

# ORIGINAL RESEARCH

## Y BALANCE TEST™ ANTERIOR REACH SYMMETRY AT THREE MONTHS IS RELATED TO SINGLE LEG FUNCTIONAL PERFORMANCE AT TIME OF RETURN TO SPORTS FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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### ABSTRACT

**Background:** Restoration of symmetrical strength, balance, and power following anterior cruciate ligament reconstruction (ACL-R) are thought to be important factors for successful return to sports. Little information is available regarding early rehabilitation outcomes and achieving suggested limb indices of 90% on functional performance measures at the time of return to sports (RTS).

**Hypothesis/Purpose:** To examine the relationship between symmetry of the anterior reach of the Y Balance Test™ at 12 weeks and functional performance measures at time of return to sports after anterior cruciate ligament (ACL) reconstruction.

**Study Design:** Retrospective Cohort

**Methods:** Forty subjects (mean  $\pm$ SD age, 17.2 $\pm$ 3.8 years) who were in the process of rehabilitation following ACL reconstruction. Each subject volunteered and was enrolled in the study during physical therapy following ACL-R. Participants averaged two visits per week in physical therapy until the time of testing for RTS. The Y Balance Test™ was assessed at 12 weeks. Participants completed a battery of tests at RTS (6.4  $\pm$  1.1 months) including triple hop distance (THD), single hop distance (SHD), isometric knee extension strength (KE), and the Vail Sport Test™. Side to side difference was calculated for the Y Balance Test™ anterior reach and limb symmetry indices (LSI) were computed for THD, SHD, and KE. Multiple regression models were used to study the relationship between variables at 12 weeks and RTS while controlling for age, gender, type of graft, and pain score. In addition, subjects were dichotomized based on a side-to-side Y Balance anterior reach difference into high risk (>4 cm) or low risk ( $\leq$ 4 cm) categories. A receiver operating characteristic (ROC) curve was used to identify individuals at 12 weeks who do not achieve 90% limb symmetry indices at time of RTS testing. .

**Results:** A statistically significant association was seen between Y Balance ANT at 12 weeks and SHD at RTS ( $\beta = -1.46$ ,  $p = 0.0005$ ,  $R^2 = 0.395$ ), THD at RTS ( $\beta = -1.08$ ,  $p = 0.0011$ ,  $R^2 = 0.354$ ) and KE at RTS ( $\beta = -1.00$ ,  $p = 0.0025$ ,  $R^2 = 0.279$ ) after adjusting for age, gender, type of graft and pain score at week 12. There was no significant association between Y Balance ANT at 12 weeks and Vail Sport Test at RTS ( $p = 0.273$ ). ROC curves indicated that the Y Balance ANT at 12 weeks identified participants who did not achieve 90% LSI for the SHD (AUC = 0.82  $p = 0.02$ ) and THD (AUC = 0.85,  $p = 0.01$ ) at RTS with a sensitivity of 0.96 (SHD) and 0.92 (THD) respectively.

**Conclusions:** Participants following ACL-R who demonstrated >4 cm Y Balance ANT deficits at 12 weeks on their involved limb did not tend to achieve 90% LSI for the SHD and THD at time of return to sports. The Y Balance ANT at 12 weeks and Vail Sport Test™ appear to measure different constructs following ACL-R.

**Levels of Evidence:** Level 3

**Keywords:** Anterior cruciate ligament, Single Leg Squat, return to sport

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## INTRODUCTION

Criteria for return to sport following anterior cruciate ligament reconstruction (ACL-R) has been extensively studied.<sup>1-11</sup> Selected benchmarks include patient reported outcome forms,<sup>6,7,12,13</sup> hop tests,<sup>11,13-15</sup> knee joint laxity,<sup>15,16</sup> quality of movement at the knee and hip,<sup>17</sup> strength<sup>5,6,8,14</sup> and functional performance tests.<sup>9,13</sup> While each of these may play a role in a patient's ability to return to sport following ACL reconstruction, emphasis is often placed on restoration of strength and power of the involved limb.<sup>5-7,10,11,14,18-20</sup> A recent study following ACL reconstruction suggests decreased quadriceps strength (> 15% deficits on the involved limb) is associated with lower distances on hop tests.<sup>14</sup> These results suggest that strength deficits of the involved limb following ACL reconstruction may be important to consider in the determination of readiness for return to sport.

Previous authors<sup>9,21</sup> have examined limb asymmetries following ACL-R and have highlighted the importance of consideration of this factor. Myer et al<sup>9</sup> used modified NFL Combine testing procedures in 18 patients who had undergone ACL reconstruction within one year of testing and compared them to healthy age, gender, and sport-matched controls. Although no differences were detected between the healthy and ACL-R groups in skills using both limbs, single limb tasks identified those in the ACL-R group as having deficits on the reconstructed side in comparison to the healthy controls. These deficits could not only impair an athlete's ability to return to sport, but could also predispose him/her to a second injury to the ACL. Paterno et al<sup>21</sup> found that ACL-R participants with single limb deficits in postural stability who had returned to sports were two times more likely to sustain a second ACL injury. Furthermore, those who went on to suffer a second injury also demonstrated sagittal plane knee asymmetries during drop-jump landing. Based upon these results, it appears that the variables of single limb performance and limb asymmetries need to be measured in the post-operative rehabilitation process.

One means of quantifying single limb performance and asymmetries is through the use of a single leg squat. This single limb movement has been studied for muscle activation,<sup>22</sup> lower limb alignment,<sup>23</sup> and strength.<sup>24</sup> Individuals who are able to perform

a "good" single leg squat display earlier activation and strength of the gluteus medius than those who perform poorly.<sup>22</sup> Similarly, those who can single leg squat with less valgus and internal rotation at the knee exhibit greater hip external rotation strength to counteract the internal rotation and valgus moment.<sup>23</sup> The ability to avoid valgus and internal rotation at the knee during movements are thought to be important as a means of minimizing stress across the ACL<sup>21,25,26</sup> and exercises that address these deficits may be prescribed in the rehabilitation process following ACL-R.<sup>2-4,14</sup> The ability to perform a single leg squat with good neuromuscular control<sup>22</sup> could help the clinician identify movement patterns such as proper knee, hip and trunk alignment that indicate readiness for progression in rehabilitation following ACL-R.

The anterior reach direction (ANT) of the Y Balance Test™ is similar to a single leg squat in that it requires knee and hip flexion,<sup>27,28</sup> ankle dorsiflexion,<sup>29</sup> strength,<sup>30,31</sup> neuromuscular control,<sup>32</sup> and balance.<sup>32,33</sup> The muscle activity of ANT<sup>31</sup> is comparable to that of the single leg squat at the gluteus medius<sup>34,35</sup> and the vastus medialis.<sup>34</sup> Because the ANT requires significant quadriceps muscle activation, the ability to perform the movement correctly has been suggested as an indicator of readiness for exercise progression following ACL reconstruction.<sup>30</sup> Likewise, performance on the ANT in the early stages of rehabilitation following ACL-R may be indicative of a patient's readiness to progress functionally<sup>30,31</sup> and may be used as an evaluative tool for future success involving single leg activities. At this time there is limited information on early post-operative ACL landmarks as a predictor of performance at time of return to sport (RTS). Therefore, the purpose of this study was to examine the relationship between single leg squat symmetry as measured by the Y Balance Test™ ANT at 12 weeks and functional measures at time of return to sport after ACL-R.

## METHODS

### Participants

Forty participants (20 males, 20 females) with an average age of  $17.2 \pm 3.8$  years volunteered for this study. Each participant was enrolled during the initial week of physical therapy following ACL

reconstruction with an average starting date of five days post-operatively. Demographics for the participants are listed in Table 1. All participants followed a standardized protocol<sup>36</sup> that included range of motion, patellar and fat pad mobility, quadriceps and hamstrings strengthening, neuromuscular control training, and hip strengthening exercises and averaged two times per week in physical therapy until the time of testing for RTS which was targeted by the surgeon for approximately six months after ACL-R. Because of the clinical nature of the study, supervision of the rehabilitation process was provided by the treating physical therapist and in conjunction with the principle investigator.

Inclusion criteria for participation in the study were 1) an isolated ACL reconstruction, 2) between the ages of 14 and 25, and 3) physically or recreationally active a minimum of three times per week in sports that involved cutting, planting, pivoting, jumping, and landing. The participants were excluded from the study if there was 1) a previous ACL tear and/or reconstruction on either side, 2) other ligamentous injuries to the knee, 3) an associated chondral defect requiring surgical intervention, or 4) a meniscus tear

requiring a repair. Participants volunteered and were consented into the study by an investigator in the outpatient sports physical therapy facility once they were confirmed to meet the inclusion and exclusion criteria. Child assent and parental permission were obtained for those participants who were minors at the time of the study. Once consented into the study, objective measurements were taken on the participant's knee and patient outcome forms were completed. The Institutional Review Board of Texas Health Resources approved the research procedures.

### Testing Procedures

The Y Balance Test anterior reach (ANT) was assessed at twelve weeks ( $12.0 \pm 0.5$  weeks) following ACL reconstruction (Figure 1). Participants were instructed to perform the ANT using a combination of verbal cues and demonstration.<sup>37</sup> All participants wore shoes during testing and began on their uninjured limb. The participants were asked to perform single limb stance on the extremity while reaching outside their

**Table 1.** Participant demographics following anterior cruciate ligament reconstruction.

	Number (%)
<b>Age (years)</b>	17.2±3.8*
<b>Gender</b>	
• Male	20 (50%)
• Female	20 (50%)
<b>Involved Limb</b>	
• Right	22 (54%)
• Left	18 (46%)
<b>Mechanism of Injury</b>	
• Non-contact	30 (74%)
• Contact	4 (10%)
• Indirect contact	6 (15%)
<b>Type of Graft</b>	
• Patellar Tendon	36 (90%)
• Hamstring	2 (5%)
• Allograft	2 (5%)

\*= reported as mean±standard deviation



**Figure 1.** The Y Balance Anterior Reach test (ANT).

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base of support to push a reach indicator box along the measurement pipe of the Y Balance Test Kit™ (Perform Better, West Warwick, RI). Elevation of the heel, toe or loss of balance resulting in a stepping strategy was recorded as a trial error indicating the trial should then be repeated.<sup>37</sup> Participants were allowed at least three practice trials in the ANT direction prior to recording the best of three formal trials. Three trials were completed on the uninvolved limb in the ANT direction followed by three trials completed on the involved limb and the maximal reach distance was recorded at the place where the most distal part of the foot reached based on the measurement pipe.<sup>37</sup> Side to side reach differences were calculated by subtracting reach distance of the involved limb from the uninvolved limb. All balance measurements were taken by two physical therapists and one athletic trainer who were trained and demonstrated acceptable reliability for ANT ( $ICC_{2,k} = .86$ ,  $SEM = 3.3$  cm).

Participants completed a battery of tests at RTS ( $6.4 \pm 1.1$  months) including triple hop distance (THD), single hop distance (SHD), isometric knee extension strength (KE), and the Vail Sport Test™. The hop tests for distance were performed according to protocols previously reported in the literature.<sup>10,11</sup> For the SHD, the participant stood on the limb to be tested with toes placed behind a straight line marked with tape and were instructed to hop forward as far as they were able while landing on the same limb and maintaining balance for a minimum of two seconds. The distance hopped was measured from the front of the marked line to the most posterior portion of the landing foot. THD involved the participant standing on the limb to be tested with toes placed behind the marked line and hopping three consecutive times as far as possible as the total distance was measured.<sup>11</sup> As with the SHD, the participant was instructed to land on the limb on which they began and maintain balance for two seconds. For each of the two hop tests, participants were not restricted on arm movement during the hopping and were given two practice trials prior to performing three measured trials. The best of the three measured trials was collected for data analysis and a Limb Symmetry Index ( $LSI = [Involved\ Limb/Uninvolved\ Limb] \times 100\%$ ) was calculated for distances hopped for both SHD and THD.<sup>14</sup>

Each participant was given a rest time between hop tests (THD and SHD) for up to two minutes and between individual hop test trials for up to 30 seconds,<sup>11</sup> although this was not usually required. An error was considered if the participants were unable to maintain their balance upon landing, required touchdown of the opposite limb or upper extremity, or if an additional hop was required following the final landing.<sup>11</sup>

Knee extension strength (KE) was measured isometrically with the participant in a seated position with both knees flexed and legs hanging from the end of the table. Participants were instructed to place their arms across their chest to minimize compensation from the upper extremity during testing. A hand-held dynamometer (HHD) (microFET2, Hoggan Health Industries, West Jordan, UT) was placed slightly superior to the malleoli of the testing limb as the knee was in approximately 90 degrees of flexion.<sup>38</sup> The participant was asked to extend the limb being tested while pushing into the HHD, gradually progressing from minimal to maximal effort over one to two seconds in duration. Maximum force produced by the participant during the three to five second effort was then recorded in pounds and converted to Newtons.<sup>38</sup> The principle investigator tested KE and met the resistance of each limb as the participant gradually attempted to extend the knee in an isometric fashion with increasing effort. Each limb was tested three times with a 25 to 30 second rest interval and the average of the three trials was used for analysis. Both the involved and un-involved limbs were tested and LSI was calculated  $[(involved\ limb\ force/un-involved\ limb\ force) \times 100\%]$ . To improve reliability and minimize error, the same person performed each of the KE muscle testing procedures throughout the study. Intra-rater reliability for KE testing was performed prior to the study and found to be acceptable ( $ICC_{3,1} = 0.97$ ;  $SEM = 1.34$ ).

The participants also performed the Vail Sport Test™ at the time of RTS. The Vail Sport Test™ is a reliable return to sports assessment that incorporates a series of dynamic multiplanar functional activities against the resistance of a sportcord® in patients attempting to return to sport or activity following ACL-R.<sup>17</sup> There are a total of four components of the test that include a single-leg squat for 3 minutes, lat-

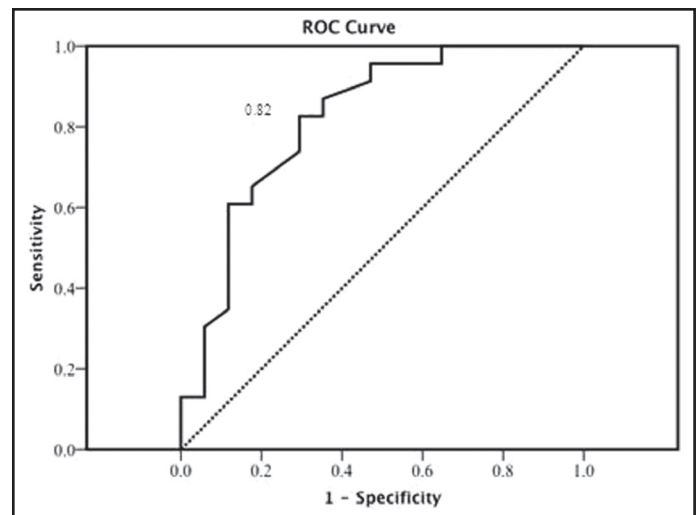
eral bounding for 90 seconds, forward jogging, and backward jogging for 2 minutes each. The participant is graded based upon the ability to demonstrate strength and muscular endurance, absorb and produce force, all while maintaining appropriate movement quality at the trunk and lower extremity with the potential maximum score of 54 points. The protocol for the Vail Sport Test™ has previously been described in the literature and was followed within this study.<sup>17</sup>

## Data Analysis

The primary goal was to evaluate the strength and functional form of the relationship between ANT at week 12 and SHD, THD, KE and Vail Sport Test™ at time of return to sport. Multiple regression models were used to study the relationship between the outcome variables Single Hop Distance (SHD), Triple Hop Distance (THD), Knee Extension Strength (KE), and Vail Sport Test™ and the primary predictor variable Y-Balance Anterior at week 12. Age, gender, type of graft and pain score (VAS) at week 12 were included as covariates in the regression model. Side to side difference was calculated for the ANT and limb symmetry indices (LSI) were computed for SHD, THD and KE. Participants were dichotomized based on side to side ANT difference into high risk ( $> 4$  cm) or low risk ( $\leq 4$  cm) categories based upon a previous criterion of greater than 4 cm anterior reach difference as a risk factor for lower extremity injury.<sup>33</sup> Receiver operating characteristic (ROC) curves were used to identify individuals at 12 weeks who did not achieve 90% LSI in SHD, THD, and KE at time of RTS testing. These three measures were part of a larger battery of tests used clinically to determine if a participant was ready for clearance for return to sport. For the secondary measure, a Fisher's exact test (since cell sizes were small, chi-square test was not appropriate) was conducted to evaluate the percent agreement between 4 cm asymmetry on ANT at week 12 and the achievement of 90% LSI in RTS measures.

## RESULTS

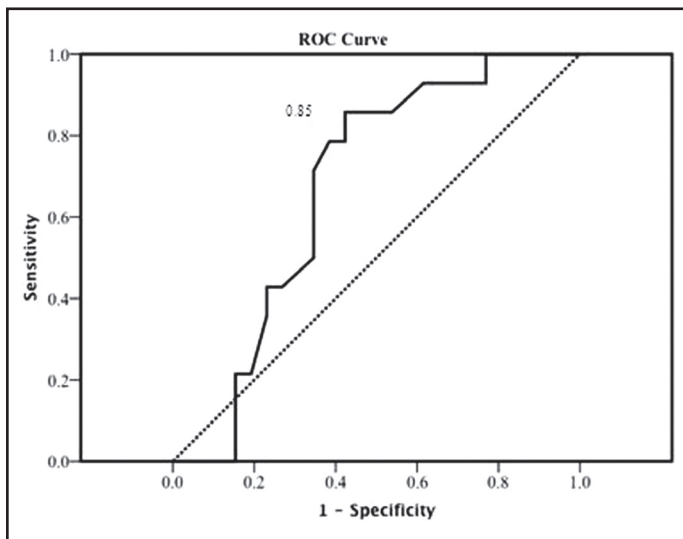
Univariate analysis using multiple regression model showed a statistically significant linear association between Y Balance ANT at 12 weeks and SHD at RTS



**Figure 2.** Receiver-operator characteristic curve, indicating that the Y Balance ANT at 12 weeks post op identified participants who did not reach 90% limb symmetry in the SHD at RTS.

SHD = single hop for distance; RTS = return to sport

( $\beta = -1.46$ ,  $p = 0.0005$ ,  $R^2 = 0.395$ ), THD at RTS ( $\beta = -1.08$ ,  $p = 0.0011$ ,  $R^2 = 0.354$ ) and KE at RTS ( $\beta = -1.00$ ,  $p = 0.0025$ ,  $R^2 = 0.279$ ) after adjusting for age, gender, type of graft and pain score at week 12. The parameter estimate ( $\beta$ ) indicates that when Y Balance ANT at 12 weeks increases by one unit, SHD decreases by 1.46 cm. Similarly, one unit increase in Y Balance ANT at 12 weeks produces a 1.08 cm and 1 pound decrease in THD and KE respectively. There was no significant association between Y Balance ANT at 12 weeks and Vail Sport Test at RTS ( $p = 0.273$ ). ROC curves indicated that the Y Balance ANT at 12 weeks identified participants who did not achieve 90% LSI for the SHD (Figure 2) (AUC 0.82,  $p = 0.02$ ) and THD (Figure 3) (AUC = 0.85,  $p = 0.01$ ) at RTS with a sensitivity of 0.96 (SHD) and 0.92 (THD) respectively. The Fisher's exact test did not find any difference in proportion between 4 cm asymmetry on ANT at week 12 and the achievement of 90% LSI in RTS measures for SHD ( $p = 0.0779$ ) and KE ( $p = 0.7431$ ). For the THD a significant difference ( $p = 0.0439$ ) was observed. The primary analysis indicates that Y Balance ANT at 12 weeks is a significant predictor for SHD, THD and KE. The secondary analysis revealed that there was no significant difference in proportion between low risk ( $\leq 4$  cm) and high risk ( $> 4$  cm) group in the achievement of 90% LSI at



**Figure 3.** Receiver-operator characteristic curve, indicating that the Y Balance ANT at 12 weeks post op identified participants who did not reach 90% limb symmetry in the THD at RTS.

THD = triple hop for distance; RTS = return to sport

RTS.

## DISCUSSION

The purpose of this study was to examine the relationship between single leg squat symmetry at 12 weeks and functional performance measures at time of return to sport after ACL-R. Participants following ACL-R who demonstrated > 4 cm Y Balance™ ANT deficits at 12 weeks on their involved limb did not tend to achieve 90% LSI for the SHD, THD and KE at time of return to sports. The Y Balance™ ANT is similar to a single leg squat in that it requires a unilateral squatting movement and elicits high EMG activity in the quadriceps and gluteal muscles.<sup>22,30,31</sup> Deficits in quadriceps strength after ACL-R have been demonstrated at 12 weeks post-operatively<sup>39</sup> and again at six months post-operatively<sup>40</sup> suggesting that this is a common issue and is not easily resolved. Although the current study did not include quadriceps strength measurements at 12 weeks following ACL-R, it is plausible that those who had smaller (< 4 cm) side to side reach differences in the ANT exhibited better functional strength than those who had greater (≥ 4 cm) differences. Likewise, Y Balance™ ANT at 12 weeks was related to KE at time of return to sports. Performance on the Y Balance™ ANT appears to be related to knee extension muscle

performance and may have some predictive value for treatment progression following ACL-R.

Clagg and colleagues<sup>41</sup> found that Y Balance™ ANT deficits are also present at time of return to sports following ACL-R. When participants who were returning to sport following primary ACL-R (6.7 mos post-op) were compared to uninjured controls, the ACL-R group produced lower modified Star Excursion Balance Test (SEBT) scores in the anterior direction on both the involved and uninvolved limbs compared to the uninjured group. These deficits were seen on not only the reconstructed limb, but also on the uninvolved limb when compared to the control group. While the current study did not include healthy controls, the differences on ANT reach in the Clagg et al<sup>41</sup> study (5.1 cm involved – ACL-R versus nonpreferred – uninjured; 4.1 cm uninvolved – ACL-R versus preferred – uninjured) were similar to the findings of the current study (4.1 cm side to side difference – ACL-R). These results suggest that ANT reach differences following ACL-R are present across the duration of the rehabilitation process and may be an important factor for clinicians to consider.

The current results suggest that early functional measures of quadriceps performance (12 weeks) may be useful in defining future performance at time of return to sport. This is in agreement with previous authors who have shown a concurrent relationship between performance on hop tests at time of return to sports with isokinetic quadriceps strength. When males who had undergone ACL-R were compared to healthy controls at six to nine months post-operatively, they demonstrated lower quadriceps strength and hop distances.<sup>20</sup> Similarly, Schmitt et al<sup>14</sup> found that quadriceps femoris strength predicted overall performance on hop tests in ACL-R patients who had been cleared for return to sports. Those patients who demonstrated higher quadriceps femoris strength subsequently performed better on both the single and triple hops for distance at time of RTS. While the current study is different in the fact that ANT performance at 12 weeks was used to predict future performance on functional measures at time of RTS, the results are comparable to the Schmitt et al<sup>14</sup> study in that participants who demonstrated ANT performance similar to the uninvolved side also performed better on the single and triple hops for distance at time of return to sport.

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The Y Balance™ ANT differences at 12 weeks were not related to the Vail Sport Test™ at time of return to sports. The Vail Sport Test™ is a functional test that evaluates muscle strength, endurance, power, and movement quality following ACL-R.<sup>17</sup> It has been shown to have good reliability in a post-operative ACL population who are attempting to return to sports. Although the Y Balance™ ANT measures lower extremity strength, neuromuscular control, flexibility, and balance,<sup>33,37</sup> the results of the current study suggest that it measures different constructs than the Vail Sport Test™. The movement of a single leg squat performed during the Y Balance™ ANT is confined to the sagittal plane while the Vail Sport Test™ measures a patient's ability to control the lower extremity in the sagittal and frontal planes of motion.<sup>17</sup> Additionally, the Vail Sport Test™ accounts for quality of movement during dynamic jumping and landing movements while also having to overcome the effects of fatigue. Thus, the Y Balance™ ANT at 12 weeks and Vail Sport Test™ appear to measure different constructs following ACL-R. Clinically, it would seem that perhaps both tasks may be important to consider during the rehabilitation process in order to cast a wider net for potential deficits that may be occurring.

The Y Balance™ ANT at 12 weeks identified those participants who did not achieve 90% LSI on functional performance measures at time of return to sports with good sensitivity on the SHD (0.96) and THD (0.92). The cut-off score indicating prediction for sub-optimal performance at time of return to sport (six months) was a side-to-side difference of  $\geq 4$  cm in the ANT. These numbers are similar to previous data that shows a  $> 4$  cm side to side reach difference in the anterior direction of the Y Balance Test™ predisposes uninjured basketball players to a 2.5 times greater risk of lower extremity injury.<sup>33</sup> Additionally, Plisky et al<sup>33</sup> suggested that a finding of limb imbalance could potentially lead to increased risk of lower extremity injury secondary to compensatory strategies through either the more or less adept limb. While the current study is not necessarily investigating injury risk, it is attempting to provide a clinical guideline that assesses a patient's progression in rehabilitation and future potential for performance for return to sport following ACL-R.

From the clinical perspective, the results of the current study propose that early activation of quadriceps and gluteal strength and neuromuscular control, indicated by single limb squatting performance, may be indicative of improved limb symmetry at time of return to sport. Athletes following ACL-R who display early deficits in quadriceps performance may require a different treatment plan and/or a greater length of time to return to sport compared to those whose functional quadriceps performance returns. Given the demonstrated Y Balance™ ANT deficits with lower extremity injury<sup>33</sup> and subsequent ACL injury risk of athletes following ACL-R,<sup>21,42,43</sup> a finding of side to side difference in single leg squat performance as measured by the Y Balance Test™ ANT may need to be closely monitored and resolved during rehabilitation and before return to sport. Thus, patients that demonstrate early quadriceps deficits may need more focused or extra quadriceps exercises, neuromuscular electrical stimulation, or bio-feedback to improve knee extension performance.

### **Limitations**

One of the limitations of the current study is the fact pain could have limited participant function during the single leg squat portion at 12 weeks. Eighty-two percent of the participants in this study had a patellar tendon autograft which has been shown to have a higher percentage of patient complaints of irritation and tenderness at the graft site than those with a hamstring graft following ACL-R.<sup>42</sup> However, pain levels (VAS =  $0.88 \pm 1.2$ ) were monitored during testing and none of the participants' performance on ANT was limited secondary to pain.

Although it appears that the participants who had less than 4 cm side to side differences on the ANT at 12 weeks demonstrated good quadriceps strength, this study is unable to objectify this belief because isometric quadriceps strength was not tested at this point in time. While standing on a single leg and squatting to reach with the opposite limb has been shown to elicit high EMG activity in the quadriceps femoris,<sup>30,31</sup> the participants' quadriceps strength in the current study was not quantified. Similarly, the role of gluteal and core strength during ANT at 12 weeks was not measured. To counteract this effect, each participant completed the same rehabilitation

protocol, which included specific hip strengthening exercises that had previously been shown to stimulate gluteal muscle activation high enough to produce a stimulus for strength.<sup>31,44-47</sup> Likewise, a recent study demonstrated smaller side to side differences in the Y Balance Anterior reach in a group of patients who had undergone a hip strengthening program in the first three months following anterior cruciate ligament reconstruction.<sup>36</sup>

At time of return to sports, KE was tested using a HHD which has been shown to have poor reliability if not using a fixed and immovable surface.<sup>48</sup> While certainly a limitation, the use of a HHD was implemented secondary to the clinical environment in which these participants were studied. A single tester was used for measurements of KE and the intrarater reliability was acceptable. In addition, rather than using the raw force data collected from the average of the three KE trials, a LSI was calculated to normalize to the un-involved or uninjured limb. None of the limbs used for comparison had any previous injury to the ACL.

## CONCLUSION

Deficits in Y Balance Test™ anterior reach at 12 weeks following ACL-R appear to identify those participants who may not achieve suggested thresholds on hop measures at the time of return to sports. These patients may benefit from a modified rehabilitation approach as they present with a knee profile that may be at increased risk for re-injury and unsuccessful return to sports. These findings are limited to a group of young and recreationally-active patients undergoing rehabilitation following ACL-R and may not apply to other types of patient populations.

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