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Functional Performance Deficits Exist in Female NAIA Collegiate Athletes With History of Anterior Cruciate Ligament Reconstruction

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ABSTRACT

This study compared preseason measures of standing long jump (SLJ) and single-leg hop (SLH) distances between female collegiate athletes with or without history of anterior cruciate ligament reconstruction (ACLR). The data from 45 female collegiate athletes (mean age: 20.6 ± 2.2 years) competing at the National Association of Intercollegiate Athletes (NAIA) level in three team sports (volleyball, soccer, and basketball) were collected as a subanalysis of measures for a prospective cohort study. There were no differences in SLJ or SLH distances between athletes with or without prior history of low back and/or lower extremity sports injuries. However, female athletes with prior ACLR jumped (SLJ; $P = .02$) and hopped (left SLH; $P = .03$) significantly shorter distances than female counterparts with no prior ACLR. Functional performance testing of female athletes in the preseason can identify athletes who may benefit from targeted exercise interventions. [*Athletic Training & Sports Health Care*. 2016;8(5):216-221.]

Returning to sport after anterior cruciate ligament reconstruction (ACLR) is a primary goal for athletes.[1-3] A majority of professional athletes are able to return to sport at their preinjury level 1 year after ACLR.[4-7] However, a majority of amateur athletes (67%) are not able to return to their preinjury level 1 year after ACLR.[3,8,9] In addition, some amateur athletes with an ACLR have not returned to their preinjury levels 2 years following surgery. Ardern et al.[9,10] reported that 66% of athletes with ACLR who did not resume sport 1 year after surgery had returned to sport 2 years after surgery; however, only 41% of those athletes resumed sport participation at their preinjury level.

One factor that may challenge an athlete's ability to return to sport is an incomplete physical recovery. There is a growing body of evidence demonstrating the presence of physical deficits after ACLR.[11-18] These include deficits in force development and force absorption,[12-16] decreased isokinetic strength,[17,18] altered dynamic postural sway,[16] and decreased functional performance test measures.[11,14,17,18] There is also concern that deficits after ACLR may contribute to subsequent ACL injury. Incidence of subsequent ACL injury 1 to 2 years after ACLR is up to 15 times greater compared to healthy controls.[15,19]

Little is known about the functional performance status of female collegiate athletes with prior ACLR. Limitations of the aforementioned studies that have reported deficits in individuals following ACLR are that they have been confined to either heterogeneous and/or non-collegiate athlete populations and/or have used measures (eg, isokinetic testing, force plate, Biodex Balance System SD [Biodex Medical Systems, Shirley, NY]) that may be cost prohibitive for a majority of clinical or training room settings found in small colleges and universities.[14-18]

Functional performance tests are frequently used to assess an athlete's readiness to return to sport after ACLR.[1,2] Davies and Zillmer included the standing long jump (SLJ) and the single-leg hop (SLH) for distance as terminal tests to provide quantitative measures of bilateral and unilateral lower extremity power

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(eg, distance jumped or hopped).[1] In addition, the rehabilitation clinician can qualitatively assess the athlete's willingness or readiness to hop and land with the involved lower extremity.[1] It has been recommended that female athletes jump for a distance at least 80% of their height, hop for a distance at least 70% of their height, and should be able to hop with the involved limb at least 85% of the uninvolved limb.[1,2] Emerging evidence suggests that SLJ and SLH distances may be associated with an increased risk of lower extremity injury.[20,21] A greater than 10% difference between SLH measures was associated with a four-fold increased risk of foot or ankle injury in Division III female collegiate athletes.[20] Shorter SLJ and SLH distances, as part of a battery of preseason functional performance tests, were associated with a nine-fold increased risk of thigh or knee injury in female collegiate athletes.[21]

The purpose of this study was to compare differences in two functional performance test measures, the SLJ and the SLH for distance, during the preseason in female collegiate athletes with and without prior history of ACLR. A secondary purpose was to compare off-season training habits between groups. The data presented in this study are a subanalysis of measures collected for a prospective cohort study.

METHODS

Participants

Forty-five female collegiate athletes (mean age: 20.6 ± 2.2 years) from three National Association of Intercollegiate Athletes (NAIA) teams (volleyball, soccer, and basketball) at the same college participated in this study. The Institutional Review Board of George Fox University approved this study.

Procedures

At the start of the preseason, each athlete completed a questionnaire collecting demographic information and off-season training habits. Athletes were asked to report the average time devoted to training each week for the 6-week period prior to the start of the preseason for the following categories: weightlifting, cardiovascular exercise, plyometrics, and scrimmaging. Each athlete's weight (measured with a standard medical scale; recorded to nearest half pound) and height (measured with a cloth tape; recorded to nearest half inch) were collected. Each participant completed a dynamic warm-up prior to performing the functional performance tests. The warm-up consisted of 5 minutes of dynamic movements (forward walking, backward walking, walking lunges, walking on heels, and walking on toes) across the width of a basketball court.

SLJ and SLH Testing Protocol

All functional performance test measures were collected by the primary investigator. The primary investigator has previously reported test–retest reliability for each measure: SLJ (intraclass correlation coefficient $[ICC]_{3,3}$ = 0.96; 95% confidence interval [CI]: 0.83, 0.97), right SLH ($ICC_{3,3}$ = 0.95; 95% CI: 0.89, 0.98), and left SLH ($ICC_{3,3}$ = 0.96; 95% CI: 0.89, 0.98).[22] Athletes performed each functional performance test (wearing shoes) on the college's basketball court. The SLJ and SLH testing sequence consisted of athletes performing three submaximal SLJs, followed by three maximal effort SLJs, and then six maximal effort SLHs (three per leg). Athletes were required to jump and hop with hands clasped behind the back and land under control holding the position for 5 seconds.[1,20] A jump or a hop was repeated if the individual failed to perform the functional performance tests with proper technique or if she was unable to land under control. The distance jumped or hopped was measured from the starting line to the heel (or rear most heel during the SLJ).

Statistical Analysis

Mean ± standard deviations (SD) were calculated for baseline demographic characteristics. SLJ and SLH distances were normalized as a percentage of height. A comparison of functional performance test measures based on prior injury history and off-season training habits was calculated by performing independent *t* tests. Data analysis was performed using SPSS for Windows software (version 22; SPSS, Inc., Chicago, IL) with an alpha level set at .05.

RESULTS

Six female athletes reported a prior history of seven ACLRs (left knee = four). There were no differences in demographic information between groups (**Table 1**). Time from surgery ranged from less than 1 year up to 7 years. ACL injuries were sustained during the athlete's primary sport (eg, soccer, volleyball, or basketball) with injury occurring more often during competition (71%) versus during practice (29%).

TABLE 1

Demographic Information

VARIABLE	TOTAL (N = 45)	FEMALES WITHOUT ACLR (N = 39)	FEMALES WITH ACLR (N = 6)	*P*
Age (y)	20.6 ± 2.2	20.6 ± 2.3	20.3 ± 1.5	.70
Height (m)	1.68 ± 0.1	1.68 ± 0.1	1.69 ± 0.1	.90
Weight (kg)	65.8 ± 8.8	65.6 ± 8.9	67.3 ± 8.8	.70
BMI	23.2 ± 2.5	23.1 ± 2.3	23.7 ± 3.3	.70

ACLR = anterior cruciate ligament reconstruction; BMI = body mass index

Table 2 presents mean ± SD normalized SLJ and SLH distances for the athletes based on prior history of injury. Thirty athletes reported at least one prior sports-related injury to the lower quadrant (eg, low back or lower extremities). There was no difference in mean jump or hop distances between athletes with a prior history of lower quadrant injury and those with no prior injury history. There were also no differences in mean distance jumped or hopped when comparing those with history of multiple lower quadrant injuries to those with one or no prior lower quadrant injuries.

Significant differences between SLJ and SLH distances were observed when comparing those with prior history of knee injury to those with no history of knee injury (**Table 2**). Athletes with a prior knee injury jumped a mean distance of 0.75 ± 0.08, whereas those with no history of knee injury jumped 0.81 ± 0.08 (P = .04). Athletes with a prior history of knee injury also hopped shorter distances than those with no prior history; however, a significant difference between groups was only observed on the left leg (P = .05). Analysis of prior sports injury history based on other lower quadrant regions (eg, low back, hip, leg, and foot/ankle) did not reveal differences between groups for jump or hop distances.

Significant differences in functional performance test distances were observed when comparing those with prior history of ACLR to those with no history (**Table 2**). Athletes with prior ACLR jumped a mean distance of 0.71 ± 0.07, whereas those with no history of ACLR jumped a mean distance of 0.81 ± 0.08 (P = .02). Athletes with a prior ACLR also hopped shorter distances than those with no prior ACLR history; a significant difference between groups was observed on

TABLE 2

Normalized Standing Long Jump and Single-Leg Hop Mean ± SD Distances Based on Prior History of Injury for Female NAIA Athletes

CATEGORY	N	STANDING LONG JUMP	*P*	SINGLE-LEG HOP (R)	*P*	SINGLE-LEG HOP (L)	*P*
Prior history of LQ sports injury							
Yes	30	0.78 ± 0.09	.20	0.70 ± 0.12	.30	0.68 ± 0.12	.30
No	15	0.82 ± 0.08	–	0.74 ± 0.08	–	0.72 ± 0.09	–
Prior history of multiple LQ sports injuries							
Yes (2 or more)	16	0.78 ± 0.10	.60	0.69 ± 0.16	.40	0.70 ± 0.11	.90
No (1 or less)	29	0.80 ± 0.08	–	0.72 ± 0.07	–	0.69 ± 0.11	
Prior history of sports injury to the knee							
Yes	12	0.75 ± 0.08	.04	0.67 ± 0.16	.30	0.62 ± 0.15	.05
No[a]	33	0.81 ± 0.08	–	0.73 ± 0.09	–	0.72 ± 0.08	–
Prior history of ACLR							
Yes	6	0.71 ± 0.07	.02	0.62 ± 0.19	.30	0.53 ± 0.16	.03
No[b]	39	0.80 ± 0.08	–	0.73 ± 0.09	–	0.72 ± 0.08	–

SD = standard deviation; NAIA = National Association of Intercollegiate Athletes; LQ = lower quadrant (eg, low back and lower extremities); ACLR = anterior cruciate ligament reconstruction

[a]May have had either no injury or prior history of LQ injury other than to the knee.

[b]May have had either no injury or prior history of any LQ injury other than ACLR.

the left leg (P = .03). Analysis of individual hop performance revealed five of the six athletes with a greater than 10% asymmetry between SLH distances (average limb symmetry index of 0.29; individual limb symmetry index: 0.04, 0.11, 0.14, 0.32, 0.46, 0.69).

Table 3 presents off-season training habits for the female athletes based on prior ACLR history. In three categories (weightlifting, cardiovascular exercise, and plyometric exercises), there were no differences in reported weekly training habits in the 6 weeks prior to the start of the sport season between those with or without prior ACLR. However, females with no history of ACLR reported scrimmaging more hours per week than their counterparts with prior ACLR (P = .002).

TABLE 3

Comparison of Off-Season Training Habits Between Female NAIA Athletes With and Without History of ACLR

OFF-SEASON TRAINING HABITS	HISTORY OF ACLR (N = 6)	NO HISTORY OF ACLR (N = 39)	*P*
Weightlifting (hr/wk)	3.2 ± 2.6	3.8 ± 2.8	.60
Cardiovascular exercises (hr/wk)	7.3 ± 2.7	9.0 ± 5.9	.30
Plyometric exercises (hr/wk)	4.5 ± 1.8	3.4 ± 2.9	.20
Scrimmage (hr/wk)	2.8 ± 2.0	7.0 ± 4.7	.002

NAIA = National Association of Intercollegiate Athletes; ACLR = anterior cruciate ligament reconstruction

DISCUSSION

To our knowledge, this is the first study to report functional performance test measures in a female collegiate athlete population at the NAIA level. This study adds to the emerging body of evidence describing physical performance deficits after ACLR.[11-18] Female athletes with prior history of ACLR jumped and hopped shorter distances than their counterparts. The distances jumped and hopped by females with prior ACLR were also of clinical significance. The mean scores for the SLJ (0.71 ± 0.07), right SLH (0.62 ± 0.19), and left SLH (0.53 ± 0.16) were below return to sport clinical recommendations (SLJ ≥ 80% one's height and SLH ≥ 70% one's height).[1,2]

The optimal rehabilitation and post-rehabilitation training programs for athletes following ACLR are currently unknown.[23-25] Athletes with ACLR are, in most cases, allowed to return to sport 9 months to 1 year after surgery.[9] In the United States, the amount of supervised rehabilitation an athlete receives may vary based on factors associated with level of play (high school, collegiate, or professional), insurance benefits or financial resources available to pay for rehabilitation services, and physician referral patterns. For high school and some collegiate athletes, the continuation of supervised care after the completion of the initial clinical rehabilitation (approximately the first 3 months after surgery) can be challenged by a lack of available athletic training services. Collegiate athletes who participate in sports at the NAIA level may compete for small institutions (colleges or universities) that possess fewer resources (eg, training facilities and athletic training staff) than larger universities at the National Collegiate Athletic Association (NCAA) Division I level. The athletes in this study played at a college with only one certified athletic trainer who was responsible for providing sports medicine services (eg, examination, sideline management, first aid, and in-season rehabilitation) for the 13 sports teams. This college also lacked a designated, certified strength training professional. As a result, strength and conditioning training for each team (including the female athletes with prior ACLR) was the responsibility of the coaching staff.

The SLJ and SLH tests are inexpensive, quick to administer functional performance tests that provide quantitative measures of lower extremity strength.[26] The primary purpose for collecting the SLJ and SLH measures was to prospectively assess aspects of preseason fitness and to subsequently track time-loss injuries during the season. The subanalysis reported in this study illustrates the significant differences between functional performance test measures in female NAIA athletes with and without prior ACLR. The results presented in this study suggest that female collegiate athletes with prior ACLR may present with suboptimal functional performance test measures. Athletes who present with suboptimal functional performance test measures after clinical ACLR rehabilitation may be at risk for future injury.[20,21] Thus, athletic trainers or strength training professionals who work at a small college/university should routinely test functional measures of performance throughout the course of rehabilitation and after formal physician discharge until the athlete's measures are normalized. In addition, some collegiate athletes with history of ACLR may have sustained their ACL

injuries while in high school. These incoming freshman athletes with prior ACLR should also be screened for measures of functional performance tests and limb symmetry. Functional performance test measures of athletes with ACLR can be used by athletic trainers and/or strength coaches to progress a rehabilitation program or to develop a post-rehabilitation strength training program to address deficits.

A unique feature of this study is that it provides insight into the training habits of some female NAIA collegiate athletes. There is paucity in the literature regarding NAIA athletes. A majority of research related to sports performance, rehabilitation, and injury prevention has been conducted with athletes who participate in NCAA Division I sanctioned sports. In three of four categories, there was no difference in reported off-season training habits. Although we cannot draw conclusions based on the time spent weightlifting, training with plyometric exercises, and performing cardiovascular exercises, we can speculate that the training programs for the female athletes with prior ACLR lacked specificity to address their jumping and hopping deficits. Of interest was the significant finding that females with prior ACLR scrimmage less during the off-season than their counterparts. It is possible that the athletes with prior ACLR participated in fewer hours of scrimmage due to fear-avoidance; however, this is only speculative.[27,28] This finding warrants further investigation.

Future investigations are warranted to describe measures of functional performance in female collegiate athletes who compete at smaller colleges and universities. This study only assessed performance on the SLJ and SLH. Comparisons between those with and without ACLR history based on balance (Star Excursion Balance Test),[29] agility (the Lower Extremity Functional Test),[20] and two-dimensional analysis of landing mechanics (Drop Vertical Jump)[30,31] is warranted. A comparison between groups of athletes in other sports (eg, softball, tennis, and track) is also warranted.

This study provides evidence of functional performance deficits in female collegiate athletes. Female collegiate athletes, especially athletes who compete at smaller colleges and universities, should be routinely assessed with functional performance tests to evaluate their recovery after ACLR. Training programs to address deficits in athletes following ACLR are warranted.

IMPLICATIONS FOR CLINICAL PRACTICE

Athletic trainers and other sports medicine clinicians should assess athletes with prior history of ACLR. The SLJ and the SLH for distance are two functional performance test measures that are inexpensive and easy to perform. Athletes presenting with deficits may benefit from targeted training programs.

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