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# Performance Function Tests in Assessing Ankle Fitness

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## Abstract

**Introduction:** A challenge for any physician caring for athletes is determining readiness for return to competition after an injury. A wide variety of performance function tests (PFTs) have been described, but no norms or minimum performance levels exist for any of them. In this study, healthy athletes were given a series of PFTs to complete. We propose that there will be a minimum performance level for each of the PFTs that all athletes can complete. We also propose, for tests that assess the right and left legs independently, that performance of the right leg will consistently be within 10% of the left. Finally, we propose that performance on one of the functional tests will be predictive of function on all the tests.

**Methods:** Athletes were put through a testing protocol, beginning with range of motion and progressing through a series of functional ankle tests of increasing difficulty. Right and left leg data were recorded separately for the first five tests. For each test, mean values, ranges, and SDs were calculated.

**Results:** Eighty-one athletes completed the protocol. A wide variation existed in performance ability between athletes; the SD for any of the tests was too high to determine a minimum performance threshold. However, when comparing right to left leg in any one athlete, the difference in performance testing was always less than 10%. Furthermore, performance on the side hop test was predictive of performance on the other tests.

**Discussion:** A wide range of performance was noted in all the PFTs, so it is not possible to define a minimum threshold. However, performance of an injured leg to within 10% of the opposite (uninjured) leg suggests achievement of normal function. The side hop test might be a good test by itself to represent overall ankle readiness.

Ankle sprains, along with other injuries to the lower leg and foot, are a common occurrence among athletes and often result in time out of sport. A great deal of effort goes into accelerating rehabilitation in injured athletes. One of the challenges for any physician caring for athletes is

determining readiness for return to competition after an injury or surgery. Premature return places the athlete at risk of reinjury, whereas too slow of a return may lose game time and could adversely affect psychological readiness. No clear standards exist for defining what is needed for safe return to play after ankle injuries.

In general, an athlete who is ready will demonstrate restoration of joint motion and recovery of strength. However, achievement of these milestones does not necessarily predict a safe return to athletics. Simple strength assessments do not correlate with functional task capability and probably are not good indicators of readiness or risk of reinjury.<sup>1-3</sup> A more complex assessment of balance and coordination will be necessary when investigating ankle capabilities.

A wide variety of performance function tests (PFTs) have been described, and many of these focus on hopping or jumping.<sup>4-8</sup> In theory, these tests assess strength, balance, and coordination together and could be good predictors of ankle fitness. Some have been studied in patients with ankle instability and in normal athletes.<sup>9</sup> An ideal PFT would be easy to administer, would not require practice or preparation, and would provide an objective quantification of ankle fitness.

The purpose of this study was to begin to define standards of ankle fitness. A large series of healthy athletes were given a series of functional tests to complete, beginning with range of motion and progressing through PFTs of increasing difficulty. We propose that there will be

a minimum performance level for each of the PFTs that all athletes can complete. We also propose, for tests that assess the right and left legs independently, that performance of the right leg will consistently be within 10% of the left. Finally, we propose that performance on one of the functional tests will be predictive of function on all the tests.

In addition, injured athletes recovering from an ankle sprain were put through the testing protocol. Performance of the injured leg was compared with the healthy leg, and performance was correlated with subjective pain scores.

## Methods

Healthy college athletes were recruited for this study from several different sports. An athlete was excluded if he or she was recovering from a recent injury or surgery. Each athlete reported no ankle pain with activity. Each athlete was tested by a single examiner.

The testing protocol begins with an assessment of motion and then moves through tests of ankle endurance and balance with increasing difficulty. If an athlete cannot complete a step adequately, the entire test is stopped.

The first test assesses the range of motion of the ankle. For the dorsiflexion (DF) lunge test, the subject stands facing a wall, with shoes off. The kneecap of the leg to be tested leans forward, resting against the wall, but the heel must remain on the ground. The foot is moved away from the wall as far as possible, so long as

the heel remains flat on the ground. The distance from the wall to the tip of the first toe is measured and reflects the degree of ankle DF achieved. Both legs are assessed.

The remainder of the tests assess leg strength, endurance, and balance. In the heel rise (HR) test, a subject stands on the leg to be tested, with the other leg held off the ground and knee flexed approximately 90°. The subject is allowed to use a wall or chair at arm's length for balance, but cannot lean on the wall or chair. Single-leg heel raises are then performed at a cadence of approximately 1 per second, until fatigued, or until the subject achieves the maximum of 50 repetitions. Both the right and left legs are assessed.

The side hop (SH) test is performed in sneakers. The subject stands on one foot, adjacent to a line on the ground, and then hops back and forth across that line on the tested leg only. Hopping is performed at a rate of 1 to 2 per second, and the subject continues until he/she loses balance or fatigues or reaches the maximum of 50 repetitions. This test is also performed on the right and left legs independently.

The front-to-back hop test (FB) is identical to the SH test, except the hopping is performed front to back, instead of side to side.

The functional hop (FH) test is also performed in sneakers. The subject starts at the base of a line that is approximately 8 m long and approximately 25 cm wide. The subject then hops from one foot to the other on either side of this line, forward and then backward. The subject makes

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four hops forward and then four backward to (more or less) end up at the starting point. This series of hops is repeated 5 times, for a maximum of 40 hops, or until the subject loses balance or fatigues. This test assesses both legs together and results in only one score (not right and left separately).

The final test is the 180° rotational jump (RJ). The athlete begins with both feet on the ground and then jumps while rotating 180° to land facing the opposite way. Then, the athlete again jumps rotating back to the original starting position. This step is repeated for 10 repetitions (20 full jumps).

For each test, mean values, ranges, and SDs were calculated. Injured athletes, recovering from ankle sprains, were administered the testing protocol. They also reported a visual analog pain score (between 0 and 10) of the level of pain they felt with athletic activity. Correlations were made between performance on components of the protocol and visual analog pain scores.

## Results

Eighty-one uninjured athletes were tested through the entire protocol. All athletes were able to complete all steps of the testing protocol; the testing did not have to be stopped for anyone. All were healthy and participating in competitive or recreational athletics. The mean age was 21 years. Ten had previous history of ankle injuries, and three had previous knee ACL injuries, but all these had recovered back to unrestricted athletics. There were 23 women and 56 men. The athletes participated in football, soccer, track, and basketball.

For all the individual tests, the range was high, representing varied levels of ability to complete the tests. For example, for single-leg heel raise on the right leg, the mean score was 26, but the SD was 10, and the range

**Table 1**

### Performance of Healthy Athletes

Test	Mean	Range	SD
Dorsiflexion lunge, right	12	0–20	3
Dorsiflexion lunge, left	12	6–19	3
Heel raise, right	27	7–55	11
Heel raise, left	27	8–70	11
Side hop, right	29	4–50	14
Side hop, left	28	4–50	13
Front-back hop, right	22	0–50	12
Front-back hop, left	21	0–50	12
Functional hop	33	8–40	18
Rotational hop	18	3–20	4

**Table 2**

### Difference Between the Right and Left Legs in Healthy Athletes

Test	Mean	Range	SD	Mean Difference (%)
Dorsiflexion lunge	1	0–6	1	9
Heel raise	3	0–15	3	10
Side hop	2.5	0–11	2	8
Front-back hop	2	0–7	2	10

was 7 to 55. SDs for any of the tests were generally 25% to 50% (Table 1), and 3 SDs (which would represent the result achieved by 99% of subjects) often had the lower 99% confidence interval at or less than zero. With such variability, it is not possible to define a meaningful level for any of the tests that would represent a basic minimum threshold. Given these data, we cannot define a minimum level of performance for any of the tests that would reliably predict an athlete who is performing at their normal level.

We then subdivided the data into groups based on sex and sport. For men's football, SDs remained high (25%–50% of the mean). For other sports, such as women's soccer, some SDs were lower (20%), but the sample size of the groups became much smaller (data not shown).

Although performance on any of the tests was highly variable between

athletes, in each athlete, the performance of the right leg was similar to the performance of the left leg. In the heel rise, SH, and front-back hop tests, the mean difference between the legs was 10% or less. Thus, although performance of any one athlete cannot be used to judge another, performance of the right leg can predict the contralateral leg in these healthy subjects (Table 2).

Although we were generally able to complete the testing in less than 15 minutes per athlete, we next sought to determine whether an abridged version of the protocol could be just as informative. With regression analysis, we found that performance on the SH test was highly predictive of performance on the front-back hop (regression coefficient of 0.694,  $P = 0.000$ ,  $R^2 = 60.1\%$ ; 95% confidence interval, 0.581–0.806). Performance on the SH test was moderately predictive of performance on the heel rise, FH, and

**Table 3****Performance of the Injured Leg Relative to the Uninjured Leg, Percentage**

Age	Injury	DF Test	HR Test	SH Test	FH Test	Pain
31	Spr	50	3	0	0	3
34	Spr	33	0	5	15	7
34	Spr	10	0	45	35	6
34	Spr	20	0	25	20	6
22	Spr	0	16	50	40	3
16	Spr	0	12	0	0	0
17		10	3	0	0	0
15	Spr	0	0	18	0	2
42	Spr	0	12	12	12	5
Correlation with pain scores		0.335351484	-0.34968965	0.37328691	0.55872365	

DF = dorsiflexion lunge, FH = functional hop, HR = heel raise, SH = side hop

rotational hop tests (regression coefficients of 0.395, 0.624, and 0.240, respectively).

Athletes participating in physical therapy after an ankle sprain were also put through the testing protocol. Nine assessments were made on subjects aged between 15 and 42 years (Table 3). For those segments that test the right and left legs separately, performance deficit (in percentage) of the injured leg relative to the uninjured leg was recorded. Performance on both the SH and front-back hop tests showed fair correlation with pain scores; a lower pain score correlated with less of a performance deficit on the injured leg. For the heel rise test, no correlation was seen, and it was common to see patients with high pain scores perform the heel raise test without deficit.

## Discussion

During athletic activity, the ankle is frequently subject to sudden forces, especially inversion. Uncontrolled inversion will lead to ankle sprains or fractures. Ankle “stability” is achieved through complex neuromuscular mechanisms.

With inversion, stretch receptors in the lateral ankle ligaments, as well as

the peroneal tendons, are activated, leading to reflexive contraction of the peroneal muscles.<sup>10,11</sup> Peroneal activation stops the uncontrolled inversion, protecting the ankle from injury. However, this closed loop control does not activate quickly enough to be the main defense against injury.<sup>12-15</sup>

Athletic training and conditioning leads to preactivation of muscles before the inversion begins, in anticipation of upcoming stress. In other words, an athlete learns through training and experience to activate appropriate stabilizing muscles at just the right time. These “open loop” mechanisms may be the most important.<sup>16,17</sup>

All these protective reflexes are disrupted with acute foot and ankle injuries, as well as in patients with chronic ankle instability.<sup>18-20</sup> The challenge for the physician or trainer counseling an athlete is determining when these reflexes are sufficiently restored so that return to competition is safe.

Restoration of range of motion and strength are often cited as indicators of ankle or knee fitness. However, normal motion and strength are not predictive of ability on performance testing, such as single-leg hopping, and probably are not sufficient for

determining readiness for return to sports participation. A wide variety of performance tests have been described for patients recovering from ankle injuries, as well as ACL reconstruction in the knee. Some of these tests, such as the FH test, require more space and are most helpful in the physical therapy suite or training room. Other tests, such as the front-to-back hop test, are more simple to administer and could even be completed on the sidelines.

Perhaps the best way to determine ankle fitness is to record baseline (preseason) performance data on all athletes. Restoration of preseason performance on testing might signify readiness for competition. However, in the absence of preinjury performance data, it is necessary to create other mechanisms to grade ankle fitness/readiness.

The simplest assessment would be to develop population norms for a performance test (such as the single-leg heel rise test). If an athlete can perform above the threshold for the test (which might be 3 SDs below the mean), that athlete is performing within the range of normal athletes. Such an approach would only be effective if the magnitude of the SDs were small (relative to the mean). In

this series, the range of normal scores (and thus the SDs) on all of the performance tests was high, and it was not possible to define a minimum fitness score. This phenomenon is not surprising, especially with athletes focusing on a specific sport (football linebackers versus basketball forwards). Given the large sample size, the high range of results most likely reflects the wide capabilities of normal athletes, not a sampling error. Even the “simplest” test, the DF lunge, can be affected by individual variations, some of which are controlled by training, and others which are intrinsic to the structure of the ankle.

In the absence of baseline (preseason) testing, and despite wide ranges of “normal” performance, there may be another way to grade ankle fitness. In athletes with a single leg injury, the contralateral leg could be used as a control. In this study, the right leg consistently performed within 10% of the left leg for all the performance tests. In the case of an athlete with a single leg injury, restoration of the injured leg to 90% of the opposite side suggests restoration of normal performance.

Furthermore, performance on the side hopping PFT was predictive of performance on the other tests. The SH test is simple to perform and can be administered in a therapy suite or even on the sidelines of a playing field. Although our protocol began with assessment of motion and progressed through many PFTs, the use of the SH test in isolation may be sufficient for determining ankle readiness in an athlete. Performance of an injured leg that is 90% or more of the uninjured side on the SH test may indicate restoration of normal ankle function.

In our small group of injured athletes recovering from an ankle sprain, performance on the heel rise test did not correlate with pain scores. Several patients with high pain scores could complete the heel rise test adequately. Although many have used a

single-leg heel raise as an indicator of fitness historically, it seems that this test may be “too easy” for an injured athlete to successfully perform. The SH or front-back hop tests may be more predictive of ankle fitness. The combination of little to no pain with activity and less than 10% deficit of the injured leg in the SH (or front-back hop) test may be the strongest indicator of readiness for unrestricted athletics.

It can be argued that pain scores in the athletes recovering from an ankle injury are not good indicators of ankle fitness. The absence of pain does not guarantee good ankle function. However, the presence of pain very likely indicates inadequate ankle rehabilitation, so it seems reasonable to conclude that the single-leg heel rise, which could be done well in the presence of pain, may not be a reliable indicator of ankle fitness after injury.

The ultimate goal would be to use performance on the SH test, or another PFT, to predict the risk of reinjury. Rates of reinjury are not known in general for athletes recovering from ankle injuries, and at this time, it is not known if restoration of performance on a PFT normalizes the risk of reinjury.

In conclusion, athletes have varying abilities to complete PFTs of the ankle, and it is not possible to set a basic minimum level of performance on any of these tests. In the absence of preseason, baseline data, the healthy (uninjured) leg can be used as a goal when assessing performance with the SH test or other PFT; normal function is restored when the injured leg reaches 90% of the ability of the uninjured side. The SH test is easy to administer on its own, performance on it correlates with pain scores, and it can independently predict results on other PFTs. The next step is to apply these tests to injured athletes, and follow progress over time, to confirm whether 90% of the contralateral leg is sufficient fitness.

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