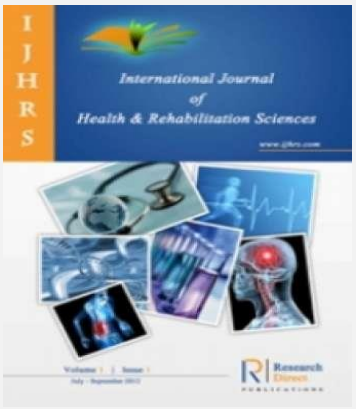

Relationship between Isokinetic Knee Strength Variables and Functional Performance testing

Sobhy M. Aly, Ayman G. Mattar, Ahmed S. Yamani

Sobhy M. Aly, Assistant Professor of biomechanics, Department of Biomechanics, Faculty of physical therapy, Cairo University

Ayman G. Mattar Lecturer of biomechanics, Department of Biomechanics, Faculty of physical therapy, Cairo University

Ahmed S. Yamani Lecturer of biomechanics, Department of Biomechanics, Faculty of physical therapy, Cairo University

Corresponding Author:
Sobhy M. Aly
E-mail:
drsobhymahmoud@gmail.com

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ABSTRACT

Background: Isokinetic is widely used for assessment of muscle performance and yields a wide range of variables. The correlation between isokinetic variables and functional performance needs to be investigated.

Purpose: To investigate the relationship between isokinetic measures of knee extensors and flexors and measures of one leg hop functional performance test in healthy subjects.

Methods: Thirty male subjects performed an isokinetic test at 60°/s and 180°/s and the four functional hop tests (single hop, timed hop, triple hop, and cross over hop). The isokinetic variables; peak torque, total work, and average power of knee extensors and flexors were correlated with the output of functional hop test.

Results: Correlation between knee extensors' and flexors' isokinetic variables and single hop, triple hop and cross-over hop were weak to moderate significant correlation; with knee extensors' average power at 180°/s showed highest correlation with cross over hop ($r = 0.69$. $p = 0.0001$). There was no significant correlation between the three isokinetic variables and timed hop test for knee extensors and flexors at both velocities. Total work and peak torque showed similar weak to moderate correlations with functional performance tests.

Conclusion: Low to moderate positive significant correlation exists between isokinetic peak, torque, total work, average power and hop functional performance test. The Higher correlation was between average power of knee extensors at 180°/s and cross over hop test. Average power is more correlated with functional performance than peak torque and total work and should be considered in the evaluation of muscle performance.

Key words: **Isokinetic, Power, Functional performance, Hop test**

INTRODUCTION

Functional performance depends on muscle force generation capacity [1]. Many daily living tasks as walking, stair climbing, and chair rising require force and power development around the knee joint [2]. Assessment of muscle strength is important to evaluate physical abilities, weakness related to aging or disease, and monitor the progress in training and rehabilitation [3]. Muscle strength is correlated with functional outcome of patients with anterior cruciate ligament (ACL) injury [4].

Isokinetic dynamometry becomes the golden standard method for strength assessment, as it allows exertion of maximal effort in a controlled environment [5], and is widely used in training, rehabilitation and evaluation of musculoskeletal function [6]. Isokinetic dynamometry provides many clinical variables such as peak torque, time to peak torque, total work, and power which can be measured at varying angles and velocities [7].

Researchers have developed various functional performance tests which mimic stresses on the knee joint that occurs during sports activities [8]. The one leg hop test, a common functional performance test, is used to assess knee function throughout rehabilitation [9], and has been utilized with high reliability in evaluating patients with ACL reconstruction [10]. Furthermore, the International Knee Documentation Committee (IKDC) recommended the single leg hop test as an assessment tool for knee function [11]. Although the hop test does not give a detailed analysis of the lower limb function similar to that obtained using more sophisticated devices, it allows a general lower limb evaluation in the clinical practice [12].

Isokinetic and functional performance tests are widely used and serve as critical components of a comprehensive physical therapy evaluation. Understanding the relationship between the isokinetic and functional performance tests increases the usefulness of the strength and functional performance measures as they relate to predicting functional outcome. To use the isokinetic data in evaluation-based protocols, relationships must be determined between the isokinetic measures and functional performance [13].

Peak torque is the most often studied strength parameter, however a previous study by Morrissey [14] suggested that total work may be a better indicator for muscle function than peak torque. Total work is the accumulated force generated across all range of motions and may be more reflective of knee function required during sports activity [7]. Also, knee power may better reflect the capacity of muscle to manage knee loads than peak torque. Knee power refers to the rate of torque development, it is the product of the torque and the velocity of movement [15]. Furthermore, power is a more robust predictor of functional outcomes than strength in the aging literature [2] and shows promise in understanding knee osteoarthritis pathology [16].

Previous research work investigated the correlation between isokinetic variables and functional performance focused on peak torque as absolute strength indicator. The results of previous studies were inconsistent and conflicting. Dauty et al. [17] found a moderate correlation between the vertical hop and the knee extensors' peak torque at 180°/s in non-injured soccer players. Low or no correlation was found between isokinetic torque of the knee extensors and several functional performance tests [18, 19]. Petschnig et al. [20] demonstrated moderate relationship between isokinetic knee extensors' peak torque and several lower extremity functional tests.

The purpose of this study was to investigate the relationship between measures of knee performance; isokinetic strength (peak torque, total work, average power) for knee extensors and flexors, and functional performance tests (single hop

test, timed hop, triple hop, cross-over hop) in healthy subjects. We intended to explore which isokinetic measures had a stronger correlation with functional performance.

METHODS AND MATERIALS

Participants

Thirty healthy male subjects volunteered to participate in this study with age ranged from 18 to 22 years were recruited from the Faculty of physical therapy, Cairo university, Egypt, for data collection in this study. All the participants were free from any musculoskeletal disorders and had no history of lower extremity injuries. Subjects were excluded if there was previous lower extremity injuries or deformities. Before data collection, all participants were given an explanation of the purpose and procedures of the study. This work is carried out in accordance with the code of ethics of the world medical association (Declaration of Helsinki) for experiments involving humans. All subjects signed a consent form prior to participation. Every subject was wearing a comfortable short, T-shirt, and appropriated shoe to perform the tests.

Instrumentation

Isokinetic dynamometer:

The isokinetic Biodex System 3 multi-joint system testing and rehabilitation (Biodex Medical System, Shirley, NY, USA) was used for collection of isokinetic data. Previous studies have demonstrated the reliability and validity of isokinetic devices for measuring muscle strength [21].

Procedures

All subjects participated in one session that consisted of both isokinetic testing and one leg hop for distance testing. Leg dominance was determined by asking the subjects which leg they would use to kick a soccer ball. Testing session was preceded by warm up. The warm-up included five minutes cycling on a stationary bicycle at free speed and was followed by stretching of the gluteus maximus, hamstrings, quadriceps, and gastrocnemius.

Isokinetic assessment

Peak torque, total work, and average power of knee extensors and flexors of the dominant limb was measured during concentric contraction mode at 60°/s and 180°/s. The dynamometer head and chair were rotated to 90° according to the standard instructions for knee testing. Subjects sat with their thighs at an angle of 110° to the trunk. The mechanical axis of the dynamometer was aligned with the lateral epicondyle of the knee. The trunk and both thighs were stabilized with belts and the knee range of motion was set to 90° (90°-10° flexion). The distal aspect of the dynamometer arm was placed 2 cm proximal to the medial malleolus. Torque was gravity corrected and dynamometer calibration was performed before every session in accordance with the manufacturers' instructions. Each subject performed 10 concentric contractions of flexion and extension at 60°/s and 180°/s. The velocity of 60°/s was chosen as once at low speeds to obtain a higher torque generation, which is closest to the athletes' maximum muscular performance [22]. The velocity of 180°/s was chosen as high speed that is similar to high contraction speed performed in sports activities [23].

Assessment of functional performance:

Subjects performed four functional performance tests as described by Noyes et a1. [12], single hop, timed hop, triple hop, and cross over hop.

For the four tests, the hopped distance was measured using a standard tape measure secured to the floor. Each subject began the test by standing on the dominant limb with their toes lined at the starting point at the tape measure's zero mark. For the single hop test, the recorded measure was the distance from the zero mark to the place where the back of the subject's heel

hit the ground upon completing the single hop. The timed hop test had a 6-m distance marked off. The test score was the time it took for the subject to hop 6 m on the dominant limb using a standard stop watch. For the triple hop test, the recorded measure was the distance from the zero mark to the place where the back of the subject's heel hit the ground upon completing three consecutive hops. For the cross-over hop test, subjects began the test by standing on the right side of the line on the dominant limb, then hopped over to the left side, back over to the right side, and then back over to the left side using only the dominant limb. The recorded measure was the distance from the zero mark to the place where the back of the heel lands firmly on the ground on the third hop.

Data analysis

Person Product Moment Correlation Coefficient was conducted to investigate the correlation between isokinetic variables and hop functional performance test. The level of significance for all statistical tests was set at $p < 0.05$. All statistical measures were performed through the statistical package for social sciences (SPSS) version 19 for Windows (IBM SPSS, Chicago, IL, USA).

RESULTS:

Subject characteristics:

Table 1, showed the mean ± SD as well as minimum and maximum values of age, weight, height, and BMI of the study group.

Table (1): Mean age, weight, height, and BMI of the study group:

	Study group		
	$\bar{X}$±SD	Min	Max
Age (years)	20.26 ± 1.76	18	24
Weight (kg)	77.13 ± 1.47	74	80
Height (cm)	176.03 ± 1.32	174	178
BMI (kg/m²)	24.89 ± 0.54	23.36	25.76

x̄, mean; SD, standard deviation

Correlation between peak torque and functional performance

The correlation between the extensors' peak torque at 60°/s and the functional performance test was moderate positive significant correlation with single hop ($r = 0.42$, $p = 0.02$) and with cross-over hop ($r = 0.43$, $p = 0.01$), while was non-significant weak positive correlation with triple hop ($r = 0.35$, $p = 0.053$).

The correlation between the extensors' peak torque at 180°/s and the functional performance test was moderate positive significant correlation with single hop ($r = 0.47$, $p = 0.009$), triple hop ($r = 0.41$, $p = 0.02$), and with cross-over hop ($r = 0.45$, $p = 0.01$).

The correlations between the flexors' peak torque at 60°/s and the functional performance test was moderate positive significant correlation with single hop ($r = 0.37$, $p = 0.04$) and with cross-over hop ($r = 0.39$, $p = 0.03$), while was non-significant weak positive correlation with triple hop ($r = 0.29$, $p = 0.11$).

The correlation between the flexors' peak torque at 180°/s and the functional performance test was moderate positive significant correlation with single hop ($r = 0.38$, $p = 0.03$), and with cross-over hop ($r = 0.41$, $p = 0.02$), while was weak positive significant correlation with triple hop ($r = 0.29$, $p = 0.11$).

The correlations between peak torque of the knee extensors and flexors with timed hop test was weak negative non-significant correlation at both 60° and 180°/s ($p > 0.05$).

Correlation between total work and functional performance

The correlations between the extensors' total work at 60°/s and the functional performance test was moderate positive significant correlation with single hop ($r = 0.45$, $p = 0.01$), triple hop ($r = 0.4$, $p = 0.02$) and with cross-over hop ($r = 0.45$, $p = 0.01$).

Table (2): Correlation between isokinetic variables and functional performance test:

		Single hop		Time hop		Triple hop		Cross-over hop	
		r - value	*p* - value	r - value	*p* - value	r - value	*p*- value	r - value	*p*- value
Peak torque at 60°/s (Nm)	**Extensors**	0.42	0.02*	-0.29	0.11	0.35	0.053	0.43	0.01*
	Flexors	0.37	0.04*	-0.32	0.08	0.29	0.11	0.39	0.03*
Peak torque at 180°/s (Nm)	**Extensors**	0.47	0.009*	-0.3	0.1	0.41	0.02*	0.45	0.01*
	Flexors	0.38	0.03*	-0.15	0.41	0.29	0.11	0.41	0.02*
Total work at 60°/s (Joule)	**Extensors**	0.45	0.01*	-0.32	0.08	0.4	0.02*	0.45	0.01*
	Flexors	0.38	0.03*	-0.26	0.15	0.29	0.11	0.45	0.01*
Total work at 180°/s (Joule)	**Extensors**	0.44	0.01*	-0.07	0.68	0.41	0.02*	0.45	0.01*
	Flexors	0.42	0.01*	-0.16	0.37	0.32	0.07	0.43	0.01*
Average power at 60°/s (Watt)	**Extensors**	0.57	0.001*	-0.16	0.39	0.64	0.0001*	0.55	0.001*
	Flexors	0.46	0.01*	-0.3	0.1	0.37	0.04*	0.47	0.009*
Average power at 180°/s (Watt)	**Extensors**	0.62	0.0001*	-0.1	0.59	0.62	0.0001*	0.69	0.0001*
	Flexors	0.48	0.007*	-0.29	0.12	0.42	0.01*	0.45	0.01*

r value: Pearson correlation coefficient; p value: Probability value; * Significant.

The correlations between the extensors' total work at 180°/s and the functional performance test was moderate positive significant correlation with single hop (r = 0.44, p = 0.01), triple hop (r = 0.41, p = 0.02) and with cross-over hop (r = 0.45, p = 0.01).

The correlation between the flexors' total work at 60°/s and the functional performance test was moderate positive significant correlation with single hop (r = 0.38, p = 0.03) and with cross-over hop (r = 0.45, p = 0.01), while was weak positive non-significant correlation with triple hop (r = 0.29, p = 0.11).

The correlation between the flexors' total work at 180°/s and the functional performance test was moderate positive significant correlation with single hop (r = 0.42, p = 0.01) and with cross-over hop (r = 0.43, p = 0.01), while was weak positive non-significant correlation with triple hop test (r = 0.32, p = 0.07).

The correlation between total work of the knee extensors and flexors with timed hop test was weak negative non-significant correlation at both 60° and 180°/s (p > 0.05).

Correlation between average power and functional performance

The correlation between the extensors' average power at 60°/s and the functional performance test was moderate positive significant correlation with single hop (r = 0.57, p = 0.001), triple hop (r = 0.64, p = 0.0001), and with cross-over hop (r = 0.55, p = 0.001).

The correlation between the extensors' average power at 180°/s and the functional performance test was moderate positive significant correlation with single hop (r = 0.62, p = 0.0001), triple hop (r = 0.62, p = 0.0001), and with cross-over hop (r = 0.69, p = 0.0001).

The correlation between the flexors' average power at 60°/s and the functional performance test was moderate positive significant correlation with single hop (r = 0.46, p = 0.01), triple hop (r = 0.37, p = 0.04), and with cross-over hop (r = 0.47, p = 0.009).

The correlation between the flexors' average power at 180°/s and the functional performance test was moderate positive significant correlation with single hop (r = 0.48, p = 0.007), triple hop (r = 0.42, p = 0.01) and with cross-over hop (r = 0.45, p = 0.01).

The correlation between average power of the knee extensors and flexors with timed hop test was weak negative non-significant correlation at both 60° and 180°/s (p > 0.05).

DISCUSSION

The purpose of this study was to explore the correlation between three important isokinetic measures of muscle performance; peak torque, total work, and average power; with hop functional performance test. Previous studies focused on the correlation with peak torque as it is the golden standard of muscle strength. This study considered total work and average power in the investigation as it measures other aspects of muscle performance different from what measured with peak torque.

Results of this study confirmed the importance of considering muscle power in investigation of muscle performance and confirm the concept that muscle power reflects important aspects of functional performance. The average power of knee extensors at 180°/s showed the highest correlation with cross-over hop (r = 0.69) followed by the correlation of average power of knee extensors at 60°/s with triple hop (r = 0.64) and the correlation of average power of knee extensors at 180°/s with triple hop (r = 0.62). The correlation between isokinetic variables of knee extensors and flexors and single hop, triple hop and cross-over hop were weak to moderate positive significant correlation at both 60° and 180°/s with knee extensors had higher correlation than knee flexors. The correlations between the three isokinetic variables and timed hop test for knee extensors and flexors were negative non-significant correlations at both velocities. Total work and peak torque showed similar weak to moderate correlations with functional performance tests.

The significant correlation between isokinetic variables and the three-functional hop test; single hop, triple hop, and cross over hop; reported in this study comes in agreement with the results of Hamilton et al. [24] and Ostenberg et al. [25] they showed that the distance hopped during single-hop and triple-hop- tests are strong predictors of isokinetic maximum strength at 60°/s and 180°/s particularly in the knee flexors and extensors. Also, Delitto et al. [26] reported that there were fair relationships of the distance of single hop to concentric quadriceps peak torque and work. Also, our results come in agreement with Greenberger and Paterno [19] as they found a significant correlation between isokinetic knee extension strength and single hop among an asymptomatic group. In same context Swarup et al. [27] found moderate to strong relationships between the single hop and concentric quadriceps peak torque for dominant and non-dominant lower extremities. Moreover Wilk et al. [28] reported significant correlation (r = 0.62) of peak torque for knee extensors at 180°/s with one leg hop test in patients with ACL-reconstruction. Similar correlations exist between isokinetic measurement and functional performance in subjects with ACL reconstruction. Laudner et al. [29] found that ACL patient's performance on an electronic jump mat system is strongly related to peak torque-to-body weight of both knee extension and flexion.

The higher correlation reported in this study between average power and functional performance test than that of peak torque may be explained as the nature

of functional performance is closely related to the concept of power more than to absolute muscle strength. The hop test requires high force development in short period of time which is the muscle power. Power is a product of force and velocity. The ability to produce high forces during high velocities is one of the most important factors in sports performance [30]. Rate of force production is the single most important neural adaptation for the majority of athletic individuals [31].

Weak to moderate correlations exist in this investigation between isokinetic variables and functional performance tests with non-significant correlation with timed hop test may be attributed to the fact that multiple factors may influence results. Balance and proprioception play important roles [32]. These functional hop tests are reported to require muscular strength, neuromuscular coordination, and joint stability in the lower limb [12,33]. The difference in nature of isokinetic and hop performance may cause this weaker correlation. Isokinetic were carried out in open kinetic chain while hop test exists in closed kinetic chain with different biomechanical consideration. English et al. [34] suggested that higher correlation would exists when the units of measurements were the same.

Also, weaker correlation may be attributed to nature of muscle contraction utilized in both tests. Isokinetic assessment was conducted in concentric mode while hop tests involved eccentric quadriceps contraction in initial phase followed by concentric contraction. Also, it may be related to the fact that the movement in human physiology is not as in isokinetic which carried out at a constant velocity. Natural human movement is performed at speeds which are higher than those that can be programmed on an isokinetic dynamometer, especially as sports activities requires speeds above 1000°/s [35].

Another important finding in this study is that the correlation becomes stronger at high velocity than at slow velocity. This come in agreement with Ostenberg et al [25] who reported similar relationships between triple hop test and quadriceps strength at 60°/s ($r = 0.43$) and 180°/s ($r = 0.52$), with the prediction model being 9% stronger at the higher velocity. This may be attributed to the nature of functional performance test that involve high velocity performance and very rapid force output. It may be that the higher velocity isokinetic strength assessment is more similar with the functional demands for rapid strength development of the quadriceps during the hop test and, therefore, yielded a stronger correlation. The active force generated by muscles rose as speed increased which requires larger increase in activation to overcome the decrease in force generation ability [36].

Clinically, the use of functional performance tests represents a more time efficient and economic method of assessing muscle function than more sophisticated expensive instruments as isokinetic. But each method utilizes different methodologic approaches. Functional performance tests assess the function of the entire lower limb in an integrated manner, incorporating strength, power, neuromuscular coordination, and stability across multiple joints. Isokinetic utilizes single joint testing procedures in evaluating muscular function and gives detailed information regarding specific muscle group. As the correlation between isokinetic variables and functional performance measures exists, even low to moderate correlation, it means that both methods may evaluate similar features of muscle performance. Clinicians may use functional performance tests to assess subject's recovery in absence of isokinetic devices. The presence of higher correlation between isokinetic power and hop test than

other parameters may provide a parameter that clinicians can rely on in decision making process regarding return to sports activities and guarantee athletes from injury. Overall both evaluation methods cannot replace each other completely.

Conclusion

Low to moderate positive significant correlation exists between isokinetic peak torque, total work, average power and hop functional performance test. The higher correlation was between average power of knee extensors at 180°/s and cross-over hop test. Average power is more correlated with functional performance than peak torque and total work and should be considered in the evaluation of muscle performance.

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Conflict of Interest

The authors have no conflicts of interest relevant to this article.

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