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Assessment of Post-Rehabilitation ACL Reconstructed Knees

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ABSTRACT

Background: Understanding objective measures of ACL-reconstructed knee function is important in determining the efficacy of rehabilitation protocols and a patient's return to activities of daily living and sport activities. **Objective:** To assess the range of motion (ROM), isokinetic strength (torque) and functional performance measures (hop test) of ACL-reconstructed and ACL-intact knees. **Methods:** Twelve volunteers (5 females, 7 males) with unilateral ACL injury and reconstruction were given a battery of tests (hop test for distance, knee range of motion, knee extensor isokinetic testing to assess both affected and unaffected lower limb function, flexibility and strength. Main effects and interactions were analyzed by mixed-model repeated measures ANCOVA. Dependent variables included hop test for distance, knee flexion and extension range of motion, and knee extensor isokinetic torque. The independent variables were the intact/reconstructed ACL knee and time from surgery. Sex was the covariate. **Results:** No statistically significant differences ($p>0.05$) were found across all dependent variables hop test for distance ($P = 0.939$), knee flexion ($P = 0.576$) and extension ($P = 0.431$) ROM, and knee extensor torque (eccentric $P = 0.923$ and concentric $P = 0.723$) for the main effects and interactions of knee (ACL-reconstructed and ACL-intact) and time (0-12 months, 13-24 months, 25-36 months and 37+ months). The covariate, sex, did produce significant differences for the hop test ($P < 0.0001$) and isokinetic testing (eccentric peak torque $P = 0.003$ and concentric peak torque $P=0.012$). C**onclusions:** Clinicians may consider present rehabilitation protocols to be adequate in developing ROM and isokinetic strength following ACL reconstruction. However, greater improvements in ROM and strength may be achieved over an extended period following ACL reconstruction surgery.

Key words: Rehabilitation, Passive Range of Motion, Knee Joint, Torque, Anterior Cruciate Ligament, Therapeutics

INTRODUCTION

Failure of the anterior cruciate ligament (ACL) is a common injury (>200k annually) that has a number of negative consequences, such as time-lost from sport, decreased quality of life and increased risk for long-term complications (Chen et al., 2020; Cavanaugh, et al., 2017). The goal of any rehabilitation program is to return a patient to a level of homeostasis and function related to their life and/or sport goals. While patients are able to perform activities of daily living through sport-related performance following anterior cruciate ligament reconstruction (ACLR), there may still be risk factors that influence the outcome (The MOON Knee Group, 2018). A number of criteria, based on time and subjective and objective benchmarks have been shown to be an integral part of assessment to allow successful return to sport (Davies et al., 2017). Despite awareness of the need for better outcomes for athletes returning to play following ACLR, there remains significant inconsistency in the criteria used for return to sport clearance and no clear guidelines on the transition from being "cleared" to being ready for full competition (deMille et al., 2017). While rehabilitation programs have transitioned from time-based to criterion-based protocols and can lead to normal function and return to activity, muscle strength and proprioceptive impairments have been found to still exist post-surgery (Ageberg et al., 2009; Cavanaugh et al., 2017; Chen et al., 2020; Kvist, 2005). Significant loss of muscle strength, primarily evidenced in the quadriceps and hamstrings, has been found up to five years post reconstructive surgery (Keays et al., 2001; Henry et al. 2005) and this loss in muscle strength has been associated with a decrease in knee joint stability (Mattacola et al., 2002). However, symmetrical quadriceps strength is an essential criterion for return to play (Risberg et al., 2016). Range of motion, an important aspect for return to normal function, is also a key component of the rehabilitative process. Even though full range of motion and strength may return to normal, knee stiffness remains up to twenty years post-surgery (Sernert et al., 1999; Cavanaugh et al., 2017). These deficits in strength and overall functioning

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may impair normal performance leaving patients at an increased risk for further injury (Keays et al., 2001; Matsumoto et al., 1991). Additional objective evaluations of ACLR include isokinetic muscle torques combined with functional tests, such as the one-leg hop for distance (Almqvist et al., 2009; Cavanaugh et al., 2017; Noyes et al., 1991; Davies et al., 2017). The one-leg hop test is used to evaluate patient-perceived knee performance and predict long-term outcomes of ACLR and is one of the most important readiness tests for the patient (Almqvist et al., 2009; Chen et al., 2020; Davies et al., 2017; Mansson et al., 2014; Moller et al, 2009). Filbay et al. (2018) concluded that a one-leg hop test for distance with a limb symmetry index (LSI) of less than 89% at 3-7 year follow-up was associated with more pain and symptoms, worse sport and recreation function and a reduced quality of life. It was the purpose of our study to assess the range of motion (ROM), isokinetic and functional performance of both ACL-reconstructed and ACL-intact knees. We hypothesized that the ACL-reconstructed knee would show less range of motion, decreased knee extensor torque production, and decreased hop test distance.

METHODS

Study Design

The study was a cross-sectional design with dependent variables of hop test distance, range of motion measurements of knee flexion/extension and concentric/eccentric peak torques. The independent variables were knee (intact vs. reconstructed ACL) and time post-operative for the surgically repaired knee. Time post-surgery in months was divided into four separate groups; 9-12, 13-24, 25-36 & 37+. The study was approved by the University Institutional Review Board. Participants volunteered to participate and were required to read and sign a university approved informed consent (#00006929) prior to participation.

Participant Characteristics

Twelve subjects (7 males & 5 females; 22 + 4 y/o) volunteered from a convenience sample of student-athletes known to have had unilateral ACLR. All subjects were at least nine months post-operative, had completed a clinician led rehabilitation protocol, and were cleared to participate in activity per their physician. The contralateral knee of each subject did not have any diagnosed cruciate or collateral ligament pathology, neurological disorders, presence of other orthopaedic-related problems, such as arthrodesis of the ankle, osteotomy of the lower extremity, or previous surgery of the unaffected knee that would hinder execution of the functional tests. The type of surgical repair (bone-patellar tendon-bone or hamstring graft) of the injured ACL was not a criterion for participation or statistical analysis.

Materials and Procedures

Subjects warmed up on a stationary bicycle for five minutes at a self-selected pace. Subjects then performed three practice trials of the hop-test, alternating legs between hops. The hop test has been used as a functional assessment in previous research and is also utilized by the International Knee Documentation Committee (IKDC) scoring to assess knee function (Ernst, 2000; Hiemstra et al., 2000; Kvist, 2005; Oiestad et al., 2010). The protocol is to perform a simple standing broad jump for distance off of one leg and landing on the same leg. The hop test for distance was performed on the ipsilateral leg (reconstructed ACL) as well as the contralateral leg (intact ACL). The subject did three trials per leg, alternating between each leg. The maximal distance hop for each leg was used as the final score for the hop test. Range of motion (ROM) was then assessed goniometrically for each limb in both flexion and extension (Norkin et al., 2017). Knee flexion was measured by placing the subject supine with the knee in extension. The hip was positioned in 0 degrees of extension, abduction and adduction. A towel roll was placed under the ankle to allow the knee to extend as much as possible. The femur was stabilized to prevent rotation, abduction and adduction of the hip. The thigh was moved to approximately 90 degrees of hip flexion and the knee was moved into flexion. The thigh was then stabilized to prevent further motion and the knee was passively flexed. Three trials of each measure were performed with the maximum measure used as the final score. Following the ROM measurements subjects were tested for isokinetic strength using a KinCom 500H Isokinetic Dynamometer (Chattecx Corporation, Chattanooga, TN). Subject placement onto the KinCom protocol was completed per the manufacturer's recommendations referenced in the KinCom 500H operator's manual. A warm-up protocol consisting of submaximal concentric and eccentric quadriceps muscle actions was performed.. Subjects performed 3 sets of 10 repetitions with a 60 second rest interval between sets for the warm-up and protocol accommodation. Subjects then completed 6 maximal concentric and eccentric quadriceps muscle actions at 90^{o}/s. Standardized auditory and visual feedback was given to each subject during the testing to help ensure maximal effort. This testing was completed on both the affected and unaffected leg. The starting leg for isokinetic testing was randomized using a random number generator with an odd number indicating that the isokinetic testing would begin with the left leg The maximum peak torque value across all concentric and eccentric trials was used as the subject's final score. All testing and measurement was completed by the same researcher.

Statistical Analysis

We analyzed the data using SPSS (v25) statistical software. Main effects (knee and time post-op) and interactions (main effects across dependent variables) were analyzed by mixed-model repeated measures ANCOVA with post hoc analysis, Tukey's HSD, where appropriate. Sex was used as the covariate. We chose to use sex as a covariate because our concern was not to examine differences between sexes but to examine differences between surgically repaired and intact ACL's, regardless of gender. The level of significance for all statistical tests was set at $P < 0.05$.

RESULTS

Descriptive statistics for the dependent variables are presented in Table 1 and Figures 1-5 (note that Figures 1-5 do not account for sex as the covariate). Table 2 presents the percent difference between repaired and intact ACL's of each dependent variable across each post-op time frame.

There were 2 subjects 9-12 months post-op, 2 subjects 13-24 months post-op, 3 subjects 25-36 months post-op, and 5 subjects 37+ months post-op. The mixed-model ANCOVA examined the effects of the knee (repaired or intact) and time post-op (0-12, 13-24, 25-36, 37+) on hop test, ROM and isokinetic torque. Sex was the covariate. The main effect of knee on flexion ROM was not significant ($F_{1,4}$ = 0343, P = 0.576). The main effect of knee on extension ROM was not significant ($F_{1,4}$ = 0.697, P = 0.431). The main effect of knee on hop distance was not significant ($F_{1,4}$ = 0.006, P = 0.939). The main effect of knee on eccentric peak torque was not significant ($F_{1,4}$ = 0.010, P = 0.923). The main effect of knee on concentric peak torque was not significant ($F_{1,4}$ = 0.136, P = 0.723).

The main effect of sex on flexion ROM was not significant ($F_{1,7}$ = 0.503, P = 0.501). The main effect of sex on extension ROM was not significant ($F_{1,7}$ = 2.270, P = 0.176). The main effect of sex on hop distance was significant ($F_{,7}$ = 42.177, P < 0.0001). The main effect of sex on eccentric peak torque was significant ($F_{1,7}$ = 20.145, P = 0.003). The main effect of sex on concentric peak torque was significant ($F_{1,7}$ = 11.155, P = 0.012).

The main effect of time on flexion ROM was not significant ($F_{1,7}$ = 1.036, P = 0.433). The main effect of time on extension ROM was not significant ($F_{1,7}$ = 0.127, P = 0.941). The main effect of time on hop distance was not significant ($F_{1,7}$ = 0.565, P = 0.655). The main effect of time on eccentric peak torque was not significant ($F_{1,7}$ = 0.337, P = 0.800). The main effect of time on concentric peak torque was not significant ($F_{1,7}$ = 0.572, P = 0.651).

The interaction effect of knee*sex on flexion ROM was not significant ($F_{1,4}$ = 0.002, P = 0.970). The interaction effect of knee*sex on extension ROM was not significant ($F_{1,4}$ = 0.817, P = 0.396). The interaction effect of knee*sex on hop distance was not significant ($F_{1,4}$ = 0.334, P = 0.582). The interaction effect of knee*sex on eccentric peak torque was not significant ($F_{1,4}$ = 0.023, P = 0.885). The interaction effect of knee*sex on concentric peak torque was not significant ($F_{1,4}$ = 1.128, P = 0.323).

The interaction effect of knee*time on flexion ROM was not significant ($F_{3,4}$ = 0.513, P = 0.686). The interaction

Table 1. Hop Test, ROM & Torque Measures (Mean + SD)

Knee with post-op time in months	Hop test (cm)	ROM (deg)		Peak Torque (Nm)	
	Mean (+ SD)	Mean(+ SD)		Mean (+ SD)	
Reconstructed knee		Flexion	Extension	Concentric	Eccentric
0-12 (n=2)	133+56	139+13	182+3	154+130	157+118
13-24 (n=2)	145+11	133+18	181+2	209+132	207+136
25-36 (n=3)	137+11	126+10	179+3	205+81	215+93
37+ (n=5)	143+27	136+7	181+4	150+52	160+33
Intact knee					
0-12	153+61	145+7	181+0	215+129	220+98
13-24	166+36	135+7	181+1	243+172	215+155
25-36	145+36	132+5	182+2	187+56	171+42
37+	150+26	136+8	181+2	164+43	193+71

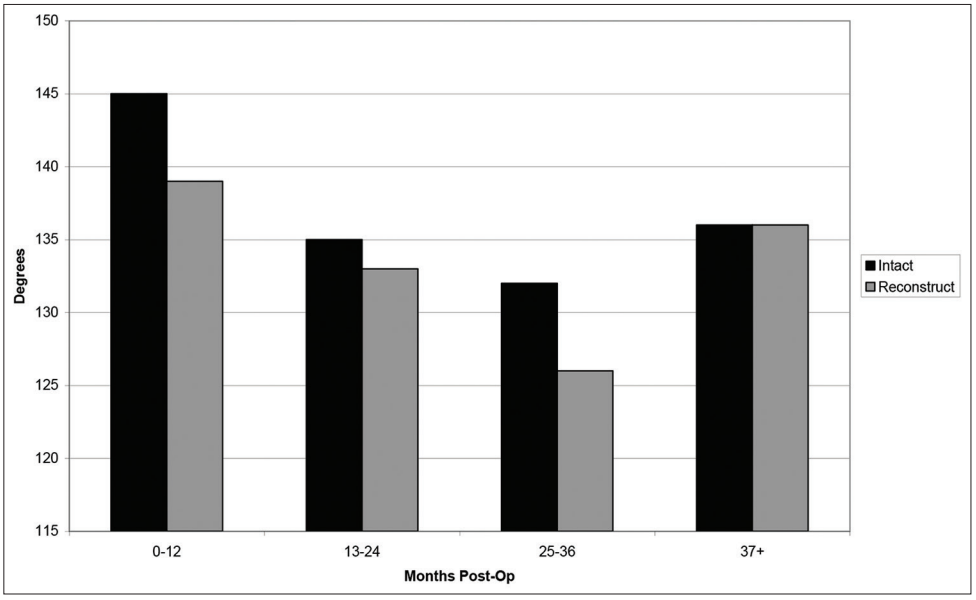

Figure 1. Flexion ROM between intact and reconstructed ACL with months post-op

effect of knee*time on extension ROM was not significant ($F_{3,4} = 0.419$, $P = 0.745$). The interaction effect of knee*time on hop distance was not significant ($F_{3,4} = 0.296$, $P = 0.827$). The interaction effect of knee*time on eccentric peak torque was not significant ($F_{3,4} = 1.453$, $P = 0.307$). The interaction effect of knee*time on concentric peak torque was not significant ($F_{3,4} = 1.453$, $P = 0.307$).

Table 2. Hop test, rom and torque % difference data between the repaired and intact acl knees

Time post-op	Hop test	ROM		Torque	
		Flexion	Extension	Concentric	Eccentric
0-12	-13%	-4%	0%	-27%	-29%
13-24	-13%	-1%	0%	-14%	-3%
25-36	-6%	-5%	-2%	+8%	+21%
37+	-5%	0%	0%	-8%	-17%

Negative value indicates the repaired knee performed worse than the intact knee.

DISCUSSION

It was the purpose of our study to assess the range of motion (ROM), isokinetic and hop test performance of both ACL-reconstructed and ACL-intact knees. These particular were chosen as some assert that tests to be included for a successful return to sport (RTS) include ROM, isokinetic strength tests and functional hop tests (Davies et al., 2017; Moller et al., 2009). We hypothesized that the ACL-reconstructed knee would show less range of motion, decreased knee extensor torque production, and decreased hop test distance (Cavanaugh, et al. 2017; Keays et al., 2001; Matsumoto et al., 1991). As noted in the methods section we chose to use sex as a covariate in our data analysis. It was

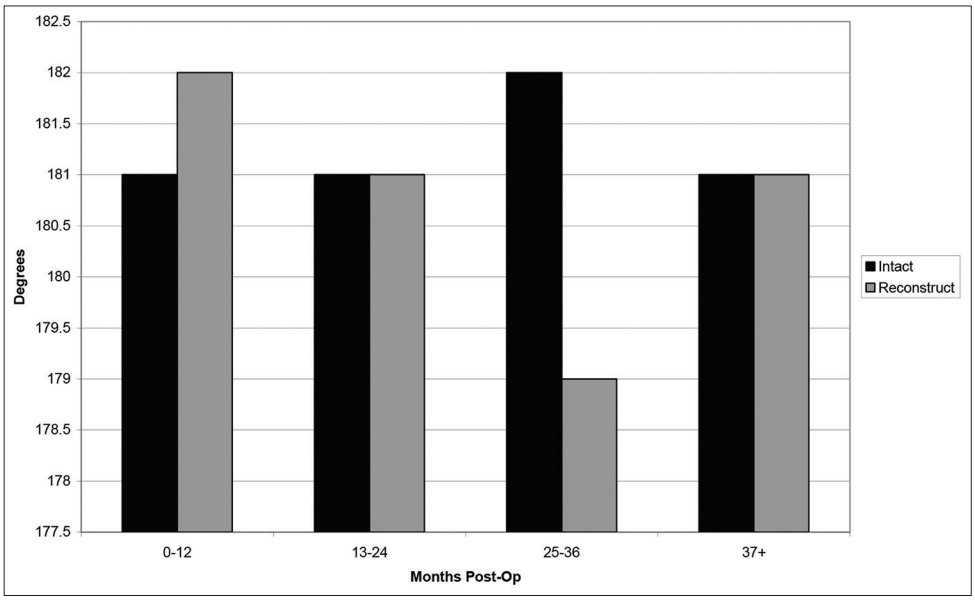

Figure 2. Extension ROM between intact and reconstructed ACL with months post-op

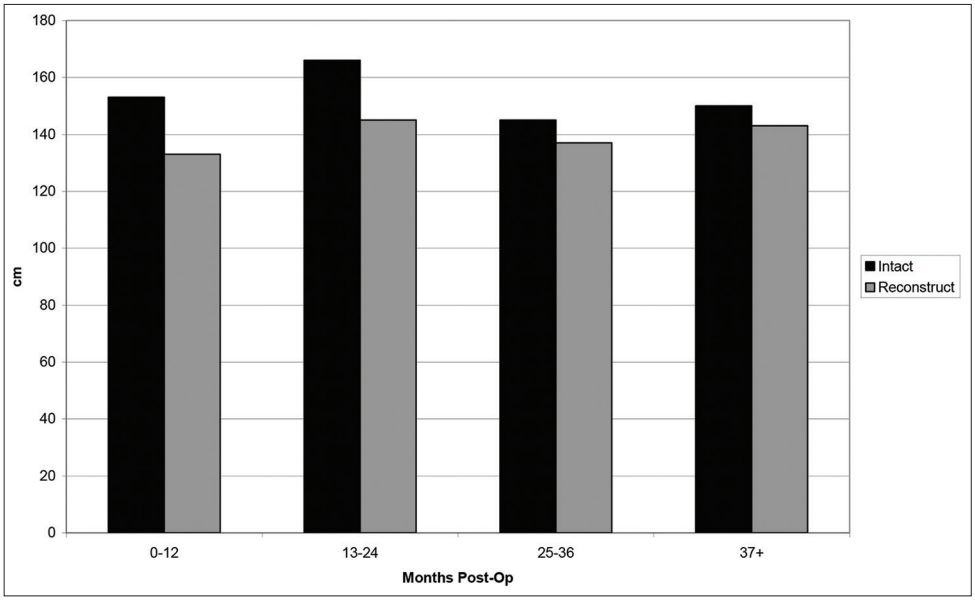

Figure 3. Hop distance between intact and reconstructed ACL with months post-op

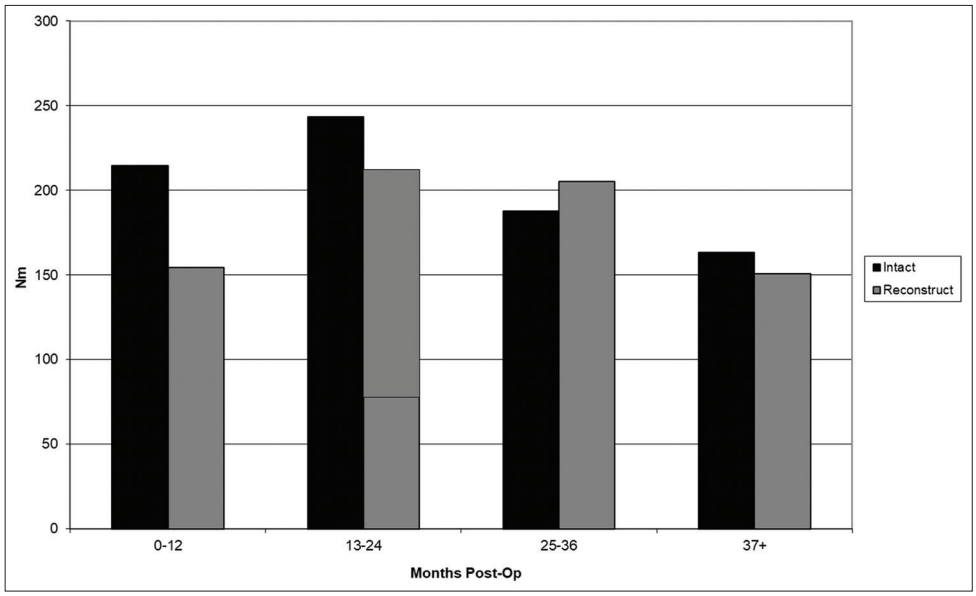

Figure 4. Knee extension concentric peak torque between intact and reconstructed ACL with months post-op

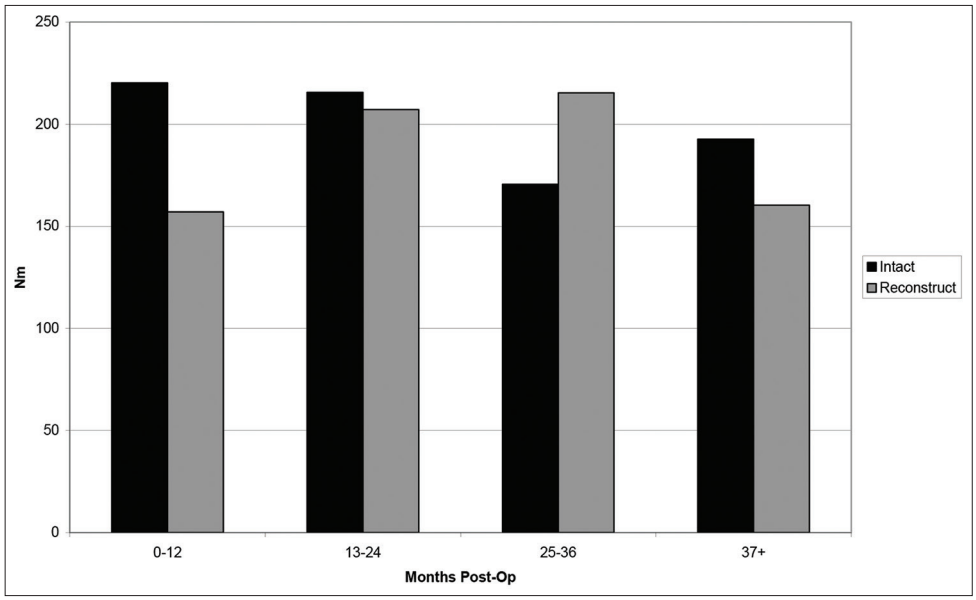

Figure 5. Knee extension eccentric peak torque between intact and reconstructed ACL with months post-op

assumed that there would be differences between the male and female subjects in the various measures of muscular performance due to the fact that men tend to have more muscle mass of the lower extremity than women. Our assumption was supported as the statistical analysis did show significant differences between the male and female subjects for the functional hop test for distance and both the concentric and eccentric peak torque values. Overall, tt was concluded that there are no significant differences between surgically repaired and intact ACL's when performing a hop test for distance, flexion and extension ROM and peak concentric and eccentric quadriceps torque values; with sex as a covariate. These are encouraging findings as one would hope that following clinically led rehabilitation protocols and

Similar to our findings, Almqvist et al. (2009) reported ROM values equal to the non-operative knee, hop test distance was within 10% of the ACL-intact limb, and extension torque was within 4% of the ACL-intact limb. Mansson et al. (2014) found that hop test values were within 93% of the ACL-intact limb. Chen et al. (2020) state that a lack of hop test difference between ACLR symptomatic and asymptomatic groups may indicate that the asymptomatic group was doing quite well functionally. Our results differ from previous reports (Anderson, 2002; Sernert, 1999) that did find significant differences across the dependent variables that we measured. However, there are notable trends that emerge when examining the percent difference data between the reconstructed and intact ACL's. For example, the hop test data indicates a shift towards no discrepancies between the repaired and intact ACL's. However, Ernst (2000) states that even though hop test scores approach that of the contralateral limb over time, there still tends to be a sizable discrepancy for isokinetic testing (within 90% of the uninvolved extremity) between the two limbs. For our study, the concentric and eccentric peak torque

values did slightly improve for the subjects as the post-op time increased. Since all subjects continued to participate in their sport/activity following appropriate rehabilitation, one would assume that these improvements would continue to take place over time. The concern, however, is how do we provide the clinician with objective data that would assist them in returning the individual to activity in a timely and safe fashion (Kvist, 2005). A combination of factors most likely affects the rehabilitation process and the extent to which someone has returned to normal levels of functioning. Stein and Mandelbaum (2019) encourage the use of a comprehensive rehabilitation program that includes functional post-operative progressions and ACL re-injury prevention strategies.

While the data support that the subjects performed better on their unaffected limb as opposed to the contralateral limb interesting subjective feedback from the subjects was received. A number of the participants felt that they would perform better during the testing and actually did feel better while testing on their affected limb. This may be due to the extent of the rehabilitation they performed. Thus, the focus on the affected limb through rehabilitation may have allowed them to improve strength and proprioception levels beyond that of the unaffected limb. Limitations to the current study may include within group sample size. For example, the 0-12 month post-op group had one male and one female subject. This created relatively large standard deviations for the hop test and isokinetic measures as the male subject performed markedly better. Future study should include a larger sample size, shifting focus to an adolescent population as long-term follow-ups after surgical treatment of ACL injuries in children are rare (Mansson et al., 2014) examining knee flexion isokinetics, subjective measures, ACL reconstruction type (Dauty et al., 2005) rehabilitation protocols and sex differences across the dependent variables.

CONCLUSION

While the results of the current study show no statistically significant differences between intact and ACL-reconstructed knees relative to measures of hop test, ROM, and isokinetic knee extensor peak torque, we find these statistical outcomes encouraging as to the progress made in physical performance by our subjects' ACLR knee. This is in support of the goals of rehabilitation to return patients to a level of homeostasis and function. Risberg et al. (2016) argue that the use of functional testing criteria should indicate that the patient has returned to (near) normal knee function. We found this to be the case for our subjects in the present study. In addition, the criteria to pass a functional return-to-sport battery, activities of daily living self-report scales, such as the Knee Outcome survey can help ensure that ACLR patients have a safe return to activity. While improvements in rehabilitation protocols can improve; current practice does seem to allow for limb asymmetries following ACLR to be remediated successfully.

REFERENCES

Ageberg, E., Roos, H.P., Silbernagel, K.G., Thomee, R., & Roos, E.M. (2009). Knee extension and flexion muscle power after anterior cruciate ligament reconstruction with patellar tendon graft or hamstring tendons graft: a cross-sectional comparison 3 years post-surgery. *Knee Surgery, Sports Traumatology, Arthroscopy*, 17(2), 162-169. DOI: 10.1007/s00167-008-0645-4.

Almqvist, K.F., Willaert, P., DeBrabandere, S., Criel, K., & Verdonk, R. (2009). A long-term study of anterior cruciate ligament allograft reconstruction. *Knee Surgery Sports Traumatology, Arthroscopy*, 17(7), 818-822. DOI: 10.1007/s00167-009-0808-y.

Anderson, J. (2002). Changes in muscle torque following anterior cruciate ligament reconstruction: A comparison between hamstrings and patella tendon graft procedures on 45 patients. *Acta Orthopaedica Scandinavia,* 73(5), 546-552. DOI: 10.1080/000164702321022820.

Cavanaugh, J.T., & Powers, M. (2017). ACL rehabilitation progression: where are we now? *Current Reviews in Musculoskeletal Medicine*, 10(3)**,** 289–296. DOI: 10.1007/s12178-017-9426-3

Chen, A.J., Tatarski, R.L., Perry, J., Quatman, C.E., Hewett, T.E., & DiStasi, S. (2020). Single-leg hop mechanics are correlated with self-reported knee function early after anterior cruciate ligament reconstruction, *Clinical Biomechanics*, 73, 35-45. DOI: 10.1016/j.clinbiomech.2019.12.2020.

Dauty, M., Tortellier, L., & Rochcongar, P. (2005). Isokinetic and anterior cruciate ligament reconstruction with hamstrings or patella tendon graft: analysis of literature. *International Journal of Sports Medicine,* 26(7), 599-606. DOI: 10.1055/s-2004-821342.

Davies, G.J., McCarty, E., Provencher, M., & Manske, R.C. (2017). ACL return to sport guidelines and criteria. *Current Reviews in Musculoskeletal Medicine,* 10(3), 307–314. DOI: 10.1007/s12178-017-9420-9.

de Mille, P., & Osmak, J. (2017). Performance: Bridging the Gap After ACL Surgery. *Current Reviews in Musculoskeletal Medicine*, *10*(3), 297–306. DOI: 10.1007/s12178-017-9419-2.

Ernst, G.P., Saliba, E., Diduch, D.R., Hurwitz, S.R., & Ball, D.W. (2000). Lower-extremity compensations following anterior cruciate ligament reconstruction. *Physical Therapy,* 80(3), 251-260. DOI: 10.1093/ptj/80.3.251.

Filbay, S.R., Andersson, C., Ardern, C., Gauffin, H., & Kvist, J. (2018). Patient-reported outcome 32-37 years following surgically treated or non-surgically treated acute ACL injury. Osteoarthritis and Cartilage, 26(1), S52-S53. DOI: 10.1016/j.joca.2018.02.117.

Henry, J.C., & Kaeding, C. (2005). Neuromuscular differences between male and female athletes. *Current Womens Health Reviews,* 1(3), 241-244. PMID: 12112976.

Hiemstra, L. A., Webber, S., MacDonald, P. B., & Kriellaars, D. J. (2000). Knee strength deficits after hamstring tendon and patellar tendon anterior cruciate ligament reconstruction. *Medicine and Science in Sports and Exercise, 32*(8), 1472–1479. DOI: 10.1097/00005768-200008000-00016.

Keays, S. L., Bullock-Saxton, J., Keays, A. C., & Newcombe, P. (2001). Muscle strength and function before and after anterior cruciate ligament reconstruction us-

ing semitendonosus and gracilis. *Knee*, *8*(3), 229–234. DOI: 10.1016/s0968-0160(01)00099-0.

Kvist J. (2004). Rehabilitation following anterior cruciate ligament injury: current recommendations for sports participation. *Sports Medicine*, *34*(4), 269–280. DOI: 10.2165/00007256-200434040-00006.

Li, R. C., Maffulli, N., Hsu, Y. C., & Chan, K. M. (1996). Isokinetic strength of the quadriceps and hamstrings and functional ability of anterior cruciate deficient knees in recreational athletes. *British Journal of Sports Medicine*, *30*(2), 161–164. DOI: 10.1136/bjsm.30.2.161.

Mansson, O., Sernert, N., & Kartus, J. T. (2014). Long-term course in adolescents after anterior cruciate ligament reconstruction. *Orthopaedic Journal of Sports Medicine*, *2*(1 Suppl). DOI: 10.1177/2325967114S00006.

Matsumoto, H., Toyoda, T., Kawakubo, M., Otani, T., Suda, Y., & Fujikawa, K. (1999). Anterior cruciate ligament reconstruction and physiological joint laxity: earliest changes in joint stability and stiffness after reconstruction. *Journal of Orthopaedic Science*, *4*(3), 191–196. DOI: 10.1007/s007760050093.

Mattacola, C. G., Perrin, D. H., Gansneder, B. M., Gieck, J. H., Saliba, E. N., & McCue, F. C., 3rd (2002). Strength, functional outcome, and postural stability after anterior cruciate ligament reconstruction. *Journal of Athletic Training*, 37(3), 262–268. PMID: 12937583

Moller, E., Weidenhielm, L., & Werner, S. (2009). Outcome and knee-related quality of life after anterior cruciate ligament reconstruction: a long-term follow-up. *Knee Surgery, Sports Traumatology, Arthroscopy*, 17, 786-794. DOI: 10.1007/s00167-009-0788-y.

Norkin, C.C. & White, D.J. (2017). *Measurement of Joint Motion 5th*. F.A. Davis Company.

Noyes, F.R., Barber, S.D., Mangine, R.E. (1991). Abnormal lower limb symmetry determined by function hop tests after anterior cruciate ligament rupture. *American Journal of Sports Medicine*, 19(5), 513-518. DOI: 10.1177/036354659101900518.

Oiestad, B. E., Holm, I., Aune, A. K., Gunderson, R., Myklebust, G., Engebretsen, L., Risberg, M. A. (2010). Knee function and prevalence of knee osteoarthritis after anterior cruciate ligament reconstruction: a prospective study with 10 to 15 years of follow-up. *American Journal of Sports Medicine*, *38*(11), 2201–2210. DOI: 10.1177/0363546510373876

Risberg, M.A., Grindem, H., & Oiestad, B.E. (2016). We need to implement current evidence in early rehabilitation programs to improve long-term outcome after ACL injury. *Journal of Orthopaedic and Sports Physical Therapy*, 46(9), 710-713. DOI: 10.2519/jospt.2016.0608.

Sernert, N., Kartus, J., Köhler, K., Stener, S., Larsson, J., Eriksson, B. I., & Karlsson, J. (1999). Analysis of subjective, objective and functional examination tests after anterior cruciate ligament reconstruction. A follow-up of 527 patients. *Knee Surgery, Sports Traumatology, Arthroscopy*, *7*(3), 160–165. DOI: 10.1007/s001670050141.

Simonsen, E. B., Magnusson, S. P., Bencke, J., Naesborg, H., Havkrog, M., Ebstrup, J. F., & Sørensen, H. (2000). Can the hamstring muscles protect the anterior cruciate ligament during a side-cutting maneuver? *Scandinavian Journal of Medicine and Science in Sports, 10*(2), 78–84. DOI: 10.1034/j.1600-0838.2000.010002078.

Stein, S.M., & Mandelbaum, B.R. (2019). Editorial Commentary: Anterior cruciate ligament injury and reconstruction in soccer players: the major challenge is always going for our goals. *Arthroscopy*, 36(1), 196-198. DOI: 10.1016/j.arthro.2019.10.005.

The MOON Knee Group. (2018). Ten year outcomes and risk factors after anterior cruciate ligament reconstruction. *American Journal of Sports Medicine*, 46(4), 815-825. DOI: 10.1177/0363546517749850.