International Journal of Medical Science and Clinical Invention 5(03): 3714-3720, 2018
DOI:10.18535/ijmsci/v5i3.28 **ICV 2016: 77.2**
e-ISSN:2348-991X, p-ISSN: 2454-9576

Systemic Review

The Relationship between Hop Performance and Lower Extremities Muscle Strength

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Abstract: This scoping review aims to identify the link between an individual's hop performance and muscle strength of hip extensors, knee flexors and extensors, as well as ankle plantar flexors through isometric or isokinetic (eccentric-concentric) testing. The literature review ascertained articles from 2005-2015 through Medline (PubMed), SPORT Discus, CINAHL and Google scholar, which included the connection between a minimum of one leg's distance performance through hop testing in comparison to muscle strength (isokinetically or isometrically). The articles were screened by the researcher through their title, abstract and assessment relevance by criteria of inclusion and exclusion. Apart from one investigation, the obtained studies utilised isokinetic measures or isometric peak force outcome for muscle strength of the lower extremities, together with a comparison of healthy individuals' hop performance. Many researchers have documented the existing connection between lower extremity strength of a subject with the overall intended function of the test. However, the data findings that were used were rigorously limited purely to the knee muscles that were tested through the use of an isokinetic dynamometer. Research has proven to be vital to this field, as the strength of muscles is affected by the performance of a hop in a functional test, although a clear unequivocal understanding is not present from prior investigations relating the connection between muscle strength (isokinetically) in an individual's legs and the performance of the hop test. Furthermore, the researcher is required to analyse particular results from training sessions in order to evaluate the improvement of a subject's performance, which will develop the benefits of the study in question, and gain a clearer comprehension of how to prevent injury.

Keywords: Hop tests, Isokinetic, Isometric

INTRODUCTION

Collecting outcome measures during a course of therapy can provide clinicians with information that can guide clinical decision making. However, the evaluation of the effectiveness of various interventions is assisted in the comparison of clinical trials[1] and in the process of discerning decisions of a clinical nature regarding patients on an individual basis[2,3]. There are a different research investigations to understand patients who undergone anterior cruciate ligament (ACL) reconstruction[4], which always incorporates a relatively high percentage of practice in physical therapy[5]. Thus, outcome measures have been standardised[3,4,12] to create an appropriate assessment of subjects who are receiving physical therapy post-ACL reconstruction, as a requirement in the comparison of alternate postoperative rehabilitation techniques and the evaluation of progress for patients.

Another form of individual performance measurement is through hop testing, which assists in the determination of integrated development in the lower extremities of an individual, relating to: confidence, neuromuscular control, and strength[6,7]. Additionally, the capability to understand the limitations of functions through various different grouped populations has been demonstrated as reliable by functional testing[8-11].

In the measurement of strength for quadriceps muscles, the evaluation has been tested by the predominate method of Isokinetic dynamometry, with a cross-section of both healthy subjects, and post-ACL injury subjects[14-16]. In fact, a great percentage of investigation into the strength of quadriceps muscles post-ACL injury have implemented peak torque as the principle form of outcome measure[16], as the value where the athlete is capable of producing the greatest force at the one point during knee extension from 90-0°[17] has been shown through the representation of quadriceps peak torque. Conversely, limited information about the muscle performance during the full selected range of motion[11] may be provided by peak torque. In addition, peak torque to bodyweight reflects the amount of peak torque in comparison to an individual's bodyweight against the estimated peak objective, which creates a value that is more relative and persistent to any function or activity[10].

Previous studies have reported a relationship between lower extremity muscular strength and measures during hop test. A correlation exists between single-leg hop testing and testing crossover hop[18,19,11]. This link has been presented in research that used Cybex (an isokinetic test) to analyse the connection between the tests on healthy and Anterior Cruciate Ligament–Deficient (ACLD) subjects[18]. The study[18] established that

when a patient produced a score from a one-legged hop test that was deemed to be obscure, they were automatically considered to be of a potential risk only have limited capabilities within sporting activities. Indeed, it has been shown that a relevant relationship that is proven statistically exists within the test of one-legged hop for distance between 60°/sec quadriceps scores and symmetry results that are not termed as "normal". Out of the total 27 patients who undertook the test for quadriceps strength, 18 produced scores that were not seen as average, and additionally 12 of these individuals for the test of distance by the one-legged hop produced scores that demonstrated that their limb symmetry was abnormal.

Researchers have documented a connection between lower extremity strength and the hop test [20-25]. Nevertheless, through the use of the isokinetic dynamometer, the accrued data was specifically restricted to the knee muscles of the participants. Only 1 group of 18 individuals demonstrated a correlation between lower limb strength (isometrically) and hop performance, as that investigation focused purely on the muscles in the knees and thighs. It has been presented as an explanation that a wide variation exists in the results, as a normal neuromotor input generally yields a greater correlation through functional-hop and isokinetic measures[11], which are stimulated by studies that utilize reciprocal leg motions.

A separate Explanation shows moderate relationship comes from the results that use two alternate units of measurement in the defined tests. The first unit of measurement focuses on a maximum unit of force or torque, which is produced through a persistent velocity, as a non-weight-bearing test is utilized to document the isokinetic peak torque. Alternatively, the second unit of measurement is a single-leg hop test, which signifies how far an individual moves in a horizontal motion during an activity of dynamic weight bearing.

Additional studies have proven that it is imperative for a functional test to present a demonstration that the hop performance is affecting an individual's muscle strength, as a distinct correlation between the lower extremity muscle strength, which is both isokinetic and isometric, and the performance of the hop test, has been documented in prior studies in relation to the topic of a healthy group, although with gaps to demonstrate the full comprehension. Furthermore, to develop the investigations that evaluate the prevention of injury it is vital that a researcher analyses results from specific training programs, as well as how the performance of an individual begins to improve.

It is necessary throughout any research that the chosen structure is standardised, reliable, valid, as well as remaining responsive to alterations that occur through time, together with relevant in a clinical nature[26]. Indeed, through research and clinical practice the outcome measures should adhere to a variety of variables: be highly cost-effective, be able to be administered in an acceptable period of time, be easy and comfortable for both clinicians and researcher to use, as well as for participants to accept their use[27]. Consequently, the current scoping review aims to present the identification and exploration of how frequently utilized outcome measures in the previous decade have generally been associated, together with performance in hop testing and the strength of lower extremity muscles strength. Scoping review approach was adopted, in order to include a wider scope of investigation and designs of research, together with systematically reviewing the methodology[28]

METHODS

This manner of scoping review is a relatively modern form of research, which provides an evaluation of evidential literature from a wide perspective of research. For instance, this establishes guidelines from the reports of clinical studies. Moreover, a scoping review enables the identification of data that a field of research lacks, as well as serving to highlight implementation recommendations[28].

Originally, Arksey and O'Malley[28] were the pioneers to present a detailed description of scoping reviews and their methodology, as they described a structural base for enabling the implementation of a scoping review. Additionally, this type of review was further enhanced by the formulation of five stages, which was proposed as a prerequisite to be adhered to: firstly, to identify a set question of research; secondly, to locate relevant studies to the research; thirdly, to select the inclusion of studies for the review; fourthly, to extract data from the selected studies; and lastly, to assemble, summarise, as well as report the review findings.

Study Selection and Sources of Literature:

From the beginning, the researcher had to implement a literature search, alongside a process of selecting studies. To perform this search, PubMed, SPORT Discus and CINAHL were selected as the electronic databases, as they would locate the connection between muscle strength of lower extremity (isokinetically or isometrically), and individual hop performance. Keywords were also used within the advanced search: *hop* OR *hop tests* OR *hop performance* AND *muscle strength* OR *isokinetic* OR *isometric*. Likewise, the same keywords were placed into Google Scholar to extract more relevant findings, although the search was limited to not exceed the initial 20 pages of findings, as this would locate the most relevant references from set literature. An expanded detailed search was also carried out, which included searching the reference lists by hand in order to summarise more relevant articles and texts, as each paper had its title and abstract analysed for the identification and exclusion of studies not related to the current research (See Table 1).

The reviewed studies had to adhere to the following inclusion criteria: firstly, the muscle strength of the lower limb (isokinetically or isometrically) had to be compared from at least one lower extremity functional performance test (hop tests for distance); secondly, analysed investigations had to be either cross-sectional, cohort designs, or randomized control trails (RCT); and thirdly, all the studies were required to be published between 2005 and June 2015, and all in the English language.

Identification of relevant studies:

Each title and abstract of every individual paper to be extracted from the search strategy was review by the researcher personally. Indeed, the complete-texts for all potential studies of eligibility were obtained in relation to the pre-determined criteria, and subsequently the reviewer reviewed them independently for an additional time, in accordance to the eligibility criteria.

2.3. Data Extraction:

Through the use of a pre-determined spreadsheet, the research extracted data individually for each eligible paper, which helped correlate the useful data to develop a set form of result extraction. This extraction form included enhanced detail on: the study's aim and structure, the details of participant, as well as the findings of both the muscle strength and hop tests.

DISCUSSION

A variety of tests are implemented to evaluate the capability of an athlete to return to physical performance following injury, and a functional test is specifically recommended as the best form. Thus, it is often believed that muscle power and strength will advance from the action of functional tests, as they include physically stimulating activities, such as hopping[29]. Nonetheless, most prior investigations have focused particularly around the measurement of knee muscles, as a correlation between the hop performance of the subject and the individual lower extremity isokinetic muscle strength has been reported[20,30,21,24].

Isokinetic measures and hop performance for distance

Through the evaluation of muscle strength in athletes, and the ability to advance to more enhanced activities, various primary assessment tools have been used that help stimulate findings that enable an athlete to return to their original state of function pre-injury. For instance, an isokinetic dynamometry (Biodex system) has been utilised on athletes to indicate their muscle strength. However, hop tests have been the frequent measurement of specific performance, as they locate and highlight the advancements of the lower limbs' neuromuscular control, strength, and confidence within an individual.

A great many studies have been formulated through a single leg hop test that measure distance as the standardised functional performance post-anterior cruciate ligament reconstruction, as the test presents an ICC that ranges between 0.86 to 0.95, which is distinctively high[31,32]. Nevertheless, certain investigations have documented that when more than two different hop tests are performed, an increase in sensitivity occurs[32]. In fact, through the use of multiple hop tests, the assessment of qualities is possible, which presents an opportunity to stipulate what is detrimental in an individual's hop performance[31].

One particular accurate and sensitive test, which consisted of three hop tests that could discriminate between injured and uninjured hop performance for patients who had undergone anterior cruciate ligament reconstruction, concluded to combine the vertical hop, the single-leg hop for distance and the side hop, which together assist in determining the most beneficial form an injured and the uninjured leg, as stated by Gustavsson et al.[31]. This form of test advances the understanding of the knee's development, as muscle fatigue is induced through a high demand on dynamic knee stability, although the side hop test has been determined as the most beneficial form of distinguishing between an uninjured and injured lower extremity.

A separate investigation[24] has shown that in the subsequent week following arthroscopic meniscectomy specific (weak to moderate) correlations are present between single leg hop performance (0.13 – 0.42) and strength, (concentric knee extensor strength at 60°/sec). However, by week 5 of the programme of rehabilitation there was a distinct decrease in correlation, as the single leg hop performance fell between 0.10 – 0.25. Indeed, this study was the original investigation to examine the correlation between isokinetic deficits in patients who underwent arthroscopic meniscectomy and functional hop tests. Nevertheless, there are many studies of a similar nature that analyse both healthy subjects[33,30,21] and patients who had undergone anterior cruciate ligament reconstruction[20,25]. Therefore, it can be perceived that a small to medium correlation exists between the functional hop and isokinetic measurements, which depends on the time that has elapsed after the surgical procedure, as well as the methodology and population.

Through analysing the individuals as a single group of subjects suffering from anterior cruciate ligament deficiency, moderate associations (r=0.30–0.50)[20] between hop performance and the strength of muscles in the knee muscles, as these results correlate to prior studies which stated moderate, although significant correlations[34]. For knee flexion angles 80° − 40°, a moderate correlation was presented for non-copers individuals, and in relation to the one leg hop test a peak torque and work was demonstrated. Contrastingly, knee flexion angles from 50° − 20°, as well as the total work and peak torque were strongly correlated from the 6-metre timed hop test ($r > 0.50$), while knee flexion angles 70°, 60° and 15° were also moderately correlated. Furthermore, it appears to be of clinical necessity to evaluate the performance of the quadriceps muscle performance post-injury of anterior cruciate ligaments, in order to provide a definition of the hop performance, together with the isokinetic curve profiles.

One study[35] incorporated healthy (injury free) athletes at college age, who had to undertake a 5-hop test battery, where they initially began on both feet before hopping onto an individual foot landing, with a subsequent performance of 4 consecutive hops, and a final hop landing onto both feet together. Consequently, it was determined that a comparison between ratios of dominant factors showed that no significant correlation existed in the imbalance, as was defined by tests that included the 5-hop test, even though the decreased *n* size in the evaluated correlation could have contributed to the results. Various reasons could affect the overall results. Firstly, it is possible that athletes may demonstrate extensive

imbalances within the strength of their lower-extremities, as well as the resulting muscular performance power, even when they exhibit formidable strength, together with past histories of training for development conditioning. Secondly, performance contributions, which function alongside force generation, may become decidedly contrasted in the results between both legs, as the performance from hop tests can create unilateral movements that alter the eventual results.

It has been reported by Hamilton et al.[21] that performance from clinical strength tests can be predicted by triple hop tests for distance, as the findings from First Division National Collegiate Athletic Association football players has suggested that the test is an indicator of strength in the lower limbs. In fact, both the strength of hamstrings and quadriceps were greatly predictable of hop distance tests of both 60°/sec and 180°/sec. The results from hamstring peak torque in a range of 0.745 to 0.753, and for quadriceps at 0.700 to 0.767. It can be observed that football is an activity that incorporates both open and closed kinetic chain strength in the performance of various multidirectional movements, which also include kicking of the ball. Furthermore, a relationship between open kinetic chain and closed kinetic chain muscle performance is supported by the formed connection between hop performance testing for distance and isokinetic testing.

When the body weight of a person is included within the measured hopped distance, the exact correlation that exists between measures of functional performance and isokinetic strength is distinctively higher because this effectually contributes in the distance during measurements of a single entity through no external factors[30]. However, as the studies from the past have structured their research through alternate protocols and various manners of investigation, as well as different forms of tested angular velocities, there is a common challenge to create a direct comparison or evaluation between prior literary investigations.

It has been previously reported that as velocity increases within testing the scale of the correlation between hop tests and knee-extensor strength increases[21], as was demonstrated[30] through the comparison of 60°/sec and 180°/sec double-legged jump tests with isokinetic hip-extensor and knee-extensor torque. Hence, it can be concluded that higher velocities produce stronger correlations, as velocity produces the strength of the correlation.

Isometric peak force and hop performance for distance

Through the utilisation of isokinetic instrumentation [33],[20],[30],[21],[24],[35] researchers have been able to evaluate the relationship that exists between functional performance and maximum lower limb strength. Nonetheless, there has only been a single group[36] that has explored how hop performance and lower limb strength (isometrically) are connected, even though specific research was purely limited to the muscles of the knees and thighs. Moreover, that specific study predicted a strong indication of peak force within the hips and thighs through the measurement of distance by functional performance tests. Conversely, the hypothesis was not fully supported by the findings, as they formed between 0.10-0.29, and the single-hop distance test was the only investigation that contributed to a distinctive percentage of the male variance of peak force for hip-flexors ($r^2 = 0.29$).

Previous researchers have reported that between 40% and 44% of the variance in knee-extensor peak torque can be predicted from the single-hop distance test with isokinetic speeds of both 60°/sec, as well as 50% at 180°/sec[30]. Moreover, the triple-hop distance test can provide an estimation of between 43% and 49% of the knee-extensor peak torque at the velocity of both 60°/sec, together with 52% - 58% at 180°/sec[21]. Additionally, Kollock et al. [36] stated that the single-hop distance test could explain up to 33% of the difference in isometric knee-extensor peak force, which was in fact similar to a previous report[30] that highlighted 40% variance through isokinetic instrumentation at 60°/sec. However, the findings are not conclusive, as it can be concluded from these results[36] that the data should be analysed separately between genders. Indeed, an overestimation of the variance can account for an invalid measure of functional performance, which occurs when genders are not individually distinguished. Consequently, prior studies are required to be evaluated in greater depth to check whether there is a direct correlation between genders, as men generally represent higher strength values than their female contemporaries.

The common values were less than those reported by investigators using isokinetic dynamometry[33,20,30,21,24,35] between the hopped distance (particularly a single hop) and the isometric peak force with both the hips and thighs. Kollock et al.[36] stated that due to the contrast in neural recruitment patterns between dynamic and static tasks[37] the findings are most probably varied from those of earlier isokinetic reports. Likewise, neural recruitment, as well as rate coding alternate between dynamic and static tasks, as it is feasible that the patterns of neural recruitment that are elicited by isokinetic mode contractions are similar to those from hop tests.

Previous researched studies have presented various limitations. Firstly[36], the studies incorporated a base sample that was not randomly selected, which created results that could not be generalised. Secondly, varied forms and levels of athletic involvement, as well as experience could have created an alternate effect upon performance with functional performance tests, through both the isometric[36] or isokinetic[33,30] strength, even though the participants would have been recreational athletes. Thirdly, it has been perceived that the relationship between isokinetic measurements and the functional hop depends on the length of time that elapses both pre- and post-surgery for the injured patients[20,24], and not only on the stated population and studied methodology.

The researcher endeavours to evaluate and comprehend the correlation that exists between the single leg hop with the performance of the crossover hop for distance, through the analysis of the previous research and studies. Subsequently, it will be plausible to measure the strength of muscles in the knee flexors and extensors, and hip extensors, as well as ankle

plantar flexors in the muscle actions that are both isometric (concentrically) and isokinetic (eccentrically and concentrically).

Conclusion:

The implementation of functional performance tests in a clinical setting represent a specific method of muscle function assessment that is better in time efficiency and low-cost than either isometric or isokinetic strength testing[21]. The functional performance testing, as well as the procedures of single-joint isometric and isokinetic testing demonstrate particular alternate approaches of methodology to evaluate muscular function, for instance integration versus isolation. Moreover, the function of the entire lower limb in an integrated manner is assessed through the testing of functional performance at different movement speeds that encompasses: neuromuscular coordination, power, strength, and stability across varied joints[38,21]. Hence, the evaluation of the correlation that exists between lower extremity strength and hop tests can assist in the improvement of validity for both genders, and within large-scale groupings, alongside examinations of pre-participation and evaluative analysis of return-to-action. In fact, results from different research groupings[36] have indicated that the measurement from hop testing can incorporate bodyweight as a more definitive indicator of peak force than purely utilising hop measurements as a foundation. It is also suggested that screening data results from both genders can create an overestimation in the connection amount that exists between peak force and hop tests. In addition, the correlation strength that is present between peak force and hop testing could be, at least to a degree, the functionality of the manner of muscular contraction, with higher remarked linkage to concentric isokinetic muscular contraction than to isometric, as the findings of isometric results and studies have described. However, different contributing physiologic factors may present themselves within the isometric peak force testing conditions, with muscle fiber characteristics and stiffness of the muscle-tendon complex as certain examples.

Nevertheless, moderate correlation results should be taken into account as well, which permit clinicians and researchers to incorporate both muscle strength testing hop testing through assessing both genders and the functionality of their lower extremities within the period of rehabilitation, as the implementation of isokinetic testing is required for purely testing lower limb strength, and functional testing in the determination of levels of performance. Therefore, it will become feasible for more informed decisions from practitioners in relation to the alterations in the muscle strength of an individual and the performance hop testing. Nonetheless, the isometric strength was not linked directly to the hop performance. Thus, additional research has been shown to be required in the overall exploration of the correlation of functional performance testing, which can be conducted over various forms of hop ability and performance, which could prove imperative in inducing fatigue within an individual's lower extremities while performing functional testing of performance that are structured to gain an emphasis for endurance that specifically adhere to the distance from crossover hop testing

Table 1. Search summary

Database	Search terms	Results	Qualified	Obtained
PubMed	*Hop performance* AND *muscle strength*	343	3	3
	Hop AND *isokinetic testing*	167	3	1 (2 repeat)
	Hop AND *isometric*	194	0	0
SPORT Discus	*Hop performance* AND *muscle strength*	31	5	1 (4 repeat)
	Hop AND *isokinetic testing*	3	2	0 (2 repeat)
	Hop AND *isometric*	10	2	0 (2 repeat)
CINAHL	*Hop performance* AND *muscle strength*	2	1	0 (1 repeat)
	Hop AND *isokinetic testing*	2	1	0 (1 repeat)
	Hop AND *isometric*	3	0	0
Google Scholar	Same key words as above			1
Hand search				1
Total				**7**

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