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Postural stability and isokinetic strength do not predict knee valgus angle during single-leg drop-landing or single-leg squat in elite male rugby union players

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Abstract.
BACKGROUND: Knee injuries have been identified as the most common injury in rugby. Knee valgus has been identified as a risk factor for ligament injuries in athletes and predictors of knee valgus may assist in the design of knee injury prevention programs.
PURPOSE: The purposes of this study were to use postural stability (PS) and strength measures to predict knee valgus angle during dynamic tasks, identify relationships between PS and strength, and compare measures between positions.
METHODS: Participants presenting positive during a gluteal dysfunction screening exam were enrolled. Participants performed PS, isokinetic strength, and biomechanical assessments. Stepwise multiple linear regression analyses were performed to identify predictors of knee valgus. Correlation coefficients identified relationships between PS and strength, and independent t-tests compared forwards and backs.
RESULTS: Backs had significantly ($p < 0.05$) better PS and greater strength as compared to forwards. Hip abduction strength was correlated ($r = -0.52$–-0.71, $p < 0.05$) with all eyes open static PS measures. Regression analysis failed to identify predictors of knee valgus angle.
CONCLUSION: Although PS and strength were not multivariate predictors of knee valgus in male rugby players, bivariate correlations suggest that hip abduction strength training may be beneficial for enhancing PS.

Keywords: Biomechanics, knee injuries, postural balance, muscle strength dynamometer, rugby union

1. Introduction

Rugby union is a popular sport played by millions of people in over 100 countries [1]. Injury rates range from 3.6–218 injuries/1,000 exposures [1–7] and are the highest for professional players with 68–218 injuries/1,000 exposures [2–4,6,7]. The knee is frequently injured [6–8] with most injuries being contact injuries during match play [4,9,10]. However, noncontact traumatic knee ligament (e.g. anterior cruciate ligament (ACL)) and meniscal injuries also account for high percentages of training and match injuries [4,9,10]. Overuse knee injuries (e.g. patellofemoral arthropathy) also occur frequently [10]. Both noncontact traumatic and overuse knee injuries are severe, resulting in high numbers of days missed per injury [4,9,10]. As such, knee injuries are a major burden for rugby players and effective knee injury prevention strategies are needed.

Rugby union is an anaerobic game demanding

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multi-directional movement patterns including running, jumping, and pushing (e.g. scrummaging) [11, 12]. Effective execution of these movement patterns depend on optimal performance of the lower limb extensors [13–15]. The lower limb extensors include the gluteus maximus and medius [16,17] which are essential for preventing lower limb collapse in single-leg stance [16–18]. Moreover, gluteus maximus muscle performance predicts sprint speed [13].

Proper frontal plane alignment of the pelvis is essential for preventing excessive knee valgus during single-leg stance [19]. Proper alignment is important because increased knee valgus is linked to high tissue loads [20–22] and is associated with knee injury [23–25]. The gluteals can limit excessive hip adduction and internal rotation, which contribute to increased knee valgus [21,26–29]. Therefore, enhanced gluteus maximus and medius muscle performance is important for improved knee valgus control [25]. Consequently, those with poor gluteal function may be at greater risk of knee injury [25–29]. Common clinical practice includes evaluating gluteal function using movement control and strength tests [27,29–34]. The premise is that gluteal dysfunction is empirically associated with knee injury [25–27,29,33,34] and gluteal tests are employed by clinicians as 'field-based' screening tools for identifying those at risk of knee injury [27,29,30,33, 34]. Although screening of gluteal function is common and statistical evidence links impaired gluteal function to knee injury [26,28], the true diagnostic relevance of many gluteal screening tests has yet to be proven.

Identifying physical variables that predict knee valgus during sport will assist in the design of knee injury prevention programs. Postural stability training can decrease knee valgus during jump-landing tasks [35] and gluteal weakness is related to excessive knee valgus and poor frontal plane alignment during double-leg and single-leg functional tasks [36,37]. Previous studies have identified hip kinematics [38] and knee/hip isokinetic strength [39] as predictors of knee valgus during dynamic tasks. Sigward et al. [38] studied female soccer players, whereas other studies [39,40] pooled males and females into one group. Results of these studies cannot be generalized to male-only populations, specifically rugby players. For this study, we chose to select our sample using clinical gluteal screening tests because we wanted to observe how those with clinical gluteal dysfunction performed in laboratory tests. The first purpose of this study was to determine whether postural stability and strength measures could predict knee valgus angle during single-leg drop-landing (SLDL) and single-leg squat (SLS) tasks in male rugby players. We hypothesized a multivariate prediction model could be built using frontal plane postural stability and knee and hip isokinetic strength measures. The second purpose was to identify the relationship between postural stability and strength measures. We hypothesized postural stability would be significantly related to hip isokinetic strength. To be consistent with rugby literature, the third purpose was to compare all measures between forwards and backs. We hypothesized that significant differences would exist between positions.

2. Methods

2.1. Participants

Professional or semi-professional males ($n = 24$; age: 24.9 ± 5.6 years; height: 182.6 ± 5.9 cm; mass: 94.0 ± 13.5 kg) with gluteal dysfunction (see Gluteal Dysfunction Screening) were recruited from local rugby clubs. Participants were excluded if they had lower extremity musculoskeletal pathology within the last three months, major ligamentous injury/surgery to the knee/hip, history of concussion within the previous year, or a history of neurological, postural, metabolic, cardiovascular, or pulmonary disorder. Participants provided written informed consent prior to participation.

2.2. Instrumentation

Kinematic data were collected at 100 Hz using an electromagnetic tracking device (Innovative Sports Training, Chicago, IL). Ground reaction forces (GRF) were collected at 1000Hz with a force platform (Kistler Instrument Corp, Amherst, NY). Analog signals from the force platform were converted to digital signals via an A/D Board (Innovative Sports Training, Chicago, IL) and synchronized with the kinematic data using Motion Monitor software V8.16 (Innovative Sports Training, Chicago, IL). Knee and hip isokinetic strength were measured using an isokinetic dynamometer (Biodex Medical Systems, Inc., Shirley, NY).

2.3. Protocols

2.3.1. Gluteal dysfunction screening

A gluteal dysfunction screening exam was administered using common gluteal tests [27,29–32] by the same Physical Therapist (PL) with more than 15 years of clinical experience. Electromyography has confirmed these tests activate gluteal muscles [41–43].

The tests were [27,29–32] bilateral bridge; unilateral bridge; gluteal amnesia; and side-lying hip abduction. The bilateral bridge Fig. 1(b) was performed in crook-lying Fig. 1(a). Participants were instructed to raise the pelvis 15 times until the spine was in neutral and the knee, hip, and shoulder lay in a straight line. The unilateral bridge Fig. 1(c) was performed the same as the bilateral bridge, but with only one weightbearing (WB) leg. The knee of the non-weightbearing (NWB) leg was fully extended and held level with the thigh of the WB leg. Participants performed 10 repetitions. The gluteal amnesia test Fig. 1(d) was performed the same as the unilateral bridge test, but participants held the NWB leg against the chest. Participants performed 10 repetitions. These tests sequentially increased demand on the gluteals. The side-lying hip abduction test Fig. 1(e) was performed with the bottom leg flexed at the hip and knee and the pelvis rotated slightly forward. Participants performed 10 lateral leg raises with the top leg, keeping the leg in the frontal plane.

For the bilateral and unilateral bridge and gluteal amnesia tests, positive gluteal dysfunction was operationally defined as the inability to maintain proper transverse plane pelvic alignment, and/or inability to maintain proper knee-hip-shoulder alignment in the WB leg(s), for all repetitions [27,29–32]. For the side-lying hip abduction test, positive gluteal dysfunction was operationally defined as the inability to keep the top leg in the frontal plane for all repetitions (Fig. 1f-g) [27,29, 32]. For all tests, positive gluteal dysfunction was also operationally defined as pain and/or cramping in the hamstring or low back muscles [30,31]. Participants were classified with gluteal dysfunction if one or more tests were positive. For unilateral gluteal dysfunction, the dysfunction leg was used as the test leg; for bilateral gluteal dysfunction, the leg with greatest dysfunction was used as the test leg.

2.3.2. *Postural stability testing*

Static postural stability was assessed on the test leg using a single-leg balance task (ICC = 0.71–0.94; SEM = 0.19–3.40 N) [44,45]. Participants stood barefoot on the force platform, hands on hips, lifted the non-test leg to the level of the test ankle, and focused on a target at eye level. Participants balanced for 10 seconds and were instructed to tap down on the force platform when needed to maintain balance. Trials were excluded if the participants removed their hands from their hips, touched their legs together, or tapped down off the force platform. Three successful trials were collected after participants were comfortable with the procedures. The task was then repeated with eyes closed. Standard deviations of GRFs in the medial/lateral, anterior/posterior, and vertical directions were calculated and averaged over the three trials.

Dynamic postural stability was assessed using a previously published protocol (ICC = 0.86; SEM = 0.01 N) [45,46]. Wearing athletic shoes, participants stood at a distance of 40% of their height from the force platform, jumped forward with both feet over a 30 cm hurdle, and landed on the force platform with their test leg (single-leg). Participants maintained single-leg balance for 5 seconds while focusing forward with their hands on their hips. Trials were excluded if participants removed their hands from their hips, touched their legs together, or touch down with the non-test leg. Three successful trials were collected after participants were comfortable with the procedures. Dynamic postural stability measures [46] of ground reaction force components were calculated from initial contact, defined a 5% of the body weight (BW), to 3 seconds after initial contact. Measures were averaged over the three trials.

2.3.3. *Isokinetic strength testing*

Isokinetic strength of the knee and hip were measured using an isokinetic dynamometer. Tests included knee flexion/extension (ICC = 0.88–0.98; SEM = 9.3–12.7 Nm) [47,48], hip flexion/extension (ICC = 0.75–0.95; SEM = 3.7–9.5 Nm) [49,50], and hip adduction/abduction (ICC = 0.68–0.95; SEM = 4.9–6.3 Nm) [49,50]. Participants were positioned and stabilized per the manufacturer's guidelines and torque values were automatically adjusted for gravity by the software. Participants performed five knee flexion/extension (seated), five hip flexion/extension (supine) and five hip adduction/abduction (side-lying) concentric-concentric repetitions at 60°/s. Three practice trials at 50% and three practice trials at 100% effort preceded testing. A 60 second rest period was provided between warm-ups and testing. Average peak torque normalized to BW was recorded for each test.

2.3.4. *Biomechanical testing*

Joint kinematics of the test leg were collected using an electromagnetic tracking device (ICC = 0.84–0.98) [36]. Participants wore spandex shorts and athletic shoes for testing. Three electromagnetic receivers were secured to the proximal tibia, lateral aspect of the thigh, and sacrum with hypoallergenic tape and elastic

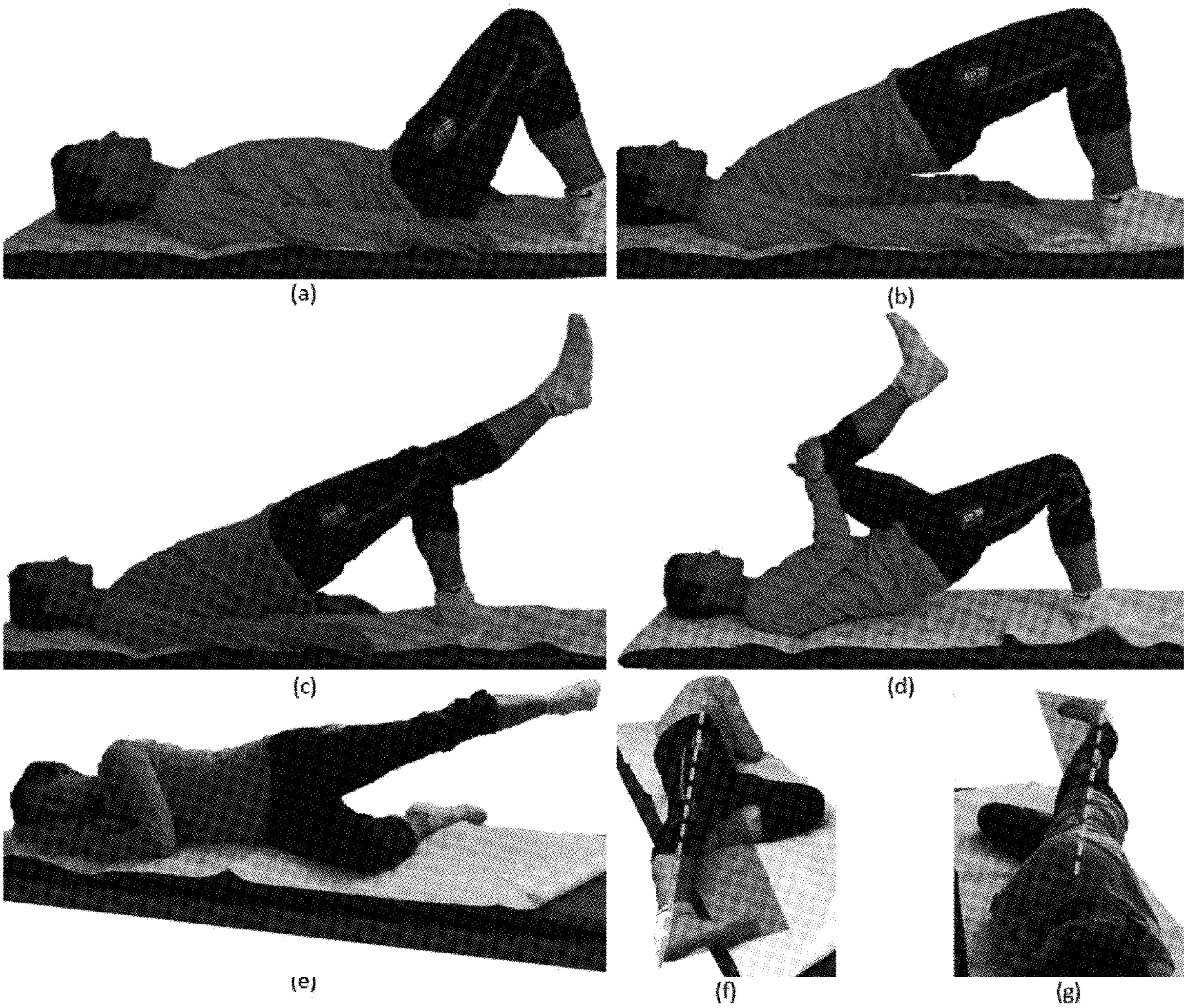

Fig. 1. Gluteal dysfunction screening: (a) crook-lying position; (b) bilateral bridge; (c) unilateral bridge (performed bilaterally); (d) gluteal amnesia test (performed bilaterally); (e) Side-lying hip abduction (performed bilaterally); (f)–(g) Proper (dashed line) frontal plane alignment during the side-lying hip abduction test.

wrap to reduce receiver-skin motion artifact. A fourth receiver attached to a stylus was used to digitize bony landmarks to define each segment, allowing calculation of three-dimensional angles of the pelvis, hip, and knee.

Participants performed three trials of a SLDL task with their test leg from a height of 34 cm Fig. 2(a). Participants dropped from the platform and landed on the force platform. Trials were discarded if participants touched down with their non-test leg during landing. Participants then performed a SLS from a 15 cm platform with their hands on their hips and looking forward Fig. 2(b). Participants balanced on their test leg and touched the heel of their non-test leg to the ground and returned to the starting position. Five repetitions were performed and the middle three used for analysis. Trials were discarded if participants removed their hands from their hips, looked down, or did not contact the ground. Tasks were verbally described and visually demonstrated without instructions on technique. Trials were collected after participants practiced and were comfortable with the procedures. Measures were averaged over three trials/repetitions.

2.4. Data reduction

Position and orientation data from the electromagnetic receivers were transformed into anatomical coordinate systems of each segment. The anatomical coor-

Table 1
Participant demographics (mean ± standard deviation)

	Total (n = 24)	Forward (n = 17)	Back (n = 7)	p-value
Age*	24.9 ± 5.6	25.7 ± 6.2	23.1 ± 3.6	0.544
Height (cm)†	182.6 ± 5.9	184.4 ± 5.7	178.1 ± 3.4	0.013
Mass (kg)†	94.0 ± 13.5	98.0 ± 13.5	84.4 ± 7.9	0.022

†$p < 0.05$.
*Mann-Whitney U test used.

Table 2
Static and dynamic postural stability (mean ± standard deviation). Lower measures indicate better postural stability

Task		Total (n = 24)	Forwards (n = 17)	Backs (n = 7)	p-value
Static eyes open	Anterior/Posterior†	2.59 ± 0.62	2.79 ± 0.54	2.11 ± 0.58	0.011
	Medial/Lateral	3.09 ± 1.05	3.33 ± 1.03	2.51 ± 0.89	0.079
	Vertical	4.00 ± 1.34	4.30 ± 1.36	3.26 ± 1.02	0.083
Static eyes closed	Anterior/Posterior	5.87 ± 1.94	6.01 ± 1.53	5.53 ± 2.82	0.593
	Medial/Lateral*	10.23 ± 4.81	10.74 ± 4.97	9.00 ± 4.51	0.546
	Vertical*	10.49 ± 4.46	10.72 ± 4.34	9.93 ± 5.05	0.775
Dynamic	Anterior/Posterior	0.12 ± 0.01	0.12 ± 0.01	0.12 ± 0.01	0.779
	Medial/Lateral	0.03 ± 0.01	0.03 ± 0.01	0.03 ± 0.01	0.729
	Vertical	0.29 ± 0.04	0.29 ± 0.04	0.29 ± 0.03	0.800
	Composite	0.32 ± 0.03	0.32 ± 0.04	0.31 ± 0.02	0.810

†$p < 0.05$. *Mann-Whitney U test used.

Fig. 2. Participant performing (a) single-leg drop-landing (SLDL) and (b) single-leg squat (SLS) tasks.

dinate systems and joint angles were defined by digitizing bony landmarks in accordance with ISB recommendations [51]. Joint kinematic and GRF data were processed using a custom script (MATLAB R2010b, The Math Works, Natick, MA). Joint kinematic data were filtered using a digital fourth-order zero-phase-lag low-pass Butterworth filter with a cutoff frequency of 10 Hz and then offset using mean joint angles from a static capture of the participants in the anatomical position. Ground reaction force data were filtered using a digital fourth-order zero-phase-lag low-pass Butterworth filter with a cutoff frequency of 100 Hz.

2.5. Statistical analysis

Stepwise multiple regression models were used to identify which variables significantly predicted knee valgus at initial contact during the SLDL and peak knee valgus angle during the SLS tasks. Predictor variables were medial/lateral static and dynamic postural stability (eyes open and eyes closed) and knee/hip strength measures. Entry into the models was set at $p < 0.05$ and removal at $p > 0.10$. Bivariate correlations for parametric and non-parametric data were assessed using Pearson's product moment correlation and Spearman's rank correlation, respectively. Positional differences for parametric and non-parametric data were assessed with independent t-tests and Mann-Whitney U test, respectively. Normality was assessed using histogram plots and Shapiro-Wilk tests. For all tests, alpha was set as 0.05 *a priori*. All statistical analyses were performed using PASW Statistics 18 (SPSS Inc., Chicago, IL).

3. Results

Sixty players volunteered for gluteal dysfunction screening and 80.4% (41/51) presented with gluteal dysfunction. Nine did not meet the inclusion criteria,

Table 3
Knee and hip isokinetic strength (mean ± standard deviation)

	Total ($n = 24$)	Forwards ($n = 17$)	Backs ($n = 7$)	p-value
Knee Flexion (%BW)†	141.9 ± 30.3	131.8 ± 27.8	166.5 ± 21.5	0.008
Knee Extension (%BW)†	280.7 ± 70.4	254.2 ± 56.1	345.1 ± 61.4	0.002
Knee F/E Ratio	51.7 ± 8.2	52.8 ± 8.7	49.0 ± 6.6	0.294
Hip Flexion (%BW)	199.6 ± 51.0	186.9 ± 54.4	230.6 ± 22.9	0.055
Hip Extension (%BW)†	226.2 ± 80.7	203.4 ± 84.8	281.6 ± 26.9	0.027
Hip F/E Ratio*	93.8 ± 24.0	98.6 ± 26.6	82.3 ± 9.8	0.112
Hip Adduction (%BW)	137.3 ± 47.0	130.0 ± 50.8	155.0 ± 32.9	0.243
Hip Abduction (%BW)†	161.3 ± 46.4	147.0 ± 42.2	195.9 ± 38.9	0.015
Hip Add/Abd Ratio	88.5 ± 28.1	92.2 ± 32.1	79.7 ± 12.4	0.332

†$p < 0.05$.
*Mann-Whitney U test used.

Table 4
Biomechanical measures of single-leg drop landing at initial contact and peak single-leg squat (mean ± standard deviation)

	Total ($n = 24$)	Forwards ($n = 17$)	Backs ($n = 7$)	p-value
Single-leg Drop-Landing				
Knee Flexion at IC (°)	19.6 ± 7.1	20.0 ± 6.3	18.8 ± 9.3	0.610
Knee Valgus at IC (°)	3.2 ± 4.7	3.8 ± 4.7	1.5 ± 4.7	0.352
Knee Internal Rotation at IC (°)	−0.1 ± 6.1	0.4 ± 6.4	−1.1 ± 5.6	0.931
Hip Flexion at IC (°)†	18.3 ± 7.9	20.8 ± 6.8	12.2 ± 7.5	0.035
Hip Abduction at IC (°)	6.1 ± 5.8	6.4 ± 6.1	5.2 ± 5.2	0.467
Hip Internal Rotation at IC (°)	−8.6 ± 5.0	−8.4 ± 4.9	−8.8 ± 5.8	0.445
Single-leg Squat				
Peak Knee Flexion (°)	65.6 ± 6.6	65.4 ± 7.3	66.3 ± 4.7	0.772
Peak Knee Valgus (°)*	4.2 ± 12.1	6.5 ± 10.4	−2.3 ± 15.3	0.834
Peak Knee Internal Rotation (°)	12.0 ± 8.4	11.8 ± 8.6	12.5 ± 8.7	0.870
Peak Hip Flexion (°)	40.9 ± 11.5	41.6 ± 10.9	38.9 ± 13.9	0.640
Peak Hip Abduction (°)	−4.2 ± 4.9	−3.9 ± 5.2	−4.9 ± 4.4	0.690
Peak Hip Internal Rotation (°)	5.7 ± 8.3	6.0 ± 8.0	4.9 ± 9.8	0.780

†$p < 0.05$.
*Mann-Whitney U test used.

10 did not present with gluteal dysfunction, and 17 did not report for testing. Twenty-four players were tested. Twelve professional players from Eccellenza ($n = 1$) and Serie A1 ($n = 11$) leagues, and 12 semi-professional from Serie B ($n = 5$) and Serie C ($n = 7$) leagues.

Several significant differences were found between positions. Forwards were significantly taller ($p = 0.013$) and heavier ($p = 0.022$) than backs and were similar in age ($p = 0.544$) (Table 1). Backs had significantly better anterior/posterior static postural stability (lower measure of variability) with eyes open ($p = 0.011$) than forwards (Table 2). Backs had significantly greater knee flexion ($p = 0.008$), knee extension ($p = 0.002$), hip extension ($p = 0.027$), and hip abduction ($p = 0.015$) strength than forwards (Table 3). For the SLDL, forwards had significantly greater hip flexion at initial contact ($p = 0.035$) and no significant differences were found for SLS (Table 4).

Hip abduction strength was negatively correlated with all eyes open static postural stability measures and with the anterior/posterior direction during eyes closed (Table 5). All strength measures were negatively correlated with anterior/posterior static postural stability (eyes open) and no correlations were found between strength and dynamic postural stability. The stepwise multiple regression models for the SLDL and SLS tasks failed to find significant predictors of knee valgus angle.

4. Discussion

Identification of physical variables that predict knee valgus during sport may assist in the design of knee injury prevention programs. The first purpose of this study was to determine whether postural stability and strength measures could predict knee valgus angle during SLDL and SLS tasks. We hypothesized a prediction model could be built using frontal plane postural stability and knee and hip isokinetic strength measures. However, no predictors of knee valgus angle were found. The second purpose was to identify the relationship

Table 5
Pearson correlation coefficients between static postural stability and isokinetic strength measures (n = 24). A/P: anterior/posterior; M/L: medial/lateral; V: vertical

	Static eyes open			Static eyes closed		
	A/P	M/L	V	A/P	M/L*	V*
Knee Flexion	−0.564‡	−0.329	−0.173	−0.348	0.013	0.082
Knee Extension	−0.662‡	−0.446†	−0.376	−0.430†	−0.281	−0.144
Hip Flexion	−0.514‡	−0.311	−0.221	−0.319	−0.149	−0.085
Hip Extension	−0.585‡	−0.262	−0.029	−0.150	0.181	0.203
Hip Adduction	−0.442†	−0.231	−0.053	−0.224	−0.073	−0.065
Hip Abduction	−0.708‡	−0.618‡	−0.523‡	−0.456†	−0.371	−0.363

†Correlation is significant at the 0.05 level (2-tailed).
‡Correlation is significant at the 0.01 level (2-tailed).
*Spearman's rank correlation test used.

between postural stability and strength measures. We hypothesized postural stability would be related to hip isokinetic strength and found several significant correlations between static postural stability and strength. The third purpose was to compare all measures between forwards and backs. We hypothesized that differences would exist between positions and several significant differences were identified.

Forwards and backs yielded significant differences for demographics, postural stability, strength, and biomechanical measures. Forwards were significantly taller and heavier (Table 1), being consistent with the literature [52,53]. Backs demonstrated significantly better eyes open postural stability (Table 2) and normalized strength (Table 3). Other studies measuring postural stability in elite male rugby union players using similar methods were not identified. Relative strength data are consistent with the literature [54,55].

Correlation analyses found relationships between postural stability and isokinetic strength (Table 5). Hip abduction strength was negatively correlated with all eyes open static postural stability measures and with the anterior/posterior direction during eyes closed. All strength measures were negatively correlated with eyes open anterior/posterior static postural stability. These results indicate better static postural stability is dependent on increased knee and hip strength, and that other physical variables may be biased during eyes closed postural tasks.

Postural stability and isokinetic strength were not significant predictors of knee valgus angle during SLDL or SLS tasks. Some authors have identified hip abduction [39,40] and knee flexion/extension strength [39] as predictors of knee valgus during dynamic tasks, while others [38], and this study, have not. The conflicting results may be due to differences in strength testing methodology, type of dynamic task performed, and participant sample. Claiborne et al. [39] measured standing isokinetic hip strength and Sigward et al. [38] measured isometric hip and knee strength. Padua et al. [40] and Sigward et al. [38] observed two-leg drop-landing tasks. All three studies [38–40] used female subjects. Thus, different genders prohibit direct comparisons between this study and others. The present findings suggest dynamic knee valgus in males is not dependent on variables of static postural stability or peak knee/hip muscle strength.

Female athletes are at greater risk of valgus collapse and noncontact ACL injury as compared to male athletes [56,57]. Video studies [57,58] revealed dynamic valgus collapse as the most common mechanism of noncontact knee injury and laboratory studies [23, 59,60] quantified higher knee valgus angles and moments in females as compared to males. Quatman and Hewett [61] proposed the mechanism of injury in females is a multi-planar loading pattern including a forward flexed torso, internally rotated and adducted hip, valgus positioned and extended knee, and external tibial rotation. The proposed mechanism of injury in men is a sagittal plane loading pattern described as an upright torso, neutral hip, knee flexion with reduced valgus, and minimal tibial rotation [61]. Mean knee valgus angles observed in this study (Table 4) are consistent with male athletes [59,60]. Combined with the lack of hip abduction strength as a predictor of knee valgus angle, the present results suggest a sagittal plane strategy may be preferred for deceleration and force absorption.

Gluteal screening tests commonly used in clinical practice were employed to select our sample and they presented with clinical gluteal dysfunction as typically defined by clinicians and researchers [27,29–32]. At the time of this study, all players were injury-free and participating in unrestricted training and matches. Moreover, mean hip extension and abduction relative strength values displayed by the players in this study (Table 3) were equivalent to or greater than those reported for healthy adult males using comparable methodologies [54,55]. Mean hip abduction, hip internal rotation, and knee valgus angles (Table 4) were also comparable to male games players performing similar dynamic tasks [59,60]. Therefore, the diagnostic relevance and clinical utility of the gluteal screening tests used in this study require further investigation.

A limitation of this study is the lack of a group without clinical gluteal dysfunction. However, since 80.4% of volunteers presented with gluteal dysfunction, the present sample may actually be representative of the majority of elite male rugby union players. A second limitation of this study is the exclusion of hip kinematics from the regression model. Padua et al. [40] found hip kinematics predicted knee valgus, but this study focused on measures that are common to injury prevention and training programs.

5. Conclusion

Static and dynamic postural stability and knee and hip isokinetic strength do not predict knee valgus during dynamic tasks in elite male rugby union players. Eyes open static postural stability was dependent on knee and hip muscle performance, and forwards and backs were significantly different across multiple physical variables. The majority of injury-free, fully competitive, elite male rugby players presented with clinical gluteal dysfunction, yet the biomechanical and isokinetic strength assessments resulted in measures similar to males from the literature. Future research should continue to investigate predictors of dynamic knee valgus in male rugby players, determine the diagnostic relevance and clinical utility of gluteal dysfunction screening tests, and investigate the existence of a gender-specific mechanism of noncontact knee injury. Such research could be used to assist the design of knee injury prevention and training programs in male rugby union players.

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Competing interests

None.

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