Do Functional-Performance Tests Detect Impairment in Subjects With Ankle Instability?

Joanne Munn, David J. Beard, Kathryn M. Refshauge, and Raymond W.Y. Lee

Objective: To determine whether the triple-crossover hop and timed shuttle run are able to discriminate between injured and uninjured limbs in subjects with functional ankle instability. Design and Setting: A comparative study involving the assessment of functional performance, conducted in a university gymnasium. Participants: A volunteer sample of 16 university-age subjects with unilateral functional ankle instability. Outcome Measures: The triple-crossover hop for distance and timed shuttle run measured functional performance, with the uninjured limb acting as a control. Subjects also rated their ankle symptoms using a self-report questionnaire. Results: The triple-crossover hop and shuttle run did not detect functional deficit despite subjects' self-report scores indicating functional impairment. Conclusions: Results of the triple-crossover hop and shuttle run used in the clinic should be interpreted with caution, because they will not necessarily identify functional impairment. Key Words: ankle sprain, hop test, shuttle run, between-limbs discrimination

Ankle injuries are the most common type of sports injury, representing 16% of all injuries occurring in sport. Inversion trauma, which results in damage to the lateral-ligament complex, is the mechanism responsible for 85% of all ankle-ligament injuries. Resultant symptoms after ankle sprain include pain, swelling, decreased range of motion, and a feeling of weakness or instability. After an ankle sprain, 40% of sufferers report chronic residual disability involving the sensation of giving way or the feeling of instability at the ankle, often in the absence of a mechanical deficit. Given the high prevalence of ankle sprains and their related functional disability, reliable and valid measurement tools indicative of function are needed to quantify clinical outcomes and assess patients' ability to return to activity. Measures of function cannot detect specific abnormalities (eg, ligament

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rupture) but are designed to evaluate lower limb function. Functional outcome measures can be categorized into 3 groups: (1) self-report scoring systems⁸,⁹ that subjectively rate items such as pain, swelling, instability, and activity level; (2) performance-based tests that attempt to provide conditions representative of sports or activities of daily living that are quantifiable and usually generate interval-level data such as time or distance, such as hopping tests¹⁰-¹⁷ and shuttle running¹¹,¹⁸; and (3) global scoring systems that encompass both self-report and performance-based tests and can also include measures of impairment such as joint range of motion.¹⁹

Several of the functional outcome measures for the ankle, such as hopping tests¹⁰ and self-report scoring systems,⁸ have been developed from functional measurements used in the assessment of patients with anterior-cruciate-ligament (ACL) injuries⁹,¹¹,¹²,²⁰ and have not been evaluated in subjects with ankle instability, despite their use in the clinical environment. Functional-performance tests for the lower limb include bilateral tests such as stair running,²¹,²² figure-8 running,¹¹,²¹,²² and shuttle running¹¹,¹⁸ and unilateral tests such as single-leg vertical hop,¹¹,¹³,¹⁴ single hop for distance,¹⁰-¹⁷ timed hop,¹⁰-¹³,¹⁵,¹⁶ triple hop for distance,¹²,¹³,¹⁵,¹⁶,²¹,²² triple-crossover hop for distance,¹²,¹³,¹⁵ single-limb-hopping course for agility,²²,²³ and 30-m agility hop.¹⁰,¹⁶ These methods, however, must provide valid and reliable measurements to be useful in recording function.

High test–retest reliability has been demonstrated for the single hop for distance,¹³,¹⁵,¹⁶ triple hop for distance,¹³,¹⁵ crossover hop for distance,¹³,¹⁵,¹⁶ 30-m agility hop,¹⁶ and shuttle run¹⁸ in normal subjects. In subjects with a past history of ankle sprain, high reliability has been demonstrated for the single hop for distance, 6-m timed hop, and 30-m agility hop.¹⁰

Functional-performance tests should be able to detect functional deficits and therefore be capable of discriminating between injured and uninjured limbs in subjects with unilateral pathology. The use of unilateral functional-performance tests assumes that neuromuscular deficits of the uninjured limb are absent and limb dominance does not influence performance. Performance symmetry between dominant and nondominant limbs has been demonstrated for single hop for distance,¹¹,²⁴,²⁵ triple hop for distance,²⁵ timed hop,¹¹,²⁵ crossover hop for distance,²⁴ and shuttle run¹¹ in normal subjects. Because limb dominance does not influence performance symmetry on these tests, valid between-limbs comparisons can be made in subjects with unilateral pathology.

Few studies have evaluated functional-performance tests in subjects with unilateral ankle instability.¹⁰,²⁴,²⁶ In 1 study, the single-leg hop, 6-m hop for time, and 30-m agility hop tests were not able to discriminate between the injured and uninjured limbs of university students with history of ankle sprain.¹⁰ In another study, however, an elaborate single-limb-hopping course with inclinations causing an uneven surface was able to detect a deficit of the unstable ankle,²⁴ although this test has not been assessed for reliability. Reliability and responsiveness of other disablement measures after
ankle sprain were investigated by Wilson et al. In their study, single-hop, crossover-hop, stair-hop, and running tests were scored dichotomously according to successful completion of each task to form a motor-activity-performance scale. Motor-performance measures were highly reliable and were responsive to change in functional performance 1 week after acute ankle sprain.

There is limited research validating the use of functional-performance tests in ankle instability, but clinically, such tests are often used to identify functional deficits by comparing performance between injured and uninjured limbs. The purpose of the present study was to determine whether functional-performance tests, specifically the triple-crossover hop for distance and the shuttle run, are able to discriminate between injured and uninjured limbs in subjects with unilateral functional ankle instability.

**Methods**

Sixteen subjects with unilateral functional ankle instability were recruited for this study, ranging in age from 18 to 29 years (mean = 22.4 ± 3.6). The sample consisted of 7 women and 9 men, with 7 of the subjects having symptoms in their dominant limb and 9 in their nondominant, with limb dominance being determined by the subjects kicking a ball. Most subjects participated in sports activities at a competitive level (Table 1). Inclusion of subjects was based on criteria adapted from Lentell et al. Subjects were included if (1) they had a history of unilateral ankle sprain on more than 1 occasion affecting the lateral ankle, with the last episode occurring no more than a year ago and no less than 4 weeks ago; (2) at the time of the study they reported symptoms of weakness, pain, or reduced function on lower limb activities secondary to the ankle sprain; (3) they had no past history of orthopedic surgery or fracture to either ankle; (4) they had no history of neurological conditions affecting balance or strength; and (5) they had no

<table>
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<th>Activity level*</th>
<th>Number of Subjects</th>
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<td></td>
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<td>III</td>
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*I indicates soccer, football, netball, basketball, and tennis (competitive); II, cricket, jogging, aerobics, tennis (social), and softball; and III, walking, golf, and house duties.
ankle pain while at rest. Mechanical instability was not assessed because this study aimed to evaluate performance in functionally unstable ankles, and it has been well established that the presence or absence of mechanical ankle instability is poorly related to symptoms experienced with functional ankle instability.6,7

Each subject’s function was scored out of 100 using a self-report functional questionnaire described by de Bie et al8 (Figure 1). Subjects’ self-report scores of function ranged from 38 to 95 (mean 77.5 ± 14.9), demonstrating self-perceived functional impairment associated with their ankle instability.

**Functional-Performance-Test Protocol**

**Triple-Crossover Hop for Distance**

The triple-crossover hop for distance was performed as described by Noyes et al.12 Subjects stood on 1 limb with their arms across their chest and were instructed to flex the knee of the nonstance limb to 90°. Each subject hopped 3 times from a start line in a zigzag fashion, crossing over tramlines that were marked on the floor 15 cm apart. The distance from the start line to where the toe landed on the third hop was recorded with a standard tape measure (Figure 2).

**6-m Shuttle Run**

Performance of the shuttle run was similar to that described by Barber et al.11 From a standing start, subjects sprinted up and back twice along a 6-m course. Subjects were required to start with 1 leg forward on the start line. The starting foot (forward foot) was used to prop and turn with each direction change on the shuttle run. Because cutting and change-of-direction movements are commonly associated with ankle sprain,1,5 the turning foot differentiated the test limb in this partially bilateral task. Each subject was timed with a handheld stopwatch. Time started from the initial forward movement of the subject and stopped when the subject crossed the line (Figure 3).

Subjects performed a warm-up and were familiarized with both tests prior to data collection. The process of familiarization and warm-up consisted of 3 submaximal trials of each of the tests on each limb, followed by 3 maximal efforts for each test. Three minutes rest between the warm-up sets was taken. Testing sequence was selected from a concealed envelope to reduce systematic error by randomizing the order of legs tested and tasks performed. The functional-hop and shuttle-run tests were performed 3 times at maximal effort on both the injured and uninjured limbs. Subjects rested for 5 minutes between trials. Booher et al16 have shown the use of the mean of 3 tests to be more reliable than the use of best-effort measures.
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**TOTAL SCORE**

**Figure 1**  Self-report questionnaire adapted from de Bie et al. Subjects rate their ankle for each category on the scale provided; then the scores are added to achieve an overall score out of 100.
for functional-performance testing. For this study, the mean performance of the 3 trials was calculated and compared for each limb, with the uninjured limb acting as a control.

**Data Analysis**

Paired Student \( t \) tests were used to determine whether there were performance differences between the injured and uninjured limbs. Pearson product–moment correlation coefficients were used to determine the relationship between functional-performance tests and self-report scores. Significance was set at \( P < .05 \).

**Results**

Although all 16 subjects completed self-report function questionnaires, 1 subject withdrew from functional-performance testing because of personal time constraints, and therefore functional-performance measures were only completed on 15 subjects. Neither the triple-crossover hop nor the shuttle run identified a functional-performance deficit of the injured limb (triple hop \( t_{14} = 0.85, P > .05 \); shuttle run \( t_{14} = 0.40, P > .05 \)) despite perceived functional deficit as indicated by scores on the self-report function questionnaire.

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**Figure 2**  Triple-crossover hop for distance. The total distance \( d \) was measured with a tape measure from the start line to where the subject’s toes landed on the third hop. With each hop the subject must cross over the tramlines, which are 15 cm apart.

**Figure 3**  Shuttle run. Subjects completed the course by running up and back twice. The experimenter recorded time with a handheld stopwatch from the initial forward movement of the subject until the subject crossed the finish line.
(77.8 ± 14.9). Group mean performance for the triple hop was 4.83 ± 0.91 m for the injured limb and 4.93 ± 1.10 m for the uninjured limb, and times for the shuttle run were 7.44 ± 0.79 seconds for the injured limb and 7.40 ± 0.75 seconds for the uninjured limb (Table 2).

A post hoc power analysis was calculated for functional-performance test data, with a clinically significant between-limbs performance deficit set at 15%. Statistical power of greater than 80% was achieved for both hop and shuttle run.

Correlation analysis showed that there was no significant relationship between self-report function scores with either the triple-crossover hop ($r = .003, P > .05$) or the shuttle run ($r = .13, P > .05$).

Data from a subgroup of 6 subjects who reported greatest symptoms of instability, as indicated by scores of 15 or below in the instability subcategory of the self-report score (Figure 1), were analyzed independently to determine whether functional-performance tests were responsive to functional deficit in more symptomatic ankles. Paired $t$ tests were performed on the data of this subgroup, with significance set at $P = .025$, the probability level being corrected with the Bonferroni technique. There was no significant between-limbs difference (triple hop $t_5 = 2.60, P > .025$; shuttle run $t_5 = 0.266, P > .025$). The mean performance for this subgroup for crossover hop was 4.75 ± 1.26 m and 4.99 ± 1.33 m and for the shuttle run was 7.48 ± 1.23 seconds and 7.49 ± 1.12 seconds for the injured and uninjured limbs, respectively.

### Comments

The triple-crossover hop for distance and shuttle run used in this study were unable to discriminate between the injured and uninjured limbs of subjects with unilateral functional ankle instability. Similarly, Worrell et al.\textsuperscript{10} were unable to find a between-limbs difference for a 30-m agility hop and 6-m timed hop in subjects with unilateral ankle sprains. The lack of ability of both the triple-crossover hop and shuttle run to detect a functional deficit might be because neither of these tests is adequately challenging, or a perceived functional deficit exists that cannot be currently measured.
This perceived deficit might be associated with adaptive changes in motor control that compensate for performance deficit.

The performance tests used in this study might have been insufficiently challenging to detect performance deficits in unilateral ankle instability. Ankle-energy contributions in simple closed-chain kinetic tasks such as jumping have been shown to be relatively low compared with contributions from more proximal segments in the kinetic chain. Lack of discrimination of functional-performance tests in assessing ankle function could therefore be a result of the fact that the role of the ankle in performing tasks such as hopping and jumping is much less demanding than the role of the knee or hip. It is plausible that more vigorous tests that place greater demand specifically on the ankle than the ones used in the current study might detect deficits in functional performance.

A hop test designed by Chambers et al to measure single-limb agility on uneven ground required subjects to hop on squares that were inclined in different directions to stress the subjects’ ability to control their ankle while hopping on sloping surfaces. Jerosch and Bischof used this test to measure function in subjects with ankle instability. They found significant between-limbs differences for hopping performance in these subjects. The greater difficulty of the hopping course used by Jerosch and Bischof could explain why a significant difference in performance was found between limbs in their study. In our experience, patients in the clinic commonly report that uneven surfaces aggravate symptoms of functional ankle instability. Although the agility-hop test developed by Chambers et al might be more suitable to measure functional performance in subjects with functional ankle instability, reliability has not been reported for this test.

It is also possible that the severity of ankle instability influences functional-performance test outcomes. Because of this we analyzed a subgroup of subjects with more severe instability, as indicated by the subcategory of instability on the self-report questionnaire. In this subgroup the triple-crossover hop and shuttle run were still unable to detect a functional deficit.

Another possible explanation for the findings of this study is that a self-perceived functional deficit exists in the absence of physically detectable functional limitations. Previous work on ACL-deficient subjects has revealed that self-report measures of function are more effective estimates of disability than functional-performance measures are. In the current study, there was no correlation between self-report scores of function and functional performance of the injured limb. All subjects in this study had perceived functional deficits, as indicated by scores of less than 100 on the self-report questionnaire, but functional deficits were not physically detected. Also, all subjects reported the feeling of instability or giving way with activity. Although all but 1 subject were able to participate in sports activity despite their perceived impairment, 75% of subjects reported having to modify their sports-activity participation or wear external support.
for the affected ankle during sport.

The triple-crossover hop for distance and the shuttle run might not have detected functional deficit in this sample population because of adaptations in motor control. It has been argued that limitations in functional-performance tests for assessing functional deficit might exist because compensation in the kinetic chain takes place proximal to the site of the injury. In support of this postulation, Gauffin and Tropp found adaptive patterns of motor control and muscle activation in the limbs of subjects with ACL deficiency compared with their uninjured limbs when performing a single-leg hop. Compensatory mechanisms in ACL-reconstructed patients have also been demonstrated with lateral step-up and vertical-jump tasks and stair climbing. Ernst et al found that although knee-extensor moments were reduced when subjects performed lateral step-ups and vertical jumps, the summed knee, ankle, and hip-extensor moments were not different between the injured and uninjured limbs, suggesting that ankle or hip extensors compensate for a knee-extensor deficiency. Similar compensatory strategies might occur in subjects with ankle instability when they are performing tests such as the crossover hop and shuttle run. For activities during which a subject reports giving way or the sensation of instability, alternative motor-activation strategies might not be available, thus limiting the performance on these specific activities.

In the future, kinetic and kinematic analysis of functional tasks in subjects with ankle instability might be useful in revealing compensatory movement strategies that take place when a physical performance deficit is not apparent. The importance of the peroneus longus and tibialis anterior in ankle stability during cutting movements has been established in asymptomatic subjects. Comparison of EMG and kinematic data for healthy subjects and those with history of ankle instability would therefore be useful to determine whether compensatory motor-activation patterns occur. Identification of such strategies could assist in directing rehabilitation toward developing alternative motor patterns for specific tasks during which subjects report symptoms of instability.

In other research on functional-performance tests, it has been recommended that the results of 2 performance tests be used to detect functional deficit in ACL-deficient knees. Using a criterion by which abnormal performance on at least 1 out of 2 functional-performance tests was used to indicate dysfunction improved detection of functional deficit by over 10%. Future research into the use of combined information from 2 or more functional-performance tests in populations with ankle instability might provide more sensitive means of assessing functional deficits.

Our findings demonstrate that the triple-crossover hop and shuttle run were unable to discriminate between injured and uninjured limbs in subjects with unilateral functional ankle instability and therefore should be interpreted cautiously if used in the clinic. Future research should attempt to discern whether lack of discrimination of these functional-performance
tests in ankle instability is because the tests are insufficiently challenging or because individuals have a false perception of their physical ability.

References


