Strength Training and Metabolic Conditioning for Female Youth and Adolescent Soccer Players

Matthew D. Wright, MPhil and Mihkel-Madis Laas, MSc
Sport and Wellbeing, Department of Student Services, Teesside University, Middlesbrough, United Kingdom

ABSTRACT

DESPITE THE RAPID GROWTH IN WOMEN AND GIRLS PLAYING SOCCER, EVIDENCE-BASED GUIDELINES TO INFORM CONDITIONING FOR GIRLS ARE SPARSE. MOST RESEARCH ON YOUTH SOCCER IS CONDUCTED IN MALES, WHICH MAY NOT BE TRANSFERABLE TO PRACTICE IN FEMALE TEAMS. THIS ARTICLE REFLECTS ON THE CURRENT EVIDENCE BASE AND DRAWS ON THE AUTHORS’ EXPERIENCES TO PROVIDE GUIDELINES TO IMPROVE CONDITIONING PROGRAMS THROUGHOUT MATURATION IN GIRLS. THE ARTICLE FOCUSES ON THE INTEGRATION OF NEUROMUSCULAR AND METABOLIC CONDITIONING METHODS TO SAFELY IMPROVE PHYSICAL PERFORMANCE AND REDUCE INJURY RISK FACTORS. GUIDELINES ARE PRESENTED FOR PLAYERS PRE, CIRCUM, AND POST PEAK HEIGHT VELOCITY.

INTRODUCTION

Women’s soccer is growing rapidly in popularity with increasing participation rates worldwide (10,13). There are now opportunities for players to become professional in both the United States of America and Europe. As such, there is an increasing demand for strength and conditioning coaches to work with youth players. However, research has often focused on male soccer players and there is less known about the development of physical qualities in young females throughout maturation. Although long-term athlete development models provide guidance for the strength and conditioning coach, these are based more on theoretical concepts rather than empirical evidence (16). Furthermore, rarely in the authors’ experiences are conditions optimal to allow for the simple application of evidenced-based guidelines. In reality, time is often limited and participation in supplementary strength and conditioning training can be a new concept to players, parents, and coaches. We have found that it takes time and education to build a culture of compliance with strength and conditioning training (60). Issues regarding the translation of scientific data to shape and drive practice in soccer have been questioned previously (11). This is evident in the compliance of female soccer players to neuromuscular training programs, which can improve physical performance (15,43,45) and reduce injury risk factors (12,44,50,51,57,58) when implemented successfully. Studies, however, often report poor compliance with the training intervention (2,12,44,58) or poor intervention fidelity (29). For example, one study demonstrated that neuromuscular training improved star excursion balance score yet 31% of players had to be excluded as they did not comply with the intervention (15). Practitioners working in girls’ soccer need to blend evidenced-based practice with practice-based evidence to be successful. This article aims to outline recommendations for practitioners based on the authors’ experience in developing strength and conditioning programs within an English Football Association (FA) girls’ center of excellence for players from 9 to 17 years of age.

KEY WORDS:
metabolic conditioning; neuromuscular training; LTAD; girls soccer
speed, clearly contribute to elite performance (18,19,36). As a rule, more successful teams perform more high-intensity running in matches although the nature of repeated high-intensity running and sprinting in elite players is highly variable (19). The frequency, duration, intensity, and rest duration of these repeated efforts are unpredictable, as is the nature of neuromuscular load and musculoskeletal strain from changes of direction or explosive jumping movements required within play. Thus, a broad range of physical qualities including neuromuscular (strength, power, balance, and proprioception), aerobic, and anaerobic qualities should be developed in female players.

It seems that girls exhibit a plateau in the development of most physical qualities compared with boys after puberty, with the exception of flexibility (7,32,56). Mujika et al. (37) suggested that female players exhibit lower soccer-specific fitness with a battery of tests including counter movement jump, speed over 15 m, agility, and the Yo-Yo intermittent recovery test. Interestingly, moderate correlations were observed between the counter movement jump and Yo-Yo test in females, but not in males. It is possible that anaerobic or neuromuscular fitness is of even greater relevance to performance in female players. Moreover, a neuromuscular deficit occurs after puberty that has been associated with increased risk of knee ligament injuries (22), but can be attenuated through appropriate conditioning (50). Injury incidence rates in girls are relatively high in soccer, and multifaceted neuromuscular training is essential for female players (5).

Participation in soccer alone is unlikely to guarantee that suitable levels of neuromuscular strength and coordination have been developed and may put players at greater risk of injury (5,14). The development of fundamental movement skills, strength, power, speed, and agility as early as possible in a players’ development may reduce injury and improve athletic performance. Success requires the careful integration of neuromuscular and sport-specific fitness training into the players’ development. In our experience, periodization of training is ineffective in this environment where we have found higher within-player variations than between-player variations in weekly training load with a large proportion of training occurring outside our planned soccer or conditioning sessions (53). Undoubtedly, factors such as transportation, access to facilities, and other commitments including schoolwork and examinations can impede on the players’ ability to complete planned training and subsequent recovery. Training should be prescribed with an understanding of the athlete’s physical capability (fundamental movement skills and soccer-specific fitness), biological maturation, and acute readiness to train.

**NEUROMUSCULAR TRAINING**

Neuromuscular training methods successfully reduce injury in female youth athletes (50), but may also improve soccer-specific physical performance. Given poor compliance associated with neuromuscular training programs for injury reduction, it may also be prudent to consider ancillary performance benefits of this training to promote athlete motivation and buy-in (2). Low-level plyometric exercise has been shown to enhance vertical jump height and kicking force in adolescent female players (45), whereas significant improvements in athletic performance measures have been demonstrated after a 6-week neuromuscular training program (43). A 10-week strength and plyometric program improved soccer-specific endurance and speed beyond traditional aerobic training in high school female soccer players, after controlling for marked differences between the groups at baseline (48).

In a case study, the results indicated likely large improvements in repeated-sprint performance when neuromuscular training was performed during a return-to-play protocol (61). In Table 1, we provide some guidelines for planning neuromuscular training in girl’s soccer teams.

It is important to understand both the players’ stage of biological maturation and their movement competence before designing a training program. Biological age can be calculated simply as a maturity offset (34) and categorized as pre, circum, or post peak height velocity (PHV). Previously, the authors have used elements of the Functional Movement Screen (FMS) and dynamic jump assessments such as drop jump (23) and tuck jump (40) to assess movement skills and provide a basis for programming. However, a clear maturation effect is present in the FMS (31), and its sensitivity to assess change in youth populations has been questioned (62).

We propose an alternative approach to assess movement competence through a curriculum (Table 1). This is similar to the model for assessing the progression of athletic movement patterns throughout athletic development proposed by McKeown et al. (33). To reduce the burden of testing on players and the potential for day-to-day variability in execution of an FMS test in youths, we propose that exercises incorporated within training are used for testing and monitoring. These should cover the ability to squat, lunge, push, pull, brace, jump, and land, and provide relevant information to inform and individualize programs based on what a player can do rather than identify dysfunctions. Figure 1 shows the example for the squat pattern based on a progression model proposed by Giles (20) (simple to complex, static to dynamic, unloaded to loaded, and slow to fast). Table 2 identifies key progressions we have included within our curriculum, which provide a framework for integrated neuromuscular training progression. The curriculum incorporates strength, balance and proprioception, proximal control, and plyometric exercise, as recommended (50).

**LONG-TERM ATHLETE DEVELOPMENT**

Integrative neuromuscular training is ideally initiated in early adolescence with the most profound effects occurring at younger ages (41,42). Training...
pre-PHV should aim to improve neuromuscular strength, fundamental movement skills, and speed (30). Exercises that require the body to work through a full range of motion or those incorporating a range of jumping, landing, or sprinting tasks in a fun and engaging way are ideal. Animal walks may engage children in these movements, and an example may include a “duck walk” (see Video, Supplemental Digital Content 1, http://links.lww.com/SCJ/A174). This is also an ideal opportunity to introduce a variety of ground-based movements, as shown in Supplemental Digital Contents 2–4 (see Videos, http://links.lww.com/SCJ/A175, http://links.lww.com/SCJ/A176, and http://links.lww.com/SCJ/A177). These can be progressed and incorporated into conditioned games to elicit multiplanar movement, and practitioners can manipulate the environment to elicit desired movement outcomes.

Given appropriate coaching and adequate recovery, advanced training methods such as plyometric training or Olympic-style weightlifting movements are perfectly legitimate training methods pre-PHV but the focus should be on execution of the skill rather than on the external load lifted. If in doubt, we would advise coaches to undertrain rather than risk over training here. We also suggest that these movements can be incorporated in many different ways and have used “gorilla” and “eagle” positions to elicit triple extension patterns, and this concept can be extrapolated to teach full weightlifting movements (e.g., Figure 2; see Video, Supplemental Digital Content 5, http://links.lww.com/SCJ/A178). In this example, the “gorilla” refers to the starting position of the snatch, and the “eagle,” the top of the triple extension. These videos provide examples of ways a strength and conditioning coach can engage children with neuromuscular training, but coaches should be encouraged to use their imagination and work with their players to develop buy-in to the training.

Players circum-PHV may demonstrate reduced coordination and joint ranges of motion concurrent with increases in...
body mass and lever length resulting in greater torque and subsequent injury potential at the knee (22). Thus, in the absence of a neuromuscular spurt seen in males (23), appropriate muscle strengthening is required to improve force absorption and increase joint stability. However, these players need to maintain their mobility and may require simplified exercise prescription. Deloaded (less than body weight) squat variations can decrease the joint loading while still providing a training stimulus and may be ideal for a player going through a growth spurt. We have used functional isometric training (25) to help provide a greater training stimulus safely in this group. Both deloaded and isometric squat variations have been recommended previously, and an additional emphasis on stability and mobility within the regressed movement skill would also be appropriate for this age group (28).

Strength and power development may be particularly important from a post-injury prevention perspective in post-pubertal girls (50). We would recommend a progressive neuromuscular and hypertrophy training program, which seeks to improve lower limb strength (30) and as such appropriately loaded squat progressions (e.g., overhead, front, or single leg squats) at this stage (29). Given technical competency progression to Olympic-type weightlifting may bring about desirable adaptations to ligament thickness and timing of muscle contractions in jumping tasks (23). Appropriate strength and conditioning exercises should also be included as part of balanced training programs (19). Particularly given the potential relationship between lower limb injury risk and the strength deficit (21), appropriate lower limb strength and muscle power should be developed in this group. Both deloaded and multiphase squat variations have been recommended previously, and additional emphasis on stability and mobility within the regressed movement skill would also be appropriate for this age group (28).

### SOCCER-SPECIFIC FITNESS

**METABOLIC CONDITIONING**

Metabolic conditioning refers to training targeting the development of both aerobic and anaerobic energy systems.

<table>
<thead>
<tr>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
<th>Level 5</th>
<th>Level 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Squat BL</td>
<td>Assisted squat</td>
<td>BW squat</td>
<td>Overhead squat</td>
<td>Overhead squat 10% BW</td>
<td>Overhead squat 25% BW</td>
</tr>
<tr>
<td>Squat UL</td>
<td>—</td>
<td>—</td>
<td>Assisted single leg squat</td>
<td>Single leg squat</td>
<td>Advanced single leg squat</td>
</tr>
<tr>
<td>Lunge (forward)</td>
<td>From floor to stand</td>
<td>Forward lunge</td>
<td>A-stand forward lunge</td>
<td>Lunge walk + rotations (forward/backward)</td>
<td>Lunge matrix + perturbations</td>
</tr>
<tr>
<td>Lunge (lateral)</td>
<td>Side lunge half depth</td>
<td>Side lunge to A-stand</td>
<td>Side lunge A-stand full</td>
<td>With ball throw</td>
<td>Lateral speed to lunge deceleration</td>
</tr>
<tr>
<td>Bear crawl</td>
<td>Quadruped arm leg</td>
<td>Static bear crawl</td>
<td>Forward 5 m</td>
<td>Backward 5 m</td>
<td>Grid (forward/ backward/side)</td>
</tr>
<tr>
<td>Jump land (BL)</td>
<td>BL drop and stick 15 cm</td>
<td>BL drop and stick 30 cm</td>
<td>Drop jump 30-cm box</td>
<td>Tuck jump ×3</td>
<td>Tuck jump ×10</td>
</tr>
<tr>
<td>Jump land (UL)</td>
<td>—</td>
<td>—</td>
<td>UL stride and stick 100% height</td>
<td>UL stride and stick 100% height + 90° rotation</td>
<td>Drop/cross step—double stride then stick</td>
</tr>
</tbody>
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These can be assessed using the scale in Figure 1 but also include elements of other assessment tools such as the drop (23) and tuck jump assessments (40).

**SOCCER-SPECIFIC FITNESS** (METABOLIC CONDITIONING)

**Table 2**

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physiological stresses experienced in match play (17). In women’s soccer players, match high-intensity running performance is important as it can differentiate levels of competition (36). A strong relationship exists between match high-intensity running and both aerobic capacity and performance on the Yo-Yo level 1 recovery test in female players (27). Anaerobic measures, such as speed or counter movement jump height, are also important to repeated, short, high-intensity activities (56) that typify a soccer match (19). Thus, development of both aerobic and anaerobic energy systems seems important in soccer.

The Yo-Yo test can differentiate between junior (age 17.3 ± 1.6) and senior female soccer players (37), but the development of soccer-specific metabolic conditioning in girls throughout maturation is less understood. Current guidelines (4) suggest that children and adolescents are trainable in all fitness components, including aerobic endurance, throughout maturation with limited evidence of a period of enhanced trainability (4). However, given the plateau in endurance performance after the onset of puberty in girls (7) and the increased injury risk associated with both fatigue and changes in body composition (22), metabolic conditioning is particularly relevant for circumpubertal and post-pubertal players.

Debate often surrounds the modality of metabolic conditioning in soccer, in particular between the use of soccer-specific small side games or traditional interval training. Data from our practice indicate that players pre-PHV do not respond to traditional high-intensity or sprint interval training, possibly due to a lower glycolytic capacity to supply adenosine triphosphate during high-intensity exercise (6). However, the same protocols provide an appropriate stimulus in those who are circum-PHV or post-PHV. In contrast, small-sided games alone do not provide adequate intensity in women soccer players (18). Given the increased neuromuscular load in small-sided games, these should be considered with caution in postpubescent girls and if they are included to be progressively introduced in line with the players’ technical and physical competence.

Alternatively, fun fast activity blasts (55), that incorporate intense game activities followed by short periods of rest, seem to be best suited to young players (e.g., those pre-PHV). This better resembles how young children actually move and play. Examples could include conditioned games of tag or relay races designed to elicit a high-intensity response. Such activities can be progressed and should include variety (38). These training methods have successfully improved markers of health and physical activity.

![Figure 2. Coaching of Olympic-style lifting derivatives through animal shapes: (A) "gorilla," (B) "stork," (C) "eagle," and (D) "gorilla roar." Supplemental Digital Content 5 (see Video, http://links.lww.com/SCJ/A178) demonstrates these combined to develop a snatch pattern.](image-url)
and elicited high-intensity responses consistently (54, 55). The use of small-sided games should provide a further cognitive stimulus and may improve compliance or engagement. This type of training can be incorporated into soccer sessions or provided within an additional strength and conditioning session targeting both metabolic conditioning and neuromuscular training techniques. An example of a 60-minute strength and conditioning session for prepubescent girls is presented in Table 3. To maximally utilize the players’ ability to learn the session is split into short periods alternating the demands from activities that are cognitively demanding with those that are more physically demanding while maintaining the same learning outcome for the session (47).

In summary, it seems that girls’ soccer players require varied metabolic conditioning stimuli based on their individual requirements. Coaches working with teams of players across maturation groups may need to be creative in the way they deliver metabolic conditioning to produce positive adaptations throughout. Repeated-sprint training methods could provide an adaptable tool for coaches within this age group given the short and sharp nature of the stimulus and potential benefits on neuromuscular and metabolic fitness (52).

**CONSIDERATIONS FOR PLANNING AND DELIVERY**

Implementation of training guidelines is unique depending on the environmental, social, and psychological nature of the soccer team. This context is critical to the translation of scientific data into applied practice (11). Neuromuscular training may be ideally suited to dedicated sessions planned within a training week yet practitioners can be limited to a 15-minute to 20-minute warm-up period to deliver their intervention. Specific warm-up protocols such as the FIFA11+ or the COREPAC (8) run before soccer training could be a time-efficient solution but only if barriers to compliance can be overcome (1, 29, 44, 49, 57).

Irrespective of the intervention, practitioners should ensure that the coaching and progression of exercise are sufficient to continue to drive adaptations (44). To promote compliance, we recommend a focus on the education of coaches (24) and players to the potential benefits from both an injury prevention and physical performance enhancement perspective, as the latter may increase player motivation (2).

Periodization of training is difficult given the lack of control over players’ additional training and demands of sports. Given current evidence on late specialization (35), variety in young players training should be encouraged. Conversely, careful planning of the design of training programs requires greater innovation and monitoring to be incorporated into busy schedules without risking overload. The planning model proposed by Kiely (26) provides a framework for this approach. The use of simple monitoring tools such as RPE and wellness ratings is ideal to use within this model (9) and may provide greater sensitivity to objective measures (46).

**PRACTICAL APPLICATIONS**

Strength and conditioning coaches working in girls’ soccer may need to be adaptable, but neuromuscular training and metabolic conditioning can be implemented to improve physical performance and reduce injury risk factors at all ages. However, the focus and methods used to develop fitness should be specific to a player’s maturation and individual needs. Initiating neuromuscular training as early as possible in

<table>
<thead>
<tr>
<th>Activity</th>
<th>Time</th>
<th>Physical demand</th>
<th>Cognitive demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balance games on arrival (e.g., single arm wrestle on 1 leg); establish key learning outcomes for the session</td>
<td>5 min</td>
<td>Low</td>
<td>Moderate/high</td>
</tr>
<tr>
<td>General movement warm-up of suppleness and skill followed by a short break</td>
<td>10 min</td>
<td>Moderate/high</td>
<td>Moderate</td>
</tr>
<tr>
<td>Learning of specific skill (e.g., squat) through different modes of activities, working in partners followed by a short break</td>
<td>10 min</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Skill-based learning task: for example, relevant game or obstacle course adapted to promote the skill or movement learned previously followed by a short break</td>
<td>10 min</td>
<td>Moderate</td>
<td>Moderate/high</td>
</tr>
<tr>
<td>Fitness game activity, using the same relevant skill in a more intense setting followed by a short break</td>
<td>10 min</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Cool down type of activity and reinforcing the practiced skill in a fun, but less intense setting</td>
<td>5 min</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Session debrief: quiz to understand what players have learned and enjoyed from the session</td>
<td>2 min</td>
<td>—</td>
<td>High</td>
</tr>
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</table>
player’s athletic development is recommended, and young players will adapt to fun activities targeting specific adaptations. Further prospective research tracking the longitudinal response of girls to structured training interventions throughout maturation would be beneficial.

**SUMMARY**

- Integrating neuromuscular and metabolic conditioning has wide spanning benefits for girls’ soccer players.
- Movement curriculums provide a framework for individual progressions and regressions of neuromuscular training in a team setting.
- Metabolic and neuromuscular conditioning should be adapted appropriately based on maturation.

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Matthew D. Wright is the sports development officer for Elite sport at Teesside University.

Mihkel-Madis Laas is a strength and conditioning coach at Teesside University and an Athletic Development/Sports Scientist at Pro Football Support.

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