Relationships between functional movement screen scores, maturation and physical performance in young soccer players

RHODRI S. LLOYD¹, JON L. OLIVER¹, JOHN M. RADNOR¹, BENJAMIN C. RHODES², AVERY D. FAIGENBAUM³ & GREGORY D. MYER⁴,⁵,⁶,⁷

¹Cardiff School of Sport, Cardiff Metropolitan University, Cardiff, UK, ²Faculty of Applied Sciences, University of Gloucestershire, Gloucestershire, UK, ³Department of Health and Exercise Science, The College of New Jersey, Ewing, NJ, USA, ⁴Division of Sports Medicine, Cincinnati Children’s Hospital Medical Center, Cincinnati, OH, USA, ⁵Department of Pediatrics and Orthopaedic Surgery, College of Medicine, University of Cincinnati, Cincinnati, OH, USA, ⁶Sport Medicine, Sports Health and Performance Institute, Ohio State University, OH, USA and ⁷The Micheli Center for Sports Injury Prevention, Boston, MA, USA

(Accepted 23 April 2014)

Abstract
The purpose of this study was to examine relationships between functional movement screen scores, maturation and physical performance in young soccer players. Thirty males (11–16 years) were assessed for maturation, functional movement screen scores and a range of physical performance tests (squat jump, reactive strength index protocol and reactive agility cut). Older participants significantly outperformed younger participants in all tests ($P < 0.05$; effect sizes = 1.25–3.40). Deep overhead squat, in-line lunge, active straight leg raise and rotary stability test were significantly correlated to all performance tests. In-line lunge performance explained the greatest variance in reactive strength index (adjusted $R^2 = 47\%$) and reactive agility cut (adjusted $R^2 = 38\%$) performance, whilst maturation was the strongest predictor of squat jump performance (adjusted $R^2 = 46\%$). This study demonstrated that variation of physical performance in youth soccer players could be explained by a combination of both functional movement screen scores and maturation.

Keywords: children, functional movement screen, squat jump, muscular strength, reactive agility

Introduction
Previous literature has noted the importance of effective movement proficiency for safe and effective long-term physical performance in young athletes (Lloyd & Oliver, 2012; Valovich-McLeod et al., 2011). For example, poor neuromuscular control and ineffective movement patterns during landing and cutting manoeuvres may predispose young athletes to an increased risk of injury (Hewett et al., 2005; Myer et al., 2009; Witvrouw, Lysens, Bellemans, Cambier, & Vanderstraeten, 2000). In addition, muscular imbalances are a significant injury risk factor for youth, as evidenced by an increased rate and risk of hamstring injury in elite junior soccer players presenting with isokinetic strength imbalances (Lehance, Binet, Bury, & Croisier, 2009).

Whilst research suggests that there may exist a relationship between movement proficiency and injury prevention and/or reduction, the association between movement proficiency and measures of physical performance in youth remains somewhat unclear, and where such data exist, results are inconclusive (Castelli & Valley, 2007; Erwin & Castelli, 2008; Okely, Booth, & Patterson, 2001). Of note, movement proficiency may have a strong association with activities that are more reliant on neural control in order to simultaneously control body segments whilst producing high levels of rapid force. It has been suggested that a deficiency in age-related motor skill performance may lead to a “proficiency barrier” that could impede progression to the learning of more complex movement patterns (Seefeldt, 1980). Arguably, the ability to execute different movements with correct technique should enable more effective force transmission within dynamic tasks and aid in postural stability and body alignment within open skilled activities.

Numerous methods for assessing movement proficiency exist; however, one popular test battery that has been examined in the literature is the functional...
movement screen (Chorba, Chorba, Bouillon, Overmyer, & Landis, 2010; Clifton, Harrison, Hertel, & Hart, 2013; Cook, Burton, & Hoogenboom, 2006a; Frost et al., 2013; Okada, Huxel, & Nesser, 2011; Parchmann & McBride, 2011). The functional movement screen was originally designed to assess muscle flexibility, strength imbalances and general movement proficiency in a range of performance tests; identify functional deficits related to proprioception, mobilisation and stabilisation; and determine the existence of pain during any of the prescribed movement patterns (Cook, Burton, & Hoogenboom, 2006b). Existing data suggest that the functional movement screen demonstrates moderate-to-excellent inter- and intra-rater agreement (kappa statistic ≥60%) for most of the assessment protocols (Teyhen et al., 2012), and as a screening tool, is routinely used within both applied and clinical settings. Although the ability of the functional movement screen protocol to determine injury risk (Chorba et al., 2010) and the effectiveness of training interventions (Frost, Beach, Callaghan, & McGill, 2012) has been examined, the relationship between functional movement screen scores and physical performance remains limited. Despite the growing interest in the use of functional movement screen (or similar screening protocols) within athletic development programmes, no published reports have examined the relationship between functional movement screen scores and physical performance in school-age youth.

Biological maturation refers to the progress towards a mature state, and the literature suggests that there exist significant inter-individual differences in the magnitude, onset and rate of change of various biological components as a result of maturational processes when children are grouped according to chronological age (Malina et al., 2004). Whilst skeletal age or sexual maturation has previously been used within the literature to determine the stage of biological maturation within an individual or groups of individuals, these techniques are often inappropriate, unrealistic or possess ethical concerns. Consequently, researchers use a surrogate of biological maturation by quantifying a range of somatic measures (such as standing height and seated height) to predict biological maturity status (Mirwald, Baxter-Jones, Bailey, & Beunen, 2002). Whilst the limitations of somatic measures are noted, they do offer a non-invasive and more realistic approach to determining maturity status, especially within field-based environments.

Early paediatric literature that focused on children suggested that both stature and muscular strength account for up to 70% of the variability in a range of motor skills inclusive of throwing, jumping and sprinting in 7- to 12-year-old boys (Teeple, Lohman, Misner, Boileau, & Massey, 1975). It is also acknowledged that biological maturation influences physical performance, largely owing to alterations in hormonal profiles, increases in lean body mass, myelination of motor neurons and enhanced inter- and intramuscular coordination (Faigenbaum, Lloyd, & Myer, 2013; Lloyd et al., 2014), all of which lead to the development of a number of physical and physiological variables (Malina et al., 2004). The rapid increases in body dimensions and limb lengths and significant development of muscle mass associated with maturation indicate that the determination of movement proficiency during this stage of development may be affected as adolescents learn to move with fluctuating levels of coordination (Quatman-Yates, Quatman, Meszaros, Paterno, & Hewett, 2012).

Therefore, the assessment of movement proficiency should be viewed as an essential factor in youth physical development programmes. These assessments, performed with consideration of biological maturation or at least a surrogate of biological maturation (somatic characteristics), may further elucidate the importance of movement proficiency in maturing youth relative to their functional movement screen performance. Whilst research has suggested that both maturation and movement proficiency might impact performance (Ford, Myer, & Hewett, 2010; Hewett, Myer, Ford, & Slauterbeck, 2006; Quatman, Ford, Myer, & Hewett, 2006), to our knowledge, there is no evidence in the literature that has compared the impact of both maturity and functional movement screen scores on a range of physical performance measures in youth. Consequently, the purpose of the current study was to investigate the relationship between functional movement screen scores, maturation, measures of squat jump height, reactive strength index and reactive agility in young athletes.

**Methods**

**Participants**

Thirty male youth soccer players from three different age groups (under 11, under 13 and under 16 years) within a professional soccer club in the United Kingdom volunteered to participate in this study. Participants were selected from these age groups to enable the examination of maturity status on functional movement screen scores and physical performance. Descriptive statistics for each age group are presented in **Table I**. All participants were free from injury and were involved in regular soccer-specific skills training (2 × 3 h per week) and physical education class activities (2 × 60 min per week). However, other than periodic exposure to isolated “core
criteria

| Table I. Descriptive statistics for each age group (mean ± SD). |
|---|---|---|---|---|
| Age group | Age (years) | Standing height (cm) | Seated height (cm) | Body mass (kg) |
| under 11 (n = 10) | 11.2 ± 0.5 | 146.0 ± 4.7 | 72.0 ± 2.9 | 37.7 ± 3.1 |
| under 13 (n = 9)  | 13.2 ± 0.2 | 157.6 ± 9.0 | 75.8 ± 5.5 | 48.6 ± 12.2 |
| under 16 (n = 11) | 15.6 ± 0.7 | 177.0 ± 4.1 | 87.5 ± 2.6 | 66.5 ± 5.6 |

Training” (e.g. isometric plank holds, gluteal bridging exercises, various balance holds) and relevant pre-habilitation/rehabilitation exercises (e.g. proprioceptive training, jumping and landing mechanics, unilateral balance drills), no participant was formally engaged in a periodised strength and conditioning programme geared towards developing high levels of force-producing capacities. The project received ethical approval by the University’s Research Ethics committee, and both participant assent and parental permission were obtained prior to testing.

Biological maturity was assessed non-invasively by incorporating measures of body mass, standing height and sitting height into a regression equation (Equation (1)) to predict age from peak height velocity (Mirwald et al., 2002). Peak height velocity reflects the age at which maximum rate of growth occurs during the adolescent growth spurt and is often used as a reference landmark to reflect the occurrence of other body dimension velocities or measures of physical performance (Mirwald et al., 2002). The equation has previously been validated for both boys and girls with standard error of estimates reported as 0.57 and 0.59 years, respectively (Mirwald et al., 2002).

\[
\text{Maturity offset} = -[9.236 + 0.0002708 \cdot \text{leg length and sitting height interaction}] -[0.001663 \cdot \text{age and leg length interaction}] +[0.007216 \cdot \text{age and sitting height interaction}] +[0.02292 \cdot \text{weight by height ratio}]
\]

\[\text{(1)}\]

Testing procedures

Participants completed a 10-min dynamic warm-up, inclusive of 3 min of sub-maximal multidirectional running and 7 min of light dynamic mobilisation and activation exercises targeting the main muscle groups of the upper and lower extremities. Following the warm-up and an opportunity to familiarise with the test protocols, all participants completed the battery of tests in the following order: functional movement screen screening (Cook et al., 2006a, 2006b), squat and maximal rebounding test (Lloyd, Oliver, Hughes, & Williams, 2009) and reactive agility test (Oliver & Meyers, 2009). Following functional

movement screen guidelines, which allow for some cueing and to ensure players were aware of the requirements of each movement task, the familiarisation session involved an initial explanation and demonstration. Paediatric researchers and a physiotherapist experienced in the administration of the functional movement screen protocol and the performance tests administered all testing on an individual basis. Data collection took place during normal after-school training hours, and the total time to complete the testing battery was approximately 1 h for each age group. Participants were asked to refrain from physical activity 24 h before testing and were asked to refrain from eating 1 h prior to testing.

Functional movement screen

Participants were screened using the functional movement screen protocol that comprised the following seven movement patterns: deep overhead squat, in-line lunge, hurdle step, active straight leg raise, trunk stability push-up, shoulder mobility and rotary stability. Participants were given three trials of each movement pattern, with each trial being scored by an experienced rater (2 years’ experience of screening) real time on a 4-point scale (Table II) according to the functional movement screen rater manual and previous research (Cook et al., 2006a). As per the functional movement screen testing guidelines (Cook et al., 2006a), the highest score from three trials was recorded and used for subsequent analysis, and in instances where the movement pattern was performed separately on left and right sides (i.e. in-line lunge, active straight leg raise, hurdle step, shoulder mobility and rotary stability), the lower of the two scores was recorded. Participants

Table II. Scoring criteria for the functional movement screen protocol (Cook et al., 2006a).

<table>
<thead>
<tr>
<th>Score</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Participant is able to perform the movement correctly without compensation</td>
</tr>
<tr>
<td>2</td>
<td>Participant is able to complete the movement but performs with compensation(s)</td>
</tr>
<tr>
<td>1</td>
<td>Participant fails to complete the movement pattern or is unable to assume the position to perform the movement</td>
</tr>
<tr>
<td>0</td>
<td>Participant has pain anywhere in the body at any time during the test</td>
</tr>
</tbody>
</table>
also completed additional movement dysfunction clearing tests to identify the presence of pain following functional movement screen guidelines (active impingement, trunk flexion and trunk extension tests). None of the participants reported pain during any of the clearing tests, and hence these data were not included in our subsequent analyses.

To assess the lower limb strength, participants performed both squat jumps and a maximal rebounding test. Previous research has noted that these tests measure unique aspects of strength; the squat jump represents concentric strength, whilst the maximal hopping tests enable the determination of reactive strength index, which more closely reflects elastic, reactive muscle actions within a competitive match or training environment for tasks such as jumping, cutting and accelerating. Both squat jump height (cm) and reactive strength index (mm · ms$^{-1}$) were measured on a mobile contact mat (Smartjump, Fusion Sport, Australia), with data instantaneously collected via a hand-held PDA (iPAQ, Hewlett Packard, USA). Squat jump. The squat jump was performed starting from an initial semi-squat position (90° knee flexion), which was determined via visual inspection to ensure that no countermovement was used (Lloyd et al., 2009). Participants were then asked to hold the position for 2 s before jumping vertically for maximum height on the command of the tester (Moir, Button, Glaister, & Stone, 2004). For the squat jump test, the participants’ hands remained on their hips for the entire movement to eliminate any influence of arm swing (Lees, Vanrenterghem, & Clercq, 2004). The mean of three trials was used for further analysis. Squat jump height collected via the contact mat has been shown to be a reliable and valid measure in paediatric populations (Lloyd et al., 2009).

Maximal rebounding test

The maximal rebounding test involved participants performing five bilateral repeated maximal vertical rebounds on the contact mat (Lloyd et al., 2009). Participants were instructed to perform the protocol with their hands placed on their hips throughout and were encouraged to maximise jump height and minimise ground contact time (Lloyd et al., 2009). The first jump in each trial was discounted as a countermovement, whilst the remaining four rebounds were averaged for the analysis of reactive strength index (Lloyd et al., 2009). The mean of three trials was used for further analysis. Reactive strength index was calculated from the equation reported in the literature (Flanagan & Comyns, 2008) (Equation (2)).

$$\text{Reactive strength index} = \frac{\text{jump height (mm)}}{\text{ground contact time (ms)}}$$

(2)

Reactive agility

The choice of a reactive agility test reflects the notion that agility is a key requirement for success in soccer at an elite level and is the primary performance variable that distinguishes between elite and non-elite youth football players (Reilly, Bangsbo, & Franks, 2000; Reilly, Williams, Nevill, & Franks, 2000). The use of a reactive element in the protocol was not used to assess perceptual abilities in the players (such as anticipatory decision-making), but rather to expose the players to joint and/or muscle loading that is reactive, requires greater levels of motor control (when compared to a pre-planned change-of-direction test) and importantly is more ecologically valid (Besier, Lloyd, Cochrane, & Ackland, 2001). Participants completed the reactive agility test protocol according to the method proposed by Oliver and Meyers (2009). The time to complete the reactive agility cut was measured using photoelectric timing gates (Smartspeed, Fusion Sport, Australia), with data instantaneously collected via a hand-held PDA (iPAQ, Hewlett Packard, USA). Participants were positioned 30 cm behind the first timing gate, and upon their own command, they sprinted through to complete the first 5 m of the course. Upon breaking the beam of the second timing gate, lights within the head unit of either the left or the right exit gate flashed, and participants were required to sprint as quickly as possible through the lit head unit. As per previous research (Oliver & Meyers, 2009), the delay time between the breaking of the timing gate light beam and the exit gate illuminating was approximately 40–45 ms. Participants were encouraged not to predict which exit gate would be illuminated, and if the athlete was deemed to have premeditated the cutting movement (i.e. completed a smooth, curved running line through one of the gates as opposed to a definitive cutting movement), then the trial was discounted and they were asked to re-perform the trial. The mean of the three trials from each side was averaged to provide one overall mean value for subsequent analysis.

Statistical analyses

Descriptive statistics (mean ± SD) were calculated for all tests in each chronological age group. A Kolmogorov–Smirnov test was used to confirm that each performance variable and the total functional
movement screen score were normally distributed, and a one-way analysis of variance was used to determine any between-group differences. A Tukey post hoc test was used to determine the origin of any differences. Effect sizes between groups were calculated on the pooled standard deviation of the groups being compared. The influence of maturation on between-group differences was then explored using analysis of covariance (ANCOVA), with age from peak height velocity entered as the covariate. Individual components of the functional movement screen battery were non-parametric, and relationships with performance variables were consequently examined using a Spearman’s rank correlation coefficient. Individual functional movement screen components and maturation were entered into multiple stepwise linear regression analyses to establish the main determinants of each performance variable. All analyses were computed via SPSS® V.20 for Windows, and the level of significance for all tests was set at alpha level $P \leq 0.05$.

Results

Descriptive performance results for each age group are presented in Table III. The oldest group (under-16s) was more mature than their younger counterparts and outperformed both younger age groups in all physical performance tests and functional movement screen scores ($P < 0.05$; effect sizes $= 1.25–3.40$). The under-13s were significantly more mature than the under-11s ($P < 0.05$), but they did not perform significantly better in any of the performance tests (Table III). When comparing the two younger groups, there were small effects for reactive strength index (effect size $= 0.43$) and functional movement screen (effect size $= 0.25$), with moderate effects for reactive agility (effect size $= 0.61$) and squat jump (effect size $= 0.88$). When comparing the under-13s and under-16s groups, there were large effects for functional movement screen, squat jump and reactive agility (effect size $>1.2$), with a very large effect for the difference in reactive strength index (effect size $= 2.63$). Differences between the youngest and oldest group demonstrated a large effect for reactive agility (effect size $= 1.82$) and very large effect sizes (effect size $>2.25$) for other performance variables. When an ANCOVA was applied to account for the influence of maturation on between-group differences in performance tests, reactive agility, squat jump and functional movement screen no longer displayed any significant differences between age groups (all $P > 0.05$). However, there was still a significant difference in the adjusted reactive strength index scores between the under-13s and under-16s ($P < 0.05$).

Across the pooled data, the median for all individual components of the functional movement screen was $M = 2$. The distribution of scoring for each individual test according to the functional movement screen scoring system was as follows: deep overhead squat ($1 = 43\%, 2 = 40\%, 3 = 17\%$); in-line lunge ($1 = 23\%, 2 = 60\%, 3 = 17\%$); hurdle step ($1 = 23\%, 2 = 50\%, 3 = 27\%$); active straight leg raise ($1 = 50\%, 2 = 50\%, 3 = 0\%$); shoulder mobility ($1 = 3\%, 2 = 70\%, 3 = 27\%$); rotary stability ($1 = 4\%, 2 = 63\%, 3 = 33\%$); trunk stability push-up ($1 = 13\%, 2 = 87\%, 3 = 0\%$). From the data pooled across all age groups, the relationships between individual components of functional movement screen and performance variables are shown in Table IV. The deep overhead squat, in-line lunge, straight leg raise, rotary stability and total functional movement screen score produced significant correlations (all $P < 0.05$) across all performance measures. Hurdle step and shoulder mobility were only significantly related to jump performance (squat jump and reactive strength index). Trunk stability push-up was not significantly related to any of the performance variables. Additionally, maturation was significantly related to squat jump height ($r = 0.69$, $P < 0.01$), reactive strength index ($r = 0.69$, $P < 0.01$) and reactive agility performance ($r = 0.58$, $P < 0.01$).

Results of the linear regression analysis are shown in Table V. The analysis revealed maturation as a primary predictor of squat jump performance but with a significant additional contribution from in-line lunge score (adjusted $R^2 = 0.54$). In-line lunge performance was the primary predictive variable explaining both reactive strength index and reactive agility

<table>
<thead>
<tr>
<th>Age group</th>
<th>Years from PHV</th>
<th>SJ (cm)</th>
<th>RSI (mm · ms$^{-1}$)</th>
<th>RA (s)</th>
<th>FMS total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 11 ($n = 10$)</td>
<td>$-2.78 \pm 0.40^{ab}$</td>
<td>$25.10 \pm 3.49^{b}$</td>
<td>$1.07 \pm 0.22^{ab}$</td>
<td>$5.05 \pm 0.51^{b}$</td>
<td>$12.0 \pm 1.5^{b}$</td>
</tr>
<tr>
<td>Under 13 ($n = 9$)</td>
<td>$-1.44 \pm 0.79^{b}$</td>
<td>$29.33 \pm 5.67^{b}$</td>
<td>$0.97 \pm 0.24^{b}$</td>
<td>$4.77 \pm 0.39^{b}$</td>
<td>$12.5 \pm 3.0^{b}$</td>
</tr>
<tr>
<td>Under 16 ($n = 11$)</td>
<td>$1.25 \pm 0.41$</td>
<td>$35.14 \pm 2.27$</td>
<td>$1.68 \pm 0.27$</td>
<td>$4.32 \pm 0.23$</td>
<td>$16.0 \pm 2.0$</td>
</tr>
</tbody>
</table>

Notes: PHV = peak height velocity; SJ = squat jump; RSI = reactive strength index; RA = reactive agility; FMS = functional movement screen.

*Significantly different from U13 ($P < 0.05$).
*Significantly different from U16 ($P < 0.05$).
performance, with maturation explaining further variation in both of these measures (adjusted $R^2 = 0.68$ and adjusted $R^2 = 0.46$, respectively). Trunk stability push-up also made a small but significant contribution to explaining the amount of variation in reactive strength index performance (see Table V).

### Discussion

The main finding of the current study was that variation in measures of physical performance in young soccer players is explained by a combination of certain tests from within the functional movement screen protocol and somatic maturation. Specifically, maturation was the strongest predictor of squat jump performance, whilst the in-line lunge test explained the greatest amount of variation in both reactive strength index and reactive agility performance. The finding that maturation was found to explain the greatest variation in squat jump performance may simply reflect the hormonal changes and consequent adaptations in muscle size and function influenced by maturity as reported in the paediatric literature (Malina et al., 2004). However, the relationships between measures of functional movement screen scores and physical performance for young athletes observed in the current study are a novel finding.

#### Table V. Regression equations explaining which components of functional movement screen and maturation significantly predict performance outcomes ($P < 0.05$).

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>Independent variables</th>
<th>Regression equation</th>
<th>Adjusted $R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>SJ</td>
<td>Constant</td>
<td>25.43</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maturity</td>
<td>+1.63</td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td>ILL</td>
<td>+3.15</td>
<td>0.54</td>
</tr>
<tr>
<td>RSI</td>
<td>Constant</td>
<td>0.31</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ILL</td>
<td>+0.28</td>
<td>0.47</td>
</tr>
<tr>
<td></td>
<td>Maturity</td>
<td>+0.11</td>
<td>0.64</td>
</tr>
<tr>
<td></td>
<td>TSPU</td>
<td>+0.27</td>
<td>0.68</td>
</tr>
<tr>
<td>RA</td>
<td>Constant</td>
<td>5.29</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ILL</td>
<td>+0.35</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td>Maturity</td>
<td>+0.10</td>
<td>0.46</td>
</tr>
</tbody>
</table>

Note: Maturity = years from peak height velocity; SJ = squat jump; RSI = reactive strength index; RA = reactive agility; ILL = in-line lunge; TSPU = trunk stability push-up.

When grouped according to chronological age, data revealed that the under-16s performed significantly better than both younger age groups in all physical performance and functional movement screen tests. Considering the maturational status of the groups, results showed that the under-16s were post-peak height velocity and significantly outperformed the under-11s and under-13s who were both pre-peak height velocity in the functional movement screen, squat jump height, reactive strength index and reactive agility. This suggests that the period immediately post peak height velocity appears to be a phase of naturally occurring accelerated development and may be an opportune time for improving physical performance. However, it should be acknowledged that aside from the potential anabolic milieu associated with post-peak height velocity, it is imperative that pre-pubertal children actively engage in youth physical development programmes to maximise performance, reduce the likelihood of injury and for the maintenance of general health and well-being (Lloyd & Oliver, 2012). These data, in addition to the fact that results from the ANCOVA analysis, showed that when maturation is entered as a covariate between-group differences no longer exist, suggest that maturation was an influencing factor on physical performance measures and functional movement screen scores. This finding corroborates existing literature, which has previously demonstrated the influence of maturation on physical performance indices (Beunen & Malina, 1988; Philippaerts et al., 2006).

Interestingly, both under-11s and under-13s were estimated to be pre-peak height velocity, and none of the performance variables were significantly different between these groups. This finding may be associated with a general plateau in performance characterised by no improvement in reactive strength index, reactive agility or functional movement screen scores during this period, which reflects the non-linear development of children and adolescents (Malina et al., 2004), with periods of relatively little fluctuation followed by periods of rapid change. Whilst speculative, it could be suggested that the plateau in performance may represent a period of “adolescent awkwardness”, which is a term used to...
reflect a temporary disruption in motor control performance associated with this stage of development (Beunen & Malina, 1988; Philippaerts et al., 2006; Quatman-Yates et al., 2012). Whilst this phenomenon has previously been associated with decrements in squat jump performance (Lloyd, Oliver, Hughes, & Williams, 2011a), it is proposed that the continued physical development of the under-13s might have been temporarily restricted as the players adjust to executing motor skills with longer limbs (Hewett & Myer, 2011; Myer et al., 2009). However, it should be recognised that “adolescent awkwardness” does not necessarily affect all youth and therefore our suggestion is speculative and warrants further investigation.

Most individual components of functional movement screen showed significant moderate-to-strong relationships ($r = 0.4–0.7$) with some or all of the performance measures (see Table IV). This demonstrates the potential importance of certain functional movement screen deficits in limiting physical performance in young soccer players. Interestingly, a moderate negative correlation between in-line lunge and agility performance, as measured by a $T$-test, has been reported, albeit in adults (Okada et al., 2011). These data indicate that unilateral lower limb function may be an important performance discriminator for agility movements involving a rapid change of direction (Young, James, & Montgomery, 2002). Owing to the fact that the correlation analysis revealed that performance in the deep overhead squat, in-line lunge, active straight leg raise and rotary stability were significantly correlated to all three measures of physical performance (squat jump height, reactive strength index and reactive agility), these may be the most useful tests from within the functional movement screen battery to predict physical performance. These results, in addition to the practicalities associated with testing and screening large cohorts of young athletes, for example, in a cross-sectional talent identification event, might suggest that practitioners may benefit from using only those tests within the functional movement screen battery that were related to all measures of physical performance. However, for a full in-depth screening process and longitudinal tracking of functional movement screen performance, practitioners are advised to complete the full functional movement screen protocol as recommended by the guidelines reported in the literature (Cook et al., 2006a, 2006b).

Results from the linear regression indicated that maturation was the primary predictor of squat jump performance ($R^2 = 46\%$). This may reflect that the squat jump is a test requiring lower levels of skill, or is at least less demanding with regard to movement mechanics, as maturation alone plays such a significant effect. The result is also supported by between-group analysis, as U13s outperformed under-11s in the squat jump test, but the only other significant difference between the pre-pubertal groups was maturity status. In-line lunge performance explained some variation for squat jump height (adjusted $R^2 = 8\%$), but was the primary predictor of both reactive agility (adjusted $R^2 = 38\%$) and reactive strength index (adjusted $R^2 = 47\%$) performance. This may reflect the more dynamic nature of those tasks and, especially in the case of the reactive agility test, a greater need for unilateral stabilisation skills and sound movement mechanics to efficiently execute unanticipated cutting manoeuvres commonly seen in open, reactive agility movements (Besier, Lloyd, Cochrane, & Ackland, 2001; Cortes, Onate, & Van Lunen, 2011). Results also demonstrated that maturity still played some role, albeit a small one, in explaining the variation associated for both reactive strength index (adjusted $R^2 = 17\%$) and reactive agility (adjusted $R^2 = 8\%$), which may suggest that performance in both reactive strength index and reactive agility was possibly related to the increased strength typically associated with increased maturational status. This notion is also reflected in the increased squat jump performance between different age groups, which has previously been used to represent concentric strength (Lloyd et al., 2011b). Interestingly, although trunk stability push-up competency did not significantly correlate with any of the performance measures, it did make a small contribution to explaining the variation in reactive strength index (adjusted $R^2 = 4\%$). This may reflect the uniqueness of the trunk stability push-up within the functional movement screen battery. It may also highlight the need for appropriate levels of trunk stability during the reactive strength index test in order to tolerate the large impact forces transmitted through the kinetic chain during dynamic vertical movements (Hewett & Myer, 2011).

A limitation of this study is that it assessed maturation using predicted age from peak height velocity and therefore biological maturation was not measured directly but instead represented by somatic maturation based on the predictive equation proposed by Mirwald et al. (2002). Despite the measurement error associated with the predictive equation ($± 1$ year in $95\%$ of cases), the standard deviations associated with each age groups ensured that any risk of incorrectly quantifying a child as either pre-, circum- or post-pubertal was avoided. However, some caution should be taken when applying the predictive equation to potentially early maturing populations. From a practical perspective, the predictive equation is a reliable, non-invasive and time-efficient measuring tool to assess biological
maturation in youths. In addition, we recommend that future research is performed on larger sample sizes to validate the findings of the current study to wider populations.

Conclusions
The current study demonstrates that selected tests (in-line lunge, deep overhead squat, active straight leg raise and rotary stability) within the functional movement screen battery can explain a portion of the variation in athletic performance in youth soccer players. Multiple regression analyses data from the current study indicate that for performance measures requiring higher reactive capabilities and greater levels of skill (e.g. reactive strength index and reactive agility), in-line lunge proficiency is more important, whilst for movements requiring less technical skill and minimal reactive qualities (e.g. squat jump performance), greater variation can be explained by maturation. These findings highlight the multidimensional nature of athletic performance and the need to develop a breadth of athletic qualities. Due to the trainability of all major fitness components throughout childhood and adolescence (Lloyd & Oliver, 2012), the current study highlights that functional movement and force-producing capabilities (strength and power) should be viewed as integral training foci within youth physical development programmes. However, these fitness qualities should be included within a holistic athletic development programme inclusive of other key athletic qualities (e.g. speed, agility, running mechanics, mobility and endurance).

References
Lloyd, R. S., Oliver, J. L., Hughes, M. G., & Williams, C. A. (2011b). Specificity of test selection for the appropriate


