

Original Research

Are Functional Performance Test Scores Better When Compared to Baseline or Contralateral Limb Scores Following LE Injury in Adolescent Athletes?

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Background

Functional performance tests (FPT) have been used with athletes following an injury to determine readiness to return-to-play (RTP), usually using limb symmetry indices to the contralateral limb or a baseline score. There is not a consensus as to which criterion scores are best compared.

Hypothesis/Purpose

This study aimed to compare common functional performance test scores from injured athletes at the time of release to RTP to both preseason baseline scores and to the contralateral limb. It was hypothesized that using baseline scores for comparison would be more responsive to residual deficits following injury than using the contralateral limb.

Study Design

Prospective longitudinal cohort study

Methods

High school athletes (n=395) from all varsity sports completed a battery of FPTs including the Y-Balance Test (YBT), single limb hop tests and T-Test for agility (TT) during their preseason to establish baseline data. Injured athletes (n=19) were re-tested using all FPT's again at the time of RTP. Paired t-tests were used to detect if significant (p<0.05) residual deficits were present at time of RTP when compared to baseline and to contralateral scores on FPTs.

Results

Differences in YBT scores were found in the anterior direction only (p=0.021) when comparing RTP to preseason, but there were no differences when compared to RTP data for the contralateral limb. Differences were detected with the single leg hop test (p = 0.001) when comparing the RTP to preseason and were also detected in both the single leg hop (p= 0.001) and triple hop (p=0.018) when compared to the contralateral limb. Differences in TT scores were detected when comparing RTP to preseason for cutting first with both the unaffected (p = 0.019) and affected (p = 0.014) limbs.

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Conclusions

The YBT in the anterior direction and the TT are better able to detect residual deficits when comparing RTP to preseason scores. Hop tests are better able to detect deficits when compared to the contralateral limb. These results could make preseason testing more efficient when creating a reference for determining RTP readiness following lower extremity injury.

INTRODUCTION

A significant number of high school students participating in various athletics in the United States. As of the 2021-2022 academic calendar year, an astounding 7,618,054 students were participating in at least one high school sport.¹ With so many students participating in sports, it is inevitable a correspondingly high number of injuries in high school athletes are reported each year. On average, two million injuries related to high school athletics are reported annually.² This includes injuries of all magnitudes, circumstances, and body regions. Nagle, et al. reported that approximately 11.6 lower extremity injuries occurred in this population per 10,000 athlete exposures over nine years across nine different sports.³ In addition, roughly 10.5% of all injuries reported in the past 10 or more years were recurrent injuries.⁴ While factors for this high rate of re-injury are unknown, one explanation could be that many athletes are returning to sport participation before achieving complete recovery of function. These numbers began to call into question the current standards for baseline injury predictors and return-to-play (RTP) criteria for high school athletes.

Most research focusing on RTP has focused on athletes following an anterior cruciate ligament reconstruction (ACLR) and not on general lower extremity injuries. In a recent systematic review, Vereijken, et al. found only eight high-quality studies that examined performance on FPTs and RTP decisions following ACLR or posterior cruciate ligament reconstruction (PCLR), and no studies were found investigating their use with any other lower extremity injury. This led to their conclusion that more prospective research is needed to determine if an association exists between standardized criteria like FPTs and return to performance following lower extremity injury.⁵ Peterson et al. surveyed surgeons performing ACLRs and found that most physicians will release an injured athlete to return to sport based on predetermined time frames for the specific injury rather than muscle function at the time of RTP; however, these time frames are not standardized among physicians.⁶ This could result in physicians releasing athletes before full recovery, thus increasing the potential for re-injury.

The 2016 consensus statement on return to sport from the First World Congress in Sports Physical Therapy identifies that the decision to RTP is complex and multifactorial in nature, which involves not only the assessment of healing factors and recovery of function following an injury but also contextual factors, including the sport demands, psychological readiness, and risk tolerance.⁷ The collaborative decision should involve all stakeholders and should be comprehensive in scope during the decision process. Historically, physical testing has received the most attention

in this decision, but biopsychosocial factors are equally important to consider.⁷ When considering physical testing, care should be taken to include a comprehensive evaluation of functional recovery to have the most complete information available in the decision process. Understanding the effect an injury has on an individual's overall balance, power, agility, and function is essential to the athlete's RTP.⁸ For this reason, clinicians and researchers have attempted to use FPTs to bring some objectivity to RTP decisions and to help quantify limb function and recovery following an injury.

Acknowledging that the RTP decision involves more than the assessment of physical function, this study focuses on identifying the criteria to which these FPTs should be compared. Functional performance tests (FPT) have been used to determine the risks of injuries in athletes, as well as following an injury to detect if an athlete is prepared to return to their sport.⁹⁻¹⁵ Several studies have successfully used some variation of functional performance testing for RTP criteria, but there is no set standard for which tests are the best to use.⁹⁻¹⁵ The most common functional tests used were the Star Excursion Balance Test (SEBT), the Y-Balance Test (YBT), single-leg hop tests, and the drop jump test.⁹⁻¹⁴ Of these functional tests, hop tests and the YBT have been used to examine the limb symmetry following ACLR.^{11,13} These studies also showed asymmetries in scores following injury compared to baseline scores. Finally, the TT has been proposed as part of RTP criteria following ankle injury as a functional measure of agility, which is an essential component in most sports.¹⁵ Despite strides made to objectify the RTP decision using FPTs there is still a lack of consistency in protocol and terminology.^{9,10}

Most studies looking at RTP criteria have focused on youth athletes or collegiate-level athletes, leaving a gap in the literature for the large population of high school athletes. Overall, the evidence suggests that there is not currently an accepted battery of functional performance tests used to inform RTP decisions with high school athletes following injury, nor is there a gold standard for which comparison measurement (baseline vs contralateral limb) is best for this population. Therefore, this study aimed to compare common functional performance test scores from injured athletes at the time of release to RTP to both preseason baseline scores and to scores of the contralateral limb. It was hypothesized that using baseline scores for comparison would be more responsive to residual deficits following injury than using the contralateral limb.

METHODS

STUDY DESIGN

The design of this study was a prospective longitudinal cohort study.

PARTICIPANTS

A convenience sample of varsity athletes from a local high school were recruited via emails and flyers, informing them and their guardians of optional participation in the study. The participants of this study were 14-19 year-old male and female high school athletes competing in any varsity sport at a single area high school. Inclusion criteria were any varsity athlete participating in a school-sponsored sport who completed baseline functional performance testing prior to the beginning of the sporting season. Participants were excluded from the study if there was any reason they could not or should not perform the tests (injury or illness, etc.). History of injury did not exclude participation, nor was it controlled for in this study. Informed consent and assent were obtained prior to participation in the study. This study was approved by the Community Health Network Institutional Review Board.

MATERIALS/MEASURES

Baseline testing was administered prior to the start of each participant's athletic season in one large group testing session at the participants' school. Research personnel completed a one-hour training session to standardize test administration. Each athlete completed the FPTs in random order. Functional performance tests included the YBT, the Single-Leg Hop, the Single-Leg Triple Hop (Triple Hop), the Single-Leg Triple Crossover Hop (Crossover Hop), and the TT. This group of tests was selected to provide a comprehensive functional assessment of the lower extremity kinetic chain, balance, strength, power, and agility. Demographic data was also collected during testing.

After baseline testing was completed, the athletic training staff completed injury surveillance at the high school. An injury was defined as missing five or more consecutive team activities due to an injury sustained during sports participation. Various definitions of injury have been proposed in the past, but missing five consecutive team activities was determined by the researchers to capture injuries that may require confirmation of functional recovery. Following any qualifying injury, the athletes were instructed to consult the athletic trainers at the school who re-administered all the functional performance tests again when the injured athlete had been cleared to RTP.

INSTRUMENTS

Y-Balance Test - The YBT was administered by a certified clinician per the YBT manual protocol using the Y-Balance Testing Kit.¹⁶ Participants were first instructed on how to perform the test. Three scores were measured in each direction, with one "do-over" allowed if any of the criteria for a valid test were not met. Trials in all three directions were

recorded on each leg, and the difference between legs was calculated. A composite score was also calculated for each leg to normalize scores relative to leg length. The equation for the composite score is shown below. The YBT is valid and reliable, with ICC values ranging from 0.89-0.93.¹⁷

$$\text{Composite Score for YBT} = \frac{(\text{Anterior} + \text{Posteromedial} + \text{Posterolateral}) \times 100}{(3 \times \text{Limb Length})}$$

Hop Tests -This study included the following hop tests: Single-Leg Hop, the Single-Leg Triple Hop, and the Single-Leg Triple Crossover Hop. Each participant was allowed two practice trials to account for a learning effect before each of the hop tests. Each participant completed three trials on each leg for each hop test. Participants were allowed one "do-over" if the test could not be successfully completed. Measurements were taken from the back of the heel, and a marker was placed to allow for accurate measurement to the nearest 0.5 cm. A symmetry index was calculated to evaluate the differences between each leg. This was done by taking the lowest-scoring leg and dividing it by the higher-scoring leg to obtain a percentage. These hop tests are reliable and valid with ICC values ranging from 0.92-0.97.¹⁸

T-test for Agility - Participants completed two trials for both cutting to the right and left of the middle cone, for a total of four timed trials. Two practice trials for each direction were allowed before the timed trials to account for a learning effect. Participants started with one hand on the ground and paused in this position for three seconds before starting. Participants ran to the middle cone, touched it, cut right first, side-stepped to the cone on the right and touched it, side-stepped to the far cone on the left, touched it and side-stepped back to the middle cone and touched it, and ended by back pedaling through the beginning cone. This same sequence was repeated on the left side. Times were measured using an electronic timing device and were rounded to the nearest 100th of a second. The participant was allowed up to 60 seconds of rest between each trial. The TT is valid and reliable with an ICC of 0.98.¹⁹

DATA ANALYSIS

Data analysis was completed using IBM SPSS Statistics for Mac, Version 25.0 (IBM Corp., Armonk, NY). The normality of data was confirmed using the Shapiro-Wilk test, and normally distributed data was analyzed using parametric testing (vs. non-parametric testing for data with non-normal distribution). Paired t-tests were used to compare means with pre-test and post-test measurements (alpha of 0.05), for each injured athlete.

RESULTS

A total of 395 athletes participated in preseason testing consisting of the Y-balance test, hop testing, and the TT. Of the athletes tested, 23 experienced lower extremity injuries meeting the criteria outlined by this study. Four injured athletes did not complete the RTP re-testing of the functional performance tests and therefore were not included. Two of the athletes transferred schools, one graduated,

Table 1. Mean YBT LQ score comparisons (in cm)

Measure	Affected RTP Mean (+/- SD)	Affected Pre Mean (+/- SD)	Mean Difference from Pre (p-value)	Unaffected RTP Mean (+/- SD)	Mean Difference from unaffected (p-value)
YBT - Ant	58.79 (+/- 7.07)	62.84 (+/- 6.12)	4.05 (0.021)	61.42 (+/- 6.90)	2.63 (0.113)
YBT - PM	98.66 (+/- 7.96)	100.03 (+/- 8.91)	1.37 (0.413)	99.16 (+/- 7.61)	1.01 (0.647)
YBT - PL	95.55 (+/- 8.50)	93.26 (+/- 8.98)	-2.29 (0.303)	96.74 (+/- 7.10)	1.19 (0.382)
YBT - Composite	92.49 (+/- 7.76)	93.72 (+/- 8.64)	1.23 (0.422)	93.86 (+/- 7.56)	1.37 (0.136)

YBT - Ant: Y-Balance Test - anterior reach

YBT - PM: Y-Balance Test - posteromedial reach

YBY - PL: Y-Balance test - posterolateral reach

YBT - Composite - Y-Balance Test Composite score

RTP: measurement at time of return to play

Pre- measurement during preseason testing

SD - Standard Deviation

Bolded values indicate statistically significant difference at $p < 0.05$

and one failed to follow up with the athletic trainer. Nineteen (11 female, 8 male) injured athletes completed testing when released to RTP and were included in statistical analysis. The 19 injuries included four knee injuries, nine ankle and/or lower leg injuries, three hip injuries, and three foot injuries. The injuries occurred in seven male football players, five female cross-country runners, two female soccer players, one female volleyball player, three female basketball players, and one male basketball player.

[Table 1](#) shows the comparison of scores for the Y-BT on the affected limb during preseason to time of RTP. The results showed a decrease in mean scores at the time of RTP for the anterior and posterior-medial directions, as well as the composite scores. There was an increase in mean score at the time of RTP in the posterior-lateral direction. However, the only statistically significant difference in the mean scores occurred in the anterior direction ($p = 0.021$).

[Table 1](#) also shows the comparison between the affected limb at RTP and the unaffected limb at time of RTP for YBT. The results showed differences in means in all three directions (anterior, posterior-medial, posterior-lateral) and in the composite scores, with the unaffected limb showing higher mean scores in each direction. However, none of these differences were statistically significant.

[Table 2](#) shows the comparison of the Single-Leg, Triple Hop, and Crossover Hops on the affected limbs during preseason testing compared to the affected limb at the time of RTP. A statistically significant difference was found between the means in the single-leg hop test ($p = 0.001$), with a decrease in the mean at the time of RTP. Although there were also decreases found in means of the Triple Hop and Crossover Hop tests at the time of RTP, these were not statistically significantly different.

[Table 2](#) also shows the comparison between the affected limb and the unaffected limb at the time of RTP. The results showed a higher mean in the unaffected limb at the time of RTP in the Single-Leg, Triple Hop, and crossover hop tests,

although only the Single-Leg Hop ($p = 0.001$) and Triple Hop ($p = 0.018$) differences were statistically significant.

[Table 3](#) shows the comparison of both the unaffected limb and the affected limb at preseason and time of RTP. Unaffected and affected are differentiated in terms of the direction the participants cut first in the test. After completing the TT and comparing preseason scores to the time of RTP, the unaffected ($p = 0.019$) and affected ($p = 0.014$) limbs both showed statistically significant differences in the means.

DISCUSSION

The purpose of this study was to compare common functional performance test scores from injured athletes at the time of release to RTP to both preseason baseline scores and to scores of the contralateral limb. It was hypothesized that using baseline scores for comparison would be more responsive to residual deficits following injury than using the contralateral limb. This study found mixed results for determining the best reference criteria. The YBT was better able to discern differences due to the residual deficits following an injury when compared to baseline measures but hop and agility testing were better able to discern differences when compared to the contralateral limb. The information about functional performance tests used in this study may help guide clinicians in making RTP decisions for adolescent athletes.

Results for the YBT indicated that it is most beneficial to conduct the anterior reach when testing athletes during the preseason and compare this to the anterior reach of the affected limb at the time of RTP. This is significant because it would allow for more efficient testing by only requiring the performance of one direction rather than all three directions. These results are consistent with findings from Plisky et al. who found that those high school athletes who had differences in the anterior reach direction between limbs were more likely to incur a lower extremity injury, sug-

Table 2. Mean of Hop Test score comparisons (in cm)

Measure	Affected RTP Mean (+/- SD)	Affected Pre Mean (+/- SD)	Mean Difference from Pre (p-value)	Unaffected RTP Mean (+/- SD)	Mean Difference from unaffected leg (p-value)
Single Leg Hop	134.22 (+/- 33.50)	152.18 (+/- 36.45)	17.96 (0.001)	147.48 (+/- 36.15)	13.26 (0.001)
Triple Hop	425.64 (+/- 98.44)	451.89 (+/- 115.11)	26.25 (0.061)	461.41 (+/- 106.84)	35.77 (0.018)
Crossover Hop	393.41 (+/- 116.41)	405.46 (+/- 136.21)	12.05 (0.344)	426.98 (+/- 120.20)	33.57 (0.061)

RTP: measurement at time of return to play
 Pre- measurement during preseason testing
 SD - Standard Deviation
 Bolded values indicate statistically significant difference at p<0.05

Table 3. T-test for agility score comparisons (in seconds)

Measure	Pre Mean (+/- SD)	RTP Mean (+/- SD)	Mean Difference pre-post (p-value)
Affected first	11.47 (+/- 1.47)	12.80 (+/-2.16)	1.33 (0.019)
Unaffected first	11.43 (+/- 1.41)	12.89 (+/- 2.26)	1.46 (0.014)

RTP: measurement at time of return to play
 Pre- measurement during preseason testing
 SD - Standard Deviation
 Bolded values indicate statistically significant difference at p<0.05

gesting it may be the most responsive direction to changes in function and symmetry. However, Plisky et al. only observed differences at pre-season and did not re-test the injured athletes at the time of RTP.¹⁷ Several other studies have looked at the Star Excursion Balance Test (SEBT) or Y-Balance Test as a means of evaluating the risk of lower extremity injury, but none of them have completed testing both at preseason and at the time of RTP.^{8,9} This cohort of athletes did not demonstrate statistically different scores from the contralateral limb at the time of returning to their sport. Furthermore, the scores from the injured limb did not differ between and preseason scores in any direction except the anterior reach. This study's findings suggest that screening the anterior reach portion of the YBT during the preseason may be better able to detect symmetry of balance and limb function when compared to the scores of the same injured limb at the time of RTP.

Results for the hop tests indicated that collecting preseason data may not be necessary, as statistically significant scores were only found in the Single-Leg and Triple Hop tests when comparing limbs at the time of RTP. Similar results were reported by Gokeler et al. who found significant differences between limbs in the Single-Leg Hop and Triple Hop following an anterior cruciate ligament reconstruction.¹⁰ Other studies examining hop tests have only completed preseason testing to determine risk of lower extremity injury and have not completed testing at time of RTP as was completed in this study.^{8,9} Simon et al. mea-

sured high school athletes at both points in time and found that scores on hop testing were decreased on both the affected and contralateral limb at the time of RTP.²⁰ This would affect comparisons looking for symmetry between limbs to determine readiness to return to sport. While limb symmetry indices are often used to determine this readiness, that was not the objective of the present study. The cohort of athletes in the present study had scores of the injured limb compared to both preseason measures and contralateral limb measures. Significant differences in power production and overall limb function were present when the reference criteria was the contralateral limb for Single-Leg and Triple Hop tests (and nearly significantly different for crossover hop test) indicating comparison to the contralateral limb was responsive to differences in scores for these athletes. Collecting preseason scores on all athletes may not be an efficient use of resources if scores of the contralateral limb are responsive enough to detect deficits in power production and overall limb function that may remain when released to sport. Therefore, the authors propose only completing Single-Leg and Triple Hop tests on athletes who have already been injured when attempting to determine RTP readiness and comparing to contralateral limb.

Results for the TT indicate that the participants recorded slower times when released to RTP compared to baseline preseason scores. This test has been used less frequently in studies examining functional performance tests and injury

risk than the YBT and hop tests. The authors believe that this reduced speed on this test indicates reduced agility as fatigue would likely not be a factor following a minimum of five days without sport participation. While it was hypothesized that differences may exist depending on which direction came first (toward or away from the injured leg) in the test, there were no side-to-side differences noted. The cohort of athletes in this study had lower/slower scores on this agility measure between the preseason and at the time of RTP. This suggests that it is beneficial to perform agility testing during preseason to establish a baseline for comparison and at the time of RTP for athletes following lower extremity injury to detect agility deficits and gain a better picture of overall limb function. These results indicate that it may be a useful tool in determining RTP readiness in high school athletes with lower extremity injuries.

There are limitations of this study to consider. Due to the large volumes of athletes in all sports, multiple testers were used throughout the different sessions. Although testers were all trained for standardization, it may have affected inter-rater reliability. Also, there was no distinction between the severity of the injury nor the specific location of the injury in the lower quarter. For instance, both ankle sprains and ACL injuries could meet our requirements for five days of missed participation. This study aimed to examine the use of comprehensive lower extremity functional tests to help further guide comparisons used in RTP decisions following injury. While this is applicable to use a set of standard FTPs in sports medicine clinical practice,

the diversity of the injuries included in this study may confound the research findings.

CONCLUSION

The results of this study indicate that high school athletes who sustained a lower extremity injury demonstrate poorer scores on functional performance testing when they return to play compared to both preseason scores as well as contralateral limb scores. The YBT in the anterior direction and the TT appear best able to detect residual functional deficits when comparing injured limb scores to preseason scores. Conversely, hop testing is better able to detect deficits when compared to the contralateral limb at the time of RTP. Overall, the results from this study could affect choices for preseason functional testing when creating a reference for determining RTP readiness in high school athletes following a lower extremity injury.

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CONFLICTS OF INTEREST

The authors report no conflicts of interest.

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