Sensitivity to change: validity evidence of a partial-weight bearing lower extremity performance measure

Sheila Tobe

Medical College of Ohio

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Concentration in Physical Therapy

Sensitivity to Change: Validity Evidence of a Partial-weight Bearing Lower Extremity Performance Measure

Submitted by
Sheila Tobe

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Academic Major Advisor
Daniel J. Cipriani, III, Ph.D., P.T.

Chairperson
Clayton Holmes, Ed.D., P.T.

Dean, School of Allied Health
Christopher E. Bork, Ph.D.

Dean, Graduate School
Keith K. Schlender, Ph.D.

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Sensitivity to Change: Validity Evidence of a Partial-weight Bearing Lower Extremity Performance Measure

Sheila Tobe, B.S.
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ABSTRACT

Study Design: A pre and post-test measure of six randomized lower extremity (LE) functional performance tests.

Objectives: To determine whether valid inferences about LE performance could be obtained using a sliding incline apparatus.

Background: Current functional tests require patients to bear full weight on their lower extremities, and are not indicated for acute recovery states that require a partial-weight bearing (PWB) status. Measuring LE performance early in the rehabilitation process is essential in determining an accurate prognosis. Two LE performance tests were designed to measure functional performance of individuals with PWB status using a commercially available sliding incline apparatus.

Methods and Measures: Patients 18 years of age or older with LE dysfunction (n=21) participated. Diagnosis included: knee joint pathology, ACL reconstruction, TKA, patellofemoral dysfunction, and tibial plateau fractures. The PWB tests were preformed on a commercially available sliding incline apparatus. Subjects completed the following tests in a randomized order: a one-legged PWB 30 repetition squat test, one-legged PWB 20 second squat test, time to ascend stairs, time to descend stairs, distance of a one-legged hop, and walking speed. Subjects completed a pre-test initially and a post-test three to four weeks following treatment.

Data Analysis: Two-way ANOVA was used to compare the rate of improvement between the uninjured and injured LE for each of the single legged tests (i.e., the two PWB tests and the hop test); paired t-tests were used to test for improvement on the stair climbing tests and the walking test. It was expected that the injured LE would improve at
a greater rate than the uninjured LE and that all subjects would improve on the stair and walking tests.

**Results:** Both the uninjured and injured lower extremities improved over the three to four weeks of treatment; the injured LE improved at a significantly greater rate than the uninjured LE ($p<.05$). In addition, all subjects improved in walking speed and stair climbing ability ($p<.05$). The two PWB tests were sensitive to the gains of the injured vs. the uninjured LE.

**Conclusion:** The two PWB tests may provide early measures of LE performance in the rehabilitation setting for individuals with a PWB status.
INTRODUCTION

Functional performance tests (i.e., dynamic closed kinetic chain activities) are expressed in the literature as the most accurate predictor of LE performance, which in turn allow for development of realistic prognoses. Functional performance tests including: single legged hop for distance, stair climbing, and walk tests are strongly supported by research, but these tests require a full weight-bearing status (FWB). Currently there are limited reliable and valid means to measure LE performance of individuals with PWB status. An accurate measure of functional ability, which may be gained from functional performance testing, is essential for rehabilitation, treatment progression, and development of accurate prognoses of individuals with PWB status.

Due to lack of reliable and valid functional performance tests for PWB individuals, LE function in this population is generally assessed through manual muscle testing, ligament laxity testing, and isokinetic testing. These types of static testing have shown poor correlation to LE functional performance as discussed in literature. Kea et al. offer data about isokinetic testing in a study comparing hip abduction and adduction movements to a hop test for distance. Their research found isokinetic tests may be valuable to assess muscular strength at various points during the rehabilitation process. However, they determined that isokinetic testing should not be overemphasized when evaluating readiness to return to prior activity level. The relationship between isokinetic measures of hip strength and the hop tests was slight to poor (r=-.26 to .27 with p>.05). From this the researchers gathered that function should not be predicted by joint-specific strength tests. Function would be better tested by means of dynamic activities.
Dynamic activities are more functional, because they relate to the way bodies act against gravity and ground reaction forces.

Mittlmeier et al. studied several different types of functional monitoring during rehabilitation following anterior cruciate ligament (ACL) reconstruction. Ten patients with ACL deficiencies were examined to determine which testing type was most related to functional ability. Isokinetic, laxity, walking, and descending stairs tests were conducted with each patient. Data revealed that static measures of the knee such as laxity testing did not indicate functional knee movement pre or postoperatively. Higher functional tests such as walking and stair climbing were found to be better indicators of dynamic ability. Dynamic testing has been expressed as a better tool for determining a subject’s level of overall functional performance when compared to static and isokinetic tests.

A sliding incline apparatus has been developed to dynamically measure LE performance of individuals with PWB status. The sliding incline design of the apparatus allows individuals to perform dynamic closed kinetic chain activities while bearing a variable amount of weight on their lower extremities. The amount of weight placed on the subjects LE varies depending on the level of incline set on the apparatus prior to activity.

In a study by Munich et. al. two LE performance tests were performed utilizing the sliding incline device including: the number of single legged squats performed in 20 seconds and the length of time required to perform 50 single legged squats. Munich et. al. concluded that the sliding incline apparatus was able to yield reliable data. However, validity or application of this protocol to an injured population has not been supported by
Validity is expressed as the degree to which a device measures what it is intended to measure. When developing a method of assessment, it is critical to determine whether a tool is testing the item in question. Although the sliding incline apparatus has been proven to yield reliable data, this tool must also demonstrate validity in order to be an accurate functional assessment tool.

Although many seriously injured subjects are required to maintain PWB status for a period of time, current tests used to measure functional ability of these individuals are substandard. Few options are available at this time for testing functional status of PWB individuals. The purpose of this study is to provide validity evidence pertaining to the effectiveness of the sliding incline apparatus in measuring LE functional performance.

The sliding incline apparatus can be used to determine functional status of a PWB individual during dynamic movement. The accuracy of this test may lead to a more clear depiction of the subject’s capabilities. This information could then be used to determine an appropriate treatment progression to transition patients back to full weight bearing status.
METHODS

Design

Pre and post-test measure of six randomized LE functional performance tests.

Subjects

Thirty subjects with lower extremity dysfunction were recruited from outpatient physical therapy clinics in the greater Toledo Ohio area. Letters describing the study were sent to local clinicians requesting distribution of the information to potential subjects. Potential subjects included those individuals referred to physical therapy for treatment of a lower extremity dysfunction who are at least 18 years of age and healthy. Lower extremity dysfunction is defined as decreased ability to accomplish daily activities that involve use of the lower extremity (e.g., walking, squatting, and jumping). Pregnant women and individuals unable to follow instructions were excluded from this study.

Apparatus

The Total Gym (Engineering Fitness International, Inc., San Diego, CA) consists of an inclined sliding board that glides upon a solid steel frame (Figure 1). This device incorporates a pulley system that may be used to create arm resistance. Adjusting the incline of the sliding board can increase resistance of the lower extremities. For this study subjects performed two separate single leg squat test on the Total Gym without the use of the arm resistance pulleys. The Total Gym 20-second (TG20) and 30 repetition squat (TG30) tests used for this study yielded reliable data during research conducted by Munich et al.
Squat depth on the Total Gym can be limited with an adjustable strap located on the superior aspect of the device. In order to ensure that the subjects performed the squat tests at the same squat depth during pre and post-test measures, a 12-inch goniometer was used to measure knee joint angles prior to the start of the pre-test. When subjects returned for post-test measures they were positioned at the same knee joint angle. A stopwatch was used to determine time measures for the Total Gym squat tests, the descending stairs test, and the ascending stairs test. A tape measure was used to measure distance hopped by subjects during the single leg hop test. All testing was conducted in the Collier Building located on the Medical College of Ohio campus in Toledo, Ohio.

**Procedures**

Subjects were asked to complete a pre-test at the time of arrival and a post-test three to six weeks after the pre-test. A three to six week period was allotted to allow subjects time to gain a measurable amount of recovery. The pre and post-test sessions were conducted in the same manner. During these sessions subjects completed six separate lower extremity tests. The tests included:
1. Timed 30 single leg squat repetition test on the Total Gym (TG30)
2. 20-second squat repetition test on the Total Gym (TG20)
3. Single leg hop test (HOP)
4. Timed ascending stair test (UPSTR)
5. Timed descending stair test (DOSTR)
6. Timed 50 feet walk test (WALK)

These tests were performed in a randomly assigned order. The single leg hop test and both of the squat tests were performed on the subjects' injured and uninjured lower extremities. Prior to the start of testing, subjects were instructed to work at a comfortable pace. Subjects were also given the option to refuse any of the above tests if they expressed inability to complete the task.

20-second squat repetition test on the Total Gym

This test involved the subject performing as many single leg squats as possible in a 20 second time period. The subject squatted from $0^\circ$ of knee extension to a maximum of $90^\circ$ of knee flexion. If subject is unable to flex to $90^\circ$ he/she was asked to flex to a comfortable position. This position will then be measured with a 12-inch goniometer to ensure that pre and post-test trials will be carried out through the same range. The subject was instructed how to perform the proper squatting technique and he/she was asked to practice the squatting technique prior to beginning the test. After the subject became familiar with the test, he/she was rest for one-minute before starting the actual test. During the test, the researcher counted the number of squats performed by the subject. Subjects were tested at level 10 on the Total Gym (65% of body weight) or level 9 (60% of body weight) depending on individual tolerance to activity.
**Timed 30 single leg squat repetition test**

This test required the subject to perform 30 single leg squat repetitions on the Total Gym. The subject squatted from $0^\circ$ of knee extension to a maximum of $90^\circ$ of knee flexion. If subject was unable to flex to $90^\circ$ he/she was asked to flex to a comfortable position. This position was then measured with a 12-inch goniometer to ensure that pre- and post-test trials were carried out through the same range. The subject were instructed how to perform the proper squatting technique, and he/she was asked to practice the squatting technique prior to beginning the test. After the subject became familiar with the test, he/she rested for one-minute before starting the actual test. When the test began the researcher measured the amount of time it took the subject to complete all 30 repetitions. Subjects were tested at level 10 on the Total Gym (65% of body weight) or level 9 (60% of body weight) depending on individual tolerance to activity.

**Single leg hop test**

To complete this test subjects performed a maximal single leg hop. The subject was instructed how to properly perform the test and prior to the test the subject performed two practice hops. The subject began the test with toes behind a starting line, and a maximal hop will be performed. The researcher then measured the distance from the starting line to the subject’s heal. The single leg maximal hop was conducted two separate times during the actual test. An average of these two distances was used for data analysis.

**Timed ascending stair test**

This test required the subject to climbing up a single flight of stairs (24 steps). The subject was instructed to climb the stairs as rapidly as possible while remaining safe.
The researcher used a stopwatch to determine the amount of time it took the subject to climb the flight of stairs.

**Timed descending stair test**

This test required the subject to descend a single flight of stairs (24 steps). The subject was then instructed to descend the stairs as rapidly as possible while remaining safe. The researcher used a stopwatch to determine the amount of time it took the subject to descend the flight of stairs.

**Walk test**

For this test the subject was asked to walk 100 feet at a comfortable pace. During the 100-foot walk two distinct points 50 feet apart were used for measurement of walking speed. When the subject’s heel reached the first mark the researcher started the stopwatch. The stopwatch was stopped when the subject’s heel reached the second mark. This method helped insure that the subject’s true walking speed was measured.

**Additional Data**

The subject’s age, gender, impairment, onset of injury, lower extremity affected, and treatment type were recorded. This information was self-reported by the subject. Subjects were compensated monetarily for the time and expenses required to participate in this study.

**Data Analysis**

Pre and post-test data were analyzed to determine if the Total Gym was able to accurately measure functional gains. Time was an independent variable. We expected subjects to show improvements over time, and we anticipate that the total gym would be sensitive to gains in function. Dependent variables included: distance hopped, time to
ascend stairs, time to descend stairs, number on squats in 20 seconds, number or repetitions in 30 seconds, and time to walk 50 feet. Paired t-tests were performed using SPSS to determine statistical significance for the walking and stair negotiation tests. A two-way ANOVA was also used to determine whether an interaction was present between uninjured LE vs. injured LE rates of improvement for the TG20, TG30, and hop tests.
RESULTS

Demographics

Seventeen subjects (11 female and 6 male) participated in this study with a mean age of 56.8 ± 10.8 years. Each subject tested presented with some type of lower extremity pathology unilaterally or bilaterally. Diagnosis included TKA, Achilles tendonitis, patellofemoral pain, and ACL reconstruction. Additional descriptive characteristics are addressed in Table 1.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>11 female, 6 male</td>
</tr>
<tr>
<td>Mean age ± SD</td>
<td>56.8 years ± 10.8 years</td>
</tr>
<tr>
<td>Lower extremity involvement</td>
<td>19 injured, 15 uninjured (n = 34)</td>
</tr>
<tr>
<td>Mean days since injury ± SD</td>
<td>159.7 days ± 187.2 days</td>
</tr>
<tr>
<td>Mean days to retest ± SD</td>
<td>23.4 days ± 2.3 days</td>
</tr>
<tr>
<td>Mean knee flexion during TG tests ± SD</td>
<td>69.3º ± 3.6º</td>
</tr>
<tr>
<td>Treatment</td>
<td>4 no treatment, 9 PT, 6 treatment other than PT</td>
</tr>
</tbody>
</table>

Reliability Data

Reliability data expressed ICC values greater than .78 for all functional performance tests conducted during this study (Table 2).
Table 2. Intraclass correlation coefficients (ICC) for lower extremity functional performance during each functional test.

<table>
<thead>
<tr>
<th>Test</th>
<th>ICC Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TG20</td>
<td>.89</td>
</tr>
<tr>
<td>TG30</td>
<td>.96</td>
</tr>
<tr>
<td>HOP</td>
<td>.78</td>
</tr>
<tr>
<td>UPSTR</td>
<td>.93</td>
</tr>
<tr>
<td>DNSTR</td>
<td>.94</td>
</tr>
<tr>
<td>WALK</td>
<td>.99</td>
</tr>
</tbody>
</table>

TG20 = number or repetitions completed in 20 seconds
TG30 = time (seconds) to complete 30 repetitions
HOP = distance (centimeters) hopped on one leg
UPSTR = time (seconds) to ascend one flight of stairs
DNSTR = time (seconds) to descend one flight of stairs
WALK = time (seconds) to walk 50 feet

LE Improvement Comparing Pre- and Post-test Performance

It was hypothesized that LE function measured during the TG20, TG30, HOP, UPSTR, DNSTR, and WALK tests would improve from pre-test to post-test. This hypothesis was correct. LE function improvements were seen on all post-test measurements. Significant improvements were seen with the TG20, TG30, UPSTR, DNSTR, and WALK tests (p < .05). There was not a significant improvement noted with the HOP test, which may be due to the low power demonstrated by the hop test. Data collected from the walking and stair negotiation tests is displayed in Table 3. Data collected from the TG20, TG30, and hop tests are displayed in Table 4.
Table 3. Results of lower extremity performance tests for the stairs and walking

<table>
<thead>
<tr>
<th>Test</th>
<th>N</th>
<th>LE tested</th>
<th>Pre-test mean ± SD</th>
<th>Post-test mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPSTR</td>
<td>15</td>
<td>bilateral</td>
<td>12.7 ± 7.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.4 ± 5.3</td>
</tr>
<tr>
<td>DNSTR</td>
<td>15</td>
<td>bilateral</td>
<td>13.3 ± 8.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.6 ± 6.8</td>
</tr>
<tr>
<td>WALK</td>
<td>6</td>
<td>bilateral</td>
<td>8.8 ± 3.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.0 ± 3.4</td>
</tr>
</tbody>
</table>

<sup>a</sup>Pre-test means significantly different from post-test means, p < .05

Table 4. Results of unilateral lower extremity performance tests (TG20, TG30, hop)

<table>
<thead>
<tr>
<th>Test</th>
<th>N</th>
<th>LE tested</th>
<th>Pre-test mean ± SD</th>
<th>Post-test mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>TG20</td>
<td>14</td>
<td>uninjured</td>
<td>20.5 ± 5.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>21.9 ± 6.3</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>injured</td>
<td>18.1 ± 6.9</td>
<td>22.1 ± 7.5&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>TG30</td>
<td>14</td>
<td>uninjured</td>
<td>33.1 ± 10.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>31.5 ± 10.2</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>injured</td>
<td>45.2 ± 28.2</td>
<td>32.2 ± 13.2&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>HOP</td>
<td>3</td>
<td>uninjured</td>
<td>120.7 ± 13.2</td>
<td>127.8 ± 20.6</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>injured</td>
<td>120.2 ± 18.5</td>
<td>130.3 ± 29.8</td>
</tr>
</tbody>
</table>

<sup>a</sup>Pre-test means significantly different from post-test means, p < .05
<sup>b</sup>Uninjured means significantly different from Injured means at pre-test, p < .05

Rate of Uninjured vs. Injured LE Improvement

It was hypothesized that the injured LE would improve at a greater rate than the uninjured LE when comparing data collected from the pre- and post-tests. This hypothesis was correct. The two-way ANOVAs for the TG20 and TG30 tests were significant for the interactions (p-values < .05). However, the two-way ANOVA for the HOP test was not significant for the interaction (p = .17). This may be due to the low power of the HOP test (power = .06). Figures 2 through 4 illustrate the differences in rate of improvement of the uninjured and injured lower extremities during the TG20, TG30, and HOP tests.
During the TG20 test the injured LE improved more rapidly than the uninjured LE by increasing the number of repetitions performed in 20 seconds at a greater rate.

**Figure 2.** Rate of LE improvement comparing injured and uninjured extremities during the TG20 test.
*Rate of gain for injured significantly greater at p < .05

**Figure 3.** Rate of LE improvement comparing injured and uninjured extremities during the TG30 test.
*Rate of gain for injured significantly greater at p < .05
**Figure 4.** Rate of LE improvement comparing injured and uninjured extremities during the HOP test.
DISCUSSION

Function tests have been discussed in literature as the ideal measure of a patient’s functional performance.\textsuperscript{1,2} Current functional tests require patients to bear full weight on their lower extremities, and are not indicated for acute recovery states that require PWB status. Although many seriously injured subjects are required to remain PWB for a period of time, few options are available for testing functional status of PWB individuals.

A sliding incline apparatus has been developed to test functional performance while maintaining a PWB status. The sliding board apparatus allows subjects to perform functional, closed kinetic chain, squat exercises while remaining PWB. In a study by Munich et al. it was determined that the sliding board apparatus was able to yield reliable data pertaining to functional performance. Currently no studies have examined the ability of the sliding board apparatus to provide valid inferences about functional performance.

The purpose of this study was to determine whether valid inferences could be made from the data obtained by use of the sliding board apparatus. The Munich et al. protocol for the sliding board apparatus was used during this study to measure functional performance of individuals with lower extremity dysfunction. The data collected from the sliding board apparatus was then compared to data collected from three other functional tests. The additional tests used include: single-leg hop for distance, walk test, and stair climbing test. The single-leg hop for distance test has been discussed in literature as a reliable method to determine functional performance.\textsuperscript{6,10,11} Walking and stair climbing tests were used because they involve functional activities that are commonly performed.

Seventeen subjects each presenting with some type of lower extremity pathology
unilaterally or bilaterally participated in this study. Subjects participating in this study were receiving varying amounts of treatment. Some subjects were attending physical therapy, others were self-treating, and the remainder reported not conducting any type of treatment for their injury during the time of the study. We expected all subjects to show bilateral LE functional improvements over time, and we anticipate that the sliding board apparatus would be sensitive to gains in function.

It was hypothesized that bilateral LE function would improve from pre-test to post-test. LE function improvements were seen on all post-test measurements. Significant improvement in functional performance was noted with all tests excluding the single-leg hop for distance. The lack of significant findings with the single-leg hop for distance may be due to the low power demonstrated by the hop test. The low power of the hop test is likely a result of few subjects being able to perform the test.

It was also hypothesized that the injured LE would improve at a greater rate than the uninjured LE when comparing data collected from the pre- and post-tests. With all tests except the single-leg hop for distance there was a significant rate of increase with the injured LE improving at a greater rate than the uninjured LE. This may also be due to the low power of the HOP test (power = .06).

**Clinical Implications**

Data yielded from the sliding board apparatus may be used to determine the functional status of a patient with a partial weight-bearing status. Use of subjects with lower extremity dysfunctions increases the external validity of this study for the clinical setting, and allows this data to be generalized to the injured population. Therefore, through use of this apparatus therapists may be able to evaluate the functional level of a
patient with a PWB status earlier in the rehabilitation process. This information could then be used to determine an appropriate progression of treatment to transition patients back to a full weight-bearing status.

Limitations

Limitations of this study include a small number of subjects who were able to perform the single-leg hop for distance test, a narrow age range of subjects, minimal variety in subject diagnosis, and inconsistency of treatments received by subjects for their injuries. The single-leg hop for distance test used during this study was too difficult for most of the subjects to perform. Resulting from the low number of individuals who were able to perform the test was a low statistical power with insignificant findings. The majority of the subjects tested for this study were recruited from the same orthopedic clinic. Therefore, many of the patients were of similar age and displayed similar injuries. In addition, with the design of this study we were unable to control the treatments received by subjects to ensure that they should or should not be making functional gains. With this study we relied on the assumption that all subjects would increase in functional performance over time.

Suggestions for future research

For future research it has been recommended that a more diverse sample be analyzed. A more diverse population of subjects may involve patients with a large variety of injuries and ages. With a more diverse population of subjects more individuals may be able to perform the single-leg hop for distance. In addition, a more diverse population would allow this study to be generalized to a larger group of individuals. Currently, this study may only be generalized to middle-aged individuals with LE injuries.
CONCLUSION

The purpose of this study was to provide validity evidence pertaining to the effectiveness of the Total Gym in measuring lower extremity functional ability. The sliding board apparatus can be used to determine functional status of a partially weight-bearing individual during a dynamic movement. The accuracy of this test may lead to a more clear depiction of subjects’ capabilities. This information could then be used to develop a more appropriate progression in order to transition individuals back to a full weight-bearing status.
REFERENCES


