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Correlation of single leg vertical jump, single leg hop, and single leg squat distances in healthy persons

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Objective: To determine the correlation among three functional tests: single leg vertical jump (SLVJ), single leg hop for distance (SLHD), and single leg squat (SLSQ).
Design: Cross sectional study.
Methods: Twenty healthy men (n=10) and women (n=10) with no history of lower extremity dysfucntion participated in this study and performed in university research laboratory. The procedures consisted of a general warm-up, a task-specific warm-up, actual testing, and a cool down. All participants performed the three tests in random order. Each test was performed three times for the dominant and non-dominant lower extremity (LE). SLVJ, SLHD, SLSQ were measured using a standard tape measure.
Results: Statistically significant difference was presented between dominant LE and non-dominant LE in each function test (p<0.05). The strongest correlation was between SLVJ and SLSQ, 0.939 and 0.883 for dominant and non-dominant LE, respectively (p<0.05). The weakest correlation was between SLVJ and SLHD, 0.713 for dominant (p<0.05) and between SLSQ and SLHD, 0.739 for non-dominant (p<0.05).
Conclusions: There is a strong correlation between SLVJ and SLSQ, suggesting that each test measures similar constructs of function and can be substitutive, while weak correlation between SLSQ and SLHD suggest these two tests do not measure the same functional components and could be paired as outcome measures for the clinical assessment of LE function. It will provide physical therapist with scientific evidence for effective test combination of LE function assessment in clinical practice.

Key Words: Adult, Exercise test, Leg, Prospective studies

Introduction

The importance of standard instrument in research and clinical practice has been repeatedly illustrated in many literatures [1]. As an attempt to quantify function, researchers devised several function performance tests to apply stress stimulation exerted to knee during the sports activities and they were developed as the form of jump test [2].

A jump test is practical and performance based measurement instrument which reflects the combination of elements including neuromuscular control, capacity to exert power, balance, flexibility, and change in direction [3,4], and it doesn't require many instruments and can be conducted relatively easily [5,6]. Also, it can compare the effect of rehabilitation strategy by quantifying the jump performance capacity of the subject with the use of lower limb symmetry index and determine the knee stability based on it [7,8]. Fitzgerald *et al*. [9] suggests that jump test is a predictive instrument to distinguish patients who possess problem caused by illness and damage in knee and a proper evaluation tools to reflect the change in condition of patients after the treatment.

Jump performance test including single leg tripod jump, single leg inside/outside jump, single leg vertical jump

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(SLVJ), single leg hop for distance (SLHD), and others is mainly used in clinical practice [10]. SLVJ and SLHD among them are the representative test and SLVJ presents test-retest reliability of 0.88-0.97 [11], and SLHD presents test-retest reliability of 0.80-0.96 [2]. However, there has been a controversy which test among function tests, particularly SLVJ and SLHD, that are used to assess the lower extremity (LE) function can perform broad and accurate assessment on neuromuscular control, capacity to exert power, balance, and flexibility. It is due to the lack of study and information on the relation between each function test that assesses the LE function [12].

In addition, the damaged part would aggravate and amount of pain would increase due to the excessive stress exerted to the knee while performing the assessment. Therefore, it is necessary to adopt a test for assessment of performance capacity that is simpler, less stressful, and more convenient for clinical application.

A test that determines the trunk alignment and integrated function performance of knee without jump movement including single leg balance, single leg squat (SLSQ), stair down, lunge, and others is used in the clinical practice [10]. Particularly, SLSQ test is clinical tools that assess the alignment of pelvis and thigh and neuromuscular control of LE during its performance [13,14] and it presents test-retest reliability of 0.61-0.80 [15]. Also, the stress exerted to knee during the performance of SLSQ is relatively smaller than the stress exerted during the jump.

Three function tests proposed above is effective in making decision to return to daily activities. However, there is lack of study on whether or not it measures similar elements of LE function and what relation is there between each function test in assessing the broad range of function performance.

Therefore, the correlation between three LE function tests will be examined first and whether or not SLSQ can substitute two other tests and what is most effective test combination will be examined second.

Table 1. General characteristics of the subjects (N=20)

Sex	Male	Female
N	10 (50)	10 (50)
Age	25.30 (4.11)	27.40 (3.56)
Height	173.10 (5.78)	160.50 (4.64)
Weight	64.10 (4.72)	50.00 (2.44)

Values are presented as n (%) or mean (SD).

Methods

Ten males and ten females with no history of LE dysfunction participated in this study (Table 1).

The test procedures consisted of a general warm-up, a task-specific warm-up, actual testing, and a cool down.

All participants performed the three tests in random order. Each subject drew a card with a random sequence of the three tests. Practice trials and a 60 second rest break between LE tests were designed to reduce error associated with learning and fatigue.

Each test was performed for the dominant and non-dominant LE. No attempt was made to randomize the order in which the lower extremities were tested.

The participant's dominant LE was defined as the LE they use to kick a ball [2].

For SLVJ, 1) it was recommended that stand on one leg, unsupported, next to a wall and tap your hand on the wall at the maximum vertical height. 2) At takeoff, the participant jumped as high as possible, tapping your hand on the wall at the maximum vertical height and landing on the same

Figure 1. Testing position for single leg vertical jump.

extremity. 3) Jump displacement was recorded as the difference between peak jump height and standing reach height. Participants were instructed that they could swing their arms freely and use a selected countermovement without stepping prior to the jump [16] (Figure 1).

For SLHD, 1) each participant stood on one leg and positioned the lead toe on a predetermined mark on the floor. 2) The participant Stood on one extremity and hoped as far forward as possible, landing on the same extremity. 3) Participants maintained the landing for a minimum of 2 seconds while the toe measurement is recorded. The investigator used a standard tape-measure to record the horizontal displacement, in centimeters, from the lead toe starting position to the heel landing mark. Participants were instructed that they could swing their arms freely and use a selected countermovement without stepping prior to the jump [16] (Figure 2).

For SLSQ, 1) the participants were asked to stand on the self-selected leg on a 20-cm box. 2) The participants were instructed to fold their arms across their chest and to squat down as far as possible three times consecutively, in a slow, without change in trunk alignment, maintaining their balance. 3) In regards to the length of squat, record the difference between the height of sciatic tuber at standing position and the lowest height reached with the performance of squat [15] (Figure 3).

Pearson Product Moment correlations was calculate among all pairs (SLVJ/SLHD, SLHD/SLSQ, SLVJ/ SLSQ), depending on normality assessment of data.

A correlation of 0.75 was established a priori as the criteria for good correlation.

IBM SPSS Statistics 19.0 (IBM Co., Armonk, NY, USA) was used for statistical analysis, by way of t-test with the significance level at 0.05.

A paired t-test was used to compare dominant and non-dominant lower extremities for each test and to compare between each tested pair.

Results

Statistically significant difference was presented between dominant LE and non-dominant LE in each function test ($p < 0.05$) (Table 2, Figure 4).

In regards to the correlation of function test pairs, the correlation between SLHD and SLVJ was the lowest (0.713) and it was the highest between SLSQ and SLVJ (0.939) in regards to the dominant LE ($p < 0.05$) (Table 3).

Discussion

The jump has been used as assessment tools of rehabili-

Figure 2. Testing position for single leg hop for distance.

Figure 3. Testing position for single leg squat.

Table 2. Differences calculated by paired t-test between dominant and non-dominant lower extremities for each test (N=20)

Test	Dominant	Non-dominant	*p*
SLVJ	23.81 (5.02)	21.46 (4.84)	0.000
SLHD	116.79 (23.09)	105.75 (22.72)	0.000
SLSQ	21.98 (2.26)	19.45 (2.45)	0.000

Values are presented as mean (SD).
SLVJ: single leg vertical jump, SLHD: single leg hop for distance, SLSQ: single leg squat.

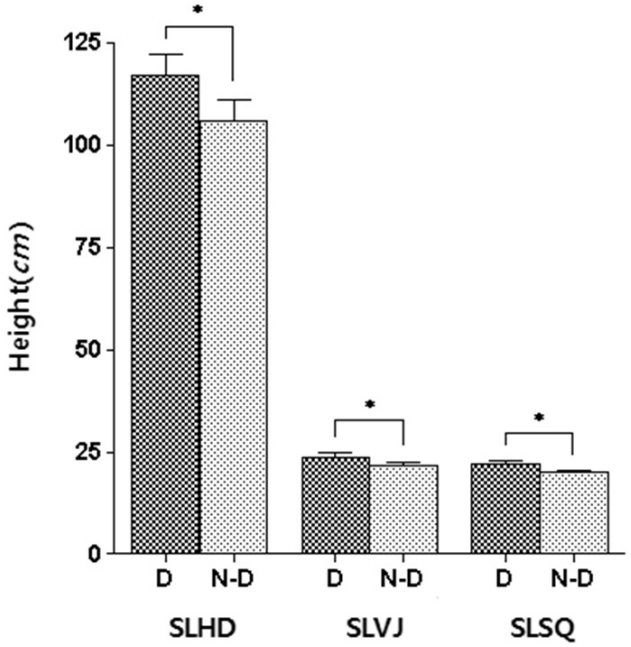

Figure 4. Difference between dominant lower extremity (LE) and non-dominant LE in each function test. *$p < 0.05$. SLHD: single leg hop for distance, SLVJ: single leg vertical jump, SLSQ: single leg squat.

tation process for the patient with damage in cruciate ligament after it was introduced by Noyes *et al*. [7] However, more statistical assessment was demanded for jump in order for it to become a function test that is used as a standard instrument [9].

Although correlation between each function test presents relatively high correlation, the highest correlation is presented between SLVJ and SLSQ pair and it presents high correlation in both between dominant LE (0.939) and non-dominant LE (0.883). This reveals that SLVJ and SLSQ measure very similar elements of LE function and illustrates it is proper not to include SLVJ and SLSQ in same combination when arranging the function test combination for the assessment.

Although SLHD and SLSQ pair and SLHD and SLVJ pair present high correlation, it did not surpass the significance level of 0.75 except SLVJ and SLHD pair in regards to non-dominant LE. It can be considered that the element of LE function assessed is vastly different and it is proper to arrange them in same combination when arranging the function test combination for the assessment.

Table 3. The results of all pairwise correlations (N=20)

Pair of tests	Pearson (r)	*p*
SLVJ & SLHD (dominant)	0.713 (a)	0.000
SLVJ & SLHD (non-dominant)	0.752 (a)	0.000
SLVJ & SLSQ (dominant)	0.939 (a)	0.000
SLVJ & SLSQ (non-dominant)	0.883 (a)	0.000
SLSQ & SLHD (dominant)	0.729 (a)	0.000
SLSQ & SLHD (non-dominant)	0.739 (a)	0.000

SLVJ: single leg vertical jump, SLHD: single leg hop for distance, SLSQ: single leg squat.

Although the center of mass needs to be moved horizontally for SLHD, SLVJ and SLSQ only require vertical movement without center of mass based artificial horizontal movement. Also, in order to perform vertical jump, it goes through similar process with squat as people maintains the posture not to lose the balance and lowers the posture in order to generate maximum elasticity. Moreover, high probability of abnormality not only in forward movement but also in left/right movement for horizontal movement may explain the low correlation with two other function tests.

Coronal plane movement of SLVJ and SLSQ, particularly capacity to maintain alignment between pelvis and thigh, has great influence on the distinction of test. Claiborne *et al.* [17] suggested that supporting side hip abductor plays important role in stabilizing the thigh against the pelvis when supporting the body weight with a single leg, and the hip abductor of supporting side LE is activated twice compared to opposite side LE while performing SLSQ [18]. It signifies that the hip abductor plays an important role in stabilizing the pelvis and thigh. it suggested that trunk alignment aggravates and stress exerted to knee increases with the lengthening of activation in gluteus medius [15], Although the longest center of mass movement was presented in the preferred posture, it did not present great difference with the preferred posture when it is below the preferred posture and it reached the point where simultaneous activation of gluteus medius and gastrocnemius is available only when it goes up to proper height as activation point of gluteus medius and gastrocnemius is delayed when it goes below the preferred posture [19]. It signifies that the activation point of gluteus medius

plays an important role in order to perform jump at maximum height. Thus it was revealed that the activation point of muscles to align pelvis and thigh among items to assess SLVJ and SLSQ is the common assessment element.

In regards to the correlation between dominant LE and non-dominant LE in each function test, it presented statistically significant difference ($p < 0.05$). It illustrates that SLHD, SLVJ and SLSQ are acute in distinguishing the difference between dominant and non-dominant and they can be used as a useful tool to make conclusive decision in performing the rehabilitation program.

High correlation between SLVJ and SLSQ was discovered in regards to the dominant LE and non-dominant LE in this study and it signifies that two tests assess common elements of LE function thus it cannot be used in same combination and SLVJ can be substituted with SLSQ.

On the other hand, low correlation was presented between SLHD and SLSQ in regards to dominant LE and non-dominant LE and it signifies that two tests assess different elements of LE function thus it can be form an effective combination to assess the broad LE function of patient with damaged LE.

I believe that above results will provide physical therapist with scientific evidence for effective test combination of LE function assessment in clinical practice.

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