

PRESEASON ASSESSMENT OF ANAEROBIC PERFORMANCE IN ELITE SOCCER PLAYERS: COMPARISON OF ISOKINETIC AND FUNCTIONAL TESTS

François Delvaux^{a,b}, Cédric Schwartz^{a,b}, Carlos Rodriguez^a, Bénédicte Forthomme^{a,b}, Jean-François Kaux^a and Jean-Louis Croisier^{a,b}

^a *Department of Physical Medicine and Rehabilitation, University of Liege, Liege, Belgium*

^b *Laboratory of Human Motion Analysis, University of Liege, Liege, Belgium*

Keywords

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Abstract

Isokinetic and functional jump tests are frequently performed for assessing the physical qualities of soccer players during preseason. The purpose of this investigation was to explore, in an elite soccer players population, the relationships between isokinetic strength and functional jump performances. Thirty- eight professional soccer players were evaluated as follows: isokinetic knee assessment in concentric (CON) mode (60, 240°/s) for quadriceps and hamstrings, and in eccentric (ECC) mode for the hamstrings only (30°/s); one-leg hop tests for distance (single hop (SH), triple hop (TH) and triple crossover hop (TCH)); one-leg vertical jump tests (countermovement jump, drop jump). Players with a low bodyweight normalised (BWN) quadriceps (Q) strength (<2.71 Nm/kg) performed, for a majority of the measured variables, significantly reduced jump performances compared to the players with high BWN Q strength (>3.14 Nm/kg; $p < 0.05$). Greater bilateral differences between uninjured and past injured lower limbs were found with isokinetics (Q CON 60°/s (mean bilateral difference (MBD): 10.3%; $p < 0.01$), Q CON 240°/s (MBD: 9.9%; $p < 0.05$), H ECC 30°/s (MBD: 16.1%; $p < 0.001$) than with functional tests (MBD: 2 to 9%; $p > 0.05$). In conclusion, due to their complementary role and implications for performance, functional and

isokinetic tests should be associated in a preseason soccer players assessment.

Introduction

A successful soccer performance is influenced by tactical, technical, mental and physical qualities of each player. Physical demands of soccer have increased in recent years, and although aerobic metabolism dominates the energy delivery during a soccer game, intense high-speed actions such as jumping, accelerating, decelerating and kicking represent the most decisive actions during match-play (Bangsbo et al., 2006). Therefore, anaerobic power is of crucial importance for soccer performance. Its preseason assessment may contribute to establish an individual profile for each soccer player, with specific information in order to highlight potential weaknesses that reduce the possibilities to perform or identify an injury risk (Croisier et al., 2008).

In soccer players, the isokinetic dynamometer is commonly used for assessing strength and balance between hamstrings and quadriceps as well as bilateral asymmetries. Even if it remains controversial because of conflicting results (van Dyk et al., 2016; Zvijac et al., 2013) or methodological questions about the application of specific threshold values (Dauty, Menu, Fouasson-Chailloux et al., 2020, 2018; Grygorowicz et al., 2017), there is evidence that an isokinetic muscle imbalance may be associated with an increased injury risk for thigh muscle strain (Croisier et al., 2008; Dauty et al., 2016) which represents the most common injury in soccer (Ekstrand et al., 2016). Recently, Opar and Serpell (2014) also discussed a possible lower hamstring muscle strength as a risk factor for anterior cruciate ligament injury. However, the isokinetic assessment is a laboratory and analytic testing that does not reflect the functional aspects of limb movements involved in soccer practice (Lehance et al., 2009). Consequently, some authors recommend the use of functional tests through performance assessment (Cometti et al., 2001; Wisloff et al., 2004) such as horizontal (hop tests) or vertical jumps. Functional hop tests require minimal equipment and time and are reported to evaluate muscular strength, neuromuscular coordination, and joint stability in the lower limb

(Barber et al., 1990; Noyes et al., 1991). Initially developed for the evaluation of postsurgical knee patients (mostly those with anterior cruciate ligament (ACL) reconstructions) (Noyes et al., 1991), hop tests can also be used to detect abnormal limb asymmetry or weakness (Ross et al., 2002) with good to excellent validity. Vertical jump tests such as countermovement jumps (CMJ) or drop jumps (DJ) can also be considered as an adequate method for performance analysis (Schwartz et al., 2017; Wisloff et al., 2004), but an accurate and reliable measure requires performance equipment. This equipment (among others: force platforms, jump apps) may vary according to the specific parameters of performance that are followed by the investigators: jump height, flight time, ground reaction forces, etc. Previous studies have shown significant correlations between various measurements of vertical (Dobbs et al., 2015; Lehanche et al., 2009; Loturco et al., 2015; Wisloff et al., 2004) or horizontal jumping (Lockie et al., 2014; Loturco et al., 2015) and sprinting speed. Because of their practicality and safeness, these results justify the implementation of jumping tests in a preseason soccer player test battery (Loturco et al., 2015).

Several authors have also investigated relationships between isokinetic muscular strength and vertical jumping performance (Hamilton et al., 2008; Jones & Bampouras, 2010; Paasuke et al., 2001; Petschnig et al., 1998). However, some associations remain unclear: the influences of a past severe injury or of low/high hamstrings-to-quadriceps ratios on the ability to jump (vertically as well as horizontally) have been poorly investigated. Most of these studies (Hamilton et al., 2008; Jones & Bampouras, 2010; Paasuke et al., 2001; Petschnig et al., 1998) have reported isokinetic absolute peak torque (in Nm), while the use of bodyweight normalised (BWN) peak torque (in Nm/kg) may be considered as a possible factor of importance for a jump performance. Furthermore, except for the article from Lehanche et al. (2009), these studies mostly included athletes from various sports, and will not specifically reflect high-level soccer players.

The aim of this study was to explore, in a high-level soccer population, the relationships between isokinetic strength and functional jump performances. Secondly, we investigated the influence of a past injury on the isokinetic strength profile and the jump performances. We hypothesised that 1) isokinetic and jump performances would be highly correlated; 2) past injured

players would demonstrate significant muscle strength and jump performance imbalances between the past injured limb and the uninjured limb.

Methods

Participants

Forty soccer players from a top Belgian first division professional soccer club (mean age: 24 ± 6 years; height: 183 ± 8 cm; body mass: 77 ± 7 kg) were enrolled in this study. At the time of testing, two players were injured (one hamstring muscle injury and one ankle sprain) and were excluded from the study. Among the remaining 38 participants, no players reported lower limb injuries or experienced any pain or discomfort in any part of their body prior to the tests. A substantial part of participants (42%—16 players) have previously experienced a severe injury, compared to 22 players who have never sustained a severe injury. According to Ekstrand et al. (2011), a past severe injury can be defined as an injury leading to at least 4 weeks of competitive break. Nineteen previous severe injuries were reported (13 players sustained one previous severe injury, and three players sustained two severe injuries): 37% out of the severe injuries were located at the knee (including 43% of anterior cruciate ligament rupture, 43% of medial collateral ligament rupture, 14% of internal meniscal tear), and 37% were thigh muscle injuries (hamstrings: 57%, adductors: 29%, quadriceps: 14%). The other injuries were hip femoroacetabular impingement (5%), Achilles tendon rupture (5%), ankle sprains (11%) and foot fracture (5%). All severe injuries occurred in a period from 3 months to 7 years before this study and, at the time of the evaluations, all players were considered fit for competitive soccer activity by the team medical staff. The University of Liège Research Ethics Committee approved the study, and all participants gave their informed consent for participation.

Methodology

Testing took place over two sessions during the preseason preparation, with at least 2 days and a maximum of 4 days between sessions.

At the first session, isokinetic testing was performed to assess hamstring and quadriceps muscle performance using a Cybex Humac Norm[®] dynamometer (CSMI, Stoughton, USA). All measurements were preceded by a standardised warm-up consisting of pedalling on an ergometric bicycle (75 to 100 W) and performing static stretching exercises of the hamstring and quadriceps muscle (20 s for each muscle groups). The participant was seated on the dynamometer (with 105° of hip flexion) with the body stabilised by several straps around the thigh, waist, and chest to avoid compensation. The range of knee motion was fixed at 100° of flexion from the active maximum extension. The gravitational factor of the dynamometer's lever arm and lower leg-segment ensemble were calculated by the dynamometer and automatically compensated for during the measurements. An adequate familiarisation with the dynamometer was provided in the form of further warm-up isokinetic repetitions at 120°/s (10 sub-maximal repetitions followed by six repetitions progressively increased to a maximal performance) during warm-up. Moreover, before assessment, preliminary repetitions routinely preceded each test speed. Verbal encouragement was given, but the participant did not receive any visual feedback during the test. The protocol included concentric exertions (angular speeds of 60°/s (three maximal repetitions) and 240°/s (five maximal repetitions)) of both flexor and quadriceps muscles. Afterwards, hamstring muscles were subjected to eccentric angular speeds of 30°/s and 120°/s (three maximal repetitions). The result analysis included the best absolute peak torque (in Nm) and BWN peak torque (in Nm/kg). A conventional hamstrings-to- quadriceps peak torque ratio was established for the same mode and speed of concentric contraction. An original mixed ratio associated the eccentric performance of the flexor muscles (30°/s) and the concentric action of the quadriceps muscle (240°/s) (Croisier et al., 2008).

At the second session, after a standardised warm-up (ergometric bicycle (75 to 100 W), short lower limb stretching exercises, and two series of 20 half squats with a 20 kg-barbell) jumping ability was assessed by both horizontal

(single-legged hop tests) and vertical jump tests. A series of three hop tests (Single Hop for distance (SH), Triple Crossover Hop for distance (TCH) and Triple Hop for distance (TH)) was administered in accordance with the original description outlined by Noyes et al. (1991). SH was performed with the player standing on the leg to be tested, hopping as far as possible, and landing on the same leg. For TCH, players stood on one leg, then hopped as far as possible forwards three times while alternately crossing over a 15-cm marked strip on the floor. The total distance hopped forwards was recorded. TH was performed with the player standing on one leg and performing three consecutive hops as far as possible. The three single-legged hop tests were considered successful if the landing was stable. To be considered a valid trial, the landing must be on one limb, under complete control of the patient. If the patient landed with early touchdown of the contralateral limb had a loss of balance, or had additional hops after landing, the hop was repeated. For each test, the total distance was recorded from the position of the stance toe before takeoff to the position of the toe at final landing and was measured in centimetres; results are presented in absolute values as well as in normalised values to body height (relative values: distance hopped (cm)/height (cm)). After two practice trials, participants completed two measurement trials for each limb, tested in random order. The participant's arms were free from restraint and could be used to propel the body and aid in balance upon landing.

The vertical jump tests were then performed on two force plates (Kistler®, Kistler Group, Switzerland). Participants performed bilateral (BDJ) and unilateral (UDJ) drop-jump landings from a wooden platform measuring 22 cm in height and placed 10 cm behind the rear edge of the landing target (force plate). Participants were instructed to simultaneously (a) minimise the contact time with the ground when landing and (b) jump as high as possible. To prevent experimenter bias, we did not give special instructions to participants regarding their landing mechanics. Practice repetitions were performed until the participant appeared to be comfortable and reported facility with the task (typically three to five repetitions) to reduce the potential for learning effects. Three jumps were recorded and the best performance was included for analyses. Maximal height (cm) and peak vertical ground reaction forces during the pushing phase were measured (N) and then normalised to body weight

(N/kg). Finally, the second testing session ended with bilateral (BCMJ) and unilateral (UCMJ) counter- movement jumps. Starting in a standing position with hands on hips for 5 s, participants were encouraged to jump as high as possible. After three practice trials, three jumps were realised, with the best performance included for analyses. The maximal jump height was recorded (cm) as well as the ground reaction vertical forces during the pushing phase with and without normalisation to body weight (N/kg and N).

Statistical analysis

All data were imported into *Statistica 10*, StatSoft® for statistical analysis. Continuous variables were tested for normality and are presented as mean $\pm$ standard deviation. The isokinetic testing permitted a bilateral comparison with asymmetries between the dominant (kicking leg) and the non-dominant sides and was expressed in percentages according to the following equation (Dominant limb - Non-Dominant limb/Dominant limb) X100.

A limb symmetry index (LSI) was calculated as the percentage of the best performance of the involved limb divided by the best performance of the uninvolved limb for each horizontal (hop) or vertical (CMJ, DJ) single-legged test. Two-tailed Student's *t*-tests were used to compare dominant versus non-dominant side, and past injured versus uninjured side for each strength or functional measure. Relationships between variables were calculated with the Pearson correlation coefficient (*r*). Statistical significance was set at $p < 0.05$.

Results

Tables 1 and 2 provide the descriptive statistics for the isokinetic assessment, hop tests and vertical jumps. For the dominant side, UCMJ and UDJ parameters are moderately correlated ($r = 0.597$ to 0.696); UCMJ and hop test are moderately to strongly correlated ($r = 0.647$ to 0.882); UDJ and hop tests are moderately correlated ($r = 0.601$ to 0.704). Except for BWN concentric quadriceps peak torque at $60^\circ/\text{s}$ and CMJ peak torque ($r = 0.463$), no correlations were found between all the isokinetic (absolute or relative performances) and the jump parameters ($r < 0.40$). Table 3 summarises the comparison of horizontal and vertical jump performances between the first

(<2.71 Nm/kg) and the third quartile (>3.14 Nm/ kg) of BWN quadriceps peak torque of the dominant limb.

Hamstring-to-quadriceps strength ratios are not correlated to hop tests or vertical jump performances ($-0.40 > r < 0.40$ for all parameters). The comparison between the first and the third quartile of H:Q ratios (H:Q ratios <0.53 or >0.65 (CON 60°/s), <0.54 or >0.68 (CON 240°/s) and <1.14 or >1.39 (ECC 30°/s/CON 240°/s), respectively) showed no significant group differences for each chosen ratio ($p > 0.05$ for all parameters).

In the past injured (PI) group, student's *t*-test revealed significant differences between the past injured and the uninjured sides for a majority of the isokinetic parameters (Q CON 60°/s (10.3%; $p = 0.006$), Q CON 240°/s (9.9%; $p = 0.033$) and H ECC 30°/s (16.1%; $p = 0.008$)) (Figure 1) and only for TCH (absolute and body height normalised values) of functional performance variables (mean difference: 8%; $p = 0.009$) (Table 4). Concerning the group with No past Injury (NI), no statistical differences were found between dominant and non-dominant sides for all the isokinetic or functional variables ($p > 0.05$).

The comparison of isokinetic and jump performances between the injured side of the PI group with the mean of dominant and non-dominant side performances of the NI group did not show any statistical differences, except for hamstrings eccentric strength (2.37 ± 0.47 Nm/kg (PI) vs 2.54 ± 0.57 Nm/kg (NI); $p < 0.01$) and single hop for distance (221 ± 19 cm (PI) vs 243 ± 15 cm (NI); $p < 0.01$).

Table 1. Descriptive data of isokinetic assessment: absolute peak torque, peak torque to body weight and H/Q ratios.

Isokinetic assessment	DL		NDL		Difference between DL and NDL		Difference between best and weakest limb		p-value
	Nm/Nm/kg		Nm/Nm/kg		%		%		
Quadriceps	CON 60°/s	226 ± 39/2.93 ± 0.50	225 ± 38/2.92 ± 0.49		<1		8		0.347
	CON 240°/s	153 ± 25/2.00 ± 0.32	158 ± 25/2.04 ± 0.32		-3		10		0.074
Hamstrings	CON 60°/s	146 ± 26/1.90 ± 0.33	140 ± 24/1.82 ± 0.31		4		9		0.060
	CON 240°/s	97 ± 12/1.26 ± 0.16	94 ± 15/1.22 ± 0.19		3		6		0.566
H/Q ratios	ECC 30°/s	191 ± 39/2.48 ± 0.51	186 ± 47/2.42 ± 0.61		3		14		0.031
	CON 60°/s	0.56 ± 0.11	0.59 ± 0.09		-5		11		0.098
	CON 240°/s	0.61 ± 0.09	0.60 ± 0.08		2		7		0.277
	ECC 30°/s/CON 240°/s	1.26 ± 0.25	1.21 ± 0.25		4		12		0.044

Notes: DL: Dominant Limb; NDL: Non-Dominant Limb; CON: concentric; ECC: eccentric. Bold type indicates statistical significance ($p < 0.05$).

Table 2

Descriptive data of functional test results.

		DL	NDL	LSI between DL and NDL	p-value	LSI between best and weakest limb	p-value
HOP tests	SH (cm)	234 ± 24	240 ± 21	0.92	0.099	0.90	0.172
	Relative SH	1.28 ± 0.14	1.31 ± 0.11	0.93	0.327	0.91	0.419
	Triple hop (cm)	699 ± 59	710 ± 51	0.94	0.245	0.85	0.021
	Relative TH	3.84 ± 0.32	3.89 ± 0.30	0.96	0.552	0.90	0.076
	TCH (cm)	678 ± 47	686 ± 42	0.91	0.148	0.89	0.197
Vertical jump tests	Relative TCH	3.68 ± 0.27	3.75 ± 0.23	0.92	0.218	0.88	0.093
	UCMJ (cm)	36.9 ± 4.7	37.7 ± 4.1	0.88	0.048	0.87	0.022
	UCMJ (N)	1534 ± 173	1541 ± 167	0.87	0.029	0.85	0.013
	UCMJ (N/kg)	19.6 ± 1.9	19.8 ± 1.9	0.92	0.320	0.93	0.432
	UDJ (cm)	33.9 ± 3.6	34.6 ± 4.1	0.91	0.289	0.82	0.005
	UDJ (N)	2505 ± 467	2572 ± 409	0.88	0.213	0.87	0.076
	UDJ (N/kg)	32.4 ± 5.6	32.9 ± 6.0	0.91	0.335	0.84	0.009

Notes: Dominant Limb; NDL: Non-Dominant Limb; LSI: limb symmetry index; SH: single hop; TH: triple hop; TCH: triple crossover hop; UCMJ: unilateral countermovement jump; UDJ: unilateral drop jump. Bold type indicates statistical significance ($p < 0.05$).

Table 3. Comparison of functional test performances between the first and third quartile of quadriceps peak torque to body weight at 60°/s.

Isokinetic strength (dominant limb)	UCMJ			UDJ			HOP tests					
	cm	N	N/kg	cm	N	N/kg	SH (cm)	Relative SH	TH (cm)	Relative TH	TCH (cm)	Relative TCH
1st quartile (n = 11)	33.5 ± 3.6	1490 ± 373	19.3 ± 3	32.7 ± 2.7	2179 ± 321	29.3 ± 5.2	224 ± 26	1.22 ± 0.15	658 ± 56	3.62 ± 0.29	652 ± 31	3.55 ± 0.17
<2.71 Nm/kg												
3rd quartile (n = 10)	39.2 ± 3.8	1588 ± 147	20.9 ± 3	34.7 ± 4.0	2857 ± 528	35.1 ± 5.1	255 ± 19	1.40 ± 0.12	729 ± 47	3.98 ± 0.27	702 ± 48	3.85 ± 0.28
>3.14 Nm/kg												
p-value	0.008	0.268	0.193	0.080	0.001	0.013	0.008	0.029	0.006	0.005	0.007	0.024
Difference (%)	14.5	6.2	7.7	5.8	23.7	16.5	12.2	12.9	9.7	10.0	7.1	9.2

Notes: UCMJ: unilateral countermovement jump; UDJ: unilateral drop jump; SH: single hop; TH: triple hop; TCH: triple crossover hop. Bold type indicates statistical significance (p < 0.05).

Figure 1. Comparison of isokinetic performances between the past injured side versus the uninjured side of the past injured group (* indicates statistically significant difference ($p < 0.05$)).

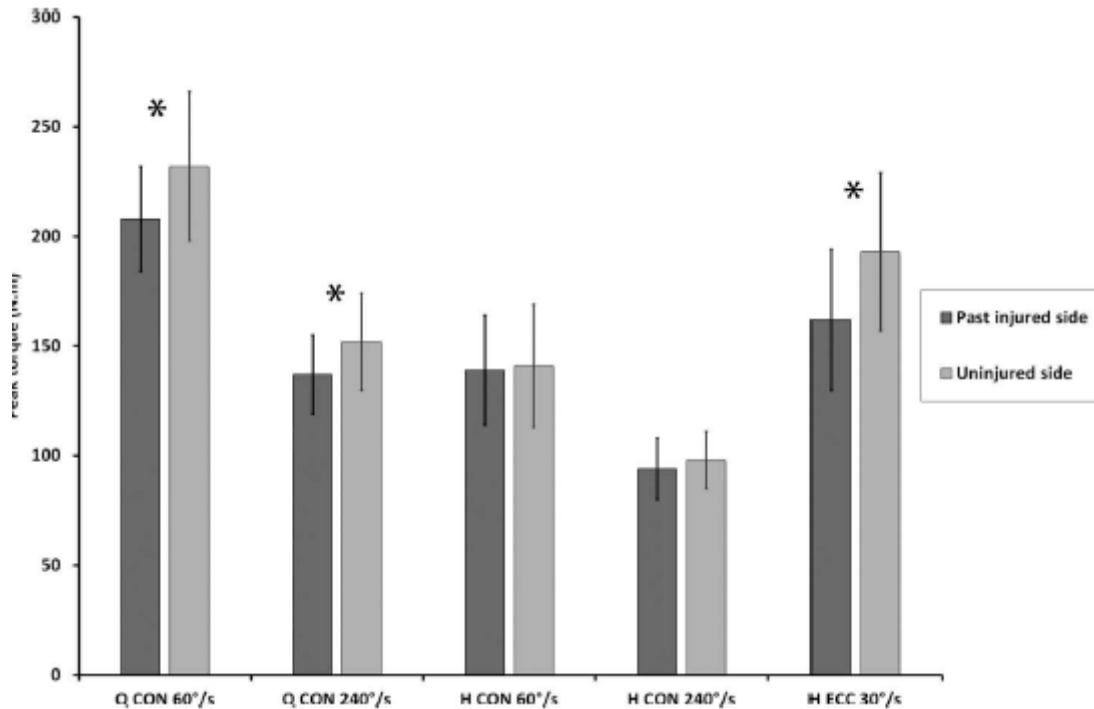


Table 4

Comparison of jump performances between the past injured limb versus the uninjured limb of the PI (past injured, $n = 16$) group.

	Injured limb	Uninjured limb	LSI	p-value
SH (cm)	219 ± 31	235 ± 33	0.93	0.084
Relative SH	1.20 ± 0.17	1.28 ± 0.17	0.94	0.159
TH (cm)	641 ± 48	668 ± 52	0.96	0.107
Relative TH	3.50 ± 0.25	3.66 ± 0.29	0.95	0.087
TCH (cm)	611 ± 39	664 ± 46	0.92	0.009
Relative TCH	3.34 ± 0.21	3.62 ± 0.24	0.92	0.063
UCMJ (cm)	34.3 ± 4.2	37.7 ± 4.0	0.91	0.081
UCMJ (N)	1438 ± 164	1567 ± 171	0.92	0.063
UCMJ (N/kg)	18.8 ± 2.1	20.6 ± 2.3	0.91	0.057
UDJ (cm)	32.9 ± 3.9	33.6 ± 4.7	0.98	0.636
UDJ (N)	2467 ± 485	2681 ± 497	0.92	0.272
UDJ (N/kg)	31.9 ± 5.8	34.5 ± 6.2	0.92	0.173

Notes: LSI: Limb Symmetry Index; SH: single hop; TH: triple hop; TCH: triple crossover hop; CMJ: unilateral countermovement jump; DJ: unilateral drop jump. Bold type indicates statistical significance ($p < 0.05$).

Discussion and implications

The main purposes of this study were to examine the relationships between preseason isokinetic and functional tests in a professional soccer players population and to investigate the influence of a past injury on the isokinetic strength profile and the jump performances. As correlations between isokinetic and jump variables were low, our first hypothesis was not supported by these results.

Secondly, the hypothesis that past injured players would demonstrate significant imbalances between the past injured limb and the uninjured limb was only supported for the isokinetic data, but not for the jump performances.

For the coaches as well as for the medical staff, having a clear comprehension of relationships between analytical and functional tests—among others the complementary or redundant potentially role of these tests—would allow to maximise the relevance of each assessment method to increase performance and injury prevention. Several differences between these assessment methods might explain the lack of correlations between isokinetic and jump variables: open versus closed kinetic chain, constant versus variable angular velocity, analytic versus multijoint task. In particular, we did not find any strong correlation between absolute or BWN isokinetic quadriceps strength and functional performances. Several studies reported that single-leg hop scores have been found not to be strongly related to isokinetic results (Greenberger & Paterno, 1995; Ostenberg et al., 1998; Petschnig et al., 1998). The triple-hop was found to be a good to strong predictor of lower limb muscular strength (Greenberger & Paterno, 1995; Hamilton et al., 2008; Petschnig et al., 1998), but it has also been shown to have low to moderate correlations with isokinetic performance (Ostenberg et al., 1998; Petschnig et al., 1998). Facing these apparent contradictions, we compared vertical and horizontal jump performances by separating our population in two subgroups according to the level of absolute or BWN quadriceps peak torque at 60°/s. We found that professional soccer players with a low BWN quadriceps strength (<2.71 Nm/kg, first quartile) showed significant reduced jump performances compared to the players with high BWN quadriceps strength (>3.14 Nm/kg, third quartile). Interestingly, except for TCH, no differences between the first (<208 Nm) and the third quartile (>242 Nm) were observed when considering absolute isokinetic performances. Thus, despite the absence of correlation between isokinetic and jump tasks, we highlighted significant differences of performances among the extremes (low or high BWN strength) of our population: players with a low isokinetic BWN quadriceps performance demonstrate a reduced ability to jump vertically as well as horizontally, and conversely. We hypothesise that this reduced capacity to perform a vertical or horizontal jumping task is related to a specific thigh muscle weakness, in particular the quadriceps muscle. Therefore, the association of preseason isokinetic and functional tests may represent the most relevant procedure, but according to our results showing a more discriminating nature of BWN muscle performances, a muscle weakness should then rather be analysed in respect of BWN strength instead of considering the absolute peak torque. Obviously, other factors may contribute to a reduced jump ability such as weakness of lower limb power, altered intra- and inter-muscular coordination, poor technical jumping qualities, weak ground force reaction, etc.

Another key point of the isokinetic dynamometry is to evaluate potential strength imbalances between the hamstrings and quadriceps muscles. The most representative agonist/antagonist strength balance parameters are the conventional hamstrings-to- quadriceps peak torque (H:Q ratio in concentric contraction mode) and the functional hamstrings-to-quadriceps ratio, where hamstrings strength is measured eccentrically (Bogdanis & Kalapotharakos, 2016; Coratella et al., 2015; Croisier et al., 2002, 2008; Dauty et al., 2016; Ruas et al., 2015). Low H:Q ratios have been reported to represent risk factors for hamstring strain (Croisier et al., 2008; Dauty et al., 2016), although conflicting results and methodological questions have been recently raised (Dauty, Menu, Fouasson- Chailloux et al., 2020; Grygorowicz et al., 2017; van Dyk et al., 2016). The relationship between H:Q ratios and functional performances has been poorly investigated (Croisier et al., 2008).

In the present study, we did not find any correlation between H:Q ratios and hop or vertical jump performances. Furthermore, the comparison between the first and the third quartile of H:Q ratios from our soccer players population showed no significant group differences for all ratios. Indeed, low H:Q ratios may be explained by a weak hamstring strength, and/or by a high quadriceps strength. In these two subgroups, BWN quadriceps peak torque (CON 60°/s) ranged from 2.21 to 3.48 Nm/kg (first quartile) and from 2.42 to 3.22 Nm/kg (third quartile); BWN hamstrings peak torque ranged from 1.54 to 2.31 Nm/kg (first quartile) and from 1.59 to 2.22 Nm/kg (third quartile). Consequently, subjects with large differences of muscle profiles were mixed in the first quartile (low hamstring or high quadriceps strength or both), leading to a very diversified group regarding knee flexion and extension strength profile. Bogdanis and Kalapotharakos (2016) found that a relatively large part of the variance in H:Q ratio may be explained by knee extension strength, showing that players with lower H:Q ratios in the knee joint had greater extension peak torque, but similar knee flexion peak torque compared with players that had an H:Q ratio around the recommended values. Considering the variability of hamstring strength and maybe more importantly the variability of quadriceps strength in the first or the third quartile of our population, the absence of relationship between functional performances and H:Q ratios was not surprising.

One original aspect of our study was to examine whether a past injury could induce lingering alterations in muscular and jump performances. In the PI group, we observed reduced performances of the past injured limb when compared with the uninjured limb. The most important bilateral differences were reported from the isokinetic assessment, with significant differences for Q CON 60°/s, Q CON 240°/s, and H ECC 30°/s. All the variables of vertical and horizontal jump performances were higher in the uninjured limb, but statistical differences were only found for TCH (absolute values). Therefore, the jump performances can be predominantly considered as symmetrical, while most of the isokinetic variables are not. As aforementioned, one of the most important differences between an isokinetic knee test and a jump task is the number of joints implicated in the exercise: one for the isokinetics and several joints for the jump task. During an isokinetic knee assessment, straps around the thigh, waist, and chest more strictly avoid any possibilities of compensation. For the management of a jumping task, it might be relevant that the athlete's past injured limb has progressively developed, since the past injury and the subsequent rehabilitation, a mechanism of compensation of a localised weakness, possibly with a greater activation of other muscle groups, a better neuromuscular coordination or a better joint stability. Considering these observations, we believe that, in a soccer players population with most of past injuries localised to the thigh or knee (74% of all reported severe injuries in our study), the isokinetic assessment may represent the most relevant method for assessing a complete or incomplete recovery. It is also emphasised that the return to sports decision after an injury needs to be based on a battery composed of subjective as well as objective criteria, rather than timed-based (Barber-Westin & Noyes, 2011; Kvist, 2004; Thomee et al., 2011). For muscle strength and functional tests, in order to increase the chances of safe and successful return to sports, it is recommended to present a high and symmetrical level of performances. For example, as demonstrated by Kyritsis et al. (2016), athletes who did not meet discharge criteria after an anterior cruciate ligament (ACL) reconstruction (including isokinetic test, single hop, triple hop, triple crossover hop) had a four times greater risk of sustaining an ACL graft rupture compared with those who met all the criteria.

Among study limitations, the number of participants included was limited ($n = 38$). Secondly, we

did not realise the follow-up of athletes' injuries during the season. It would have been relevant to investigate a possible relationship between injury and isokinetic or functional performances. However, it is suggested that at least 30 injured players would be needed to detect any association between the occurrence of an injury and some of these variables, which was difficult to expect with our cohort. Finally, despite no correlation was found between bilateral imbalances assessed by the isokinetic or the functional tests, it is noteworthy that our population does not present significant asymmetries between dominant and non-dominant side. Indeed, we only observed a few statistically significant differences for some parameters but these asymmetries can not be considered as clinically relevant (mean side-to-side difference = 3.2%). As a consequence of the absence of bilateral imbalances in our population, it has not been possible to determine which method was the most relevant to detect dominant versus non-dominant performance asymmetries. These side-to-side differences observed in our cohort appear to be lightly reduced in comparison with those found by other studies (Impellizzeri et al., 2007; Menzel et al., 2013; Newton et al., 2006). In previous unpublished data including a hamstring-injured population, we found significantly superior asymmetries from the isokinetic assessment than from unilateral vertical jumps. By contrast, Menzel et al. (2013) found that relevant bilateral differences in vertical jumps may persist even if the isokinetic assessment does not indicate any relevant bilateral difference in the tested muscle groups. Despite contrasting results with those from Menzel et al. (2013), combining an isokinetic evaluation with functional tests appears to represent the best option for detecting side-to-side imbalances.

Conclusion

The most important findings of the present study are (1) isokinetic and jump assessment methods are poorly correlated in a professional soccer players population; (2) despite no strong correlations between isokinetic strength and functional performances were found, soccer players with a weak bodyweight normalised quadriceps strength showed significant reduced jump performances compared to the players with high bodyweight normalised quadriceps strength; (3) Hamstring-to-Quadriceps ratios are not correlated with hop or vertical jump performances; (4) isokinetics showed greater side-to-side differences between uninjured and past injured lower limb than functional tests. According to our results, it might be appropriate to associate vertical jump tests on force plates or hop tests with an isokinetic assessment during a preseason soccer players screening. Furthermore, given that bilateral differences between past injured and uninjured limb were mostly highlighted by the isokinetic test than by functional tests, the isokinetic test seems to be an essential tool for preseason assessment. Finally, as a low bodyweight normalised quadriceps peak torque at 60°/s is related to a weak jump performance, strength and conditioning professionals should take into consideration this parameter in the player's assessment.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

ORCID

François Delvaux <http://orcid.org/0000-0002-7375-7237>

Cédric Schwartz <http://orcid.org/0000-0002-7307-7821>

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