e.g., untrained versus athlete) during interpretation of results could be an example of failing to use best practice to elucidate proposed sex-based differences for female athletes (63,75,219). As a result, findings stated to be sex-based differences may be confounded, moderated, or mediated by socially constructed gendered differences in sporting experience, exposures, and opportunities for women and girls (32,161).

Therefore, these position statements on female athletes will use evidence from research that describes women by gender or female athletes by sex and collectively review as if all subjects are female as assigned by birth. Furthermore, to be considered evidence most appropriate to inform strength and conditioning for female athletes, the population should be at least a tier 2 or above, as outlined in the operational terms. Using an evidence-based practice approach, the authors integrated scientific evidence, professional expertise, and practical considerations to develop recommendations for the physiological growth and development, training adaptations, needs, interests, choices, and goals of female athletes. Key steps in the evidence-based approach involved: (a) collecting the evidence, (b) assessing evidence, (c) integrating the evidence with practical aspects, and (d) making each recommendation or conclusion based on evidence. A summary of evidence in Table 1 demonstrates the body of literature on lifespan development, injury, and health considerations that overwhelmingly supports that topics presented in more detail throughout this study.

female athletes in a two-part paper. As a result, we have broadened the scope in comparison to the original position statement that was principally focused on resistance training; whereas, Part I of the position statement focuses on lifespan development, injury, and health considerations for female athletes, and Part II focuses on training adaptations and program design for female athletes.

Lifespan for the Female Athlete

The female athlete is an evolving person who begins their sporting journey likely in childhood and retires into adulthood. Understanding how female growth, maturation, and motor development are impacted helps practitioners develop optimal training interventions. Strength and conditioning for young female athletes can elicit positive adaptations in performance outcomes, reduce injury risk, and enhance aspects of health and psychosocial well-being. Maximizing system efficiencies (e.g., neural pathways) and levels (e.g., bone density, muscle mass) to facilitate maintenance, reduce decline, and mitigate injury risk is important during adulthood.

Pregnancy, postpartum, and menopause are conditions unique to women and have a direct effect on training and performance through the physiological changes that occur during each of these transitions. Modifications and adaptations to training during puberty, pregnancy, and menopause can maintain or improve function, and/or decrease some negative side effects.

Youth Development

Effects of Growth and Maturation on Physical Performance and Injury Risk. Researchers have shown that during childhood, boys and girls experience similar rates of biological development; however, researchers have found gender-related differences in psychosocial determinants of motor skill development and engagement in physical activities (247). For example, research suggests boys have greater throwing accuracy, velocity, and distance than girls from ages 4 to 7 years, which could be partly

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Table 1
Position statements on lifespan development, injury, and health considerations in female athletes.

Topic	Position statements
Lifespan for the female athlete	Youth: Training interventions (e.g., endurance, resistance, plyometric, and speed) can significantly enhance performance outcomes beyond natural development (20,117,140,146). The responsiveness to strength and conditioning-oriented training programs in girls is similar to that of boys (13,20,134,168). Engagement in these programs should commence in the prepubertal years when levels of neural plasticity are heightened (38,121) to prioritize the synergistic development of fundamental motor skills and muscular strength (121,123,155) in a fun and positive psychosocial environment (94,132,163,209) Pregnancy: Pregnancy and postpartum are conditions unique to female athletes and have a direct effect on training and performance through the physiological changes that occur during each of these conditions. Modifications and adaptations to training during pregnancy can maintain, improve, or decrease negative side effects before, during, and after pregnancy (25,26,33,152,268). Program design should include a needs analysis specific to the athlete, as well as specific to the physiological changes that occur during pregnancy and postpartum (19,59,108,113,119,217,231,232,250,255,257) Perimenopause, menopause, and postmenopause: Hormonal changes in estradiol, progesterone, follicle-stimulating hormone, and testosterone coincide with the onset of menopause; physiological changes during the transition to menopause are characterized by an increased risk of osteoporosis, abdominal adiposity, and poor lipid profiles, which can result in an increased risk of cardiovascular disease (75,207). Resistance training should be focused on maintaining or improving muscle mass and bone mineral density, which will also enhance performance (5,24,149,189,216,251)
Injury considerations	Some injuries present at a higher rate or incidence in female athletes compared with male athletes. The delivery and progression of strength and conditioning programming to female athletes have been shown to be critical factors to further reduce the risk of musculoskeletal injury, including that of ACL, bone stress, and concussion injuries (65,102,103,249,252) Anterior cruciate ligament (ACL) injuries: Neuromuscular, biomechanical, hormonal, and anatomical differences between male and female athletes may influence ACL injury, based on the literature. However, only neuromuscular and biomechanical risk factors can be addressed from a training perspective. Strength and conditioning programs should integrate ACL prevention program components to mitigate the risk of lower extremity injury. In addition, sociocultural factors related to the amount of motor experience, training opportunities, gendered development, and gender inequality in sport provision and resources (34,165,179) should be examined as influencing factors for the higher ACL injury risk for female athletes, as these factors directly relate to greater muscular support to withstand knee loading Concussions: Biomechanical and hormonal differences may contribute to increased susceptibility to concussions in female athletes, and there is a need for an individualized approach to concussion management and return to play based on clinical presentation, regardless of sex (137,197,210). Menstrual cycle disturbances can occur following concussion and should be included within management and return to play outcomes Patellofemoral pain syndrome (PFPS): Mechanisms of injury for PFPS are multifactorial, and the athlete should be assessed individually to determine which factors are increasing the symptoms of PFPS. Factors include: Malalignment of the lower extremity (185,244), muscle imbalances in knee extensor strength, and quadriceps weakness and activation, hip weakness and gluteal muscle activation (14,27,151,161,178,244), and core musculature weakness (14,27,151)
Health considerations	Mental health: Strength and conditioning practitioners must have an awareness of how mental health issues commonly manifest (43,79,184) and promote environments that nourish athletes' mental health (79,95) and destigmatize support and treatment (39)

attributed to greater exposure and practice time (84,247). Within this period of development, a *preadolescent spurt* has also been identified during the mid-childhood phase, whereby accelerated gains in muscular strength, speed, and power are apparent in boys and girls (240). These improvements have been attributed to rapid developments in the central nervous system, specifically relating to factors such as greater levels of neuroplasticity and enhanced muscle recruitment and coordination (38,240).

With the onset of puberty, female individuals experience a cyclical menstrual rhythm, beginning at an average age of 12 years and continuing to menopause (average age 51 years) (71). The age of the first menstrual cycle has, however, been declining around the world and has been related to many psychosocial and behavioral factors, including sedentary behavior (191,244). Menstrual dysfunction is common in female athletes but varies widely among sports and competition levels. This can be characterized as primary amenorrhea, which is defined as no menarche by age 15; or secondary amenorrhea, which is an absence of at least 3 consecutive menstrual cycles postmenarche (82). Chronic amenorrhea can lead to long-term negative health effects and reproductive dysfunction (128). The menstrual cycle is characterized by predictable fluctuations in ovarian hormones, including estrogen and progesterone. A regular menstrual cycle in premenopausal female individuals lasts an average of 28 days (ranging from 23 to 48 days) and consists of 3 main phases: the follicular phase (FP), ovulation, and the luteal phase (LP). At the beginning of the FP, estrogen and progesterone levels are low (menstrual phase; day 0) and then increase (days 4–5) to prepare the body for ovulation (61,174). As the FP ends (days 11–13), estrogen levels rise and fall, with a spike in follicle-stimulating hormone and luteinizing hormone inducing ovulation (day 14). In the second half of the cycle, the LP (day 15), estrogen levels rise again with a concomitant increase in progesterone (days 20–24) to prepare the body for pregnancy. If pregnancy does not occur, estrogen and progesterone levels fall, and the premenstrual phase begins (61,174) (Figure 1). Most of the studies on elite female athletes have shown no significant change in physical performance across the menstrual cycle (40). However, some research has shown differences in acute responses to a resistance training session over the natural menstrual cycle (no hormonal contraception employed) (235). It should be noted that performance differences (or lack of) in controlled laboratory testing situations may not accurately reflect performance in actual sporting environments.

Following the onset of adolescence and associated body changes, both female and male adolescents experience positive adaptations in performance, although sex-related differences in physical fitness become more apparent (69,240). Adolescent male athletes experience positive absolute gains in physical performance capabilities, resulting in natural reductions in fat mass, increases in muscle mass and stature, as well as rises in certain hormonal concentrations (e.g., testosterone and growth

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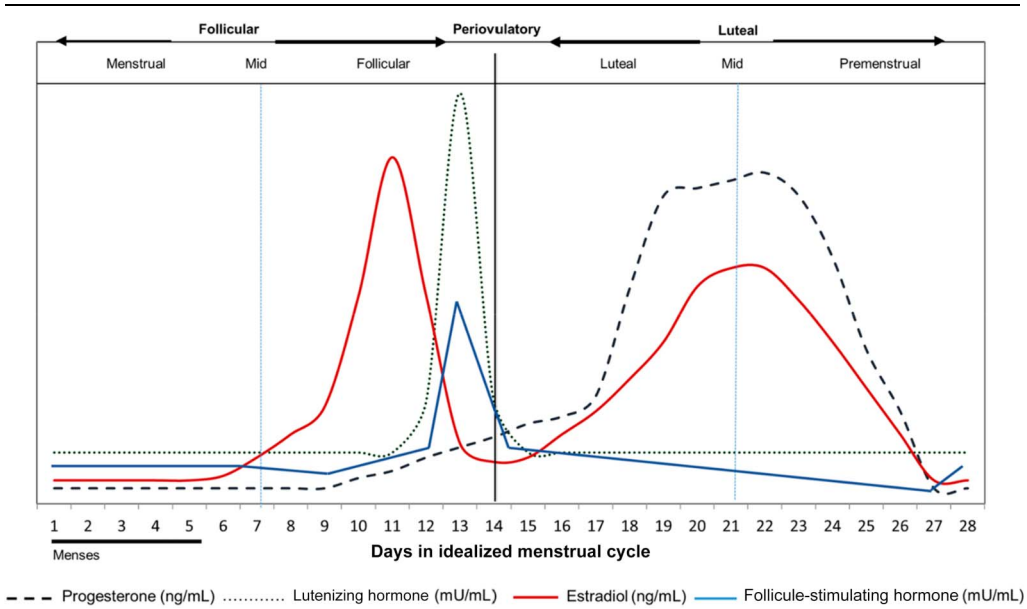


Figure 1. Hormonal fluctuations across the menstrual cycle (61).

hormone) (22,123,128,129). Adolescent female athletes may experience similar positive adaptations but in some instances to a lesser extent, with maturation enhancing some aspects of physical performance but not others (128). For example, female athletes experience natural increases in fat mass and changes in the distribution of body weight and pelvic width, which can negatively impact certain motor skills that involve the movement of body mass (e.g., jumping) (128). A systematic review reported boys, male athletes, plus preadolescent and adolescent female athletes had significant performance differences by their chronological age within sport age groups—typically spanning one to 2 years—such that older individuals outperformed younger individuals (213). The greatest differences occurred among (a) elite, adolescent (12–14 years old) athletes, and (b) athletes in high physiologically demanding sports compared with high-skill/technical or weight categorization sports (213). Thus, for strength and conditioning coaches working with young female athletes across a variety of ages, it is important to consider their athletes' exposure to training (sport and strength and conditioning), as this may have been influenced by their relative age, particularly in female adolescents. As participation in strength and conditioning becomes more normalized for youth, it will be important to re-examine these relative-age trends across both sport and strength and conditioning training to determine whether there continue to be gender differences, perhaps due to pubertal development/maturation, or whether exposure to quality training earlier acts as an equalizer.

From an injury perspective, maturation has been linked to an increased risk of overuse and growth-related injuries (e.g., Sever disease, Osgood-Schlatter disease, and patellofemoral knee pain) with incidences heightened around the time of adolescence (187,239). There is some research that suggests young female individuals sustain more overuse injuries than their male counterparts; however, the causative factors for this difference were not explored (227). Excessive volumes of sports training, improper technique, repetitive stress, and inadequate rest are extrinsic factors that can be modified to help reduce overuse injuries in youth (239). Common changes resulting from maturation have also been shown to increase female individuals' risk for certain acute injuries, such as an anterior cruciate ligament (ACL) tear (186). There is strong evidence to support that relative to prepubertal female athletes, female athletes after puberty have changes in their lower extremity kinematics and kinetics that increase their risk of ACL injury. This includes higher peak abduction angles and peak external knee abduction moment and internal rotation moments (189). Therefore, it is important for practitioners working with youth to have an awareness of the sex-related differences in fitness development and injury risk profiles during different stages of growth and maturation.

Assessments of Growth and Maturation. Research shows that children and adolescents of the same chronological age can differ up to 5 years in biological maturity (128). Given the impact of growth and maturation on physical performance and injury risk in youth, it is recommended that practitioners estimate young female athletes' maturity status approximately every 3 months (123). Maturity data can be used alongside training age and technical competency to aid programming decisions and assist with the interpretation of physical fitness testing data (120,237). Existing assessments of biological maturation (47,232) (e.g., Fels Method, Tanner criteria), prediction of peak height velocity (PHV) (143), and percent of predicted adult height (%PAH) attained (110) in youth have been categorized into skeletal, sexual, or somatic measures. Although skeletal age is considered the "gold standard" assessment of biological maturity, somatic measures are likely to be most appropriate because of their simplicity, equipment accessibility, cost-effectiveness, expertise required, and noninvasive nature (228).

Estimating a young athlete's maturity offset (the number of years an individual is before or after PHV) (143) or determining their %PAH attained (110) are both viable options, involving the collection of anthropometric and descriptive data. These equations can provide an indicator of the athlete's maturity status at the time of observation (i.e., pre-, circa-post-PHV), in addition to whether they are an early-, on time-, or late-maturer (54). In practice, the estimation of somatic maturity is particularly useful

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in sports where stature influences performance (e.g., gymnastics, basketball) (228) and when athletes are experiencing rapid growth (i.e., PHV), as injury risk may be heightened (108). Therefore, it is important for practitioners working with youth to have an awareness of the sex-related differences in fitness development and injury risk profiles during different stages of growth and maturation.

Psychosocial Development

In addition to their physiological development and maturation, an important aspect for training youth is recognizing that they are developing cognitively as well (163). Research has shown that at ~13 years old, individuals can distinguish ability from effort and luck, as well as understand objective difficulty levels (163). However, it should be noted that some children will develop this understanding at different stages. Once this cognitive development is reached, it is possible for individuals to define success not only by their effort, mastery, and improvement (i.e., task goal orientation) but also by how they compare with others and/or normative standards (i.e., ego goal orientation) (163). Importantly, the adoption of these orientations is influenced by coaches' feedback and is associated with whether athletes persist or drop out of training (18,76,201). Specifically, a task goal orientation is associated with adaptive behaviors and outcomes (e.g., effort, enjoyment, perceived competence, persistence, and continued participation), while an ego orientation does not have these same positive relationships (18,76,201). In fact, an ego orientation is positively associated with anxiety, tension, pressure, dropout, and burnout (18,76,201). In a comprehensive review of literature, Lochbaum et al. (124) found support for girls and women reporting greater task goal orientation than boys and men and conversely, strong support for boys and men reporting greater ego orientation than girls and women. Thus, girls and women athletes tend to be more likely to define their success by effort, learning, and improvement; therefore, providing feedback focused on these aspects will align more with their own definition of success and further promote their task goal orientation, which is associated with continued participation and decreased dropout and burnout.

Across a diverse set of countries, including the United States, Malaysia, and Iran, girls reported having low self-efficacy compared with boys, as well as facing more barriers to engage in exercise (7). Adolescent girls' self-efficacy and engagement can be influenced by their peers and broader social pressures. On the negative side, barriers to girls' engagement include fearing judgment and lacking social support for engaging in sport and strength and conditioning training (51). The more similar a role model (e.g., coaches) is to others (e.g., gender, shared beliefs/expectations about each other), the more strongly self-efficacy is positively influenced (96,198,226), which is why it is important to be aware that the proportion of women to men for strength and conditioning coaches remains low (140,158). On the other hand, when girls experience positive social influences from peers and parents, this can facilitate sport and training engagement (109). Hamilton and White (91) found that, with a sample of Australian adolescent girls, the greatest predictor of future engagement in moderate-to-vigorous physical activity was their past behavior, followed by their intention, and self-identifying as being an active person. This highlights the importance of positive, early experiences to facilitate their continued engagement in sport and training. Unfortunately, there are other sociocultural aspects influencing girls' engagement in sport and training to greater degrees than boys, which have the potential to keep otherwise motivated girls out of training. A family's socioeconomic status can negatively impact girls' training in multiple ways, including accessibility, equipment cost, and time to train (7,60). A second critical aspect is the neighborhood environment being safe enough year-round for outdoor activities and to safely get to and from training (7,60). Although many of these factors are outside the control of the coach, creating a psychologically and culturally safe climate to facilitate athletes feeling welcomed and valued has been shown to be foundational to initiating and maintaining engagement of youth and adolescents from a wide variety of socioeconomic statuses (94,131,162,208).

Long-Term Athletic Development Programs

The most recent global data from 146 countries shows that ~84% of adolescent female girls aged 11–17 years failed to meet the World Health Organization (WHO) recommendations for physical activity (35,86). Although physical activity levels have slightly improved in boys from 2001 to 2016, this was not the case in girls, leading to widening differences in physical activity levels between adolescent boys and girls (86,154). Therefore, practitioners working with girls have a critical role in providing a positive, holistic, and developmentally appropriate training experience to promote engagement in long-term athletic development programs to enhance performance, reduce injury risk, and increase life-long physical activity levels (120).

Although female athletes will experience some natural increases in athleticism due to growth and maturation (128,240), research has shown that training interventions (e.g., endurance, resistance, plyometric, and speed) can significantly enhance performance outcomes beyond natural development (20,116,139,145). Furthermore, it appears that young female athletes' responsiveness to strength and conditioning-oriented training programs is similar to that of boys (13,20,133,167). National associations also advocate for children (up to ~11 years in girls and ~13 years in boys) an early "sampling" approach over "early specialization" to promote long-term athletic development and develop a broad range of motor skills to increase athleticism (115,120). Of note, the ability to learn new motor skills becomes more challenging throughout adolescence and adulthood, as research suggests a nonlinear decrease in the volume of gray brain matter occurs with age (80,120). Therefore, engagement in these programs should commence in the prepubertal years when levels of neural plasticity are heightened (38,120) and to prioritize the synergistic development of fundamental motor skills and muscular strength (120,122,154).

Sex-related differences in the prevalence of certain injuries emphasize the need for individually targeted neuromuscular training programs, which physically prepare girls to tolerate the demands of modern sport (154). Effective strategies to combat these injury patterns could include targeting modifiable factors, for example, implementing neuromuscular training programs (99,185,192,217). Research shows neuromuscular training interventions can reduce injury risk factors in girls and adolescent girls and have typically included elements of strength training, proprioception, plyometrics, and technique training (e.g., soft landings with good lower-limb alignment) (72,104,155,156). Given the increased risk of ACL injuries in postpubertal female athletes, early exposure to neuromuscular training (i.e., in the

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prepubertal years) to improve jump-landing biomechanics is advised (156,189). However, positive responses to training are dependent upon compliance with the program and effective dosage of training. A recent meta-analysis in youth female athletes reported moderate, significant reductions in knee valgus following neuromuscular training, which ranged from 16 to 24 weeks in duration (190). The authors concluded that longer training durations are necessary to allow young female athletes to be progressively exposed to higher training intensities and accumulate a greater dosage of training (190).

The inclusion of fun and developmentally appropriate strength and conditioning for female individuals (and all youth) should be prioritized during childhood and adolescence to increase movement proficiency for sports, reduce injury risk, and improve health outcomes (121,122). Regular moderate- to high-intensity weight-bearing activities (e.g., gymnastics, resistance training) have also been recommended for youth to promote bone mineral accrual and to optimize long-term bone health (e.g., reduce osteoporosis risk) (85,100,121). Although there are many factors to consider when designing programs for young female individuals (e.g., training age, biological, and psychological maturity), progression and regression should primarily be based on the individual's movement competency to ensure safe practice. For example, if incorporating resistance training or plyometrics into a beginner's program, initially prescribing lower loading schemes and emphasizing movement quality is important (i.e., bodyweight to 60% 1RM and lower eccentric loading), with subsequent progressions in volume and/or intensity implemented gradually (69). It should also be emphasized that transition periods must be periodized for all youth to promote recovery and regeneration, and to facilitate growth-related processes (120,145). For further information and guidance on long-term athletic development pathways for youth, refer to the NSCA Consensus Position Statements on LTAD (120) and Youth Resistance Training (121).

Adult Athlete Development

Training that targets cognitive and physiological pathways can effectively support continued athletic development, as these systems may mature into the late 20s or even late 30s, depending on the individual and the system involved (3). For example, maximum bone density is typically reached by age 25–30, which is particularly important for women, who are at a higher risk for osteoporosis later in life, which increases the risk of fractures. Therefore, it is critical to take advantage of the window before and during early adulthood and maximize the development of bone density through weight-bearing and loaded exercises (e.g., bodyweight, resistance training, running, and plyometrics) (147,197).

Visual-perception skills can also continue to improve into individuals' 30s with certain types of training (e.g., including reactivity training as part of agility training) (3). The more athletes improve their reaction time and cognitive processing, the more they can help delay and reduce the risk of falls later in life with continued training (3). Adult female athletes' change of direction improvement is also positively influenced by resistance training, though possibly not as much as adult male athletes (41). Furthermore, the improvement in change of direction performance by resistance training is less for adults compared with children and adolescents (41). In addition, without appropriate and consistent training, age-related losses in skeletal muscle mass and function start around age 30 (29,200). Therefore, female athletes should be encouraged to participate in long-term resistance training programs to counteract the skeletal muscle changes that will occur otherwise with aging. Although maintaining or increasing muscle mass is important for athletes' performance during adulthood, it is particularly important for extending the years female athletes can engage in sport and reduce their risk of injury (197). It is important to counter muscle loss through training that stimulates growth to, at a minimum, maintain the muscle mass gained earlier in a female athlete's life. Fortunately, increasing muscle mass can be accomplished through targeted programming and exercise prescription using certain training modalities, which can also be used for bone density maximization (e.g., strength and hypertrophy resistance training) (197).

Pregnancy

Pregnancy occurs after puberty (~age 12) and before menopause (variable but on average ~ age 51) and is marked by significant physiological changes over the 40-week period of gestation (107). Recognizing the physiological and anatomical adaptations that occur during each of the trimesters of pregnancy and postpartum periods, and how those changes may impact exercise, is important (Table 2). Guidelines and recommendations for exercise and physical activity can be obtained from the American College of Obstetricians and Gynecologists (5), the Canadian Guidelines for physical activity throughout pregnancy (151), the Australian guidelines for physical activity in pregnancy and postpartum (33), and from the International Olympic Committee expert group meeting (25,26). All these statements describe conditioning and strength training exercises as minimal risk with increased benefits for most women during pregnancy and postpartum (112,153), while modifications to some exercises may be required as pregnancy progresses due to normal anatomic and physiologic changes that occur (5,23,26,33,151) (Table 2).

As in all training, selecting the appropriate exercise, frequency, intensity, and duration is critical and should be centered on the baseline level of fitness of the athlete immediately before the confirmation of pregnancy (5,33). Studies on elite athletes have shown that they are able to manage a variety of training loads and intensities and still deliver healthy babies and return to their sport (118,256). Athletes do tend to decrease their volume of training while they are pregnant compared with prepregnancy levels but appear to return to activity at a faster rate (within 6 weeks postpartum) than active controls (229). Athletes participating in high-impact sports do not experience more complications or perineal tears during childbirth compared with nonathletic women (210). Vigorous intensity exercise in the third trimester is tolerated well in healthy pregnancies among women who previously engaged in vigorous intensity training, even though some voluntarily reduced their intensities. Still, caution is elicited in exceeding 90% of the maximum heart rate until more research is performed (19). Resistance training at moderate intensity during pregnancy has been shown to improve blood sugar levels, insulin usage, and the prevention of gestational diabetes (257) as well as feelings of increased energy and reduced fatigue (249). High-intensity interval training during pregnancy appears to be safe and well tolerated by athletes, with no adverse effects observed; however, there were no specific guidelines presented for exercise prescription, just general recommendations (231). Another study supported high- and low-impact aerobics and pelvic floor muscle exercises to be included in the exercise prescription (230). Pregnant athletes typically can continue training and competing at prepregnancy fitness and

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Table 2

Physiological and anatomical changes in pregnancy and implications for exercise (adapted from Soma-Pillay, (214); Kazma, (104); Kimber, (109); Wowdzia, (253); L'Heveder, (115); Wise, (251) (24,108,113,119,217,255,257).

Trimester	Cardiorespiratory	Musculoskeletal	Endocrine/metabolic	Exercise implications
First	• Increased cardiac output by 20% • Decrease in peripheral vascular resistance • Increase in blood volume • Increased tidal volume • Increase in minute ventilation (40–50%) and $\dot{V}o_2max$ • Hypercoagulative state	• Weight gain and increased forces on joints • Increase in ligamentous laxity • Changes in micro-architecture of bone in pregnancy but not overall bone mass	• Increase in estrogen concentrations • Increases in metabolic rate and body temperature • State of hypercortisolism • Increase in insulin secretion and increased insulin sensitivity • Increases in angiotensinogen and aldosterone • Increase in circulating relaxin	• Continue activity at prepregnancy levels and intensities but monitor for adverse signs and symptoms • Misinterpretation of maximum heart rate, reaching it sooner in pregnancy. Use a combined approach of heart rate and perceived exertion to monitor intensity • Symptom of being out of breath • Increase in range of motion and potential for increased injury risk • Initiate pelvic floor exercises to assist in labor and delivery and help with urinary incontinence • Increase squatting activities with body weight and loaded to maintain strength and improve labor and delivery • Increase nutritional requirements beyond the extra 300 kcal daily intake required to maintain the metabolic demands of pregnancy • Increase water intake
Second (in addition to prior trimesters)	• Increased cardiac output by 40% • Decrease in peripheral vascular resistance by 25–30% • Increase in blood volume, with a steady fall in hemoglobin • Fluid retention and edema • Supine positions decrease venous return to the heart, which will decrease stroke volume and cardiac output	• Changes in the center of gravity, an increase in loss of balance	• Insulin resistance begins • Maintain circulating relaxin	• Unable to complete some exercises due to loss of balance • Edema may cause tightness and a limited range of motion • Avoid supine positions and exercises, switch to incline, side-lying, or vertical positions • Continue pelvic floor exercises to assist in labor and delivery and help with urinary incontinence • Continue to monitor for adverse signs and symptoms
Third (in addition to prior trimesters)	• Slight decrease in cardiac output at term, with stroke volume decreasing and heart rate increasing • Peripheral vascular resistance begins to increase from 32 wk • Blood volume increases 50% of prepregnancy levels with a 50% increase in plasma volume by 34 wk • Supine positions decrease venous return to the heart, which will decrease stroke volume and cardiac output • Hypercoagulative state	• Increase in lumbar lordosis • Increase in foot size • Increase in compression neuropathies	• State of hypercortisolism with cortisol level 3 times that of prepregnancy values • Insulin resistance peaks	• Modify activity based on signs, symptoms, and maternal comfort • Continue to monitor for adverse signs and symptoms • Misinterpretation of maximum heart rate, reaching it sooner in pregnancy • Increase in joint laxity and potential for increased injury risk • Unable to complete some exercises due to loss of balance, watch stop-and -go activity, which may increase falls and injury • Edema may cause tightness and a limited range of motion • Avoid supine positions and exercises, switch to incline, side-lying, or vertical positions • Modify activities to decrease discomfort or symptoms of neuropathy

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Table 2

Physiological and anatomical changes in pregnancy and implications for exercise (adapted from Soma-Pillay, (214); Kazma, (104); Kimber, (109); Wowdzia, (253); L'Heveder, (115); Wise, (251) (24,108,113,119,217,255,257). *(Continued)*

Trimester	Cardiorespiratory	Musculoskeletal	Endocrine/metabolic	Exercise implications
10- weeks postpartum	• Most cardiovascular and respiratory changes return to prepregnancy within the first 1–2 wk after delivery • Hypercoagulative state up to 12 wk after delivery	• Increase or changes in breast size and intrinsic support • Pelvic floor dysfunction/urinary incontinence • Diastasis recti • Increase in ligamentous laxity may persist up to 4–5 mo after delivery	• Insulin sensitivity becomes restored within 2–3 d after delivery in normal-weight individuals, may take up to 15 wk for obese individuals • Decreases in angiotensinogen and aldosterone within 6–8 wk after delivery • Lactation begins 3–4 d after delivery • Maintain circulating relaxin throughout breastfeeding	• Good support bra to decrease pain/discomfort • Pelvic floor exercises (i.e., Kegel exercises) immediately after delivery for at least 12–24 wk • Core stabilization exercises immediately after delivery for at least 12–24 wk (consider diastasis recti in programming) • Work with the health care provider to establish a safe return to sport time frame • Gradual return to physical activity and sport-related activities • If breastfeeding, increase nutritional requirements beyond the extra 300 kcal daily intake required to maintain the metabolic demands of lactation • Increase water intake • With cesarean deliveries, more time may be needed to restore abdominal muscles to prepregnancy strength and stabilization

exercise intensity levels but should work closely with their medical team (physician, coach, athletic trainer, exercise physiologist, nutritionist, and gynecologist) to create a program that meets their individual needs throughout pregnancy and postpartum (254). Contraindications for exercise and warning signs to stop exercise (Table 3). Return to sport postpartum can be successful and should focus on medical clearance and recovery from childbirth trauma, managing musculoskeletal injury, pelvic floor health, and the psychological readiness of the new mother (59). An interprofessional team, including the obstetrician, gynecologist, athletic trainer, strength coach, and sport-specific coach, should be used to develop an individualized return-to-performance program for the athlete.

Perimenopause, Menopause, and Postmenopause

Perimenopause refers to the years leading up to menopause, and is characterized by symptoms which include sleep problems, genitourinary symptoms, changes in sexual functioning, vasomotor symptoms, mood changes, and weight gain. Menopause is defined as the point at which 1 year has passed since a woman's last menstrual period and typically occurs between the ages of 40 and 58, with an average age of 51 (63). However, the physiological changes that women undergo during the menopause transition (perimenopause) can occur over a period of 4–6 or more years. Postmenopause is defined as the years after reaching menopause, meaning the 12 months after menstrual period cessation through the rest of one's life. The symptoms experienced during the transition period typically continue into the postmenopausal years. Although these physiological changes are a normal part of the aging process, some of the changes result in impacts to physical performance and health that are best addressed by exercise interventions and nutritional alterations (24,148). The primary definition of menopause from a hormonal perspective is the loss of ovarian function and the subsequent reduction in the production of estradiol (part of the estrogen family) and progesterone. Estradiol has a key role in bone formation and helps regulate body fat distribution and blood lipids. Thus, low levels of estradiol increase the risk for osteoporosis, abdominal adiposity, and poor lipid profiles, which can result in cardiovascular issues (75,206). There are some pharmacological interventions, such as hormone replacement therapy, that assist with reducing the severity of menopause symptoms that are the result of hormone deficiencies (hot flashes, night sweats, sleep disturbances). These therapies also mitigate some changes in bone density, muscle mass, and body fat by introducing estrogen and progesterone in various forms to provide a minimal level of hormones to preserve some premenopausal function (161). However, there may be an increased risk of various cancers that should be discussed with the healthcare provider (64).

Osteoporosis risk increases throughout menopause and postmenopause and is defined as low bone density resulting in weaker bone structure with a greater risk of fracture (3). Professionals need to exercise caution when designing exercise training programs for individuals of any age with this condition, as low bone density can impact physical performance. Female athletes who develop osteoporosis are at a much higher risk for stress fractures, which can impede aerobic and anaerobic performance (127). Although resistance training is necessary to maintain or improve bone density (250,259), use of and progression in the types of resistance training modalities should be designed based on the severity of the osteoporosis to avoid more serious issues and may need to avoid certain movements (e.g., spinal flexion) and/or use alternative training modalities, including bands, suspension trainers, and manual resistance (24,148,259).

Another common change during menopause is the reduction in whole-body metabolism and the subsequent increase in body fat levels, and potential losses in muscle mass (sarcopenia), all of

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Table 3
Contraindications and warning signs to stop exercise during pregnancy.

Absolute contraindications to exercise	• Hemodynamically significant heart disease • Restrictive lung disease • Incompetent cervix/cerclage • Persistent second or third trimester bleeding • Placenta previa after 26 wk of gestation • Premature labor during current pregnancy • Ruptured membranes • Severe anemia • Preeclampsia or pregnancy-induced hypertension • Higher order multiple pregnancy (triplets, etc.) • Other serious cardiovascular, respiratory, or systemic disorder
Relative contraindications to exercise	• Severe anemia • Poorly controlled type 1 diabetes • Extreme morbid obesity • Extremely underweight (BMI <12) • Intrauterine growth restriction • Orthopedic limitations • Poorly controlled hypertension • Poorly controlled seizure disorder • Poorly controlled hyperthyroidism • Heavy smoker • History of spontaneous preterm birth • Eating disorder • Malnutrition
Warning signs for the athlete to stop the exercise session	• Vaginal bleeding • Painful contractions • Amniotic fluid leakage • Dizziness • Headache • Chest pain • Calf pain or swelling • Dyspnea before exercise
Warning signs for the coach to stop the athlete from exercising	• Athlete grabbing stomach • Observable fluid leakage • Athlete having trouble breathing/catching breath • Athlete not performing like previous session • Noticeable sluggishness/fatigue • Unsteadiness/decreased balance during activity

which depend on activity levels (130,215,224). Combined with the hormonal changes that result in more negative blood lipid profiles, cardiovascular disease risk also increases during menopause, which could negatively impact aerobic performance, in particular, as a result of atherosclerotic changes (220,224). Therefore, exercise programs should be designed to address both muscle maintenance and fat management, which will help reduce cardiovascular disease risk. The most effective programs include both aerobic and resistance exercises (24,132), and resistance exercise should be of sufficient volume and intensity to increase and maintain muscle mass, including some heavy-load phases in the overall training program (188).

Although older female athletes experiencing menopause-related changes should not need to make significant alterations in their training programs, addressing individual needs that result from the menopause-related physical changes that have occurred should be a priority. These include resistance training loads that will preserve muscle mass and bone density, and conditioning activities that will maintain cardiovascular performance.

Injury Considerations

Injuries and health considerations that are prevalent in female athletes should be understood by strength and conditioning coaches and implemented in the development of strength and conditioning programs for female athletes. Although not all female athlete health domains (146) are within the scope of this position statement, there are selected injuries and health considerations that are specific or more prevalent in female athletes (ACL injuries, RED-S, bone stress injuries, concussions, patellofemoral pain syndrome, breast injuries, pelvic floor dysfunction, sleep issues, mental health), which should be monitored and assessed on individual basis when prescribing a training program.

Vulnerability to skeletal muscle injury in female athletes may be attributable to sex differences in knee flexor to extensor strength (166), hip ab- and adduction, extension, range of motion, genetic factors affecting the tissue properties (144), and the biomechanics that may be altered when compared with male athletes due to these differences. Emerging evidence shows a role of genetics (type I collagen alpha 1 chain gene [COL1A1] variant polymorphism) on fatigue fracture and muscle injury among female athletes by altering the properties of these tissues (144). Neuromuscular training for the lower extremity may aid in injury prevention through improved joint awareness and postural control for the female athlete (207). In addition, strength endurance training (i.e., high reps, shorter rest) can increase eccentric strength and reduce fatigue, which are factors to reduce hamstring injury in female athletes (56). Following injury, some training adaptations (e.g., fiber area and maximal dynamic strength) may be retained for long periods during detraining and may contribute to a rapid return to "competitive" form (222). Detraining had relatively little effect on fiber cross-sectional area but resulted in an increased percentage of type IIb fibers with a concomitant decrease in IIa fibers in previously trained female athletes (222).

Anterior Cruciate Ligament Injuries

Female athletes are 4–6 times more likely to sustain an ACL injury than male athletes, with the majority occurring in a noncontact situation during the deceleration phase of a dynamic movement such as landing from a jump or performing a cutting activity (189). This difference in risk is multifactorial and influenced by hormonal, neuromuscular, anatomical, biomechanical, and environmental elements, with neuromuscular factors dominating in the contribution to ACL rate increases in female athletes compared with male athletes (83). Moreover, the rate can differ by sport, age, and competition level (30,149). In sports such as soccer, basketball, and lacrosse, the rate of ACL injuries at the collegiate level is significantly higher for female athletes (5,6). Adolescent female athletes have 1.56 times greater risk of ACL injury compared with male athletes. The highest risk sport for female adolescent athletes is soccer. In addition, club sport rates of ACL injury are higher than those of school sports (46). Reduced knee and hip flexion angles, greater knee abduction angle, external moments, and peak vertical ground reaction force during jump-landing movements are associated with an increased risk of

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experiencing a noncontact ACL injury. Hewett et al. (98) propose 4 theories to explain ACL injury risk. The ligament dominance theory suggests that female athletes demonstrate excessive knee valgus, hip adduction, and hip internal rotation during dynamic activities such as cutting and landing from a jump. Trunk dominance theory suggests that poor trunk control may increase risk for ACL injury during athletic activities. Quadriceps dominance theory suggests an imbalance between quadriceps and hamstrings, where quadriceps forces are greater and place the ACL at high risk of tear. Finally, the leg dominance theory suggests that asymmetries between legs affect athletes' injury risk negatively. Pappas et al. (176) assessed and presented a model to quantify the prevalence of the previously discussed biomechanic theories associated with ACL injury risk using an unanticipated cutting task in a large cohort of female athletes. They determined risk profiles based on presence of one or more of these biomechanical deficits as determined by 3D motion analysis. Of the 721 female athletes, approximately 40% of female athletes were considered low risk as no biomechanical deficits were noted. A combination of quadriceps and leg dominance was the second most commonly noted profile (24%). Twenty-two percent of subjects demonstrated the combination of trunk and leg dominance biomechanical deficits, with less notable ligament dominance characteristics. Finally, 14% of female athletes in this sample exhibited excessive ligament dominance only. Understanding biomechanical deficit profiles can be used to develop exercise programs that target movement patterns with a goal of reducing injury risk.

In an in vivo study, the combination of tibial internal rotation, knee impulsive compression, a knee flexion moment, and large muscle forces surrounding the knee induced the largest ACL strain during pivot landings. Adding unique anatomical features of the female knee (i.e., steeper lateral tibial plateau slope and smaller ACL cross-sectional area), increased ACL strain further relative to male subjects of the same body weight and height (17,255). In addition, repeated submaximal knee loads occurring during the scenario described previously may cause microdamage to the ACL, resulting in a potential ACL fatigue failure during seemingly submaximal knee loading (255). This fatigue-failure hypothesis may have implications for explaining the higher risk of ACL injury in female athletes when combined with lower training age relative to the level of competition, providing an area for forthcoming research, evidence evaluation, and position statement clarification (258).

From an environmental standpoint, the influence of sociocultural factors related to the amount of motor experience, training opportunities, gendered development, and gender inequality in sport provision and resources (34,164,178) should also be examined for the higher ACL injury risk for female athletes, as these factors directly relate to greater muscular support to withstand knee loading. Given the increasing rates of female athletes experiencing ACL tears, it is vital to determine how to prevent these injuries, given the cost of surgical reconstruction, the high rate of re-injury, the likelihood of osteoarthritis in the future, and the fact that many female athletes do not return to the level of competition they were at before the injury. Various ACL injury prevention programs (IPPs) have been investigated over the past several years, with a more recent focus on identifying the necessary components that provide injury reduction in the most effective and efficient manner. Evidence suggests that multimodal training programs (e.g., strength, plyometrics, agility, balance, and mobility) can reduce ACL injury risk by approximately 50% (52,185). Most evidence relies on short-term group-based warm-up programs and not progressive, cyclic, individualized, and variable training programs. However, factors contributing to positive outcomes are based on principles of strength and conditioning, such as compliance, proper load, proper technique, sufficient frequency, and duration. Therefore, delivery of training by accredited strength and conditioning professionals across the lifespan of a female athlete would be ideal and should be considered a critical component of reducing ACL injury risk. Thus, the recommendation is to ensure female athletes are exposed to progressive overload in their training program, particularly for female athletes playing pivoting sports. or sports where jumping and landing are a frequent occurrence (74,106,181,185). Tailoring prevention programs to the unique requirements of the sport is a key factor in successfully preventing ACL injury. Ideally, IPPs should progress beyond field-based warm-up or injury prevention programs to long-term athletic development programs that integrate injury prevention concepts in programming and are cyclic, individualized, and variable, which increases muscle support to counter loads at the knee joint (251) and ensures proper movement patterns are performed during sports activities, which can be unpredictable in their nature. Strength training should focus on hip, knee, and ankle musculature (97,181), incorporating unilateral strength exercises (203), eccentric movement exercises, and jump/hop and hold patterns to focus on landing and stabilization (185).

Bone Stress Injuries

Bone stress injuries, including stress fractures, frequently occur in female athletes (1,199), with the injury rate consistently higher in female athletes than male athletes (44,199). These injuries are considered cyclical overuse injuries where abnormal bone remodeling occurs due to accumulated repetitive stress exceeding the tissue tolerance (248). Although strength and conditioning can monitor the loading cycles of bone or, in essence, an athlete's workload, it is more challenging to know the individual bandwidth of tolerance before a bone stress injury. However, a key contributor to reducing bone health and increasing bone stress injury risk is RED-S (111).

There are additional intrinsic and extrinsic risk factors for bone stress injuries, such as Vitamin D status and early sport specialization, which should be considered through an appropriate screening process (2,248). The exercise prescription of periodized sprinting, plyometrics, and strengthening of lower extremity muscles is osteogenically stimulating to protect against bone stress injuries (117). Consideration of workload changes through the season, particularly in connection with energy availability (248), is critical to managing bone stress injuries and stress fractures in female athletes.

Concussions

A concussion, or mild traumatic brain injury, is a bump, blow, or impact to the head or body that causes the brain to move rapidly back and forth in the skull, which disrupts normal brain function (92). The American Medical Society for Sports Medicine has a position statement on concussion in sport that focuses on the clinical diagnosis, assessment, and management of the athletic population that can be used as a guide (92). The incidence of sport-related concussions among female athletes is higher than that of male athletes in comparable sports, with soccer, basketball, softball, and ice hockey having the highest incidence of

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concussion among female athletes (45,49,169). Evaluation of injury mechanisms revealed that player-to-player contact was similar between male and female athletes; however, contact with equipment (i.e., balls, goals) was 2.5 times greater in female athletes, and contact with surfaces was 2 times higher among female than male athletes (42,119). Biomechanical (e.g., weaker neck muscles and difficulty absorbing and dissipating mechanical forces) and hormonal differences (e.g., estrogen, progesterone, phase of the menstrual cycle) may contribute to increased susceptibility to concussions in female athletes (136,196,209). Recovery time or time lost from sport participation with prolonged symptoms after a concussion is greater in female athletes than in male athletes (42,49,136,209). Female athletes with multiple concussions demonstrated lower cerebral blood flow in the posterior aspect of the brain compared with those with a single concussive event, whereas male athletes demonstrated no significant effects on cerebral blood flow (90). Greater changes in cadence between single-task and dual-task gait activities are observed in female athletes compared with male athletes after a concussion (103); therefore, performing more agility training with athletes after multiple concussions is recommended.

Programs for concussion management, prevention, and return to play should consider the sex differences in injury mechanics and biomechanics. Although the use of soft-shell headgear for concussion prevention has been supported as a deterrent, a systematic review determined that there was no reduction in head injuries with the use of soft-shell headgear, and an increased injury risk to all other body regions with its use (113). A systematic review provided evidence that higher neck strength may be associated with a lower risk of concussions and supports the inclusion of cervical muscle exercises into an injury prevention program to increase neck stiffness and strength to better stabilize the head during contact or collisions (65). Vision training or sensorimotor training has shown promise for decreasing overall injury rates in athletes with and without a history of concussions (195), and may help to prevent concussions by improving eye discipline when contacting an opponent, ball, or object (48,102); for example, keeping the eyes focused on the soccer ball during heading. The faster reaction time an athlete has, the greater their ability to protect their head and body from severe impacts and injuries by anticipating contacts or moving away from impact; therefore, training reaction time may decrease the incidence of concussions (102). Despite sex-based differences in clinical measures, female individuals remain an understudied population, which results in a lack of sex-specific guidelines for treatment and recovery. Therefore, there is a need for an individualized approach for concussion management and return to play based on clinical presentation, regardless of sex (136,196).

Patellofemoral Pain Syndrome

Patellofemoral pain syndrome (PFPS) is a broad term used for pain arising from the patellofemoral joint or adjacent soft tissues, which gets worse over time (especially in activities such as squatting, sitting, climbing stairs, and running), and is also known as runner's knee (27). The National Athletic Trainers Association (NATA) has a position statement on the management of individuals with patellofemoral pain that can be used as a guide (27). The incidence of PFPS is 2.23 times more likely to develop in female athletes compared with male athletes (28). Early sports specialization in female adolescents is associated with an increased risk of anterior knee pain compared with multisport female athletes (88).

The mechanism of injury for PFPS is multifactorial, and the athlete should be assessed individually to determine which factors are causing the symptoms of PFPS. Factors include malalignment of the lower extremity (184,243), muscle imbalances in knee extensor strength, weak knee extensors (eccentric control), hip weakness and gluteal muscle activation (14,27,150,160,177,243), and core musculature dysfunction (14,27,150). A study on female athletes before and after puberty demonstrated that maladaptive hip mechanics may contribute to PFPS before puberty; however, altered knee mechanics were associated with PFPS throughout the maturation process in female athletes (77).

Programs for PFPS should focus on prevention, biomechanics and exercise technique, retraining, and muscle strengthening in areas of imbalance and weakness for each athlete individually according to their needs. Of note for the strength and conditioning professional is the focus on exercise technique and biomechanics of motions performed during activity and while correcting imbalances and weaknesses. A study on the squat exercise demonstrated increased PFPS pain in all types of squats from 60 to 90 degrees of flexion (182), although there were multiple reasons why this occurred. By modifying the squat exercises to 0–60° and focusing on valgus control exercises, PFPS pain has been shown to decrease (67) until the underlying cause of the pain can be addressed. General strengthening and rehabilitative exercise in areas of weakness of the lower extremity and core musculature has demonstrated decreased pain and improved functional outcomes in athletes with PFPS. Program design should be specific to the athlete and may require taping, bracing, or other modifications; refer to the NATA position statement for more detailed information (27).

Breast Injuries

There are several different types of breast injuries, including friction injuries to the nipple, blunt force trauma to the breast (168), and excessive movement or inadequate support leading to ligament sprains and sagging breasts (134,135). The incidence of breast-related injury has been reported in at least 50% of collegiate athletes, but less than 10% report the injury and only 2.1% receive treatment (213). Sports with the highest reported incidence of breast-related injuries are collegiate basketball, soccer, softball, volleyball (213), and water polo (214). With the low rates of reporting and only half of the athletes using any prevention strategies, it is important to facilitate breast health conversations to increase injury reporting and appropriate treatment (31). Another study reported that female contact football players wearing a sports bra did not feel that it provided protection and that they were unaware of breast protective equipment or found the breast protective equipment uncomfortable or poorly fit (32).

Eighty-three percent of female athletes rated their breast/bra knowledge as below average, and most wore ill-fitting, unsupportive bras and wanted bra advice (245), with 85% of the subjects in one investigation found to be wearing ill-fitting bras (134). Good prevention strategies to reduce breast injuries include education on proper fit and support of bras for the individual athlete, as well as protective equipment that may be available (e.g., compressive sports bra, compressive sport bra with additional padding, rigid exterior chest protectors with padding). Providing bra education improved the ability to correctly fit a bra and select a bra with appropriate support for the level of physical activity (135). Using professional bra-

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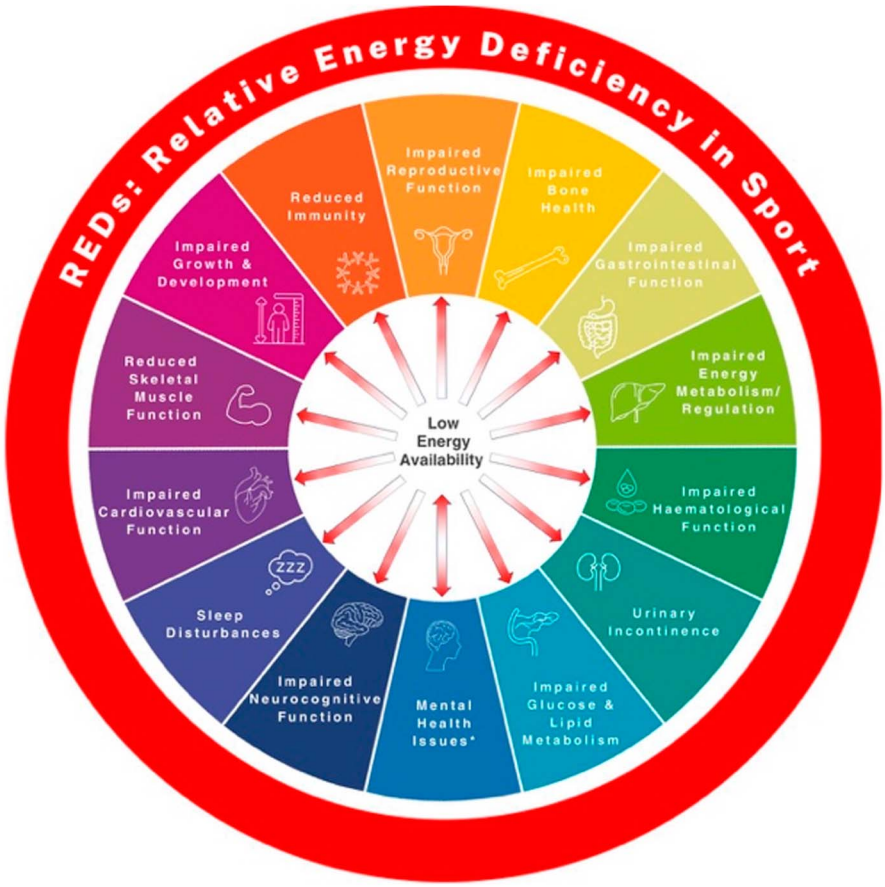


Figure 2. Relative Energy Deficiency in Sport (RED-S) Health Conceptual Model showing the effects of low energy expenditure on a continuum (153).

fitting criteria improves the accuracy of bra fit, which in turn provides better breast support (134).

Health Considerations

Relative Energy Deficiency in Sport

Previously known as the Female Athlete Triad, Relative Energy Deficiency in Sport (RED-S) was coined to identify the myriad of health and performance consequences affecting all athletes (152). Relative Energy Deficiency in Sport syndrome encompasses the physiological functioning of the individual resulting from an imbalance between dietary intake and energy expenditure required for daily living (thermogenesis, sleep) and physical activity divided by fat-free mass (173). A study that included 150 male and female athletes aged 14–34 years found that 87% expressed at least one symptom of RED-S syndrome (180). Another study on 112 female athletes (15–32 years) representing 9 different sports at the pre-elite and elite levels demonstrated 87% had at least one indicator, 81% exhibited 1–3 indicators, 11–55% were reported and identified at risk for low energy availability, and 33% had a diagnosed psychiatric condition (204). The prevalence of RED-S varies among sports, but the incidence in weight-class activities or where body physique is important to performance appears to demonstrate higher levels of RED-S (152). Resistance training in caloric restriction situations, where muscle wasting is common, appears to have a lean mass sparing effect (242). When resistance training is combined with high-impact exercises, it has a maintenance effect on bone density (105). Low energy availability (<30 kcal/kg, fat-free mass) leads to the potential health consequences represented in Figure 2 (173). This figure illustrates the interplay of both the cause and result between low energy availability and the multitude of physiological systems and performance-related factors (152). It is important to understand that overtraining syndrome and RED-S share similar pathways, symptoms, and diagnostic complexities, so early intervention may possibly alleviate the negative impact on athletes (225). Providing information on RED-S for athletes and coaches to make training recommendations, referrals for nutritional guidance, and psychological counseling is an important part of the process.

Relative Energy Deficiency in Sport has significant endocrine and metabolic consequences, resulting in decreased reproductive and thyroid hormone production and increased growth hormone and cortisol (173). Suppression of the hypothalamus and pituitary can lead to a decrease in gonadotropin-releasing hormone and luteinizing hormone, in turn ceasing menstruation due to low circulating levels of estradiol (153,173). Meanwhile, bone formation and bone resorption are believed to be altered due to the abnormal levels of cortisol and estradiol (252). High levels of activity in addition to low energy availability place stress on the athlete's body before even considering any other factors, such as sleep deprivation or psychological stressors. These factors disrupt the immune system (152). Similarly, changes in sleep hygiene, injury, increased physical activity, and inadequate diet can all influence the gastrointestinal system (173). Implications of RED-S on the systems can take their toll on one's performance

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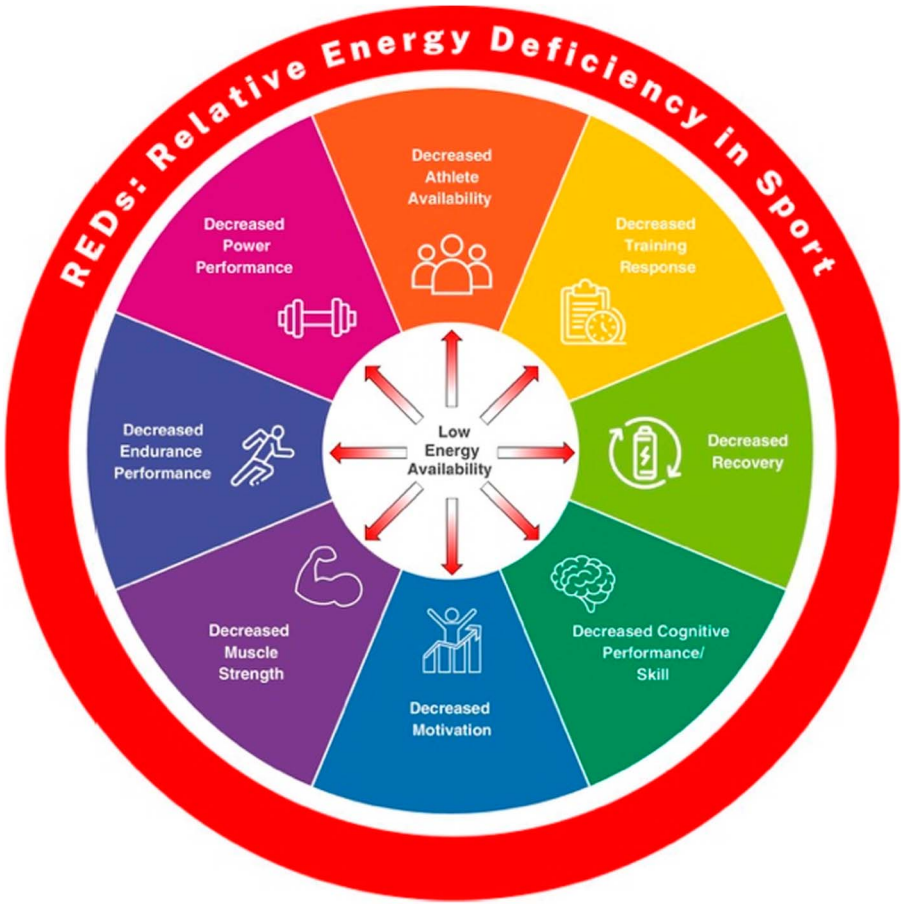


Figure 3. Relative Energy Deficiency in Sport (RED-S) Performance Conceptual Model showing the effects of low energy expenditure on a continuum (153).

(Figure 3), whether it be due to nutritional deficiencies, musculoskeletal injury, infection, or fatigue (152). Prevention of RED-S should involve a multidisciplinary approach that includes the athlete, sports medicine personnel, performance team, coaches, and sport organizations, which focuses on the athlete's health, identification, recognition, and treatment of impairments, supporting the athlete, and providing a safe environment for participation (238).

Pelvic Floor Dysfunction and Urinary Incontinence

Pelvic floor dysfunction (PFD) is a term used to identify various impairments of the pelvic floor muscles that support the pelvic organs and promote continence (125,58). Urinary incontinence (UI), including stress urinary incontinence (SUI), is the most common type of PFD; however, other conditions such as pelvic organ prolapse, fecal incontinence, dyspareunia, vaginal laxity, and sexual dysfunction can occur (9,53,58). Urinary incontinence is an involuntary loss of urine, with SUI defined as an involuntary loss of urine with any physical exertion or effort (194). Although UI can occur in both male and female athletes, it occurs approximately 5.45 times more among female athletes, with an overall prevalence of 27.6% (53,194). Female athletes had a 36% prevalence of UI and a 2.77 times greater risk of UI compared with sedentary women (219,233). Generally, the main risks for PFD include age, obesity, pelvic surgery, menopausal status, pregnancy, and surgery. High-impact sports participation seems to be one of the main risk factors of UI in female athletes, which may be due to the imbalance of contraction strength and reaction time, and an increase in abdominal pressure that results in deformation of the connective tissue (125,58). High-impact sports involving jumping and/or rapid movements (e.g., basketball, volleyball, handball, gymnastics, track, and combat sports), sports involving heavy loads (e.g., weight training), and an increase in the amount of training hours show an increased incidence of SUI (36,53,126,58).

Programs for PFD and UI may include prevention, education, lifestyle modifications, pelvic floor muscle training, biofeedback, and pharmacological methods. Women should be taught how to properly engage their pelvic floor muscles (PFMs) and be aware of the interactions between their PFM, diaphragm, hip muscles, and abdominal muscles. One study found that a 3-month program of 30 daily sustained contractions followed by 4 quick contractions of the PFM showed a decrease in the amount of urine leakage by 45.5% in volleyball players (70). Other studies have shown that UI episodes can be greatly reduced, and PFM strength can be increased within 6–12 weeks (58). In addition, 56–70% of women do recover from UI with proper education and pelvic floor strengthening (62,70).

Sleep

Loss of sleep has been recognized as a risk factor for increased injury risk and negative mental health outcomes in athletes (21,23,242). A majority of athletes receive less than age-

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Table 4
Future research considerations.

Topic	Considerations
Lifespan and the female athlete	Youth: Longitudinal research in young female athletes, which accounts for maturity and explores the interaction effects of training and maturation in young female athletes (particularly well-controlled training interventions), is needed to advance the knowledge base of the field. More advanced mechanistic measures (e.g., muscle architecture and neuromuscular measures) are also needed to evaluate the effectiveness of training interventions, as opposed to relying solely on performance outcome measures (e.g., jump height) Psychosocial: There is a need for increased research on the psychosocial influencers (e.g., motivational climates, goal orientations, competence, self-efficacy, and body image perceptions) of female athletes' participation in strength and conditioning training, as well as the effects of strength and conditioning training on female athletes' mental health, well-being, and self-perceptions (e.g., goal orientations, competence, self-efficacy, and body image perceptions) Adult: Research on between-set resistance training recovery intervals is needed in female athletes who have strength and conditioning experience (i.e., trained), as well as comparative studies in female athletes where subjects' training history is a key variable. Research on athletes using the different types of hormonal contraceptives is also needed to clarify the effect of hormones on performance Pregnancy: Although there are general guidelines regarding resistance training during pregnancy, many of these are based on anecdotal evidence. Studies examining specific program design variables during the different phases of pregnancy, as well as postpartum, are needed to legitimize and strengthen current training recommendations Perimenopause, menopause, and postmenopause: Investigations that further parse out training responses during different phases of menopause (peri-, menopause, postmenopause) are needed. More research is needed on the causal effects of sex hormones on performance or adaptation to training
Injury considerations	Anterior cruciate ligament (ACL) injury: More research is needed on multimodal training programs (e.g., agility, balance, mobility, plyometrics, running, and strength), with consideration of technique feedback and cueing/focus of attention principles, that investigate reducing ACL injury risk in a variety of sport and highly trained female athletes Concussions: More research is needed in female athletes on clinical measures to determine whether specific guidelines are needed for treatment and recovery

appropriate sleep levels, with 44–52% reporting poor sleep quality, insomnia, and daytime sleepiness, with differences occurring between male and female athletes (37,89). Female athletes demonstrated longer sleep onset latencies (time to fall asleep) and greater daytime dysfunction than male athletes (89). Sleep complaints are common before and after competitions in elite female athletes, with 63% of studies reporting total sleep time decreased posttraining and 75% of studies reporting total sleep time decreased postcompetition (142). Salivary cortisol levels were higher following competition compared with training or rest days, and salivary melatonin levels were lower after training in the evening or at night. Both higher salivary cortisol and lower melatonin levels decreased sleep quality and quantity (170,172). Sleep parameters that include trouble falling asleep, sleeping fewer hours, and having less deep sleep when concerned about sanitary products are more variable in female athletes during menses (114). Other factors that negatively affect sleep regardless of sex are early morning training, increases in training load, exposure to hypoxic conditions, air travel departure times, and jet lag (202,211). In addition, it has been hypothesized that a decrease in sleep could decrease the activity of protein synthesis pathways and increase the activity of protein degradation pathways, consequently resulting in loss of muscle mass and hindering muscle recovery after exercise (55).

Education on sleep hygiene is effective in improving sleep quality in elite female athletes acutely (171). Education of coaches, sport science support staff, and athlete medical personnel relative to sleep hygiene and the importance of sleep may help to address some of the barriers and contributors to poor sleep quality in athletes (141). For more information, the National Sleep Foundation provides recommendations for sleep duration for healthy populations (101). Sleep hygiene for optimal recovery in athletes is critical to overall health and well-being and involves many approaches to improving sleep quality and quantity (241).

Mental Health

There has been growing attention surrounding athletes' mental health, with recent international consensus statements emphasizing the need for sports organizations and practitioners to adopt a holistic approach to both physical and mental health (43,73,95,193). Athletes are exposed to additional mental health risk factors (e.g., intense performance demands, rigorous training schedules, injury, body image), and research shows mental health symptoms and disorders are prevalent among this population (95,193). For example, research shows that depressed mood or depression are common symptoms of overtraining syndrome among athletes (12). However, differences in prevalence and type of mental health symptoms appear to exist between male and female athletes (8,246). Female athletes may be at greater risk of certain disorders (e.g., burnout, eating disorders, disordered eating, anxiety, and depression) (8,183,193) and subjected to increased aesthetic/appearance-based pressure (11,183), discrimination, and financial strain than male athletes (246), which could contribute to poor mental health outcomes. Furthermore, some evidence suggests that certain mental health disorders are more likely to manifest at certain stages of female athletes' development. For example, recent global epidemiological data reported that eating disorder rates were more prevalent in children and adolescents than in adults, particularly in women (93).

Consistently, researchers have found the prevalence of depression and anxiety, as well as other mental health disorders, to be over 2 times more prevalent among women than men (11). Similarly, a meta-analysis reported that high-level female athletes were twice as likely to self-report symptoms of depression as their male counterparts (81). The high prevalence of clinical and subclinical depression and anxiety symptoms can inhibit individuals' health and performance. In 2021, the NCAA found that across a large sample of female student-athletes, nearly 40% reported experiencing overwhelming anxiety compared with 22% of male student-athletes, over the previous 30 days (160). The importance

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of detecting mental health issues early in athletes has been emphasized in recent consensus statements, including those from the American Medical Society for Sports Medicine (43,212). Therefore, strength and conditioning practitioners must have an awareness of how these issues commonly manifest (43,79,183) and promote environments that nourish athletes' mental health (79,95) and de-stigmatize support and treatment (39). As emphasized in the NSCA's Endorsement of the NCAA Sport Science Institute's Mental Health Best Practices, as part of the integrated care team for athletes, strength and conditioning coaches often are in the unique position to build relationships with athletes, recognize signs of mental health diseases/disorders among athletes (e.g., behavior, appearance, performance), destigmatize help-seeking behavior among athletes, and refer athletes to the appropriate, qualified members of the support team responsible for detection, prevention, and treatment strategies of mental health disorders.

Conclusions

Understanding foundational aspects of growth and maturation, common injuries, and specific health considerations in female athletes is critical for designing not only research studies for this population but also training programs for improvement of health and performance. Therefore, greater scrutiny in the interpretation of existing research and methodological approaches to future research on female athletes is warranted. With increased participation in organized sports and sports training, there are now more individuals who fit the criteria of training necessary to study the physiological variable in question (50,175,236), as well as examining female athletes from a biopsychosocial perspective (133,164,178). More specific future research recommendations are presented in Table 4.

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