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Anterior cruciate ligament reconstruction and dynamic stability at time of release for return to sport

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ABSTRACT

Objective: Examine dynamic stability using Dynamic Postural Stability Index (DPSI) in athletes following anterior cruciate ligament reconstruction (ACLR) at time of release for return-to-sport (RTS), compared to matched controls.
Design: Cross-sectional case-control study.
Setting: Sports medicine clinic.
Subjects: Fifteen ACLR athletes who had completed post-operative rehabilitation and were within 6 weeks following release to RTS were age-, gender-, and activity-matched to 15 healthy controls.
Main outcome measures: Ground reaction forces (GRFs) were collected using a portable force plate during stabilization from three different single-leg landing tasks. A composite DPSI was calculated using GRFs.
Results: Compared to matched controls, ACLR athletes within 6 weeks of release for RTS did not significantly differ in dynamic postural stability and there were no significant differences between the involved and uninvolved limbs in the ACLR group.
Conclusion: Current findings indicate that dynamic postural stability, as measured using the DPSI, is not significantly different in ACLR subjects at time of release for RTS compared to matched controls. In addition, the DPSI was not significantly different between the involved and uninvolved limbs in the ACLR subjects. The results suggest that the post-ACLR rehabilitation program utilized may have adequately restored postural stability in this particular sample.

1. Introduction

Anterior cruciate ligament (ACL) injuries are common among young, active individuals, with an estimated 1 in 3500 suffering ACL tears each year in the United States (Baer & Harner, 2007). Because of the debilitating nature of ACL injuries, many athletes opt to undergo ACL reconstruction (ACLR) with the goal of returning to full sports participation (Barber-Westin & Noyes, 2011); however, athletes returning to sport following ACLR are at an elevated risk for ACL re-injury. A recent systematic review and meta-analysis indicates the risk of a second ACL injury (ipsilateral or contralateral knee) following ACLR is 15% in athletes who return to competitive activities (Wiggins et al., 2016). Poor postural stability has been implicated as one factor contributing to this increased risk of re-injury (Paterno et al., 2010).

Postural stability of the lower extremity is often assessed using single-leg static measures as the athlete attempts to maintain center of mass over a stable base of support (Riemann, Caggiano, & Lephart, 1999); however, the performance of athletic activity requires dynamic postural stability. Dynamic postural stability can be defined as an individual's ability to maintain balance while transitioning from a dynamic to a static state (Gribble, Hertel, & Plisky, 2012). Dynamic activities, such as landing from a jump or hop, may be more appropriate for testing postural stability, as these tasks more closely mimic athletic activity and may present a more

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suitable challenge for the neuromuscular system than static testing (Colby, Hintermeister, Torry, & Steadman, 1999; Gribble et al., 2012; Webster & Gribble, 2010).

There are currently two measures of dynamic postural stability that have been reported to be reliable and sensitive to group differences in active populations: Time-to-Stabilization (TTS) (Colby et al., 1999; Ross, Guskiewicz, & Yu, 2005) and the Dynamic Postural Stability Index (DPSI) (Wikstrom, Tillman, Smith, & Borsa, 2005). The TTS measurement assesses the time required to minimize resultant ground reaction forces (GRFs) following a single-leg landing task (Colby et al., 1999). Similar to TTS, the DPSI indicates how well an individual can dissipate GRFs following a single-leg landing task; however, it differs from TTS in that it assesses the variation of the GRFs upon landing. The DPSI calculates a composite modified root mean square using all three GRF components (medial-lateral, anterior-posterior, and vertical), with higher scores indicating decreased dynamic stability (Wikstrom, Tillman, Kline, & Borsa, 2006). While both TTS and DPSI are regarded as functional measures of dynamic postural stability, the DPSI is considered to be more reliable and precise. Wikstrom et al. demonstrated a higher intraclass correlation coefficient (ICC = 0.96) and a smaller standard error of measurement (SEM = 0.03) as compared to TTS (ICC = 0.66–0.80; SEM = 55.00–290.00) in healthy individuals (Wikstrom, Tillman, Chmielewski, Cauraugh, & Borsa, 2007).

As deficits in postural stability have been found to contribute to the risk of second ACL injury upon return to sports participation (Paterno et al., 2010), objective assessment of dynamic postural stability should be considered in the return-to-sport (RTS) decision-making process following ACLR. To the author's knowledge, DPSI has not been utilized to compare dynamic postural stability between patients following ACLR at the time of release for RTS and healthy matched controls.

The primary purpose of this study was to examine dynamic postural stability using the DPSI in athletes following ACLR at the time of release for RTS, and to compare these findings with healthy controls. A secondary purpose was to examine differences in dynamic postural stability between the involved and uninvolved lower extremities in the ACLR group. The ability to verify postural stability deficits would not only be valuable in determining an athlete's readiness to RTS following ACLR, but also useful in focusing rehabilitation efforts on improving postural stability during dynamic, athletic tasks. As postural stability is a modifiable risk factor, results of this study can potentially impact ACLR rehabilitation in that appropriate treatment measures can be implemented to address postural stability deficits prior to return to activity. It was hypothesized that following ACLR, 1) athletes would exhibit significantly decreased dynamic postural stability on the involved lower extremity compared to age-, gender-, and activity-matched controls and 2) athletes would exhibit significantly decreased dynamic postural stability on the involved lower extremity compared to the uninvolved.

2. Methods

2.1. Study design

The current study employed a cross-sectional case-control design. All study procedures were approved by the institutional review board.

2.2. Subjects

A-priori power analysis (G*Power version 3.1) indicated that a total of 28 subjects (14 per group) were needed in order to demonstrate a significant difference between groups (p-value <0.05, Power = 0.80, d = 0.5). A total of 30 subjects (15 ACLR subjects (ACLR) and 15 matched controls (CONT)) were recruited. All subjects provided informed consent or the parent/guardian provided permission and the child assented prior to participation in the study. For each subject recruited for the ACLR group, a control subject matched on age (±1yr), gender, and activity level using the Tegner Activity Scale (±1) was recruited. A score of ≥6 on the Tegner Activity Scale was used to operationally define the criterion of athlete. The Tegner Activity Scale has been validated for a variety of knee conditions, including ACL injury (Briggs, Lysholm, et al., 2009a; Letchford, Sparkes, & van Deursen, 2015). Inclusion criteria for the ACLR group included male or female athletes aged 15–35 years, who had undergone primary, unilateral ACLR and subsequent rehabilitation and were within 6 weeks following medical release by the surgeon for full RTS. Exclusion criteria for the ACLR group included concomitant knee ligamentous repair/reconstruction, revision ACLR, previous history of lower extremity surgery on the involved or uninvolved limb, and/or history of lower extremity injury on the uninvolved limb within previous 3 months. Exclusion criteria for the CONT group included previous history of lower extremity surgery, and/or history of lower extremity injury within the previous 3 months. Exclusion criteria common for both groups included neurological disease, vestibular deficits, and/or subjective complaints of knee instability.

2.3. Outcome measures

The Dynamic Postural Stability Index (DPSI) was calculated using GRF data collected from an AMTI (Advanced Mechanical Technologies Inc., Watertown, MA) 40 × 30 inch portable force plate, sampled at 1200 Hz. As the DPSI is a composite of the medial-lateral, anterior-posterior, and vertical GRFs, stability indices for the medial-lateral (MLSI), anterior-posterior (APSI), and vertical (VSI) directions were also calculated. The directional stability indices and DPSI were calculated using the following root mean square equations, where GRFx corresponds to the medial-lateral GRF data, GRFy corresponds to the anterior-posterior GRF data, GRFz corresponds to the vertical GRF data, and BW refers to body weight (Sell, 2012; Wikstrom et al., 2005, 2010):

$$\mathrm{MLSI} = \sqrt{\left[\sum(\{0-\mathrm{GRFx}\}/\mathrm{BW})^2 \middle/ \text{number of data points}\right.}$$

$$\mathrm{APSI} = \sqrt{\left[\sum(\{0-\mathrm{GRFy}\}/\mathrm{BW})^2 \middle/ \text{number of data points}\right.}$$

$$\mathrm{VSI} = \sqrt{\left[\sum(\{\mathrm{BW}-\mathrm{GRFz}\}/\mathrm{BW})^2 \middle/ \text{number of data points}\right.}$$

$$\mathrm{DPSI} = \sqrt{\left[\left(\sum\left(\frac{\{0-\mathrm{GRFx}\}}{\mathrm{BW}}\right)^2 + \sum\left(\frac{\{0-\mathrm{GRFy}\}}{\mathrm{BW}}\right)^2 + \sum\left(\frac{\{\mathrm{BW}-\mathrm{GRFz}\}}{\mathrm{BW}}\right)^2\right) \middle/ \text{number of data points}\right]}$$

2.4. Procedures

Upon arrival to the clinic, subjects completed a standardized questionnaire to collect demographic information. Anthropometric data were then measured, including height, weight, and limb lengths. Limb lengths were measured for bilateral lower extremities from the anterior superior iliac spine to the distal tip of the medial malleolus with subjects in a supine position (Jamaluddin et al., 2011). All subjects then completed the Tegner Activity Scale to determine subjective level of activity.

As functional ankle instability (FAI) could potentially impact the results of the present study, subjects reporting ankle instability on the demographic questionnaire were asked to complete the Cumberland Ankle Instability Tool (CAIT) to determine eligibility to continue participation in the study. The CAIT has been demonstrated to be a valid and reliable tool for discriminating and measuring the severity of FAI (Hiller, Refshauge, Bundy, Herbert, & Kilbreath, 2006). Gribble et al. (Gribble et al., 2014) reported a cutoff score of ≤24 on the CAIT as a classification of FAI, therefore, subjects scoring ≤24 were disqualified from further participation in the study.

Following a 5-min warm-up on a stationary bike, baseline measures of body weight during a static stance were recorded on the force plate during a 5-s window (Ross & Guskiewicz, 2003). Subjects then completed a series of single-limb jump-landing tasks, including a forward jump (FJ), lateral jump (LJ), and diagonal jump (DJ), landing on the force plate. The FJ required subjects to begin in double-leg stance at a distance of 40% of their body height from the center of the force plate and jump forward over a 12-inch hurdle, landing on the pre-determined leg (Sell, 2012). The LJ required subjects to begin in double-leg stance at a distance of 33% of their body height from the center of the force plate and jump laterally over a 6-inch hurdle, landing on the pre-determined leg (Sell, 2012). For the DJ, subjects began in a single-leg stance on the non-test leg at the posterior-lateral aspect of the force plate. The starting position was 110 cm from the center of the force plate with an angle of progression of 55° in an anterior-medial direction. Subjects were required to jump diagonally to the center of the force plate and land on the pre-determined test leg (Patterson & Delahunt, 2013).

For all jump-landing tasks, subjects were instructed to land on the pre-determined test leg in the center of the force plate, stabilize as quickly as possible, and balance for 10 s with hands on hips, facing straight ahead. Subjects were allowed to perform as many practice trials as needed to become comfortable with the task, with a minimum of 3 practice trials in order to minimize possible learning effects (Webster & Gribble, 2010; Wikstrom, Tillman, Schenker, & Borsa, 2008). Following a 2 min rest period to minimize fatigue, subjects then completed 3 successful trials on each leg for each jump-landing task with a 2-min rest period between tasks (Sell et al., 2018; Wikstrom et al., 2005, 2006, 2008). If the subject lost their balance, missed the force plate, touched the hurdle, or touched the ground with the non-test leg, the trial was discarded and repeated. Likewise, if excessive swaying of the non-test leg, arms, and/or trunk occurred or if an additional short hop occurred upon landing, the trial was discarded and repeated (Wikstrom et al., 2008). Order of the limb tested was randomized with a coin toss for the first jump-landing task and counter-balanced for subsequent jump-landing tasks. Order of jump-landing tasks was randomized for the first subject using a random number generator and then counter-balanced for the remaining subjects using a Latin Square design (Wikstrom et al., 2008).

2.5. Data reduction and analysis

A custom MATLAB (MathWorks, Natick, MA) program was used to process the GRF data for calculating the directional stability indices and the DPSI. Data were passed through a zero-lag 4th order low pass Butterworth filter with a 20 Hz cutoff frequency. The DPSI was calculated using the first 3 s of the GRFs immediately following initial contact, defined as the instant the vertical GRF exceeded 10 N (Meardon, Klusendorf, & Kernozek, 2016; Wikstrom et al., 2005). The average of the 3 trials for each jump-landing task was used for final analyses.

Independent-samples t-tests were used to assess differences in demographic measures between groups. A 2x3 (group x jump-landing task) mixed-model ANOVA was used to compare the DPSI between the ACLR group and the CONT group. A 2x3 (limb x jump-landing task) repeated measures ANOVA was used to compare the DPSI scores between the uninvolved and involved limbs for bilateral comparison in the ACLR group. When statistical significance was demonstrated with the 2x3 mixed-model ANOVA and/or the 2x3 repeated measures ANOVA, post-hoc analysis was used to evaluate pairwise comparisons for group differences with a Bonferroni adjustment for multiple comparisons (Portney & Watkins, 2015). An alpha level of ≤0.05 was set a priori to determine significance for all statistical analyses and effect sizes were assessed using the partial eta-squared coefficient. All statistical analyses were performed using SPSS version 25.0 (SPSS Inc., Chicago, IL).

3. Results

For the 2x3 mixed model ANOVA, Mauchly's test indicated that the assumption of sphericity had been violated [$W(2) = 6.76$, $p = 0.034$], therefore the Greenhouse-Geisser corrected values are reported. All other statistical assumptions were met. Subject demographics are reported in Table 1.

Twenty-two females and eight males participated in the study with a mean age of 18.1 years (range 15–26). The average time from surgery for the ACLR group was 7.6 months (range 5.3–10.3). The means, standard deviations, and 95% confidence intervals for the DPSI scores for each jump-landing task are presented in Table 2.

The results of the 2x3 mixed-model ANOVA, including effect size and power, are presented in Table 3.

No significant group × task interaction effect ($F = 0.036$, $p = 0.941$) and no significant main effect for group ($F = 0.826$, $p = 0.371$) were found; however, there was a significant main effect for task ($F = 7.215$, $p = 0.003$). Results from post-hoc pairwise comparisons for the main effect of task are presented in Table 4.

Results demonstrated that the DJ significantly differed from both the FJ ($p = 0.001$) and LJ ($p = 0.010$), while there was no significant difference between the FJ and LJ ($p = 1.00$). Subjects demonstrated the greatest stability with the DJ.

The results of the 2x3 repeated measures ANOVA, including effect size and power, are presented in Table 5.

No significant task × limb interaction effect ($F = 1.254$, $p = 0.301$) and no significant main effect for limb ($F = 1.513$,

Table 1
Subject demographics.

	ACLR (n = 15)		CONT (n = 15)		Total (n = 30)		p-value
	Mean	±SD	Mean	±SD	Mean	±SD	
Age (yrs)	18.1	2.9	18.1	2.9	18.1	2.9	0.95
Height (in)	65.7	3.6	67.6	4.0	66.7	3.9	0.20
Weight (lb)	159.7	29.1	147.2	31.2	153.4	30.3	0.27
Tegner Score	8.7	0.6	8.6	0.7	8.7	0.7	0.59

Table 2
Mean ± SD (95% CI) for Dynamic postural stability index (DPSI).

	ACLR	CONT
Forward Jump	0.340 ± 0.143 (0.261–0.420)	0.374 ± 0.162 (0.284–0.464)
Lateral Jump	0.321 ± 0.188 (0.217–0.425)	0.344 ± .0104 (0.286–0.401)
Diagonal Jump	0.232 ± 0.034 (0.213–0.251)	0.248 ± 0.025 (0.235–0.262)

SD: Standard deviation, CI: Confidence intervals, DPSI: Dynamic Postural Stability Index.

Table 3
Summary of 2x3 mixed ANOVA for DPSI.

	F-ratio	p-value	Partial η^2	Power
Main effect				
Task	7.215	0.003[a]	0.205	0.877
Group	0.826	0.371	0.029	0.142
Interaction effect				
Group x Task	0.036	0.941	0.001	0.055

DPSI: Dynamic Postural Stability Index.
[a] Statistically significant.

Table 4
Summary of pairwise comparisons between jump-landing tasks.

Task Comparison		Mean Difference	p-value	95% CI
DJ	FJ	−1.17	0.001[a]	−0.189–−0.045
	LJ	−0.092	0.010[a]	−0.165–−0.019
FJ	DJ	0.117	0.001[a]	0.045–0.189
	LJ	0.025	1.000	−0.075–0.125
LJ	DJ	0.092	0.010[a]	0.019–0.165
	FJ	−0.025	1.000	−0.125–0.075

DJ: Diagonal jump, FJ: Forward jump, LJ: Lateral jump, CI: Confidence intervals.
[a] Statistically significant.

Table 5
Summary of 2x3 repeated measures ANOVA for DPSI—ACLR group.

	F-ratio	p-value	Partial η^2	Power
Main effect				
Task	5.616	0.009[a]	0.286	0.818
Limb	1.513	0.239	0.098	0.209
Interaction effect				
Task x Limb	1.254	0.301	0.082	0.250

[a] Statistically significant.

$p = 0.239$) were found; however, there was a significant main effect for task ($F = 5.616$, $p = 0.009$). Results from post-hoc pairwise comparisons for the main effect of task are presented in Table 6.

Results demonstrated that the DJ significantly differed from the FJ ($p = 0.002$) with no significant difference otherwise. Subjects demonstrated the greatest stability with the DJ.

Table 6
Summary of pairwise comparisons between jump-landing tasks—ACLR Group.

Task Comparison		Mean Difference	p-value	95% CI
DJ	FJ	−0.082	0.002[a]	−0.133–−0.032
	LJ	−0.050	0.246	−0.123–0.023
FJ	DJ	0.082	0.002[a]	0.032–0.133
	LJ	0.032	0.809	−0.044–0.108
LJ	DJ	0.050	0.246	−0.023–0.123
	FJ	−0.032	0.809	−0.108–0.044

DJ: Diagonal jump, FJ: Forward jump, LJ: Lateral jump, CI: Confidence intervals.
[a] Statistically significant.

4. Discussion

Decreased postural stability has been found to be a contributing factor in the risk of second ACL injury upon return to athletic activity (Paterno et al., 2010). As such, measurement of postural stability is a critical component for the RTS decision-making process. The primary purpose of this study was to examine dynamic stability using the DPSI in athletes with ACLR at the time of release for RTS, and to compare these findings with healthy controls. A secondary purpose of this study was to examine differences in dynamic postural stability between the involved and uninvolved lower extremities in the ACLR group. It was hypothesized that following ACLR, athletes would exhibit significantly decreased dynamic stability on the involved lower extremity compared to age-, gender-, and activity-matched controls at the time of release for RTS, and that athletes would exhibit significantly decreased dynamic postural stability on the involved lower extremity compared to the uninvolved. Surprisingly, the results of the statistical analysis do not support these hypotheses. While a significant main effect was demonstrated for jump-landing task, there was no significant difference between groups when comparing the DPSI between the ACLR involved lower extremities and matched controls, and no significant difference between limbs when comparing the uninvolved to involved limbs in the ACLR group.

A comparison between the results of this study to previous literature is somewhat limited, as currently there is only one published study comparing dynamic postural control using the DPSI in an ACLR population at the time of release for RTS (Heinert, Willett, & Kernozek, 2018). Heinert et al. compared DPSI scores between the surgical and non-surgical limbs of 14 ACLR subjects, following a forward jump-landing task. The authors found significant differences between limbs, with the surgical limb demonstrating persistent deficits in dynamic postural control (Heinert et al., 2018).

While the current study investigated differences between ACLR surgical limbs and matched controls, similar findings to Heinert et al. were expected. Inconsistent findings could be due to differences in the sample population, for example, graft type utilized in the ACL reconstructive surgery. Hamstring grafts were performed in 8 of the 14 subjects (57%) included in the Heinert et al. study, while only 3 of 15 subjects (17%) in the current study reported the use of hamstring grafts. Papalia et al. reported higher post-operative knee-abduction moments (KAM) during jump-landing tasks in ACLR subjects with hamstring grafts compared to patellar tendon grafts (Papalia et al., 2015). Increased KAM values may contribute to the risk of ACL injury or re-injury as a result of altered neuromuscular strategies or decreased neuromuscular control during a landing maneuver (Myer, Ford, Khoury, Succop, & Hewett, 2011).

A higher reported athletic activity level may have also contributed to the lack of significant findings in our study. Heinert et al. reported a mean Tegner score of 6 ± 2 (range 1–10) with a mean time from surgery of 14 months (range 8–24 months), while ACLR subjects in our study demonstrated a mean Tegner score of 7.7 ± 1.2 (range 6–9) with a mean time from surgery of 7.6 months (range 5.3–10.3 months). The Tegner activity scale is commonly used to measure a subject's perception of activity level and has been validated for a variety of knee conditions, including ACL injury (Briggs, et al., 2009a). The Tegner scale is a numerical scale from 0 to 10, with each value representing specific activities. The higher the score, the higher the activity level. An individual participating in competitive sports such as soccer, football, and rugby at an elite level is considered to have an activity level of 10. An individual participating in recreational sports such as jogging at least 5 times per week, tennis, and racquetball is considered to have an activity level of 6. An individual who performs sedentary work has an activity level of 1 (Briggs, et al., 2009a). ACLR subjects in our study had a minimum Tegner of score of 6, while Heinert et al. included 3 subjects (21%) with scores <6, with one subject reporting a Tegner score of 1. Briggs et al. (Briggs, Steadman, Hay, & Hines, 2009b), reported an average Tegner score of 5.7 in normal healthy individuals, with an average score of 6.5 in subjects 18–35 years of age. The higher Tegner scores reported by the subjects our study were more closely representative of the normative data reported by Briggs et al. and may have contributed to our findings regarding DPSI.

The lack of statistical difference between groups in our study may also be a result of subjects using a variety of different landing strategies to regain postural stability after landing. Landing mechanics have been shown to play an important role in force attenuation during jump landing tasks, with positioning of the hip, knee, and ankle contributing to the body's ability to absorb forces and recover postural stability (Doherty et al., 2015). It is possible that subjects in the ACLR group had a stiffer landing compared to the CONT group. A study by Gokeler et al. demonstrated that following ACLR, subjects stiffened the involved limb both before and during landing in an effort to increase joint stability (Gokeler et al., 2010). This landing strategy may lead to less anterior-posterior and medial-lateral motion when stabilizing from a jump-landing maneuver (Bansbach et al., 2017). In addition, dos Santos et al. demonstrated decreased postural sway in individuals with CAI as a strategy to counteract perturbations to posture during a dynamic activity (dos Santos, Gorges, & Rios, 2014). As the DPSI assesses the variation of GRFs in all three planes of motion, this compensatory landing strategy would result in a lower DPSI score, therefore masking deficits in postural stability. This could potentially be a limitation in utilizing the DPSI for assessment of dynamic postural stability in the ACLR population. While a lower DPSI score is desirable when assessing dynamic postural stability, landing with a stiff knee may increase the risk of ACL injury because of the greater knee extensor load (Griffin et al., 2000). Future studies combining lower limb kinematics with GRFs could provide better insight into the relationship between landing mechanics and postural control strategies.

Another possible explanation for the results demonstrated in our study is that dynamic postural stability of the ACLR limbs in our subjects had returned to baseline levels through rehabilitation. All subjects completed a post-operative physical therapy program that included neuromuscular training. Paterno et al. (Paterno, Myer, Ford, & Hewett, 2004) demonstrated that postural stability deficits were modifiable with neuromuscular training. Neuromuscular training is used to improve the ability to generate optimal muscle firing patterns and to increase dynamic joint stability during activities of daily living and athletic activities (Nessler, Denney, & Sampley, 2017). Neuromuscular training incorporates balance and proprioceptive exercises such as training on unstable surfaces (Soderman, Werner, Pietila, Engstrom, & Alfredson, 2000), dynamic joint stability exercises, agility training, plyometric training (Wilk, Macrina, Cain, Dugas, & Andrews, 2012), single-leg stability exercises (Hewett & Myer, 2011), and jump training (Kiani, Hellquist, Ahlqvist, Gedeborg, & Byberg, 2010; LaBella et al., 2011; Sugimoto, Myer, McKeon, & Hewett, 2012). While the efficacy of neuromuscular training on the reduction of second-ACL injury has not been studied, the use of such training in reducing primary ACL injury has proven effective (Myer, Sugimoto, Thomas, & Hewett, 2012; Sugimoto et al., 2012).

Finally, it is possible that the DPSI may not be capable of detecting deficits in dynamic postural stability in the ACLR population. The majority of studies utilizing the DPSI to examine dynamic postural stability have been performed in subjects with ankle instability (Brown, Bowser, & Orellana, 2010; Wikstrom et al., 2007, 2012). Wikstrom et al. demonstrated decreased dynamic postural stability using the DPSI in subjects with functional ankle instability compared to a control group. These authors suggest that the DPSI is a sensitive measure of dynamic postural stability and is capable of detecting differences between individuals with ankle instability and those with functionally stable ankles (Wikstrom et al., 2007). Brown et al. found similar results when comparing females with CAI to a control group (Brown et al., 2010). In comparison, Shiravi et al. found no significant differences in dynamic postural stability using the DPSI between athletes with and without CAI during a lateral jump landing (Shiravi, Shadmehr, Moghadam, & Moghadam, 2017). While the current study found no significant difference in DPSI scores between the ACLR and CONT groups, there may be other neuromuscular factors that were not examined, yet could have been affected, such as neuromuscular trunk control. Decreased neuromuscular control of the trunk has been demonstrated to influence dynamic stability of the knee during athletic activity (Zazulak, Hewett, Reeves, Goldberg, & Cholewicki, 2007). Further studies are necessary to examine the sensitivity of the DPSI as a measure of dynamic postural stability in the ACLR population.

A potential limitation of our study is the lack of control for variation in jump height, as this may influence dynamic stability; however, the use of standard height hurdles and standardized jump distances helps to minimize the potential variation. In addition, we did not provide specific instructions for jumping technique, other than landing on one leg and stabilizing as quickly as possible with hands on hips. It is likely that subjects used a variety of movement patterns to jump over the hurdle, which may alter the landing strategy. Future research should explore the relationship between kinematic variables and dynamic postural stability following single-leg landing from a jump.

5. Conclusions

The findings of the current study demonstrated that dynamic postural stability, as measured using the DPSI, was not significantly different in ACLR subjects at the time of release for RTS compared to healthy matched controls. In addition, the DPSI was not significantly different between the involved and uninvolved limbs in the ACLR subjects. The results suggest that the post-ACLR rehabilitation program utilized may have adequately restored postural stability in this particular sample. More research is needed to assess the value of the DPSI as a measure of dynamic postural stability in the ACLR population.

Conflicts of interest

None declared.

Ethical approval

All study procedures were approved by the Institutional Review Boards of the University of Tennessee Health Science Center and Rocky Mountain University of Health Professions.

All subjects provided written informed consent, or the parent/guardian provided permission and the child assented prior to participation in the study.

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