

Do You Have Any Correlations Between Multidirectional Single Leg Hop Tests And Isokinetic Knee Strength In Athletes?: A Control Study On Dominant And Nondominant Sides

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Abstract

The aim of this study is to examine the correlations between multi directional single leg hop tests (SLHTs) and isokinetic knee strength tests in elite athletes. The study consists of 20 elite male athletes from different branches who were between the ages of 18 and 30. Isokinetic extension (Ex) and flexion (Flx) knee strength tests at different angular velocities (60° 180° and 240°/sec.) and five different SLHTs single hop (SL), triple hop (THD), crossover hop (CHD), medial side triple (MSTH) and 90o medial rotation (MRH) were applied on dominant (DS) and non-dominant (NDS) sides. Paired sample t, One Way ANOVA, Tukey and Pearson tests were used in the statistical analyses of the study. When knee strengths between DS and NDS were compared, significant differences were found at 60°/sec. Ex and Flx and 240°/sec. ex phases in favor of DS (p<0,05). No significance was found when isokinetic tests and limb symmetry index (LSI) obtained from SLHTs were compared (p>0,05). Negative correlations were found between SLHTs and isokinetic tests (p<0,05). It was found that weight and body mass index (BMI) had positive correlations with isokinetic tests and negative correlations with SLHTs (p<0.05). Although our revealed showed that DS and NDS showed strength differences in different measurement methods, both test groups gave reliable results in terms of LSIs. However, expected positive correlations were not found between isokinetic tests and SLHTs, this is thought to be due to the result that weight and BMI had positive correlations with isokinetic tests and negative correlations with SLHTs.

Keywords: Single Leg Hop Tests, Isokinetic Knee Strength, Limb Symmetry, Athletes.

INTRODUCTION

In addition to being one of the main neuromuscular variables in the evaluation of performance, lower extremity muscle strength in athletes is of great importance in terms of evaluating injury trends, rehabilitation processes, and the effects of specific training models. [1–4] Low extremity strength, which can be evaluated with different measurement methods, is most commonly evaluated with isokinetic dynamometers and single hop tests (SLHTs). [5–8]

Isokinetic dynamometers are computer-based and high cost systems that require expertise for implementation and evaluations. Although these devices, which allow for the comparison of strength values of dominant (DS) and non-dominant (NDS) extremities and agonist and antagonist muscle groups, provide objective data, their constant speed and single joint application is an important limitation in terms of functionality. [9–13] On the other hand, SLHTs are of great importance in the evaluation of functional status with the detection of asymmetries between the extremities in terms of requiring minimum equipment and less time, being easily applicable, not requiring expertise and most importantly in terms of functionally conforming to movement forms during daily life and sports activities. [7,8,14]

While SLHTs allow for a more integrated evaluation of movement forms compared to isokinetic measurements, conventional tests mainly consist of straight and forward movements. The fact that SLHTs are generally applied in forward direction although movements are performed multi directionally during sportive performance is stated as a limitation in terms of the functionality of these tests. [15–19]

For a better analysis of lower extremity strength and functional structure, in addition to forward SLHTs, there are different jump tests developed for multidirectional and fast moving. Although there are studies in literature evaluating isokinetic tests and forward SLHTs together on healthy and injured sample groups, there are limited number of studies researching medial and

lateral SLHTs. [20] Evaluation of both forward and multi-directional SLHTs together revealed the thought that the results in terms of main structure and functionality of the movement could be healthier and more objective. As a matter of fact, researchers reported increased lower extremity asymmetry during side jump compared to forward SLHTs and they also reported that medial and lateral hop tests evaluated with forward SLHTs could lead to satisfactory extremity symmetry in the evaluation of patients with reconstructed lower extremity injuries such as anterior cruciate ligament (ACL). [21–23] Therefore, inclusion of multi directional jump tests in the process of deciding to return to sports after ACL reconstruction has been suggested to detect limb asymmetries. [16]

The present study aims to examine the relationships between isokinetic tests and forward and medial SLHTs in elite athletes and to show the similarities and differences between the two test groups. This study will contribute to literature since it is one of the first studies to evaluate both forward and medial SLHTs. The hypothesis of our study is that there will be significant associations between isokinetic tests and conventional SLHTs and jump tests applied in different directions in healthy athletes.

METHODS

Experimental Design and Participants

This study has randomized crossover experimental design. In line with this design, the subjects visited the laboratory four times at 24-hour intervals. At the first visit, the subjects' height, weight and BMI measurements were taken, application protocols and tests were introduced and familiarization measurements were made. At the subsequent visits, the subjects were randomized with application cards and the measurements were completed by applying any of the three different applications. The tests applied are as follows:

1. Single leg hop for distance (SL) + Triple hop for distance (THD)
2. Crossover hop for distance (CHD) + Medial side triple hop for distance (MSTH) + 90° Medial rotation hop for distance (MRH)
3. Isokinetic knee Extension (Ex) and Flexion (Flx) strength measurement at 60°, 180° and 240° angular velocities.

The dominant leg of all subjects was determined as the right side and all tests were performed on dominant side (DS) and non-dominant side (NDS). Before tests, the subjects warmed up for lower extremity muscles. [24] The applications were carried out at the same time of the day (14.00-16.00) and the subjects were warned not to do any physical activity or exercise during the applications. The study was carried out in accordance with the Declaration of Helsinki. Approval was taken from Ondokuz Mayıs University Clinical Researches Ethics Committee for the study (OMU KAİK 2021/122).

20 male athletes (average age 23,37 years, average height 183,58 cm, average weight 82,53 kg and average BMI 24,50 kg/m²) between the ages of 18 and 30 from different branches who had at least 5 years of active sports history and who trained regularly participated in the study. All subjects completed informed consent forms.

Table 1: Descriptive data of subjects (at column width)

	Mean	SD	Min.	Max.
Age (year)	23,37	3,68	19,00	30,00
Height (cm)	183,58	7,94	170,00	200,00
Weight (kg)	82,53	13,04	63,00	108,00
BMI (kg/m²)	24,50	3,86	18,02	37,37
Training Age (year)	12,00	4,63	5,00	20,00

SD: Standart deviation; Min: Minimum; Max: Maxiumum; BMI: Body mass index

Procedures

Single Leg Hop Tests

In SLHTs, the application area was created by determining the 5 cm wide lines and 30 cm long starting line and the 6 m long jumping line extending vertically from the middle of this line (Figure 1). The subjects performed hop tests as three repetitions at 2 minute intervals. The best value between the three tests was recorded in centimeter. The subjects were allowed to use arm and leg movements on one leg before and during movement. Success criterion in the tests was determined as 3 seconds of

stability by landing with full stabilization on one leg.

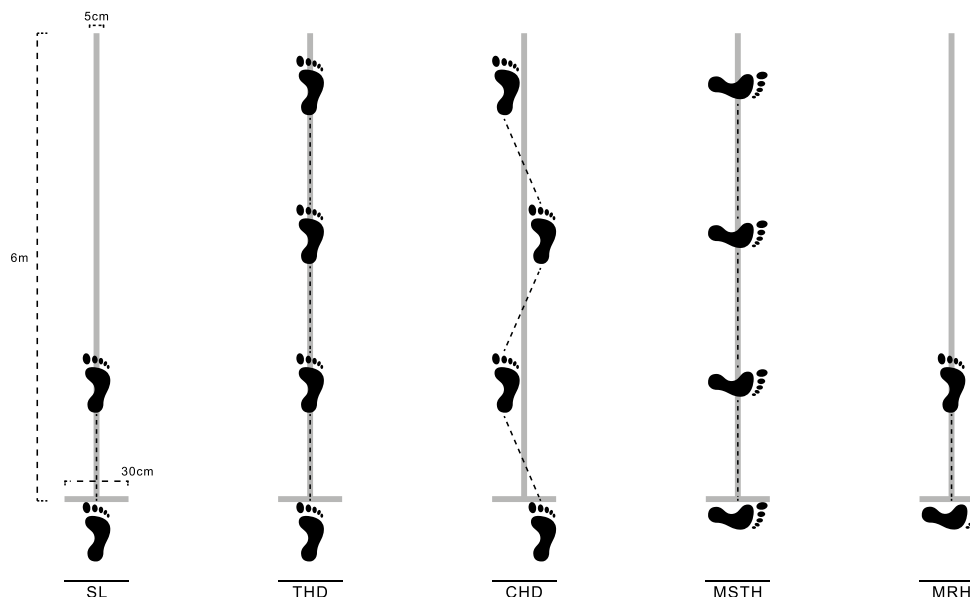


Figure 1: SLHTs Applications (at column width)

In SL and THD tests, the subjects stood on one leg with their toes in the middle of the starting line and on the boundary of the line. In SL, the subjects were asked to perform the best possible forward step on one leg, while in THD, they were asked to perform the best possible successive three-step jump. The subjects were asked to complete their jumps on one leg on the line determined in the forward direction and asked to wait for three seconds in this position. After the subject completed the tests successfully, the distance between the heel level and the starting line was measured and recorded in cm.

In CHD test, the subjects stood one foot, close to the direction of the foot they stood on the starting line (right, left) and with their toe tips on the border of the line. The subjects were asked to perform the best possible successive three-step jump with forward cross steps on one leg. The subjects were asked to complete their jumps by continuing on one leg without touching the line determined in the forward direction and to wait for 3 seconds in this position after the third jump. The subjects were warned to move as close to the line as possible in order to cover the best forward distance in diagonal steps. After the subject's successful completion of the test, the distance between the heel level and the starting line was measured parallel to the jump direction and recorded in cm.

In MSTH test, the subjects stood on one foot in the middle of the starting line and medial parts of their feet on the border of the line. The subjects were asked to perform the best possible successive three-step jump in medial direction on one leg when they were ready. The subjects were asked to complete their jumps by continuing on one leg in the line determined in medial direction and to wait for three seconds in this position after the third step. After the subject completed the tests successfully, the distance between the foot medial level and the starting line was measured and recorded in cm.

In MRH test, the subjects stood on one foot in the middle of the starting line and medial parts of their feet on the border of the line. The subjects were asked to complete the movement by performing a right angle medial rotation with the best possible one-step jump in the medial direction on one leg. The subjects completed their jump on one leg on the line determined in forward direction and they were made to wait for three seconds in this position. The subjects were warned that the right angle medial rotation had to be performed from the moment contact with the ground was lost. After the subject completed the tests successfully, the distance between the heel level and the starting line was measured and recorded in cm.

Isokinetic Knee Strength

Humac Norm (CSMI, USA) computer controlled isokinetic dynamometer was used to determine isokinetic knee Ex and Flx knee strength. The subjects were prepared with general warm-up protocol before tests. Before the tests, seat, adapter, and other adjustments of the dynamometer were completed by taking the fixed protocol for the measurement of knee Ex and Flx measurements as reference. The subjects' knee joint range of motion (ROM) was position in the range of 0-90° and the chair back support was adjusted to provide 85° hip joint angle (0°=full Ex). Dynamometer arm centre of rotation was determined as the level of lateral femoral epicondyle and fixed in the proximal of the lateral malleus of the lower leg attachment. In order to stabilize the trunk and thighs, the belts in the regions were tightened and the subjects were able to grasp the hand grips on the sides of the seat throughout the test. Stabilization was achieved by placing the ankle on the non-measured extremity to the

stabilizer located on the armpit. In order to exclude the gravitational effect from the evaluation, before the test, the torque value produced freely by the knee joint in 90° Ex was determined in all subjects and it was ensured that the data obtained after the measurements were only strength-specific torque values.

Isokinetic knee Ex and Flx strengths of the subjects were determined by adjusting fixed protocol performed with concentric/concentric (Con/Con) contractions at 60°/sec (4 repetitions of trial, 15 sec rest, 5 repetitions of test), 180°/sec (4 repetitions of trial, 15 sec rest, 5 repetitions of test) and 240°/sec (4 repetitions of trial, 15 sec rest, 15 repetitions of test) angular velocities. 30 seconds of rest intervals were given between angular velocities. In order to obtain the best results in tests, the subjects were supported orally to increase motivation during the measurements. Peak torque (PT) values obtained as a result of measurements were recorded in Newton meter (Nm).

Statistical Analyses

SPSS 25.0 package program was used in the statistical analysis of our study. Shapiro Wilk test was used to examine whether the data were normally distributed and it was found that the data were normally distributed. Homogeneity tests were conducted by using Levene test and the variances were found to be homogeneous. Paired sample t test was used to compare paired groups, while One Way ANOVA test was used to compare three or more groups. Multiple comparisons were made with Tukey test. Pearson correlation analysis was used to find out the correlations between the variables. In the comparison of paired groups, effect sizes were found according to Cohen's d effect size $(M2 - M1)/SD$ pooled). According to this formula, $d < 0.2$ was defined as weak effect size, while $d = 0.5$ was defined as moderate and $d > 0.8$ was defined as strong effect size. The data were presented as mean and standard deviation and analyzed at $p < 0,05$ level of significance.

RESULTS

Comparative isokinetic and SLHTs results of the subjects are presented in Figure 2. In isokinetic tests, statistical significance was found in 60°/sec Ex ($p=0,002$, %95 CI=6,77-26,81), 240°/sec Ex ($p=0,002$, %95 CI=6,77-26,81) and 60°/sec Flx ($p=0,002$, %95CI=6,77-26,81) values. However, no significance was found in 180°/sec Ex, 180°/sec and 240°/sec Flx values and all of the SLHTs ($p > 0,05$).

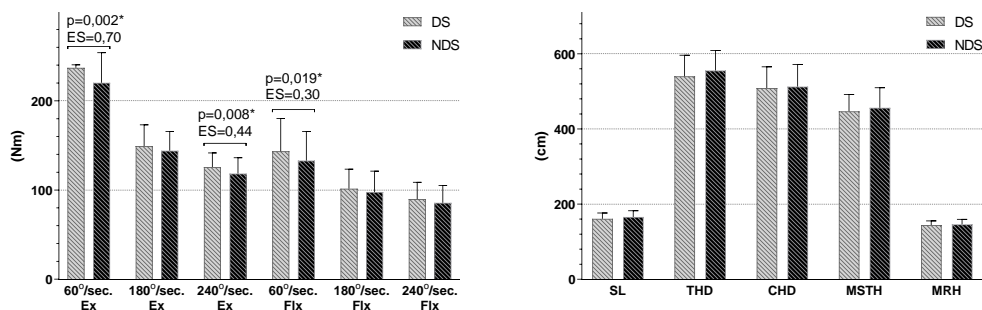


Figure 2: Comparisons of isokinetic knee strength and SLHTs with DS and NDS (at column width)

Figure 3. compares the strength values of subjects on DS and NDS and the predetermined H/Q ratios and Q/Q and H/H ratios. When the results are evaluated, no statistical significance was found at all of the angular velocities ($p > 0,05$).

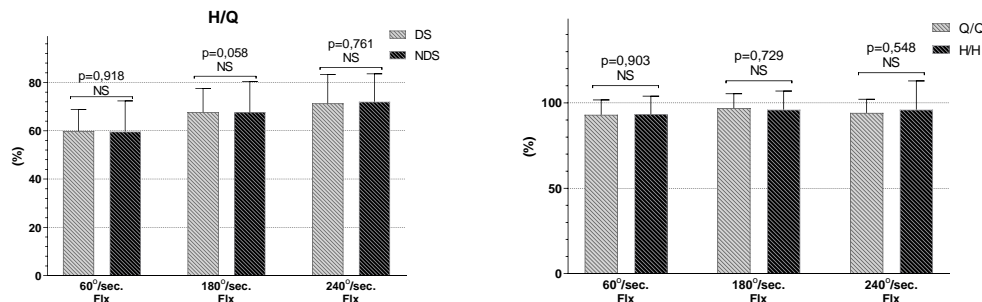


Figure 3: Comparison of H/Q ratios and Q/Q and H/H ratios of subjects on DS and NDS sides (at column width)

Table 2. shows the asymmetry rates by comparing the strength values of the subjects on DS and NDS found by isokinetic tests and SLHTs. When the results are evaluated, no statistical significance was found in isokinetic tests and SLHTs ($p > 0,05$).

Table 2: Comparison of LSIs revealed by subjects in isokinetic tests and SLHTs (at column width)

Variable (%)	Mean ± SD	%95 CI		Min.	Max.	F	p
		LB	UB				
SL	97,35±6,81	94,16	100,54	89,00	117,00		
THD	97,65±5,87	94,90	100,40	89,00	110,00		
CHD	99,80±7,55	96,27	103,33	86,00	120,00		
MSTH	98,60±7,08	95,29	101,91	87,00	111,00		
MRH	99,75±7,18	96,39	103,11	84,00	115,00		
60°/sec. Q/Q	93,00±8,72	88,78	96,72	76,00	104,00	1,352	0,205
60°/sec. H/H	93,37±10,52	87,96	97,84	75,00	116,00		
180°/sec. Q/Q	96,91±8,43	91,44	100,36	76,00	117,00		
180°/sec. H/H	96,05±10,87	91,43	101,47	77,00	116,00		
240°/sec. Q/Q	94,13±8,01	90,72	97,98	78,00	112,00		
240°/sec. H/H	96,07±16,73	89,28	105,32	76,00	134,00		

SD: Standart deviation; LB: Lower bound; UB: Upper bound; Min: Minimum; Max: Maximum; SL: Single leg hop test; THD: Triple hop for distance; CHD: Crossover hop for distance; MSTH: Medial side triple hop for distance; MRH: 90° Medial rotation hop for distance; Q/Q: Quadriceps/quadriceps; H/H: Hamstring/hamstring

Table 3. shows the analysis of the correlations between isokinetic tests applied on the DS of the subjects and SLHTs. According to analysis results, it was found that isokinetic tests had high and moderate level of positive correlation among one another at all angular velocities ($p < 0,01$, $p < 0,05$). Moderate and negative correlations were found between SL test and 60°/sec Ex ($r = -0,598$), 60°/sec Flx ($r = -0,544$) and 240°/sec Flx ($r = -0,499$) tests, while moderate and positive correlations were found between SL test and THD ($r = 0,682$) and MSTH ($r = 0,564$) tests ($p < 0,01$, $p < 0,05$). Moderate positive correlations were found between THD test and CHD ($r = 0,750$) test, while high positive correlations were found between THD test and MSTH ($r = 0,839$) test ($p < 0,01$). Moderate high positive correlation was found between CHD test and MSTH ($r = 0,739$) test ($p < 0,01$).

Table 3: Correlations between isokinetic tests applied to the DS side and SLHTs values (at full page width)

60°/sec. Flx	<i>r</i>	,925**									
180°/sec. Ex	<i>r</i>	,725**	,630**								
180°/sec. Flx	<i>r</i>	,797**	,864**	,755**							
240°/sec. Ex	<i>r</i>	,643**	,522*	,939**	,686**						
240°/sec. Flx	<i>r</i>	,845**	,900**	,729**	,892**	,611**					
SL	<i>r</i>	-,598**	-,544*	-,364	-,324	-,243	-,499*				
THD	<i>r</i>	-,211	-,239	-,029	,038	,170	-,225	,682**			
CHD	<i>r</i>	-,049	-,077	-,077	,051	,098	-,038	,424	,750**		
MSTH	<i>r</i>	-,143	-,153	,098	,135	,220	-,101	,564*	,839**	,739**	
MRH	<i>r</i>	-,376	-,197	-,049	,054	-,045	-,071	,455	,250	,161	,322
		60°/sec. Ex	60°/sec. Flx	180°/sec. Ex	180°/sec. Flx	240°/sec. Ex	240°/sec. Flx	SL	THD	CHD	MSTH

Flx: Flexion; Ex: Extension; SL: Single leg hop test; THD: Triple hop for distance; CHD: Crossover hop for distance; MSTH: Medial side triple hop for distance; MRH: 90° Medial rotation hop for distance

*Statistically significant differences (P≤ 0.05).

**Statistically significant differences (P≤ 0.01).

Table 4 shows the evaluation of the correlation between isokinetic tests applied to subjects' NDS and SLHTs with Pearson correlation tests. According to the analysis results, it was found that isokinetic tests had high and moderate level of positive correlation among one another at all angular velocities (p<0,01, p<0,05). Moderate and negative correlations were found between SL test and 60°/sec Ex (r=-0,482) test, while moderate and positive correlations were found between SL test and THD (r=0,616), CHD (r=0,732) and MSTH (r=0,541) tests (p<0,01, p<0,05). Moderate positive correlations were found between THD test and CHD (r=0,749) test, while high positive correlations were found between THD test and MSTH (r=0,856) test (p<0,01). Moderate positive correlation was found between CHD test and MSTH (r=0,736) test (p<0,01).

Table 4: Correlations between isokinetic tests applied to the NDS side and SLHTs values (at full page width)

60°/sec. Flx	<i>r</i>	,593**									
180°/sec. Ex	<i>r</i>	,490*	,577**								
180°/sec. Flx	<i>r</i>	,627**	,941**	,682**							
240°/sec. Ex	<i>r</i>	,484*	,635**	,815**	,761**						
240°/sec. Flx	<i>r</i>	,562*	,902**	,521*	,944**	,726**					
SL	<i>r</i>	-,482*	-,361	-,270	-,335	-,053	-,232				
THD	<i>r</i>	-,216	-,259	,003	-,133	,201	-,006	,616**			
CHD	<i>r</i>	-,289	-,424	-,231	-,338	-,051	-,210	,732**	,749**		
MSTH	<i>r</i>	-,195	-,151	,150	-,021	,284	,083	,541*	,856**	,736**	
MRH	<i>r</i>	-,285	-,077	-,314	-,175	-,198	,059	-,010	,199	,189	,198
		60°/sec. Ex	60°/sec. Flx	180°/sec. Ex	180°/sec. Flx	240°/sec. Ex	240°/sec. Flx	SL	THD	CHD	MSTH

Flx: Flexion; Ex: Extension; SL: Single leg hop test; THD: Triple hop for distance; CHD: Crossover hop for distance; MSTH: Medial side triple hop for distance; MRH: 90° Medial rotation hop for distance

*Statistically significant differences (P≤ 0.05).

**Statistically significant differences (P≤ 0.01).

Table 5 shows the analysis of the correlations between subjects' descriptive data and the data obtained from isokinetic tests applied on the DS and SLHTs. According to correlation analysis results obtained, moderate and positive correlations were found between the subjects' weights and isokinetic tests applied on the DS, while moderate and negative correlations were found between the subjects' weights and SL test (p<0,01, p<0,05). When the correlations between subjects' BMI values and the test results applied on DS were examined, moderate and positive correlations were found between BMI values and 60°/sec. Ex and Flx test, while moderate and negative correlations were found between BMI values and SL, THD and MRH tests (p<0,01, p<0,05).

Table 5: Correlations between subjects' descriptive data and DS knee strengths (at full page width)

		60°/sn. Ex	60°/sn. Flx	180°/sn. Ex	180°/sn. Flx	240°/sn. Ex	240°/sn. Flx	SL	THD	CHD	MSTH	MRH
Age	<i>r</i>	,047	-,011	,298	-,011	,173	,105	-,231	-,274	-,263	-,257	-,160
	<i>p</i>	,849	,966	,216	,964	,478	,668	,342	,257	,276	,288	,514
Height	<i>r</i>	,224	,187	,372	,393	,385	,166	,045	,123	-,111	,182	,169
	<i>p</i>	,357	,443	,117	,096	,104	,497	,854	,617	,650	,456	,490

Weight	r	,621**	,528*	,574*	,359	,492*	,472*	-,535*	-,375	-,274	-,250	-,399
	p	,005	,020	,010	,131	,032	,041	,018	,113	,257	,302	,091
BMI	r	,540*	,463*	,373	,138	,278	,407	-,608**	-,472*	-,230	-,392	-,526*
	p	,017	,046	,116	,574	,249	,083	,006	,042	,343	,097	,021

BMI: Body mass index; Flx: Flexion; Ex: Extension; SL: Single leg hop test; THD: Triple hop for distance; CHD: Crossover hop for distance; MSTH: Medial side triple hop for distance; MRH: 90° Medial rotation hop for distance

*Statistically significant differences (P≤ 0.05).

**Statistically significant differences (P≤ 0.01).

Table 6 shows the analysis of the correlations between subjects' descriptive data and the data obtained from isokinetic tests applied on the NDS and SLHTs. According to correlation analysis results obtained, moderate and positive correlations were found between the subjects' weights and 60°/sec. Ex and 180°/sec. Ex test tests applied on the NDS, while moderate and negative correlations were found between the subjects' weights and SL, THD and CHD tests (p<0,01, p<0,05). When the correlations between subjects' BMI values and the test results applied on NDS were examined, moderate and positive correlations were found between BMI values and 60°/sec. Ex test, while moderate and negative correlations were found between BMI values and SL, THD, CHD and MSTH test (p<0,01, p<0,05).

Table 6: Correlations between subjects' descriptive data and NDS knee strengths (at full page width)

		60°/sn. Ex	60°/sn. Flx	180°/sn. Ex	180°/sn. Flx	240°/sn. Ex	240°/sn. Flx	SL	THD	CHD	MSTH	MRH
Age	r	-,039	-,163	,126	-,192	-,349	-,396	-,268	-,149	-,070	-,048	-,215
	p	,873	,506	,608	,430	,143	,093	,268	,542	,775	,845	,377
Height	r	,011	,379	,478*	,357	,373	,369	-,124	,074	-,177	,325	,255
	p	,965	,109	,038	,133	,116	,120	,612	,764	,469	,175	,292
Weight	r	,524*	,411	,517*	,412	,215	,264	-,670**	-,522*	-,566*	-,253	-,259
	p	,021	,080	,023	,079	,377	,275	,002	,022	,012	,295	,285
BMI	r	,589**	,220	,261	,237	,023	,076	-,669**	-,596**	-,525*	-,487*	-,435
	p	,008	,367	,281	,329	,925	,756	,002	,007	,021	,034	,063

BMI: Body mass index; Flx: Flexion; Ex: Extension; SL: Single leg hop test; THD: Triple hop for distance; CHD: Crossover hop for distance; MSTH: Medial side triple hop for distance; MRH: 90° Medial rotation hop for distance

*Statistically significant differences (P≤ 0.05).

**Statistically significant differences (P≤ 0.01).

DISCUSSION

Isokinetic tests and SLHTs, which are commonly preferred in the evaluation of lower extremity muscle strength, provide important data about strength differences between extremities and disability tendencies. [4,25] In fact, bilateral and ipsilateral strength ratios obtained from isokinetic tests and LSIs obtained from both SLHTs and isokinetic tests are considered as possible screening tools for the risk of disability. [26–28]

Our study showed different major results. These results were significant difference between DS and NDS in 60°/sec. Ex and Flx, 240°/sec. Ex phases of isokinetic tests in favour of DS, and the result that there was no significance in all SLHTs. In terms of strength, while significant differences was found between DS and NDS in isokinetic tests, bilateral (Q/Q and H/H), ipsilateral H/Q and LSIs were within statistically similar and reliable (100%±15) ranges. Different levels of negative and positive correlations were also found between isokinetic tests and SLHTs.

Studies conducted in athletic population found different results between DS and NDS at 60°, 180° and 240°/sec angular velocities. Different studies conducted on judo, jumping, athleticism and sedentary groups reported that only in sedentary group DS had higher strength than NDS, as in the present study. [29–31] Unlike the present study, studies conducted on tennis, volleyball, futsal, football and triathlon athletes showed different levels of significance in the comparison of both strength and

bilateral asymmetry rates. [32,33] Results found in different studies conducted showed that there will not be differences in combat sports such as judo in which balance and body stabilization are at the forefront or in sports where both extremities are expected to develop at the same rate such as athleticism; while on the contrary, lower extremity, which can show a dominant structure in branches such as football, volleyball, basketball and tennis, may have higher strength ratios on DS.

In isokinetic tests, the term asymmetry refers not only to unequal bilateral torque values, but also to the balance between torque ratios of agonist and antagonist ipsilateral muscle groups [34] and it is stated that these ratios are valid tools to evaluate the effectiveness of rehabilitation protocols. [35–38] In these evaluations, researchers make use of not only ipsilateral H/Q ratios, but also of ratios such as bilateral Q/Q and H/H. Low values of concentric H/Q ratios have been associated with higher risk of injury. [39] Typical H/Q ratio of a healthy knee varies between 50% and 80% depending on the knee angle and angular velocity. [40] This ratio is considered normal as 60-65% for 60°/sec. angular velocity and it was found to increase as angular velocity increased. [41,42] The results of the present study also showed increase in H/Q ratios at both DS and NDS as angular velocity increased, as stated in literature and ratios between 50 and 80% were found. These results showed that the subjects in our study had H/Q ratios within normal ranges. Although strength differences were found on DS and NDS in isokinetic measurements performed on healthy athletes with different branches, H/Q ratios were found to be within normal ranges at all angular velocities. [40,43] Studies conducted have reported that especially soccer players have higher H/Q ratios when compared with other branches. [1,44,45] Higher H/Q ratios in soccer players brought to mind the idea that higher number of specific rates in Ex phase in soccer, where lower extremity strength is one of the main factors, may be reflected in ipsilateral and even bilateral ratios depending on the extra development in Q muscle. We could not make comparisons between branches because there were few subjects in our study and these subjects were from different branches, which was one of the main limitations of our study.

SLHTs, which are frequently used together with isokinetic evaluations, allow realistic interpretations of the results between both extremities because they are similar to the forms of movement performed during physical activity in terms of muscle contraction and functionality. [46,47] In addition, these tests are tests the validity and reliability of which have been proven, just like isokinetic tests. [14,48,49] The present study found that mean LSI ratio obtained from five different SLHTs was 98.63%. Similar to the results of our study, these rates were reported as between 90 and 100% in studies conducted on healthy subjects or athletes. [8,50] However, these studies focused on forward and vertical SLHTs and did not use medial tests. Literature results have shown that medial SLHTs report higher lower extremity asymmetry when compared with forward SLHTs. [21–23,51,52] Similar to the results of our study, Dingenen et al. (2019) found mean LSI as 100,65% in a study they examined asymmetry rates in healthy athletes on whom they applied SL, THD, MSTH and MRH tests. [20] Although studies conducted on athletes from different branches showed different results in jump distance, LSI values were found to be within normal ranges (90-100%). [51,53] These results show that asymmetry can be considered normal to a certain extent in athletes who have not had injuries, while LSI ratios of athletes may become more prominent in the medial and lateral SLHT tests of athletes when compared with forward SLHTs. It has also been reported that medial SLHTs activate hip abductor and rotator muscles more and these muscles which contribute to the production of knee strength have influences on knee strength asymmetry. [54] With these aspects, the present study conducted on healthy athletes is unique in terms of performing both forward and medial SLHTs and it has results that support literature findings for both test groups.

The relationship between isokinetic tests and SLHTs has attracted the attention of researchers. Studies conducted on athletes with different branches have reported high and moderate significant correlations between isokinetic knee strengths and SLHTs. [27,55,56]

A large number of studies focused on specific branches and in general showed positive correlations in both test groups; however, it is thought that the reason why the correlations found in our study were not as we stated in our hypothesis is due to the fact that the subjects in the study consist of athletes doing sports which have different training and movement structures. In addition, while positive correlations were found between weight and BMI and isokinetic tests in our study, negative correlations were found with SLHTs. This result brought to mind the idea that our subject group with different branches caused inverse correlation between both test groups related to body weight and BMI. Studies conducted with higher number of subjects can associate SLHTs applied in different directions with different angular velocities in isokinetic tests and find out which SLHT is associated with which isokinetic angular velocity and contribute to making evaluations in a short time by performing branch-specific tests by saving time.

CONCLUSION

Although our study showed difference between DS and NDS in knee isokinetic strength at different angular velocities, these rates were similar in SLHTs. In addition, our study showed similar results in terms of bilateral, ipsilateral and LSI ratios. These results showed that both forward and medial SLHT tests produced similar results in healthy athletes. In our study, we did not find the significant results between isokinetic tests and SLHTs as we expected with our hypothesis. Future studies with specific

sports branches and higher number of subjects will show the relationship between forward and medial SLHTs and isokinetic tests at different angular velocities more clearly.

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