# THE EFFECTS OF MATURATION ON MEASURES OF ASYMMETRY DURING NEUROMUSCULAR CONTROL TESTS IN ELITE MALE YOUTH SOCCER PLAYERS

**SUBMISSION TYPE:** ORIGINAL INVESTIGATION

**RUNNING HEAD:** EFFECTS OF MATURATION ON ASYMMETRY


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## ABSTRACT

**Purpose:** Asymmetry is a risk factor for male youth soccer players. There is a paucity of data confirming the presence of asymmetry using practically viable screening tasks in players at different stages of maturation.

**Method:** A cross sectional sample (N = 347) of elite male youth soccer players who were either (pre-, circa- or post-peak height velocity (PHV)) completed the following single leg assessments: Y-Balance anterior reach (Y-Bal); hop for distance (SLHD); 75% hop and stick (75%Hop) and countermovement jumps (SLCMJ).

**Results:** SLCMJ landing force asymmetry was higher in both circa and post-PHV groups, ($p < 0.001$; $d = 0.41 – 0.43$). 75%Hop landing force asymmetries were also highest in circa PHV players but between group comparisons were not statistically significant and effect sizes were small. SLHD and Y-Bal asymmetries reduced with maturation; however, no group differences were significant, with small to trivial effect sizes ($d = \leq 0.25$).

**Conclusion:** Stage of maturation did not have a profound effect on asymmetry. Between-limb differences in functional performance seem to be established in early childhood; thus, targeted interventions to reduce this injury risk factor should commence in pre-PHV athletes and be maintained throughout childhood and adolescence to ensure asymmetry does not increase.



**Key words**

Leg dominance, functional performance, injury risk

## INTRODUCTION

Epidemiological data indicate that injury rates increase linearly from 9 to 18 years of age in elite male youth players (32) and a period of heightened risk occurs during peak height velocity (PHV) (38). Rapid changes in stature and mass are likely contributing factors to altered movement and disruptions in motor control strategies underlie these periods of increased injury risk (2, 30, 39).

Between-limb asymmetry in functional performance is a potential risk factor for male youth soccer players where preferred lower limb dominance is evident (11). This may be further confounded by heightened volumes of training and match play during key developmental periods (33). Due to the physical demands of youth soccer, the associated injury risk, and the number of children and adolescents who participate in the sport, there is a clear need for research within male youth soccer players to identify normative values for asymmetry across different tasks for players at different stages of growth and maturation as these may be linked to increased injury risk (1)..

Asymmetry during jumping and landing tasks places additional stress on the soft tissue structures of the non-dominant leg which may reduce performance and predispose athletes to a range of lower extremity injuries (15). In adult populations, a between limb difference of greater than 15% has been identified as a predictor of injury (7). There is a paucity of data confirming the presence of asymmetry and associated injury risk in youth players at different stages of maturation. Also, it is unclear if asymmetry thresholds are consistent for different tests or if a range of values exist across different tasks in this cohort.

While some level of asymmetry is to be expected in male youth soccer players, there is a paucity of literature to examine the magnitude of between limb differences in commonly used tests that measure neuromuscular control. Elite male youth soccer players has shown isokinetic strength imbalances of the hamstrings and quadriceps combined with reduced dominant leg hip range of motion (8, 17). Kinetic differences between limbs in propulsion and force absorption during single leg jumping tasks have also been observed (Sannicandro), in addition to contralateral differences in peak ground reaction forces during a deep squat exercise (Atkins). However, only the work of Kellis et al. (17) and Atkins et al. (2) examined different chronological age groups which would reflect players who are either pre-, circa- or post-PHV. Specifically, Kellis et al. (17) reported that asymmetry in a variety of strength parameters tested via isokinetic dynamometry was not affected by age, whereas, Atkins et al.

(2) showed increases in asymmetry in the U14-U16 age groups which are representative of periods associated with rapid growth. These data provide a useful insight into changes in asymmetry at different stages of childhood and adolescence which may be linked to growth and development; however, due to the variation in biological maturity present in soccer players of the same chronological age (19), further examination of the effects of maturation on between-limb differences using practically viable screening tasks is warranted.

Another pertinent risk factor for lower extremity injury is dynamic balance (28, 31), which is dependent upon accurate sensory input and reflexive motor responses to control and maintain the position of the body's centre of mass during dynamic actions (14). Improving dynamic balance has also significantly reduced the risk of ankle sprains in high school soccer and basketball players (23), and decreased knee injuries in male youth soccer players across the course of a season (22). In high school male basketball athletes, players with an anterior right-left reach difference of greater than 4 cm on the star excursion balance test were at 2.5 times greater risk of lower extremity injury (31). Recent research has examined longitudinal changes in dynamic postural stability using a repeated measures design with five formalized testing sessions across a two-year period in a sample of adolescent school children (N = 184; mean age, 13 ± 0.34) (16). The authors did not report asymmetry values; however, upon examination of their data, between-limb differences in the anterior reach direction were small (< 2% asymmetry) and the level of asymmetry reduced at each time point across the duration of the study (16). To the knowledge of the authors, no research is currently available that has examined the effects of stage of maturation on dynamic balance asymmetry, and specifically using the anterior reach of the y-balance test in elite male youth soccer players.

Cumulatively, there is lack of available evidence to report the effects of maturation on measures of asymmetry during field-based tests of neuromuscular control. An awareness of the potential for limb dominance emerging at different stages of growth and maturation using a range of practically viable screening protocols will aid practitioners in determining what 'normal' values of asymmetry are in this cohort. The aim of the current study was to examine possible maturation-related differences in asymmetry for measures of dynamic balance, single leg jumping distances and landing forces using a cross-sectional sample of elite male youth soccer players.

## METHODS

### *Participants*

Three hundred and forty-seven elite male youth soccer players (aged 10-18 years) from the academies of six English professional soccer clubs volunteered to take part in this study. Descriptive statistics for each maturation group are displayed in table 1. Predicted maturational status was calculated using a previously validated regression equation (26). None of the players reported injuries at the time of testing and all were participating regularly in football training and competitions. Parental consent, participant assent and physical activity readiness questionnaires were collected prior to the commencement of testing. Ethical approval was granted by the institutional ethics committee in accordance with the declaration of Helsinki.

**Table 1** Mean (s) values for participant details for each maturation group

| Maturation group | N | Age (years) | Body mass (kg) | Stature (cm) | Leg length (cm) | Maturity offset |
|---|---|---|---|---|---|---|
| Pre PHV | 135 | 11.9 ± 1.1 | 39.7 ± 6.4 | 148.2 ± 7.5 | 74.6 ± 3.5 | -2.2 ± 0.6 |
| Circa PHV | 83 | 14.4 ± 0.9 | 51.8 ± 6.7 | 164.8 ± 7.6 | 82.3 ± 3.6 | 0.0 ± 0.3 |
| Post PHV | 129 | 16.1± 1.1 | 66.8 ± 8.0 | 176.6 ± 6.7 | 88.6 ± 4.7 | 2.0 ± 0.8 |

PHV = peak height velocity

### *Experimental design*

This study used a cross-sectional design to examine maturation-related differences in asymmetry for a variety of field-based measures of neuromuscular control. Players were required to attend their respective club training grounds on two occasions separated by a period of seven days. The first session was used to familiarize participants with the test equipment and assessment protocols. In the second session, data were collected from four different assessments, including: (1) y-balance test (anterior reach direction only); (2) single leg horizontal hop for distance (SLHD); (3) single leg 75% horizontal hop and stick onto a force plate (75%Hop) and; (4) single leg countermovement jump and stick (SLCMJ) onto a force plate. A 10-minute standardized dynamic warm up was completed prior to each test session. The order of testing and sequence of leg tested was randomized using a counterbalanced design to reduce the potential for an order effect. Three trials of each test were performed with the mean score reported. One minute of recovery was allowed between trials based on previous recommendations (9). Participants were asked to refrain from strenuous exercise at least 48 hours prior to testing. Subjects were also asked to eat according to their normal diet and avoid eating and drinking substances other than water one hour prior to each test session.

*Procedures*

*Anthropometry:* Body mass (kg) was measured on a calibrated physician scale (Seca 786 Culta, Milan, Italy). Standing and sitting height (cm) were recorded on a measurement platform (Seca 274, Milan, Italy).

*Biological Maturity:* Stage of maturation was calculated in a non-invasive manner utilizing a regression equation comprising measures of age, body mass, standing height and sitting height (Mirwald, 2002). Using this method, maturity offset (calculation of years from PHV) was completed (equation 1). The equation has been used previously to predict maturational status in paediatric research with a standard error of approximately 6 months (Mirwald et al., 2002).

Maturity offset =

–9.236 + [0.0002708 x leg length and sitting height interaction]

– [0.001663 x age and leg length interaction]

+ [0.007216 x age and sitting height interaction]

+ [0.02292 x weight by height ratio]

[equation 1]

*Y-Balance(Y-Bal) (anterior reach):* Participants placed their hands on their hips and began in a unilateral stance with the most distal aspect of their great toe behind the line on the centre of the Y-Balance test kit™ (Move2Perform, Evansville, IN). Distances were then recorded by pushing the target reach indicator in the anterior direction. Trials were performed on both legs with the order of testing counterbalanced. Throughout, subjects were required to keep the heel of the non-reach leg on the testing platform, maintain balance in a single leg stance, and return the reach foot back to the start prior to attempting the next direction. Also, no visible kicking of the target reach indicator was permitted. Maximal reach distances were recorded to the nearest 0.5 cm marker on the Y-balance kit. Anterior reach only was included due to the heightened associations with injury of this specified direction (31) and the practicalities of performing a range of tests in a time-efficient manner using a large sample of players.

*Single leg hop for distance:* Hop distances were recorded using a tape measure that was taped to the floor and marked out for a length of three metres. Participants began by standing on the designated test leg with their toe on the marked starting line, the hip of the free leg flexed at 90° to avoid contralateral propulsion, and their hands on their hips. When the subjects were ready, instructions were to hop forward as far as possible, landing on the same leg with the hands remaining on their hips throughout. For each test to be recorded, players had to stick the landing and hold for three seconds without any other body part touching the floor in accordance with previous guidelines (13). Reduced hop distances during this test have been associated with a greater risk of lower extremity injury (13). Players performed the task on both legs and the distance in line with the heel was recorded to the nearest 0.1 cm using a ruler stick to increase accuracy of the measurement.

*Single leg 75% horizontal hop and stick (75%Hop):* The test set up and procedures have been described previously (34) and involved a tape measure that was taped to the floor and marked out to a three metre distance on a horizontal line with the 0 cm mark positioned in line with the centre of a force plate (Pasco, Roseville, California, USA). Participants began by standing in line with the force plate on the designated test leg, hands on their hips, and toe in line with a distance marker on the tape measure representing 75% of their predetermined maximal single leg hop and stick performance. When the subjects were ready, instructions were to hop forward onto the force plate, landing on the same leg with hands remaining on their hips throughout. For each test to be recorded, players had to stick the landing and hold for five seconds, remaining as still as possible without any other body part touching the floor. The test was performed on both legs.

*Single leg countermovement jump and stick (SLCMJ):* Participants began standing on a force plate (Pasco, Roseville, California, USA) in a unilateral stance with their hands on their hips and the opposite hip flexed at 90° to ensure minimal contributions from the contralateral leg (34). Instructions were to jump as high as possible using a countermovement by dropping into a quarter squat and then immediately triple extending at the ankle, knee and hip in an explosive concentric action. On landing, subjects were required to stick the landing and hold for a period of five seconds remaining as still as possible. For standardization, bending of the knees whilst airborne was not permitted, and hands remained in contact with hips throughout the test.

*Force plate variables:* Kinetic data were captured from a portable force platform (Pasco, Roseville, California, USA) including pVGRF recorded in the first 100 ms following ground contact. This cut-off point was used to evaluate landing peak vertical ground reaction forces due to the reported timing of non-contact injuries which occur within the first 50 ms following initial ground contact (18). Forces experienced after this point are unlikely to contribute to acute injury risk and were therefore not included in the analysis. Vertical force only was calculated due to the fact that the force plate is only able to measure this vector; thus, not allowing analysis of anterior-posterior or medio-lateral force vectors. All data were recorded at a sampling rate of 1000 Hz and filtered through a fourth-order Butterworth filter at a cut-off frequency of 18 Hz.

*Asymmetry calculation:* Different classifications of limb dominance have been suggested within the available literature. For example, a greater incidence of anterior cruciate ligament (ACL) injuries has been shown in player's preferred push off leg during a cutting manoeuvre (40). Conversely, epidemiological data in elite male soccer players reported that 74.1% injured their dominant kicking leg. However, no studies are available in male youth soccer players. Whilst classifying the performance of the dominant versus non-dominant leg may provide useful information, accurately defining a participant's dominant leg (i.e. kicking leg vs. push off leg) may be challenging for practitioners. Also, factors such as previous injury may result in neuromuscular inhibition (12, 29) and subsequent performance reductions. Therefore, to quantify asymmetry and determine injury risk, a more appropriate method may be to calculate the percentage difference between the highest vs. lowest performing limb. The value obtained is expressed as the absolute percentage of performance achieved using the higher performing limb as the reference (equation 1).

$$\text{Asymmetry \%} = ((\text{highest performing limb} - \text{lowest performing limb}) / \text{highest performing limb} * 100)$$

$$\text{\% of Performance achieved} = 100 - \text{\% Asymmetry}$$

[equation 1]

*Statistical analysis*

Test descriptive statistics were calculated for each maturation group. A one-way analysis of variance (ANOVA) was performed to examine between-group differences for all measures of asymmetry. The level of significance was set at alpha level $p \leq 0.001$. Homogeneity of variance was tested by Levene's statistic, and where violated Welch's adjustment was used to calculate the F-ratio. Post-hoc analysis to determine significant between-group differences was assessed using Gabriel's or Games-Howell tests when equal variance was or was not assumed respectively. Players were grouped by their stage of maturation (pre-, circa- or post-PHV). To account for the reported error (approx. 6 months) in the equation (26), players were grouped into discrete bands based on their maturational offset (pre -PHV = < -1, circa-PHV = - 0.5 to 0.5, post-PHV = >1). Players tested who recorded a maturational offset between -1 to -0.5 and 0.5 to 1 were subsequently removed from the data set. The original sample of players was N = 400; subsequently, 53 players were removed during this process with an adjusted sample of N = 347 to be included in the analysis. Cohen's *d* effect sizes (ES) were calculated to interpret the magnitude of between-group differences using the following classifications: standardized mean differences of 0.2, 0.5, and 0.8 for small, medium, and large effect sizes, respectively (5).

A secondary analysis included a repeated measures ANOVA to examine differences between asymmetry scores for each test with all the players combined. Sphericity of the data was checked by Maulchy's statistic, and where violated Greenhouse-Geiser adjustment was applied. Bonferroni post-hoc tests were used to identify the origin of any between-test differences in asymmetry score. The reliability of all jump-landing assessments used in this study has been published previously (Rea force) and deemed acceptable (CV <10%) based on previous guidelines (6). Intra-rater reliability for the y-balance test was assessed using an intraclass correlation coefficient (ICC). All data were computed through Microsoft Excel® 2010, while ANOVAs and t-tests were processed using SPSS® (V.21. Chicago Illinois).

## RESULTS

Intra-rater reliability of the y-balance test was (ICC = 0.85). Asymmetry scores for each test and respective maturation group are displayed in figure 1. SLCMJ asymmetry increased in the later stages of maturation, with significantly higher scores in both the circa and post-PHV players, although this corresponded to a small effect size ($p < 0.001$; $d = 0.41 – 0.43$). During the 75%Hop, asymmetries were also highest in players who were circa PHV but between group comparisons did not reach statistical significance and effect sizes were small ($d = < 0.31$). For both the SLHD and Y-Bal, asymmetries reduced with each stage of maturation; however, minimal differences in mean score were shown with small to trivial effect sizes ($d = \leq 0.25$), and between-group comparisons were not statistically significant.

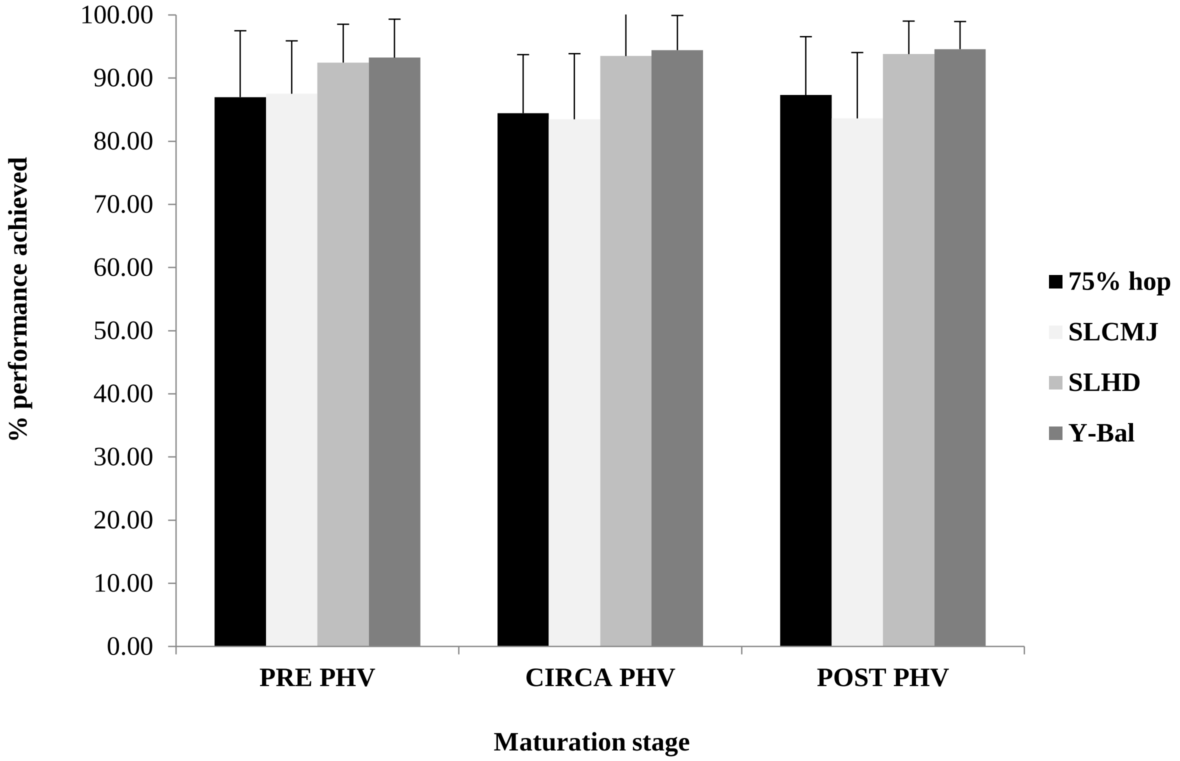


**Figure 1**. Asymmetry scores for each maturation group

75%hop = *single leg 75% horizontal hop and stick; SLCMJ = single leg countermovement jump; SLHD = single leg hop for distance; Y-Bal = y-balance anterior reach*

The magnitude of asymmetries was significantly greater for landing force variables during the 75%Hop and SLCMJ than both the SLHD and Y-Bal anterior reach distance ($p < 0.001$). With all the players combined, asymmetry was greatest during SLCMJ (85%), followed by the 75%Hop (86%) and these values were statistically greater than all other tests ($p < 0.001$). No significant differences were shown between SLCMJ and 75% hop. Y-Bal and SLHD asymmetry were markedly lower than landing force variables (94% and 93% respectively); no significant differences were reported between these tests.

## DISCUSSION

The current study utilized a cross-sectional evaluation of elite male youth soccer players to examine the effects of maturation on measures of asymmetry in different field-based neuromuscular control tests. A variable pattern was observed in asymmetry scores across each group and test measured. SLCMJ landing force asymmetry was increased in circa- and post-PHV players, and those in the circa group also recorded the highest asymmetries in the 75%Hop. Conversely, the youngest age groups had the highest asymmetries in the SLHD and Y-Bal anterior reach test. However, between-group statistical comparisons did not show clear differences indicating that a player's stage of maturity does not appear to have a profound effect on asymmetry for the different constructs of neuromuscular control assessed in this study. Asymmetries were also greater for landing force variables than single leg hop and anterior Y-Bal reach distances which suggests task dependency and that these tests may be more sensitive for the identification of between-limb differences.

During the SLCMJ, significantly greater landing force asymmetry was shown in circa- and post-PHV players. It could be inferred that the majority of players would preferentially utilize their right leg for kicking actions due to preferred limb dominance during soccer match play. Greater stability and force absorption would therefore be expected on the contralateral limb due to the requirement to repeatedly stabilize on their stance leg. These data indicate the emergence of increased leg dominance which has been shown in elite male youth soccer players (2, 8) and could be due to the accumulated exposure of sport-specific training and competitions. Elite soccer in the United Kingdom has recently adopted an early sport specialization approach, whereby, youth boys participating in academy programs are now required to attend multiple weekly training sessions and competitions, with formal registration commencing at 8 years of age (10). There is a considerable risk of injury in early soccer specialization programs (4), and recent data indicate that early sport specialization is an independent injury risk factor even after controlling for age and hours of total training and competitions completed each week (35). Thus, coaches are advised to monitor for the emergence of asymmetry in landing forces using the SLCMJ, particularly following periods associated with rapid growth.

In the present study, asymmetry was significantly greater for circa- and post-PHV players during the SLCMJ and heightened between-limb differences were also present for those in the circa group during the 75%Hop. Previous literature has shown that asymmetries in peak force during an overhead squat task were greatest in the U15 age group in elite male youth soccer players (2). Significant differences between limbs were also identified for all age groups except for the U13s and U17s (the youngest and oldest groups respectively) (2). The authors suggested that asymmetry increased during the period of PHV and the early stages of adolescence. These data correspond to the heightened asymmetries shown by circa-PHV players in the current study. Furthermore, injury risk has been shown to increase around the time of PHV (38, 39), which also corresponds with the circa-PHV group in the current study. These players should be considered a target group for injury risk reduction programs focusing on optimizing landing mechanics on both their dominant and non-dominant limbs while focusing on enhancing limb-to-limb symmetry.

An unexpected finding of this study was that the stage of growth and maturation does not appear to have a profound effect on the level of asymmetry in functional performance tasks performed by elite male youth soccer players. A period of adolescent awkwardness has previously been reported, whereby, due to rapid increases in limb length, young soccer players may experience temporary decrements in motor skill performance occurring approximately 12 months prior to PHV (30), potentially increasing the likelihood of asymmetry. In the current study, while significantly greater landing force asymmetry was shown in the SLCMJ for circa- and post-PHV players, measures of dynamic balance and horizontal jumping and landing performance did not reveal any meaningful between-group differences. Previous research in school aged boys has shown that asymmetry in a variety of spatiotemporal variables recorded during maximal velocity sprinting were largely unaffected by chronological age or stage of maturation (25). The data in the current study indicate that maturation does not affect the magnitude of asymmetry across the different constructs of neuromuscular control measured; thus, players who display heightened asymmetry scores should be targeted for injury risk reduction programs regardless of their stage of maturation. Also, SLCMJ asymmetry appears to emerge around periods associated with rapid growth, possibly due to the demands of accumulated soccer-specific training and competitions remaining unchanged thereafter unless a specific intervention is applied. Cumulatively, it could be suggested that limb asymmetry in functional performance tasks is established early in a child’s life; therefore, interventions to target this injury risk factor should commence in pre-PHV athletes and maintained throughout childhood and adolescence.

In the present study, although there was more variability in these measures, landing forces during the 75%Hop and SLCMJ reported significantly greater asymmetries than both the SLHD and the Y-Bal test indicating that asymmetries may be task dependent. Differences could be due to task complexity but these data also highlight that peak landing forces are more sensitive than measures of hop or reach distance in their ability to identify asymmetry. Previous literature has reported differing asymmetry values for a range of variables; distance

(3.9 – 6.0%), peak force (0.4 – 7.6%), and peak power (2.1 – 9.3%) for the same jumps across different directions (24). The authors also suggested that measures of jump height and distance may be less sensitive for determining limb asymmetry. Such contralateral imbalances are an important component of predicting subsequent injury risk (3), and are inherent to soccer where preferred limb dominance is evident. Thus, practitioners are advised to ensure tests used to measure asymmetry are reliable and display adequate sensitivity to be able to identify those players who may be at a greater risk of injury.

An asymmetry threshold of 15% has been identified previously in the available literature as a critical threshold for heightened injury risk prediction (7). Values equal to, or greater than this level were identified in circa- and post-PHV players during the SLCMJ and 75%Hop, which indicates this level of asymmetry may be considered normal for elite male youth soccer players. A recent study that included functional hop for distance tests with recreationally active students showed that all participants achieved a limb symmetry index of less than 10% (27). The authors suggested a minimum symmetry of 90% is a more appropriate target for assessment and rehabilitation protocols (27). In the present study, SLHD and Y-Bal anterior reach distances displayed asymmetry scores less than 10%, whereas, peak landing force asymmetries were approximately 15% when all the players were combined, ranging from 12.5–16.5% across the different maturation groups. Task complexity and sensitivity of the outcome measures used could be cited as plausible explanations for the reported differences in asymmetry again suggesting that asymmetry is task dependant. Also, higher kinetic asymmetries in youth athletes are to be expected, with horizontal (14.8–15.4%) and vertical force (18.1–20.8%) force discrepancies identified between limbs during a maximal running task (36). The authors stated that asymmetries between 15–20% appear typical in developmental athletes. Therefore, further investigations are warranted to determine if an asymmetry threshold can be identified that increases injury risk for the outcome variables used on each respective test included in this study.

When interpreting the results of the current study, practitioners should be cognizant of identified limitations. Firstly, only the anterior reach direction of the y-balance test was examined and differences may be shown in the other specified reach directions of this test. However, it should be considered that currently it is only the anterior reach direction whereby an asymmetry has been identified which is associated with injury (31). Secondly, stage of maturation was calculated via a somatic equation (26). In using this approach, the following limitations have been proposed: 1) age at PHV for both early and late maturing boys has reduced accuracy when compared to the criterion measure of skeletal imaging (21); 2) variables included in the equation (sitting height and leg length) are subject to ethnic variation and may be likely confounders in maturity estimates (19); and 3) the equation has a tendency to classify boys as average maturers, and this has been shown in youth soccer players (20). However, this approach displays practical merit for testing large numbers of athletes and can be performed in a non-invasive manner showing reasonable agreement with skeletal imaging (20), Also, to account for the reported error (approx. 6 months) in the equation (26), players were grouped into discrete bands based on their maturational offset (pre -PHV = < -1, circa-PHV = - 0.5 to 0.5, post-PHV = >1) where players with a maturational offset between -1 to -0.5 and 0.5 to 1 were subsequently removed from the data set to reduce the risk of incorrect group allocation.

## PRACTICAL APPLICATIONS

The current study provides cross sectional analysis for a range of field-based tests of neuromuscular control in a large sample of elite male youth soccer players. The findings may assist practitioners by providing a clearer understanding of expected trends in asymmetry across growth and maturation, from which players at a heightened injury risk may be identified. Whilst a variable pattern was observed in asymmetry scores in each group and test measured, in most cases, stage of maturation did not have a profound effect on asymmetry in the different constructs of neuromuscular control examined in this study. Limb asymmetry in functional performance seems to be established in early childhood and targeted interventions to reduce this injury risk factor should commence in pre-PHV athletes and be maintained throughout childhood and adolescence to ensure asymmetry does not continue to increase. Furthermore, SLCMJ landing force asymmetry appeared to emerge around periods associated with rapid growth, possibly due to the demands of accumulated soccer-specific training and competitions, remaining unchanged thereafter unless a specific intervention is applied. Finally, greater asymmetries were shown for landing force variables versus hop and reach distances, and these values were in accordance with those previously associated with heightened injury risk. Therefore, the SLCMJ and 75%Hop may be considered more sensitive for the identification of between-limb differences and should be considered as part of injury risk screening battery for elite male youth soccer players.

## CONCLUSION

For the range of field-based tests of neuromuscular control examined in this study, in most cases, stage of maturation did not have a profound effect on asymmetry in a large sample of elite male youth soccer players. Therefore, limb asymmetry in functional performance seems to be largely established in early childhood. This may warrant the inclusion of training interventions at each stage of a young player’s development to reduce the risk of lower extremity injury.

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