International Journal of Yoga, Physiotherapy and Physical Education
ISSN: 2456-5067
Impact Factor: RJIF 5.24
www.sportsjournal.in
Volume 3; Issue 3; May 2018; Page No. 05-08

Normative values for single leg triple hop test for normal, college aged students

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Abstract
Background: Objective, reliable, and valid functional tests may assist with the decision-making process for rehabilitation as well as assist in pre-participation screening for targeted interventions to prevent non-contact lower extremity injuries. Establishing normative data can provide clinicians reference points with which to compare their patients, potentially aiding in the development of future injury-risk assessment and injury mitigation programs.
Aim: The purpose of this study was to determine normative values of single leg triple hop test in College aged students.
Method: A convenient sample of 100 (67 females, 33 males) healthy collegiate student were included in the study (mean age 19.71 years, range 18-24). Participants performed one practice hop and three measured hops for each hop test on each limb. The maximum hop score for each limb was used for calculations.
Results: There was statistically significant difference between sexes but there was no statistically significant difference amongst right and left lower limb values in males as well as female subjects.
Conclusion: This study provides normative values for single leg triple hop test in normal college-aged students and it provides a reference point to clinicians for comparison in their patients.

Keywords: single leg triple hop test (SLTHT), triple hop distance (THD), limb symmetry index (LSI), anterior cruciate ligament (ACL)

Introduction

Single-leg hop tests were designed to assess functional performance in an injured extremity. These functional hop tests are reported to require muscular strength, neuromuscular coordination, and joint stability in the lower limb and are considered useful in the clinical setting because they require minimal equipment and time and allow one to use the contra lateral (e.g., uninjured) limb as a reference for comparison.

Clinicians have used single leg hop tests to assess their patients' lower extremity muscular strength and ability to perform tasks that challenge knee stability. Single leg hop tests are also commonly used to evaluate progress in knee rehabilitation programs [1-5].

R. Tyler Hamilton *et al* conducted a study in 2008 on triple hop distance as a valid predictor of lower limb strength and power and concluded that triple hop distances are a useful clinical test to predict an athlete's lower extremity strength and power although triple hop distance was not a predictor of static balance [6].

Betsy A Myers *et al* (2014) collected normative data for hop test in high school and collegiate basketball soccer players stated that separate hop test standards should be used based on participant sex and level of competition. While some statistically significant differences were found between limbs, these differences did not appear to be functionally relevant [7].

James A. Onate *et al* (2018) also collected normative functional performance values in high school athletes: The Functional Pre Participation Evaluation Project demonstrated differences in normative data for lower extremity functional performance during participation physical evaluations across sex and grade levels. The result of this study will allow clinicians to compare sex and grade specific functional performances and implement approaches for preventing musculoskeletal injuries in high school aged athletes [8].

Because of the disproportionate percentage of female athletes with ACL injuries, it is important to identify if there are any differences in hop test performance between sexes. Maturation has been found to lead to sex differences in landing forces. Barber-Westin's study demonstrated an interaction between age and sex for both drop landing and crossover hopping. Therefore, it would appear wise to compare hop tests results with individuals of similar age and sex [9-13].

Previous hop test studies have provided information on use of hop test as indicators of functional performance capacity in patients with ACL injury and reconstruction procedures, as a measure of lower limb function, reliability of three single leg hop tests as well as their test retest reliability. Hop tests have also been used in studies as a clinical measure of progress in response to surgical or rehabilitation intervention. Hop tests are typically scored by computing a limb symmetry index (LSI) by comparing the involved lower extremity to the uninvolved. However, there are some concerns regarding the use of the uninvolved limb as the sole standard for the involved limb with any objective testing. The uninvolved limb's abilities may decline during the rehabilitation process and may be affected by prior injury or surgery. Additionally, an athlete may have perfect limb symmetry and yet be underprepared to compete because both extremities are much

weaker or more poorly controlled than the "average" individual [10, 14, 15]. Unfortunately there are no studies that provide normative values for single leg triple hop test in healthy individuals which can be used for comparison so the purpose of this study is to provide normative values for both right and left limbs in males and females in the age group of 18-25.

Method

Participants

A total of 100 collegiate students were included in the study (mean age 19.71 years, range 18-24). A sample of convenience was recruited from Government physiotherapy college, Jamnagar. Inclusion criteria for the study were: voluntary participation and 18-24 years of age. Participants were excluded if they had prior ankle, knee, or hip surgery, inability to comprehend and execute the test, any recent or acute injury in lower limbs and those who were not willing to participate.

Procedures

Testing was performed on dry, level, debris-free surface, such as a Room floor. Due to the potential for surface irregularities, testing was not performed on grass. A tape measure was fixed to the ground perpendicular to a starting line. Subjects stood on the designated testing leg, with their heel on the starting line. 2 minutes warm up was given prior to the test.

The subject took three consecutive maximal single-leg hops forward. The investigator measured the distance hopped, from the starting line to the point where the heel struck the ground upon completing the third hop. Participants were required to maintain postural control for at least 2 seconds. Because upper extremity movement is a usual component of hop performance, there were no restrictions on arm motion during testing. Subjects were given 1-3 practice trials and then completed three test trials. Subjects were given 2minutes rest between 2 consecutive trials. A test trial was repeated if the subject was unable to complete a triple hop without contacting the ground with the opposite leg. The maximum distance recorded from the three trials was used for analysis [16].

Statistical analysis

Mean and standard deviation was calculated for both right and left lower limbs and also for males and females.

Results

Total number of participants were 100 out of which 33 were male and 67 were female (fig 1)

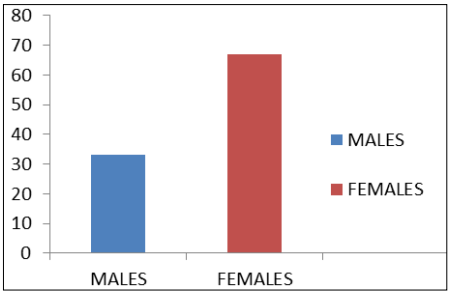

Fig 1: No. of male and female participants

Table 1: Participant characteristics

	Male	Female
Mean Age	19.09 years	20.05 years
Mean Height	170.27 cm	180.06 cm
Number	33	67

Mean value for single leg triple hop test in males for right lower extremity was 544.06 cm and 543.03 cm for left lower extremity. Standard deviation for right and left lower limb was reported 86.58 cm and 87.89 cm respectively. Mean value for single leg triple hop test in females for right lower extremity was 374.84 cm and 367.23 for left lower extremity. Standard deviation for right and left lower limb was reported 50.87 cm and 49.55cm respectively. Paired t-test indicated no statistically significant differences between right and left side in both males and females. Unpaired t-test showed extremely statistically significant difference with p <0.0001 when male vs. female values for right and left lower extremities were compared.

Table 2: MALE (RT) vs. MALE (LT) shows no significant difference in single leg triple hop distance on right and left sides in males.

	Mean	SD	P-Value	Results
Male (RT)	544.06 cm	86.58cm	>0.05	Not Significant
Male (LT)	543.03 cm	87.89cm		

Table 3: FEMALE (RT) vs. FEMALE (LT) shows no statistically significant difference in single leg triple hop distance on right and left sides in females.

	Mean	SD	P-Value	Results
Female (RT)	347.84 cm	50.87 cm	>0.05	Not Significant
Female (LT)	367.23 cm	49.55 cm		

Hence, there was no statistically significant difference found in right and left lower extremity values in male and female subjects. Although, males performed better than females. (Table 2 and 3). However, when right lower limb values for males and females were compared, there was a statistically significant difference in the values and same were the results when left lower limb distance for males and females was compared using unpaired t-test (Table 3).

Table 4: MALE (RT) vs. FEMALE (RT) and MALE (LT) vs. FEMALE (LT) comparison.

	Mean	SD	P-Value	Results
Male (RT)	544.06 cm	86.58cm	<0.0001	Statistically Significant
Female (RT)	374.84 cm	50.87cm		
Male (LT)	543.03 cm	87.89cm	<0.0001	Statistically Significant
Female (RT)	367.23 cm	49.55cm		

Discussion

We selected single leg triple hop test because it is cost effective, time efficient, easy to administer and requires limited space and equipment [17]. The findings of differences between the two sex are similar to previous studies in which males performed better than females [18-21]. Triple-hop distance was designed originally as a test for those recovering from injury or surgery to gauge readiness for activity and frequently

has been reported to require a combination of muscular strength, power, and balance [22-23]. However, the extent to which the SLTH accurately relates to or measures deficits in any of the components has not previously been quantified. We demonstrated that the SLTH is a good predictor of lower limb muscular strength and power in a healthy soccer population. Therefore, it may be suggested that the SLTH is useful as a pre-season screening test in a soccer population. Previous authors have examined the relationship between performance on a single-leg hop test and lower limb strength tests. However, we found only 1 group that investigated the validity of (triple hop distance) THD in accurately predicting lower limb strength in a healthy population, and this was limited to knee extensor strength. In the study by R. Tyler *et al* they stated THD was an equally strong predictor of quadriceps and hamstrings strength as measured at 60 degrees and 180 degrees. In this study, THD was an equally strong predictor of quadriceps and hamstrings strength as measured at 60 degrees and 180 degrees. Also THD was a powerful predictor of lower limb power [23]. While single-leg hop tests can be measured objectively and have been shown to be valid and reliable as stated by Barber *et al*. the clinical implications of performance deficits are not well understood. Noyes and others (1991) tested anterior cruciate ligament-deficient subjects on four hop tests, and found 52% of subjects were unable to perform satisfactorily on a single-leg triple hop test.[4] However, they concluded that the tests were not able to detect the subject's specific functional limitations. That is, although limb asymmetries were noted, investigators were unable, from their study design, to determine the primary cause of abnormal function in injured subjects (e.g. Strength or balance deficits) [3]. Single leg hop tests are commonly used as physical performance measures of function and are also commonly used to evaluate progress in knee rehabilitation programs, particularly for individuals recovering from anterior cruciate ligament injury or reconstructive surgery. To date, there is limited information that would allow for a differentiation between what could be considered normal performance versus pathological performance within the context of these variables, and this seems to be a necessary starting point for research to identify comprehensive neuromuscular and biomechanical mechanisms mediating performance of hopping and landing tasks. Once normative databases are established, the performance criteria will be in place to evaluate restoration of normal performance and describe those pathological profiles that include adaptive mechanisms contributing to functional stability in subjects with ACL deficient and ACL-reconstructed knees [24]. According to a study by Andrea *et al*., hop test provides reliable and valid performance-based outcome measures for patients undergoing rehabilitation after ACL reconstruction. These findings support the use and facilitate the interpretation of hop tests for research and clinical practice [25]. This study provides normative values for single leg triple hop distance in healthy college aged males and females which can be useful in clinical implication as an outcome or rehabilitation measure. Values of involved and uninvolved limbs can be used as a comparison for decline in functional status following knee surgery. In this study male participants performed better than females. This is because males have comparatively higher hamstring and quadriceps strength. Also, hamstring to quadriceps ratio is higher in males compared to females. However, this is only hypothesized and future studies are needed to know the probable reasons for gender differences.

Limitations

Leg dominance was not taken into consideration and hence it is not possible to comment whether it has any effect on the distance hopped.

Future recommendations

1. Studies are needed to examine limb symmetry indices within large population grouped by age, sex, activity level and prior injury/surgery.
2. Studies to determine sport-specific or position specific normative values.
3. Studies are needed to determine if there are any co-relation between hop test performance and future lower extremity injury.
4. Studies investigating if dominance has any effect on distance hopped.

Conclusion

This study provides normative values for single leg triple hop test in normal college-aged students and it provides a reference point to clinicians for comparison in their patients. However, the absence of normative values for functional assessments has created challenges for clinicians who attempt to determine if their patient's functional characteristics are abnormal.

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