Consistency of Field-Based Measures of Neuromuscular Control Using Force-Plate Diagnostics in Elite Male Youth Soccer Players

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Abstract

Read, P, Oliver, JL, Croix, MD, Myer, GD, and Lloyd, RS. Consistency of field-based measures of neuromuscular control using force-plate diagnostics in elite male youth soccer players. *J Strength Cond Res* 30(12): 3304–3311, 2016—Deficits in neuromuscular control during movement patterns such as landing are suggested pathomechanics that underlie sport-related injury. A common mode of assessment is measurement of landing forces during jumping tasks; however, these measures have been used less frequently in male youth soccer players, and reliability data are sparse. The aim of this study was to examine the reliability of a field-based neuromuscular control screening battery using force-plate diagnostics in this cohort. Twenty-six pre–peak height velocity (PHV) and 25 post-PHV elite male youth soccer players completed a drop vertical jump (DVJ), single-leg 75% horizontal hop and stick (75%HOP), and single-leg countermovement jump (SLCMJ). Measures of peak landing vertical ground reaction force (pVGRF), time to stabilization, time to pVGRF, and pVGRF asymmetry were recorded. A test-retest design was used, and reliability statistics included change in mean, intraclass correlation coefficient, and coefficient of variation (CV). No significant differences in mean score were reported for any of the assessed variables between test sessions. In both groups, pVGRF and asymmetry during the 75%HOP and SLCMJ demonstrated largely acceptable reliability (CV $\leq$ 10%). Greater variability was evident in DVJ pVGRF and all other assessed variables, across the 3 protocols (CV range = 13.8–49.7%). Intraclass correlation coefficient values ranged from small to large and were generally higher in the post-PHV players. The results of this study suggest that pVGRF and asymmetry can be reliably assessed using a 75%HOP and SLCMJ in this cohort. These measures could be used to support a screening battery for elite male youth soccer players and for test-retest comparison.

Key Words landing force, injury, screening

Introduction

The demands of soccer impose high physiological demand and an inherent risk of injury because of frequent repetitions of movements that involve significant musculoskeletal forces and joint loads (10). Existing injury incidence data in elite male youth soccer indicate that injuries occur mainly in the lower extremities (71–80%) and are largely noncontact in nature, with a high proportion of ligament sprains occurring at the ankle and knee (26,39). Deficits in neuromuscular control and aberrant movement patterns such as cutting, turning, and landing occurring frequently during game activities (Price et al., 2004) are suggested pathomechanics (1,47) that underlie sport-related injury (16).

Assessments of neuromuscular control have been analyzed previously in adults and female athletes including a predominance of jump-landing tasks using force-plate diagnostics (18,33,34,36,45). To accurately assess neuromuscular control in male youth soccer players, there is a need for reliable and valid testing protocols (41). Currently, in youth males, the most common mode of assessment is measurement of landing forces during a drop vertical jump (DVJ) (24,25,40). This protocol has shown strong reliability in male and female high school athletes (intraclass correlation

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30(12)/3304–3311

Journal of Strength and Conditioning Research

coefficient (ICC) range = 0.89–0.98) (40). However, single-leg horizontal and vertical jumps should also be considered because of the type and frequency of related movements during game play. Strong test-retest reliability has also been reported for measures of concentric peak force and power during a single-leg vertical jump (ICC range = 0.88–0.97) in healthy teenagers (5). Available data in male youth soccer players and assessments of landing force are sparse.

In addition to the quantification of landing forces, measurement of dynamic stability may also provide useful information. "Time-to-stabilization" (TTS) calculations report deficits in postural control and reflex stabilization in subjects with functional ankle instability (44) and anterior cruciate ligament (ACL) deficiency (50). Time to stabilization is the speed in which individuals stabilize within a predetermined ground reaction force range on landing (11,45). Although TTS has been quantified from a variety of jump-landing tasks (11), the most common method is a single-leg horizontal hop onto a force plate (3,33,43). Limited data are available in youth athletes; however, ground reaction force measures in adults during single-leg horizontal hops seem to be more reliable than center of pressure values (ICC range = 0.87–0.97 vs. 0.53–0.75) (6,45). Strong within-session reliability has also been reported for both dominant ($r = 0.82$) and nondominant ($r = 0.87$) limbs (33).

Despite this growing body of evidence, kinetic landing assessments have been used less often in pediatric male athletes. Poor attenuation of ground reaction forces during landing tasks may increase the risk of lower extremity injury (27). Practitioners using such assessments for preparticipation screening require a greater understanding of their accuracy in this cohort. Previous research investigating the effects of age, growth, and maturation on jumping tasks has shown a trend of increased performances with age (12,37). However, variation across growth and maturation may also be evident (28,37), and movement variability during jumping tasks is more evident in younger athletes (16). To the author's knowledge, no data currently exist to confirm the reliability of jump-landing kinetic assessments for male youth soccer players. This paucity of literature does not permit accurate interpretation of results after intervention or deficit assessments relative to the typical error. Research is also required to examine the effects of maturation on these measures because of the likelihood of greater movement variability in younger players. Therefore, the aim of this study was to determine the within-subject reliability of a field-based neuromuscular control screening battery using force-plate diagnostics in elite male youth soccer players at different stages of growth and maturation.

Methods

Experimental Approach to the Problem

This study used a repeated-measures design to determine the intersession reliability of a range of field-based neuromuscular control assessments. Participants were required to attend the club training ground on 3 occasions separated by a period of 7 days. The first session was used to familiarize subjects with the test equipment and assessment protocols. In the second and third sessions, data were collected to determine test-retest within-subject variation for the reliability study. Three different force-plate diagnostic assessment protocols were used, including a DVJ, a single-leg 75% horizontal hop and stick (75%HOP), and a single-leg countermovement jump (SLCMJ). A 10-minute standardized dynamic warm-up was completed before each session. The order of testing was randomized using a counterbalanced design to reduce the potential for an order effect. This randomization process was also applied for all unilateral jumps to determine the order of which leg was tested first. For the purposes of data collection, 3 trials were analyzed and 1 minute of recovery was allowed between trials based on previous recommendations (11). Testing was completed at the same time on each day, and participants were asked to wear the same training kit and footwear and to refrain from strenuous exercise at least 48 hours before testing. Subjects were also asked to eat according to their normal diet and avoid eating and drinking substances other than water 1 hour before each test session.

Subjects

Participants were grouped as either pre–peak height velocity (PHV) or post-PHV, which has been defined as the maximal rate of growth during the adolescent growth spurt (29). This group separation was applied to examine whether a players' stage of maturation affects the reliability of the test measures included in this study because of previous research indicating that greater movement variability is present in younger children (15). Twenty-five pre-PHV (age, 11.93 ± 0.43 years; height, 151.40 ± 4.84 cm; body mass, 41.05 ± 5.62 kg; maturity offset, −2.34 ± 0.41 years) and 25 post-PHV (age, 17.26 ± 0.69; height, 178.22 ± 5.47; body mass, 72.27 ± 6.93 kg; maturity offset, 2.91 ± 0.81 years) youth soccer players from the academy of a professional English Championship soccer club volunteered to take part in the study. Subjects were familiar with regular performance evaluations, and none of the players reported injuries at the time of testing. Parental consent, participant assent, and physical activity readiness questionnaires were collected before the commencement of testing. Ethical approval was granted by the institutional ethics committee in accordance with the Declaration of Helsinki.

Procedures

Anthropometry. Body mass (kg) was measured on a calibrated physician scale (Seca 786 Culta; Milan, Italy). Standing and sitting heights (cm) were recorded on a measurement platform (Seca 274). Seated height was measured with subjects sat on a box and their back against an upright stadiometer. The height of the box was then subtracted to provide the recorded value. Using anthropometric measures, age, body mass, standing height and sitting height,

TABLE 1. Pre-PHV group mean results and reliability statistics for all test measures.*

Test variable	Mean test 1	Mean test 2	Change in mean	ICC	CV% (95% CI)
75%HOP pVGRF (N)	1642 ± 297	1617 ± 253	−24.9 ± 254.65	0.62	10.2 (8.5–13.2)
75%HOP TTS (s)	1.740 ± 0.709	1.963 ± 0.642	0.223 ± 0.789	0.25	43.6 (35.6–56.6)
75%HOP time to pVGRF (s)	0.022 ± 0.005	0.023 ± 0.006	0.001 ± 0.006	0.57	20 (16.6–25.3)
DVJ pVGRF (N)	890 ± 217	844 ± 235	−45.59 ± 227.69	0.50	20.5 (17.1–25.8)
DVJ time to pVGRF (s)	0.044 ± 0.022	0.045 ± 0.024	0.001 ± 0.02	0.54	49.7 (40.6–64.4)
SLCMJ PVGRF (N)	1221 ± 170	1251 ± 245	30.92 ± 194.65	0.59	10.1 (9.1–14.1)
SLCMJ TTS (s)	1.226 ± 0.648	1.438 ± 0.508†	0.212 ± 0.614	0.37	39.2 (31.9–51.9)
SLCMJ time to pVGRF (s)	0.067 ± 0.043	0.054 ± 0.023	−0.012 ± 0.039	0.64	33.3 (28.6–48.9)

*PHV = peak height velocity; ICC = intraclass correlation coefficient; CV = coefficient of variation; 75%HOP = 75% horizontal hop and stick; TTS = time to stabilization; DVJ = drop vertical jump; SLCMJ = single-leg countermovement jump; pVGRF = peak vertical ground reaction force.

†Denotes significantly different ($P < 0.05$) to testing session 1.

and biological maturation were measured using the regression equation of Mirwald et al. (32). The equation has previously been validated for boys with a standard error of estimate of 0.57 years (Mirwald et al., 32).

Drop Vertical Jump. Participants were positioned on top of a box at a height of 30 cm. Instructions were to drop directly down with no vertical elevation onto 2 separate force plates (Pasco, Roseville, CA, USA) positioned 8 cm apart. On ground contact, players immediately performed a maximum vertical jump aiming to jump as high as possible and then land on the plates and stick the landing as per previous guidelines (34). Hands were freely available to replicate a natural jump-landing position (34,40). Only the data from the first landing were used for subsequent analysis.

Single-leg 75% Horizontal Hop and Stick. A tape measure was marked out to a 3-meter distance on a horizontal line with the 0-cm mark positioned in line with the center of a force plate (Pasco). 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. Instructions were to hop forward onto the force plate, landing on the same leg with the hands remaining on their hips throughout. Players were required to stick the landing and hold for a period of 5 seconds, remaining as still as possible without any other body part touching the floor (11).

Single-Leg Countermovement Jump. Participants stood on a force plate (Pasco) 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. Instructions were to jump as high as possible using a countermovement by dropping to a self-selected depth and then immediately triple extending at the ankle, knee, and hip in an explosive concentric action. On ground contact, subjects were required to stick the landing and hold for a period of 5 seconds remaining as still as possible. Bending of the knees

TABLE 2. Post-PHV group mean results and reliability statistics for all test measures.*

Test variable	Mean test 1	Mean test 2	Change in mean	ICC	CV% (95% CI)
75%HOP pVGRF (N)	2825 ± 551	2755 ± 539	−70.92 ± 230.73	0.91	6.1 (5.1–7.8)
75%HOP TTS (s)	1.160 ± 0.384	1.326 ± 0.434	0.165 ± 0.544	0.09	35.2 (28.4–46.5)
75%HOP time to pVGRF (s)	0.027 ± 0.011	0.029 ± 0.009	0.001 ± 0.010	0.62	22.5 (18.3–29.2)
DVJ pVGRF (N)	1781 ± 450.96	1751 ± 462	−29.66 ± 313.39	0.76	13.8 (11.6–16.9)
DVJ time to pVGRF (s)	0.056 ± 0.023	0.052 ± 0.018	−0.004 ± 0.016	0.77	23 (19.4–28.2)
SLCMJ pVGRF (N)	2369 ± 396	2372 ± 391	−0.03 ± 302.24	0.75	9.5 (8.1–11.5)
SLCMJ TTS (s)	1.033 ± 0.435	1.112 ± 0.462	0.079 ± 0.631	0.08	48.4 (40.3–60.3)
SLCMJ time to pVGRF (s)	0.060 ± 0.019	0.057 ± 0.018	−0.002 ± 0.013	0.72	21.8 (18.4–26.8)

*ICC = intraclass correlation coefficient; CV = coefficient of variation; 75%HOP = 75% horizontal hop and stick; pVGRF = peak vertical ground reaction force; TTS = time to stabilization; DVJ = drop vertical jump; SLCMJ = single-leg countermovement jump.

TABLE 3. Pre-PHV and post-PHV group asymmetry mean values and reliability statistics expressed as % of performance achieved.*

Group	Test variable	Mean test 1	Mean test 2	Change in mean	ICC	CV% (95% CI)
Pre-PHV	SLCMJ pVGRF	88.08 ± 7.18	86.34 ± 7.70	−1.74 ± 11.63	−0.22	10.9 (8.7–14.2)
	75%HOP pVGRF	86.63 ± 10.39	90.68 ± 10.21	4.05 ± 13.21	0.17	11.8 (9.2–14.5)
Post-PHV	SLCMJ pVGRF	89.84 ± 7.71	88.53 ± 8.78	−1.38 ± 9.78	0.25	8.6 (6.8–11.6)
	75%HOP pVGRF	84.15 ± 9.51	77.09 ± 10.60	−1.80 ± 14.00	0.01	13.2 (10.1–14.5)

*PHV = peak height velocity; ICC = intraclass correlation coefficient; CV = coefficient of variation; SLCMJ = single-leg countermovement jump; pVGRF = peak vertical ground reaction force; 75%HOP = 75% horizontal hop and stick.

while airborne was not permitted, and hands remained in contact with hips throughout the test (11).

Force-Plate Variables. Kinetic landing data captured from the force platform included peak vertical ground reaction force (pVGRF) recorded in the first 100 milliseconds following ground contact, time to pVGRF, and pVGRF asymmetry during for all tests. A cutoff point of 100 milliseconds was used to determine pVGRF because of the reported timing of noncontact injuries, which occur within a similar time frame following initial ground contact (22). Forces experienced after this point are unlikely to contribute to acute injury risk and were therefore not included in the analysis. In the SLCMJ and 75% HOP protocols, TTS was also quantified from the vertical force vector. Vertical TTS was calculated as the time taken from ground contact to the first point when the vertical force component reached and stayed within 5% of body weight for a period of 1 second (11,14). The point of ground contact was then subtracted from this value in accordance with previous guidelines (11). For the DVJ and 75%HOP protocols, initial contact was defined as the point when VGRF first exceeded 10 N. In the SLCMJ, the same criteria were used to determine initial contact after the preceding propulsive and flight phases. All data were recorded at a sampling rate of 1,000 Hz and filtered through a fourth-order Butterworth filter. A cutoff frequency of 18, 21, and 26 Hz was used for the SLCMJ, DVJ, and 75%HOP, respectively.

Asymmetry Calculation. To quantify asymmetry, the percentage difference between the highest- and lowest-performing limbs was used (equation 1). The value obtained is expressed as the absolute percentage of performance achieved using the higher performing limb as the reference (equation 2).

$$Asymmetry\% = ABS([lowest - performinglimb - highest - performinglimb]/highestperforminglimb * 100)[equation 1]$$

$$\%ofperformanceachieved = 100 - \%asymmetry \quad \text{[equation 2]}$$

Statistical Analyses

The data were checked for normality, and descriptive statistics for each test were calculated across the 2 testing sessions. To determine systematic bias between trials, a series of paired samples *t*-tests were used for all measures with a p value ≤0.05 indicative of a significant difference between the 2 trials. Within-subject variation was determined using mean coefficients of variation (CV, %). Further reliability statistics included change in mean and ICC. The 95% CIs were used, and all reliability data were computed through Microsoft Excel 2010 using a freely available spread sheet (20). Paired samples *t*-tests were processed using SPSS (V.21; Chicago, IL, USA).

RESULTS

Descriptive statistics and all reliability measures calculated for each test are displayed in Tables 1 and 2 for pre-PHV and post-PHV groups, respectively. No significant differences were reported for the test variables when the mean scores of the 2 test trials were analyzed using a series of paired samples *t*-tests ($P > 0.05$).

After the analysis of all variables, measures highlighted with acceptable CV values (≤10%) (8) were then further investigated to determine the reliability of lower-limb asymmetry (Table 3). In both groups, all measures reported acceptable CV values (≤10%) with the exception of 75% HOP pVGRF in pre-PHV (CV = 11.8%) and post-PHV (13.2% post-PHV) cohorts.

DISCUSSION

This study assessed the reliability of a field-based neuromuscular control screening battery using force-plate diagnostics in elite male youth soccer players who were either pre-PHV or post-PHV. In both groups, pVGRF in the 75% HOP and SLCMJ demonstrated acceptable reliability (CV ≤ 10%). However, greater variability was evident in the DVJ test as indicated by higher CV values. Irrespective of test protocol, variability was more pronounced in the pre-PHV group than in the post-PHV cohort. Asymmetry values for the measures identified (CV ≤ 10%) were also analyzed and reported largely acceptable reliability (CV $\leq$ 10%). The within-subject variance of all other assessed variables, across all 3 protocols, exceeded the threshold for acceptable reliability (CV >10%) in both groups.

In both groups, pVGRF was the most reliable kinetic measurement reflected by the lowest CV%. These findings are commensurate with Cordova et al. (7) who reported excellent reliability values (ICC = 0.94; *SEM* = 0.003% body weight) during a SLCMJ onto a force plate. Other studies have also reported high within-session reliability in adults for pVGRF during a single-leg hop and stick (ICC = 0.82–0.87) (3) and intersession reliability of a single-leg horizontal drop jump (CV = 5.71) (46). Conversely, vertical impulse (a measure comprised both force and time) was shown to display greater test-retest variation (8.28%) (46). In this study, although not a direct measure of impulse, time to pVGRF also showed higher CV values, indicating greater within-subject variation for these metrics in male youth soccer players.

In this study, pVGRF in both the SLCMJ and 75%HOP tests demonstrated lower within-subject variation than the DVJ. In school children, strong reliability for measures of pVGRF force at landing (ICC = 0.89) and take-off (ICC = 0.98) has been reported (40). In this study, lower reliability was displayed in the pre-PHV group, which may be indicative of reduced skill levels and immature prefrontal motor cortex activation for cognitive control resulting in greater variation in the execution of motor control tasks (4). Additionally, increased jumping skill has been associated with an enhanced ability to absorb landing forces (38). As males progress through adolescence, they seem to display an increased ability to attenuate landing forces, possibly because of the presence of the neuromuscular spurt (40). Conversely, younger children seem to land with greater knee and hip extension, which combined with heightened muscle co-contraction on impact will lead to higher pVGRF (9,48). Supporting this notion, lower pVGRF related to body mass during the breaking phase of a DVJ has been reported in adults versus boys (25). This may be due to more efficient stretch reflex utilization and greater levels of muscle activation before landing and during the breaking phase of the jump (24). Data also show that as children mature, they become more reliant on supraspinal feed forward input and short latency stretch reflexes (28). Cumulatively, the combination of movement inefficiency and higher landing forces may provide a rationale for the greater variability in pVGRF within the pre-PHV soccer players in this study.

During the 75%HOP and SLCMJ, high CVs were reported for TTS in both groups. These values indicate large within-subject variance, and thus, caution should be applied when using this measurement in male youth soccer players. Obtaining high reliability for repeated trials during tasks requiring dynamic postural stability is difficult (11). Single-leg jumping and landing activities that rely on reflexive muscle responses, proprioceptive, and kinesthetic feedback will typically use a range of movement strategies and therefore increase variability (11,51). No data are available to compare the results of this study to those of similar populations; however, reliability statistics in adults suggest strong test-retest comparisons in single-leg hop tasks (ICC = 0.87–0.97) (6,45). A plausible explanation for the high CV% in this study in comparison to adult data could be age-related factors, such as growth, maturation, and skill. Previous literature has suggested that maturation of the neurological, visual, vestibular, and proprioceptive systems may lead to enhanced performance during single-leg balancing tasks (31). Also, younger subjects demonstrate greater postural sway during single-leg balance maneuvres, which may compromise stability (31). Thus, measures of reflex stabilization may be subject to greater variability in male youth soccer players.

Task demands are another factor that may explain the differences in reported reliability from this study and those of previous investigations. In this study, 2 single-leg landing assessments were used to provide data for both horizontal and vertical jumping tasks. Conversely, the aforementioned studies used horizontal tasks only and a standardized distance from the force plate of either leg length (6) or an arbitrary distance of 70 cm (45). The utilization of anthropometric measures or standardized distances may subsequently overestimate or underestimate an individual's performance. For example, an athlete with short legs may demonstrate a reduced TTS because of the relatively shorter hopping distance required. However, during a maximal single-leg hopping task, the same athlete may be capable of much greater jump distances than that of their leg length. These abilities are likely to be replicated under conditions of competitive soccer match play; thus, an individual's inherent risk of injury is likely a product of how far they can jump and how well they can attenuate the resultant forces on landing.

The methods of calculating TTS could also account for inconsistencies with the available literature. In this study, TTS was measured based on previous recommendations (11,14). Conversely, Colby et al. (6) and Ross et al. (45) used both anterior-posterior and medio-lateral force vectors and a static hold of 20 seconds, scanning the components from the last 2 windows of the last 10 seconds (i.e., at 10–15 and 15–20 seconds), and the smallest ground reaction force range was accepted as the optimal range variation (43). This method, although displaying sound reliability, raises concerns of ecological validity when screening male youth soccer players. For example, if young soccer players are required to spend up to 20 seconds standing still on a force plate, they are likely to demonstrate greater postural sway, thus affecting their ground reaction force range. The shorter recording period of 5 seconds used in this study as opposed to 20 seconds (43) also has implications for testing a large number of athletes, particularly youth athletes who may demonstrate lower levels of concentration.

Despite their frequency of use, limited data are available to report the reliability of limb asymmetry statistics during unilateral jumping tasks. One available study in ACL patients determined the "limb symmetry index" for a range of hopping-based tests using ICC and standard error of measurement (ICC = 0.82–0.93; *SEM* = 3.04–5.09) (42). The authors assessed differences between the injured and noninjured leg, whereas previous research has analyzed the difference between the dominant and nondominant legs although no reliability data were reported (2,30). In high school male and female soccer players, strong reliability of force production and attenuation measures has been shown (ICC >0.97); however, specific outcome measures were not reported (17). This study showed acceptable reliability values for most of the measures included and calculated asymmetry using the highest versus lowest performing leg. This accounts for neuromuscular inhibition, which can occur after an injury to a specific limb (13,35), and the requirement to jump and land repeatedly on both legs during a soccer competition. No data are available in youth male soccer players to compare the findings of this study; further investigations are needed to examine the reliability of asymmetry values using the aforementioned methods during a variety of jump-landing tasks.

A number of the variables measured in this study demonstrated low ICC statistics. It has been suggested previously that an ICC value >0.75 is acceptable and values below this provide inadequate reliability (23). However, retest correlations measure how closely the values of 2 trials track each other specific to each individual and the reproducibility of the rank order of subjects during the retest (19). Low values indicate that subjects did not retain their order during the retest. Furthermore, a homogenous sample will also likely demonstrate a low value (19). The subjects in this study are reflective of a homogenous sample, and this provides a plausible explanation for lower ICC values than those in other studies. Specifically, a number of the test variables in this study reported lower ICC values in the pre-PHV players. Because of their status as prepubescent athletes, performance levels may be more clustered as they have not yet experienced their peak growth spurt; the possibility of players changing their rank order is high. The post-PHV players were likely at different stages of physical development with some players further past the period of PHV than others; changing of rank order may be less frequent, as evidenced by predominantly higher ICC values.

Practical Applications

Reliability data are now available for a field-based battery of neuromuscular control assessments using force-plate diagnostics to screen male youth soccer players for potential injury risk. Practitioners can benefit from these data by selecting from the wide range of assessments available in the literature by considering their reproducibility as a basis for test-retest comparison. Furthermore, using the reliability statistics derived from this study, the smallest worthwhile change can be determined by calculating the between-subject *SD* for each test and multiplying this number by 0.2 or by using 0.5% of the CV (21). If this value is outside of the error range (CV%) reported by the test, then it can be deemed reliable for use (49). Also, coaches applying interventions to reduce injury risk can accurately establish if the measured effects are reflective of a true change in performance.

Acceptable reliability values were reported for a variety of measures. In both the pre-PHV and post-PHV groups, pVGRF in both the 75%HOP and SLCMJ demonstrated acceptable reliability (CV ≤ 10%). These variables should be considered reliable for assessing elite male youth soccer players. However, greater within-subject variation was evident during the DVJ for all recorded variables; thus, caution should be applied when using these protocols in this cohort. Overall, the results of this study suggest that pVGRF and asymmetry can be reliably assessed using a 75%HOP and SLCMJ in male youth soccer players. These measures could realistically be used to support a screening battery for elite male youth soccer players and for test-retest comparison. Future research should examine whether these measures can discriminate between injured and noninjured soccer players to determine their sensitivity in prospectively predicting injury risk.

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