Review

Recommendations for the isokinetic test of female's soccer players knee: A systematic review

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Review

Recommendations for the Isokinetic Test of Female's Soccer Players Knee. A Systematic Review

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Abstract: Isokinetic testing of the knee joint is the "gold standard" in strength assessment in sport, especially in soccer, where is part of pre-season screening to establish norms in case of injuries. Many devices on the market make it difficult to use of normative data. Isokinetics normative data in females' soccer players is scarce in comparison to males. Furthermore, evaluation protocols used in female's studies, strongly differ from each other, using different ranges of speeds and movement patterns, thus producing different output data. Thus, it is difficult for the researcher and the clinician to choose a correct protocol for knee isokinetic test in female soccer players. This paper aims to review the literature to provide updated information on how to interpret a knee isokinetic testing in healthy females. In this review some common features of isokinetic testing in female soccer players of different levels of qualification are highlighted. The indexes of isokinetic performance that are widely accepted are the hamstring/quadriceps (H/Q) ratio and dominant/non-dominant (D/ND) ratio. It also emerges that, for a reliable test, 3 reps at the speed of 60°/sec in knee flexion/extension is preferable due to the high reliability and that the optimal H/Q ratio in healthy female soccer players of different level of qualification and age is 50%, while the interlimb differences (D/ND) should be below 10%.

Keywords: female soccer; isokinetics; hamstring/quadriceps ratio; dominant non dominant limb ratio; errors in isokinetic dynamometry

Introduction

Female sport research has received less attention than research on male counterpart [34]. Soccer is not an exception to this conduct. The reasons for this under-consideration of female soccer are many, but mostly reside in social factors [34]. As consequence, re-search on female soccer players has been under funded and the availability of laboratories and instrumentation to perform research in females is scarce. Further, the same evaluation protocols used in male are applied in females. Among research in female football, injuries on the knee is of special interest and strength is a basic physical quality which is largely investigated. Isokinetic testing is the most used tool for knee strength assessment in soccer and require expensive equipment, which are less affordable to female clubs [34], however, isokinetic testing provides useful information for performance and injury prevention and rehabilitation of the knee [10] but few studies exist in females.

In sport performance testing, there are 3 mains factors to be considered: a) Validity (the protocol reproduces the functional task as closely as possible and this is the case of isokinetic testing, which reproduce the ball kicking; b) Reliability (the protocol gives similar result from day to day when no intervention is used; and c) Sensitivity: the protocol must be able to detect small, but significant, changes in performance [9]. Sen-sitivity of isokinetic machine is high [3], if the system is kept in proper working order. As a preliminary consideration, must be noted that knee injuries are most common in females compared to males' football players [48], and especially anterior knee pain is reported more often in females. Isokinetic pre-season and in-season screenings are a standard part of the functional screening of soccer's players, and the reference values are used as landmarks in case

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of injuries, to quantify the extent of strength losses and to establish the return to play after rehabilitation [21]. Quantify the bilateral strength deficit is also useful for insurance compensation procedures [19] as well to compare of the outcomes of different surgical methods, e.g. for the reconstruction of the anterior cruciate ligament [6]. Isokinetic testing is a well-established mean of testing and is not new [20,25].

Considering females muscle testing, it worth noting that the strength characteristics of males and females' muscle are different. Males and females with the same muscle size show different levels of strength, being females' quadriceps muscles weaker by a 12% to 24 % in comparison to male's when normalized for muscle thickness [23]. Furthermore, knee injuries rate risk is higher in females than in males due to the morphological condition of "genus valgus" [42], in fact, the prevalence of knee injuries in females is further worsened by the presence of the valgus knee, which is a common feature in the female Asian biotype [18].

Isokinetic testing can be performed in several joints and using different modalities of muscle contractions. Normally concentric (CON) and eccentric (ECC) mode of muscle contractions are employed and a wide range of speeds, normally from 1° to 500/sec for the knee joints. The eccentric force/velocity curve in an isolated muscle, was first time measured using an isokinetic device [18]. The so-called eccentric contraction, or con-traction-in-lengthening happens when a muscle contracts while it is stretched, thus re-sisting to the stretch in a controlled way. It is proven that eccentric "contraction" produces higher strength levels and strength gains in comparison to purely concentric contraction, and thus, it is worth to measure eccentric isokinetic strength to have a complete strength profile. Laterality, or dominance, is another important parameter in the physical evaluation of soccer players. It was found that male professional soccer players of the English premiere league displayed a greatest level of inter-limb asymmetry in isokinetic strength measures (5.9-12.7%. This measure is consistent with gait asymmetry (1.6-7.7% varia-bility in running stride length between the two legs) and jump asymmetry (0.9-7.0%) [33]. Considering the psychology, isokinetic testing is strictly depended on sincerity of effort [1]. In fact, studies on sincerity of effort in healthy young females, showed that a coef-ficient of variation lower than 10% in strength between 5 repetition is necessary to as-certain the subject performed at his maximal capacities [1].

Left/Right, dominant, (D) and non-dominant (ND), knee extensors (EXT) and flexors (FLEX) strength and quadriceps/hamstrings (H/Q) ratios are widely used informative parameters of isokinetic testing that has been related with several performance parameters, occurrence of injuries and recovery [37]. It worth noting that the Dominant leg not necessarily coincide with the Right leg, and this factor led to negative values when looking at the side ratios in isokinetic testing. Hamstrings testing is of special interest because hamstrings present an important eccentric action during quadriceps contraction, thus is more prone to injuries and is weaker than quadriceps [13].

It has been proposed that the unbalanced ratio between muscle which act against gravity in comparison with muscle which act in favor of gravity (e.g. Quadriceps and Hamstrings), on the long run, can be detrimental to the safety of the knee because of muscle imbalance, and thus predisposing to injuries [29]. To compensate for the meas-urement error due to the influence of gravitational force, isokinetic devices are equipped with a gravitational compensation procedure [11].

However, the assumption that an imbalance necessarily relates to an injury, is contro-versial, and recent studies cast some doubts on the clinical relevance of H/Q and D/ND ratio for injury prevention [8,16]. Further, isokinetic, being an artificial form of muscle work, presents in addition some issues. The technical problem of "torque overshoot" (or strength artifacts at high speeds of testing) suggest being not reliable the use of high speed of testing [41,47]. In fact, the isokinetic phase of movement, shortens with the increasing speed [5,32]. Thus, the aim of this paper is to review the literature about isokinetic testing in female soccer players, to identify possible errors in the testing methods used and to provide sound modalities of testing in females soccer players. The reference values for H/Q, D/ND and L/R ratios and angles of occurrence of maximal strength will be reviewed to provide a guideline for the interpretation of isokinetic testing in females.

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Methods

A survey of the existing literature was conducted in May 2023 in four different da-tabases from inception to 10 May 2023 (PubMed, Sport Discus, Ebsco, and Psychinfo) and on Google Scholar. The authors performed the search using the same method inde-pendently and collate, summarized, aggregated, organized, and compared the evidence extracted from the included studies. As one objective is to highlight the problems in isokinetic testing in healthy females' soccer players, the quality of the retrieved studies was one of the selection criteria of the literature. Thus, only studies published in peer reviewed journals were considered.

Identification of the paper was made using the following keywords in different combinations on the abstracts: "isokinetics and females soccer players", "female soccer players and isokinetics", "isokinetics and knee and females and soccer", "isokinetics and soccer and females", "reliability of isokinetic systems". The word "football" was also used instead of "soccer" and along this paper we use it interchangeability. The search strategies were combined, and duplicates were removed using Endnote X7 (Clarivate Analytics, previously Thomson Reuters, Philadelphia, PA, USA). The databases were queried in hierarchical order (e.g., first the broader database), starting from Google Scholar, followed by PubMed, Sport Discus, and Psychinfo. On Sport Discus only paper of higher level (level = advanced) was considered. Screening: All titles and abstracts were carefully read, and relevant articles were retrieved for review. In addition, the reference lists from both original and review articles retrieved were also reviewed.

The eligibility criteria limited the search to studies performed on females' soccer players with no previous history on injuries, e.g., pure functional or normative studies. The review complied with the PRISMA statement for a systematic review [27]. The inclusion criteria were studies related to isokinetics in healthy female soccer players of different levels of qualification, no presence of knee pathologies. The exclusion criteria were: (i) studies written in languages other than English, (ii) studies involving injured athletes. No limits were set concerning the year of publication. The inclusion or exclusion of articles was determined by applying the above criteria on the title and abstract as a first screening and on full texts as a second screening. and power in watts) but the ratios and when ratios were not reported, were calculated from the raw values. Data extraction: We can generally observe that different devices for isokinetic testing were employed in the studies, with a high heterogeneity in the raw results. Thus, when considering interlimb and ago-nists/antagonist muscles ratios, we didn't consider the absolute strength values (torque in newton meters, Nm or power, Watts, in one case) but the differences in %, using the formula: (Limb with higher strength – weaker limb) / Limb with higher strength x 100 and reported as % to allow a comparison between different test conditions. Risks of bias: results can be biased by the following source of biases: players are of different level of qualification, belong to different countries with different cultural backgrounds which can influence training habits. Also, the unclear definition of expert and recreational players can introduce a bias and must be considered. Any of the studies reported information about training and/or fatigue status and menstrual phases. The use of the different isokinetic machine is not a risk of bias, because the data are presented as ratios. Data synthesis: data were extracted from the paper's tables or from the papers texts and synthesized in two tables. The review has been registered in Prospero database with nr. 446185. The retrieved papers were also checked for the Sackett critical appraisal criteria which showed (on the mean) a Level II: Small randomized trials with uncertain results (and moderate to high risk of error) [40].

Results

16 papers met the eligibility criteria and were included in this review. The majority of studies were randomized controlled trials (RCT) (n = 10), while the rest of the studies were trials with a controlled group, but with no randomization (CT) (n = 6). PEDro [31] scores revealed a tendency towards the 'fair' category (PEDro of score 4–5) (n = 7), followed by the 'good' category (PEDro score from 6 to 8) (n = 6) and the other studies were classified as 'excellent' (PEDro score of 9–10) (n = 3).

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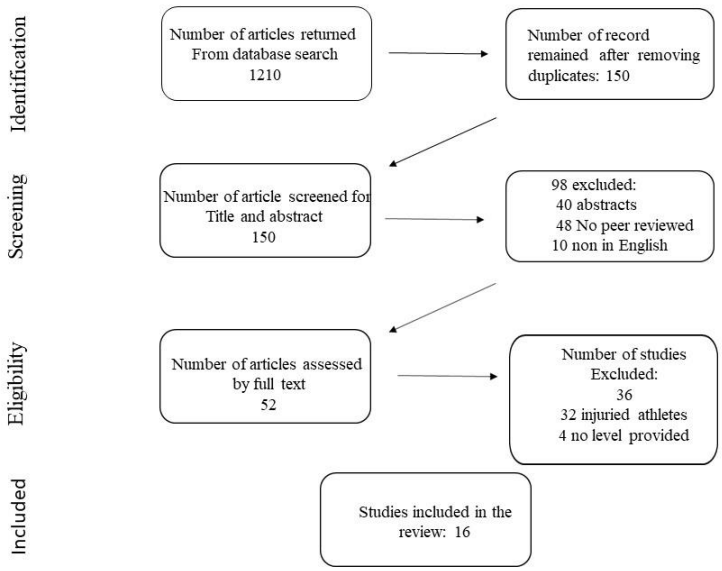

Figure 1. Search strategy.

Table 1. Studies included in the review and subject's characteristics.

Study nr.	Author	Device	Age (years ± sd)	N	Level
1	Fillyaw 1986	Cybex	19	27	collegiate
2	Jones 2020	Kin Com	21.2 ± 4.1	25	prof
3	Ostenberg 1998	Cybex II	20.3 ± 4.1	101	collegiate
4	Brigido Fernandez 2022	Isomed 2000	21.9 ± 4.19	68	prof
5	Westing 1989	Lido	20	20	collegiate
6	Knapik 1991	Biodex	18.9	36	collegiate
7	Chrisman 2012	Biodex 3	11-14	92	50 elite 42 sub-elite
8	Rosene 2001	Biodex Pro	19.3± 1.3	10	collegiate

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9	Vargas 2019	Biodex 4	18.21 ± 0.41ł	19	prof
10	Hannon 2022	Biodex 4	11-14, 15-18	64	recreational
11	Zhang 2021	Contrex	24.7±4.2	14	prof
12	Parpa 2020	Humac	23.6±4.3	18	prof
13	Eustace 2019	Biodex 4	21.31 ± 4.51	17	elite
			16.91 ± 1.16 17	17	young
14	Manson 2014	Cybex Norm	19-36	15	prof
15	Risberg 2018	Rev 9000	29 ±4	196	collegiate
16	Andrade 2012	Biodex	21.3±5.5	17	olympic

16 papers matched the inclusion criteria and were included in the review. Tables 2 and 3 report the results for H/Q and D/ND ratio.

Table 2. H/Q: (hamstrings/quadriceps) ratio. EXT: extension; FLEX: flexion; CON: concentric mode; ECC: eccentric mode. Results are reported as mean between the two legs in %.

	Mode	CON	CON 60	CON	CON	CON	CON	CON	ECC	ECC
	Vel °/s	30		120	180	240	270	360	60	240
Study nr.										
1			54			51				
4			52		57	62				
5			46	44	45	47		50		

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6		62												
8						50								
9			44.9				72						35.4	
10			50			50								
12			74											
13			49.5			57.8			58.1					
14			75								90			
15			59.6											
Mean			56,1			50,5	52							
St.D.			±11,29			±4,93	±16,6							

Table 3. Dominant/Non dominant leg differences. EXT: extension; FLEX: flexion: CON: concentric; ECC: eccentric. E: expert players; R: recreational players. Results are reported as %.

Study nr.	Mode	EXT CON	EXT CON	EXT CON	EXT CON	EXT CON	FLEX CON	FLEX CON	FLEX CON	FLEX CON	EXT ECC	EXT ECC	EXT ECC	FLEX ECC
	Vel.°/s	60	180	240	270	300	60	180	240	300	60	180	270	60
2		9.5					10.9				9.9			13.05
3		7.8	6.4											
4		5.6	3	3.6			8.2	6	6.5					
7			4.65 (E) 0,5 (R)			-1.27 (E) -1.5 (R)		2.45 (E) 2.2 (R)		5.69 (E) 5.63 (R)				
10		3.5	3.2											
11		-1.1	-0.3	-1.1			0.5	2.1	-3.4					
12		-2.1					1.9							

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13	1.7	8	5.3	14.9	6.6	9.7	

Comparability of different isokinetic systems.

Few studies exist on the comparability of measurement between isokinetic systems. Mostly of the available literature compares two isokinetic systems and no study on comparison of several machines exist. A first observation can be made about the heter-ogeneity of the isokinetic machine that has been used. In fact, several different isokinetic systems were used. 8 out of 16 studies used a Biodex machine, followed by Cybex (3 studies) while Kin Com, Lido, Rev9000, Humac, Contrex and Isomed were employed in 1 study each. This heterogeneity makes absolute normative data difficult to summarize. Especially hamstring muscles testing showed a poor reliability of measurement and especially in female's athlete [11]. In fact, for CON testing r was reported an ICC of 0.964 for EXT peak torque at 60°/sec on the Kin Com dynamometer [26], while on the Cybex 6000 was 0.84 [43]. One study compared Kin Com and Lido isokinetic machine and found no difference in muscle strength (Nm) between the Biodex and Lido for CON FLEX and CON EXT [43]. Isomed system was used in one study [4], and no ICC is available.

Modalities of Contraction and Velocities

The isokinetic variables were collected mostly in Concentric (CON) mode, and less frequently in Eccentric (ECC) mode. We can hypothesize the reason for the preference of CON testing is because ECC reliability of the eccentric test is low [44], especially at the speed of 60°/sec, and eccentric contraction can be risky for the knee safety. Even at low contraction speed (60°/sec) isokinetic eccentric testing has been shown to have poor re-liability [28].

An important point is, the reliability of concentric test decrease with the increase of the speed because of the shortening of the "pure" isokinetic range of motion, due to the acceleration and deceleratio [14]. The chosen test speeds in the reviewed papers, ranged from 30° to 300°/sec. Albeit some evidence in the literature suggest not to use speeds above 180°/sec because of limb acceleration and deceleration time, which reduce the true isokinetic phase [41], speeds above this limit were used in 12 studies of 16.

Left-Right Limb Differences

The differences between left and right limbs, which normally increase with increasing speeds, ranges from -1.7 % to 9.7 at 60°/sec up to 14.9% at 270°/sec in concentric leg extension and from 2% up to 8% in concentric knee flexion.

Dominant/Non Dominant Limb Ratio

Dominant (D) and Non-Dominant (ND) limb (D/ND) and Hamstring to Quadriceps (H/Q) ratio were calculated mostly using Peak Torque (PT, e.g the maximum torque registered along the range of motion), one paper measured peak power (W) and mean work (MW). 12 of 16 studies didn't report how they selected the Dominant limb, while the others selected the kicking limb as Dominant. Thus, limb dominance (laterality) must be carefully assessed before isokinetic testing. 3 to 5 repetitions at slower speed (60°/sec) were measured, while at higher velocities 10 (180°sec) to 25 (300°/sec) repetitions were measured. Range of motion was in all cases 90° (from full knee extension to 90°of knee flexion).

Three studies [4,36,49] show a small negative D/ND ratio. This fact can be ex-plained by the presence of left sided players in the examined sample.

Normalized values for kg of body weight were used only in two studies where young elite players presented a lower difference between D/ND leg [12,30]. One study found a small D/ND non-significant differences between under 17 and senior elite player in CON EXT (2.04 Nm/kg vs 2.10 Nm/kg) and 2.82 Nm/kg vs 2.06 Nm/kg, while a significant in CON FLEX difference was found at 60°/sec [17]. Professional players show small D/ND differences on the velocity's spectrum of

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60,180,240°/sec, with higher differences in the extensor muscles [43]. Healthy professional female players show a difference of 13% in EXT ECC at 60 ° and of 10% in CON EXT strength [22].

Hamstrings to Quadriceps Ratio

H/Q ratio varies between 44.9% at 60°sec (except for one study which found a 75% ratio - uncompensated for gravity) to 72% at 300°/sec [12].

Very young (11-14 y.o.), elite soccer players, were found to have a H/Q ratio of 50% [7]. Olympic soccer players showed a H/Q ratio of 54% at 60°/sec and of 72% at 300°/sec [2]. Three large studies in collegiate (196, and 138, and 101 players) reported an H/Q ratio of 59.6% and of 62% at 60°/sec [24,38] and a D/ND ratio of 7,8% and 6.46 % [45]. These H/Q values are higher than those found in another study in professional players which show a ratio of 44.9% at 60°/sec [35] and in collegiate who shows H/Q values at 60 °/sec equal to 49.5%, 54% and 46% [15,39,46], middle way between Professional and young players.

Discussion

H/Q Ratio

Our objectives were to provide the available data on functional evaluation of female soccer players of different level of qualification. In our review, we found that there is a wide variation in the H/Q and N/ND ratio. H/Q at 60° sec is almost stable at around 50% through the literature and it is lower for young and recreational athletes. Professional athletes showed higher H/Q ratio. This result is explained with the higher quadriceps strength of professional players. At higher speeds the H/Q values vary considerably among the different studies, and this is an index of lower reliability of the isokinetic test also at relatively fast speeds (120° and 180° /sec).

Dominant/Non Dominant Limb Ratio

The N/ND in healthy females' soccer players is quite small and below 10%. These can be reference values for healthy female soccer players. We found some negative N/ND mean ratio in CON EXT and CON FLEX which is probably determined to the non-coincidence of Left and Right with ND and D leg. ECC values for knee EXT also increase with the speed and this is explainable with the difficulty to control high eccentric speeds which are less reliable. As isokinetic testing is often assumed as the "golden standard" in knee strength evaluation, it quite surprising the lack of information on the used protocols. Also, the warmup procedure before isokinetic tests differed widely (when described) and sometimes were not reported. The protocols were sometimes poor described (e.g no rest time between series were reported, and no previous training schedule of athletes or menstrual cycle phase at the time of test were reported). These observations agree with a recent study [3], which critically evidenced that, considering the available evidence, it need more investigations and an improving in standardization of methodology and analysis to optimize interpretation (e.g., within session and between session), adoption, and implementation of interlimb asymmetry testing, and subsequent appropriate interventions [3]. The same study also calls for a greater methodological rigor, to be applied in study design, data analysis, and interpretation of isokinetic (and other tests for asymmetry) and when reviewing the current literature.

Isokinetic testing is widely used in soccer, albeit few studies are available in females. Thus, a limitation of our review is inherent to the topic, in fact, also in this field, females research is underrepresented, and few papers are available. This paucity of information about isokinetic muscular performance in females, is explainable with social factors (e.g., less economic interests in female soccer players). In addition, the available literature used different isokinetic devices, different protocols of testing (speeds and number of repeti-tions, recovery) and the rationale for the choice of speeds are not reported. Also, in several studies how the dominant leg was chosen is unclear. There are some constants which emerge from the literature that can be summarized and can be useful for the practice and interpretation of isokinetic testing in females' soccer players.

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Conclusions

We can conclude, that for clinical practice, an isokinetic test for the female soccer athletes at 60°/sec in concentric mode for EXT and FLEX is the most reliable, employing 3 reps. H/Q should be 50% (a little bit less for young athletes), while the N/ND in healthy female soccer players should be less than 10%. Several papers for research purposes employed high velocities, but previous literature shows they are less reliable and do not add further information to the 60°/sec test. A recommendation that can be drawn from this review, is to increase the hamstring strength in professional players. These results can help establish milestones in the functional isokinetic evaluation of the knee machine in healthy female soccer players.

Author Contributions: Cheng Zhan: conception of the study, data gathering and writing, data gathering and analysis, Antonio Cicchella, conception of the study, analysis, and writing. All authors read and approved the final version of the manuscript and approved the manuscript in full.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board (or Ethics Committee) of Tongji University (approval code: tjdxsr029 22/12/2022

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data are kept by the corresponding author for privacy reasons and will be given upon request.

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Conflicts of Interest: Authors declare no conflict of interest.

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