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# RELATIONSHIP BETWEEN ISOKINETIC KNEE STRENGTH AND JUMP CHARACTERISTICS FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

**Kevin Laudner, PhD, ATC**[1]
**Daniel Evans, PT**[2]
**Regan Wong, PT**[2]
**Aaron Allen, CSCS**[2]
**Tom Kirsch, PT**[2]
**Brian Long, PT**[2]
**Keith Meister, MD**[2]

## ABSTRACT

***Background:*** Clinicians are often challenged when making return-to-play decisions following anterior cruciate ligament reconstruction (ACL-R). Isokinetic strength and jump performance testing are common tools used to make this decision. Unfortunately, vertical jump performance standards have not been clearly established and many clinicians do not have access to isokinetic testing equipment.

***Purpose:*** To establish normative jump and strength characteristics in ACL-R patients cleared by an orthopedic physician to return-to-play and to determine if relationships exist between knee isokinetic strength measurements and jump characteristics described using an electronic jump map system.

***Study Design:*** Descriptive laboratory study.

***Methods:*** Thirty-three ACL-R patients who had been cleared to return to athletic competition participated in this study. Twenty-six of these ACL-R participants were also matched to 26 asymptomatic athletes based on sex, limb, height, and mass to determine isokinetic strength and jump characteristic differences between groups. Jump tests consisted of single leg vertical, double leg vertical, and a 4-jump single leg vertical jump assessed using an electronic jump mat system. Independent t-tests were used to determine differences between groups and multiple regression analyses were used to identify any relationships between jump performance and knee strength ($p < 0.05$).

***Results:*** The ACL-R group had lower vertical jump capabilities and some bilateral knee strength deficiencies compared to the matched control group. The ACL-R group also showed several moderate-to-strong positive relationships for both knee extension and flexion strength with several jump performance characteristics, such as single and double leg vertical jump height.

***Conclusion:*** The current results indicate that ACL-R patients present with several knee strength and vertical jump differences compared to a matched control group at the time of return-to-play. Also, ACL-R patient's performance on an electronic jump mat system is strongly related to isokinetic knee strength measures.

***Keywords:*** Anterior cruciate ligament, functional tests, isokinetic strength, jump mat, return-to-play, vertical jump.

***Level of Evidence:*** 2b

[1] Illinois State University, Normal, IL, USA
[2] Texas Metroplex Institute for Sports Medicine and Orthopedics, Arlington, TX, USA

Investigation performed in the School of Kinesiology and Recreation at Illinois State University, Campus Box 5120 Normal, IL, 61790, USA

**CORRESPONDING AUTHOR**
Kevin G. Laudner, PhD, ATC
Phone: 309-438-5197
Fax: 309-438-5559
E-mail: klaudner@ilstu.edu

## INTRODUCTION

One of the challenges during the rehabilitation of athletes recovering from anterior cruciate ligament reconstruction (ACL-R) is gauging their functional ability and when it is safe to return to competitive sports. Post-operative assessment often includes laxity, flexibility, proprioception, strength, and functional testing.[1-4] Functional testing has been reported to show how patient's performance during physical tests, such as laxity and range of motion, correlate to more functional physical performance, such as those used in specific sports.[2,3,5]

Knee extension and flexion strength deficits have been reported to place unnecessary stress on the ACL due to a loss in lower extremity control.[6-8] Knee extension and flexion strength are often assessed during the various stages of an ACL rehabilitation protocol and used as a gauge of functional ability and subsequently in the decision of when to return to participation.[1-4,9-11] A survey of 40 international knee experts suggested that "adequate leg extension power" needs to be accomplished prior to return to play.[11] Unfortunately, isokinetic testing systems that can measure extension/flexion power among other aspects of strength and endurance are not readily available for many clinicians due to limited space and budget.

Jump specific training has been used in various populations for the purpose of improving functional strength and power.[13,14] Researchers have shown significant relationships between knee strength testing and jump testing, such as hop tests for distance.[15, 16] Jumps for distance have been recommended to be useful for determining functional ability among ACL deficit patients.[17-21] However, little research has investigated the relationship between isokinetic testing and vertical jump tests among athletes. Although Petschnig et al[22] did investigate the relationship between strength and jump tests, these authors did not use athletes or faster isokinetic speeds, which may be more indicative of athletic performance.

The purpose of this study was twofold. The first was to establish normative jump and strength characteristics in ACL-R patients cleared by an orthopedic physician to return-to-play. The second purpose was to determine the relationship between knee isokinetic strength and several jump characteristics determined using an electronic jump map system among ACL-R patients who had been cleared to return-to-play. An improved understanding of the usefulness of these jump mat systems may provide clinicians an additional means for making return-to-play decisions.

## METHODS

Thirty-three participants volunteered for the ACL-R group (17 females, 16 males; age: 18.1 ± 3.5 yrs; height: 176.0 ± 9.9 cm; mass: 71.8 ± 11.5 kg; involved limb: 14 dominant leg, 19 non-dominant leg). The same orthopedic surgeon performed all of the participants' reconstructive surgeries using a bone-patellar tendon-bone autograft technique. These participants also completed a standardized therapeutic rehabilitation protocol at the same outpatient clinic under the guidance of a physical therapist. The rehabilitation protocol utilized is a combination of various evidence based programs and includes the use of modalities, open and closed chain strengthening exercises, patellar mobilizations, flexibility exercises, proprioceptive exercises, and functional activities, such as shuttle runs and forward and lateral jumps. At the time of testing, all of the ACL-R participants were at least six months post-operative (7.8 ± 1.9 months) and had been cleared by an orthopedic physician to return-to-play. All return-to-play decisions were based on a combination of factors which include isokinetic strength testing, full pain free ROM, arthrometry testing, as well as physical therapist input based on biomechanical deficiencies and satisfactory completion of the rehabilitation program.

Twenty-six of the ACL-R participants (11 females, 15 males; 7.8 ± 1.9 months post-operative, involved limb: 10 dominant leg, 16 non-dominant leg), were matched to 26 control participants based on limb, sex, height, and mass (Table 1). Dominant leg was defined as the preferred leg to kick a ball. The control group had

**Table 1.** *Descriptive participant demographics*

| Group | Age (yrs)* | Height (cm) | Mass (kg) |
|---|---|---|---|
| ACL-R (n=26) | 18.7±3.5 | 176.8± 9.4 | 72.8±10.2 |
| Control (n=26) | 21.8±3.6 | 179.9±8.6 | 74.8±13.1 |

*Statistically significant between group difference (*p*=0.003).
ACL-R = anterior cruciate ligament reconstruction.

no recent history of lower extremity injury (past six months) and no history of lower extremity surgery. All participants were members of an organized sports team (e.g. basketball, soccer, football, volleyball).

The Just Jump system (Probotics, Huntsville, AL) was used to assess jump performance. This system consists of a 27 x 27 inch mat interfaced with a handheld computer (Figure 1) capable of measuring several leg strength characteristics, such as vertical jump height, lateral movement times, and ground contact time (i.e. quickness). Kenny et al.[23] has shown that electronic jump mats are valid when compared to force plate data, while Nuzzo et al.[24] showed good intratester reliability for using this system (ICC = 0.90-0.93; SEM = 1.6-2.3 cm).

The Biodex 2 Multi-Joint Testing and Rehabilitation System (Biodex Medical Systems, Shirley, NY) utilizes a specialized software package, combined with a dynamometer containing strain gages, potentiometer, and remote range of motion set switches, along with several limb attachments, for testing, rehabilitation, and diagnostic purposes of a variety of joints and muscle groups. The system allows for several resistance and speed options for individualizing testing procedures, including isometric, concentric, and eccentric modes in speeds of 0-500°/sec.

All participants attended one testing session. All participants signed an informed consent form approved by the university institutional review board prior to all data collection and these participants rights were protected throughout the study. Anthropometric data (i.e. age, height, mass) for all participants was collected. The first phase of testing consisted of three jump tests using the electronic jump mat system (i.e. double leg vertical jump, four repeated single-leg vertical jumps, single leg vertical jump). Following a five minute rest period, the second phase of testing began and consisted of measuring bilateral isokinetic knee extension and flexion strength at two speeds. All tests were conducted by the same investigators. Investigators provided instructions for all testing procedures; however no verbal feedback was given during testing.

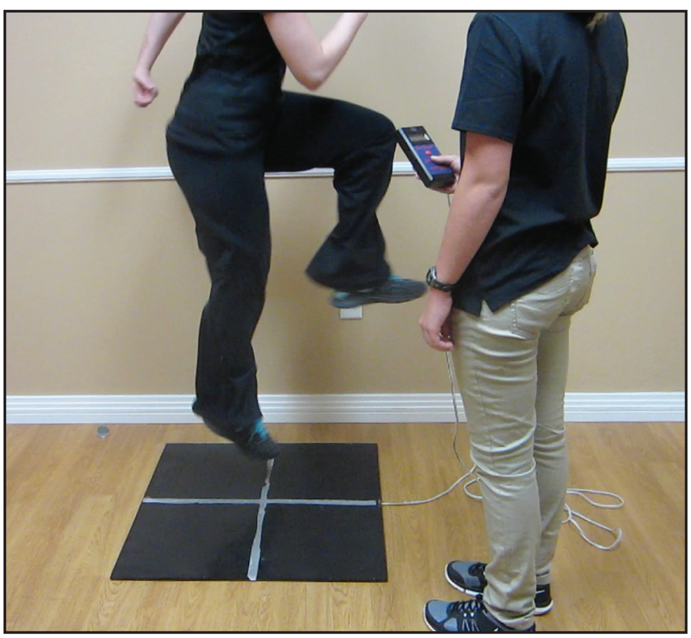

**Figure 1.** *The Just Jump system used to assess jump performance.*

For the first phase of testing, participants warmed up for five minutes on a stationary bike using a self-determined pace. Following this warm-up, the participants completed three different jump tests: double-leg vertical jump, one-legged vertical jump, and four repeated single-leg vertical jump tests using the electronic jump mat system. Subjects were allowed to move their arms during the jump tests in whatever fashion felt most comfortable and natural. Subjects were allowed three practice trials for each procedure to ensure familiarity with the tasks. All practice trials and tests were followed by a 1 minute rest prior to the next test to minimize fatigue.

For the double-leg vertical jump test participants were asked to complete a total of three maximum effort vertical jumps using both legs. For the single-leg jump test participants also completed maximum effort jumps bilaterally; however, only the test leg was used for analysis. For both the double- and single-leg tests participants were allowed one minute of rest between each maximum vertical jump to minimize fatigue. The vertical jump heights for each jump test were displayed on the electronic jump mat system's handheld computer, expressed in inches, and the average of the three jumps was used for data analysis. For the four repeated single-leg vertical jump test each participant was instructed to jump as high and as fast as they could for four repeated jumps on the test limb. After the four consecutive single leg vertical jumps the averages of ground reaction time, power ratio consisting of air time divided by ground time, and vertical jump height expressed in inches were calculated by the jump mat system hand held computer. Failure to land the test limb(s) on the mat during any test resulted in discarding of that trial and the participant was allowed to re-test. Investigators also instructed each participant to use their natural jumping motion and visually monitored each for any variations in their jump mechanics.

For the second phase of testing participants were seated on the Biodex system and secured with padded straps around the thigh, pelvis, and torso to minimize accessory and compensatory movements during testing. The test limb femoral condyle was aligned with the Biodex axis of rotation as per the manufacturer instructions. To ensure familiarity with the procedures participants performed five submaximal knee extension/flexion repetitions prior to each of the strength tests. To measure knee strength at 180°/sec, participants performed five maximal concentric contractions consecutively. To measure knee strength at 300°/sec, participants performed fifteen maximal concentric contractions consecutively. Knee strength at 180°/sec was always tested prior to 300°/sec. Thirty seconds of rest were provided between the two strength tests in order to minimize fatigue and the averages of the repetitions were used for data analysis. Specific variables for knee strength consisted of peak torque-to-body weight (PT/BW) and percent bilateral difference in PT/BW.

Independent t-tests were used to determine differences in jump performance and knee strength between the ACL-R and matched control groups. These variables were determined for both knee extension and flexion at speeds of 180°/sec and 300°/sec. Effect sizes were determined to provide an indication of clinical meaningfulness of differences between groups. Effect size was calculated as ACL-R group mean – control group mean / control group standard deviation. Effect sizes were interpreted according to Cohen's guidelines.[25] Findings were considered significant at an alpha level of $p < 0.05$.

Multiple regression analyses were used to determine the strength of the relationships between knee strength and the jump performance tests within the ACL-R participants. Relationships were interpreted as follows: r = 0.10-0.29 (weak); r = 0.30-0.49 (moderate); r = 0.50-1.0 (strong). The independent variables for the single leg and double leg vertical jump tests were jump height and percent bilateral difference in jump height. The independent variables for the 4-jump single leg vertical jump test were vertical jump height, ground contact time, and the ratio of air time divided by ground time. Knee extension and flexion strength characteristics (PT/BW and percent bilateral difference in PT/BW) were the dependent variables.

## RESULTS

Independent t-tests showed there were no demographic group differences other than a difference in age with the control group being 3.2 ± 5.0 years older than the ACL-R group ($p = 0.003$). Between group differences in jump performance can be viewed in Table 2. The ACL-R group had significantly lower single leg vertical jump height in the involved knee than the control group ($p = 0.02$). The inter-limb difference in the single leg vertical jump height was also found to be greater in the ACL-R group when compared to the controls ($p = 0.001$). Similarly, the ACL-R group had less vertical jump height ($p = 0.009$) and air time-to-ground time ratio ($p = 0.01$) in the involved leg during the 4-jump test compared to the control group.

Between group differences in knee extension and flexion strength can be viewed in Table 3. There was a significant bilateral difference in knee extension strength at 180°/sec ($p = 0.001$), with the ACL-R group having a larger differential than the control group. There was a similar bilateral difference in knee extension strength at 300°/sec ($p = 0.001$) again with the ACL-R group having the larger differential. The ACL-R group also had significantly more PT/

**Table 2.** *Between group descriptive statistics for jump tests (mean ± standard deviation)*

| Test | ACL-R | Control | *p*-value | Effect Size |
|---|---|---|---|---|
| *Single Leg Vertical (cm)* | | | | |
| Involved* | 27.2±5.6 | 31.2±6.4 | 0.02 | 0.63 |
| Non-Involved | 32.5±6.4 | 31.2±6.6 | 0.48 | 0.20 |
| Bilateral Difference* | -5.3±4.3 | 0.1±2.3 | 0.001 | 2.35 |
| *Double Leg Vertical (cm)* | 51.8±9.7 | 54.6±10.9 | 0.34 | 0.23 |
| *4-Jump (involved limb)* | | | | |
| Ground contact time (sec) | 0.45±0.2 | 0.42±0.1 | 0.25 | 0.30 |
| Ratio* | 0.94±0.2 | 1.1±0.2 | 0.01 | 0.80 |
| Vertical height (cm)* | 20.3±5.3 | 24.9±6.9 | 0.009 | 0.66 |

*Indicates statistically significant difference between groups p < 0.05).

**Table 3.** *Between group descriptive statistics for knee strength tests (mean ± standard deviation)*

| Test | ACL-R | Control | *p*-value | Effect Size |
|---|---|---|---|---|
| *Extension at 180°/sec* | | | | |
| Involved PT/BW (%) | 60.5 ± 12.0 | 65.7±12.4 | 0.13 | 0.42 |
| Non-Involved PT/BW (%) | 73.9±12.4 | 67.7±10.8 | 0.06 | 0.57 |
| Bilateral Difference* | -13.4±9.9 | -2.0±6.0 | 0.001 | 1.90 |
| *Flexion at 180°/sec* | | | | |
| Involved PT/BW (%)* | 40.7±6.9 | 36.4±7.4 | 0.04 | 0.58 |
| Non-Involved PT/BW (%) | 39.6±7.6 | 36.0±7.2 | 0.08 | 0.50 |
| Bilateral Difference | 1.1±4.5 | 0.5±6.0 | 0.66 | 0.10 |
| *Extension at 300°/sec* | | | | |
| Involved PT/BW (%) | 46.9±8.6 | 49.8±9.2 | 0.25 | 0.32 |
| Non-Involved PT/BW (%)* | 57.9±9.0 | 50.8±9.4 | 0.008 | 0.76 |
| Bilateral Difference* | -10.9±7.7 | -1.0±5.2 | 0.001 | 1.90 |
| *Flexion at 300°/sec* | | | | |
| Involved PT/BW (%)* | 33.7±6.3 | 30.1±5.6 | 0.03 | 0.56 |
| Non-Involved PT/BW (%) | 34.1±6.0 | 31.7±6.0 | 0.16 | 0.54 |
| Bilateral Difference | -0.4±3.8 | -1.6±4.8 | 0.31 | 0.37 |

*Indicates statistically significant difference between groups ($p < 0.05$).
ACL-R=anterior cruciate ligament reconstruction group, PT/BW=peak torque-to-body weight.

BW extension strength in the non-involved knee at 300°/sec compared to the controls ($p = 0.008$). No other extension strength differences existed between groups ($p > 0.06$). Group differences for flexion strength showed that the ACL-R group had greater PT/BW in the involved limb at 180°/sec ($p = 0.04$) and 300°/sec ($p = 0.03$) as compared to the control group. No other flexion strength differences existed between groups ($p > 0.08$).

Several relationships were found between the various isokinetic strength tests and the summation of single and double leg vertical height. Fifty-one percent of PT/BW extension strength at 180°/sec was explained by the summation of the single and double leg jump height variables ($r = .71$ , $p = .001$) with single leg jump height contributing the most to this relationship ($r = .32$, $p = .02$). Twenty-five percent of the bilateral difference in knee extension strength at 180°/sec was explained by the summation of the single and double leg jump height variables ($r = .50$, $p = .01$). Although, double leg jump height accounted for the largest portion of this relationship ($r = .50$, $p = .004$) single leg jump height also made a large contribution ($r = .44$, $p = .009$). Fifty-five percent of peak torque extension strength at 300°/sec was explained by the summation of the single and double leg jump height variables ($r = .74$ , $p = .001$) with single leg jump height accounting for the largest portion of this relationship ($r = .39$, $p = .003$). Thirty-four percent of peak torque flexion strength at 180°/sec was explained by the summation of the single and double leg jump height variables ($r = .59$ , $p = .002$); however neither single or double leg jump height significantly contributed to this relationship ($p > .10$). Twenty-five percent of peak torque flexion strength at 300°/sec was explained by the summation of the single and double leg jump height variables ($r = .50$, $p = .01$); however no single variable contributed significantly to this relationship. No other strength variables (bilateral difference in extension strength at 300°/sec, bilateral difference in flexion strength at 180°/sec, bilateral difference in flexion strength at 300°/sec) showed any relationship with the jump test variables ($p > .07$).

Several relationships were found between the various isokinetic strength tests and the summation of the 4-jump test variables. Forty percent of PT/BW extension strength at 180°/sec was explained by the summation of the 4-jump test variables ($r = .64$, $p = .002$) with vertical height contributing the most to this relationship ($r = .61$, $p = .001$). Fifty-five percent of PT/BW extension strength at 300°/sec was explained by the summation of the single and double leg jump height variables ($r = .74$, $p = .001$) with vertical height contributing the most to this relationship ($r = .71$, $p = .001$). Thirty-four percent of PT/BW flexion strength at 180°/sec was explained by the summation of the single and double leg jump height variables ($r = .58$, $p = .007$) with vertical height accounting for the largest portion of this relationship ($r = .52$, $p = .002$). No other strength variables (bilateral difference in extension strength at 180°/sec, bilateral difference in extension strength at 300°/sec, bilateral difference in flexion strength at 300°/sec) showed any relationship with the 4-jump tests variables ($p > .17$).

The independent relationships between jump performance with knee extension and flexion strength for the ACL-R group can be viewed in Tables 4 & 5, respectively. The ACL-R group showed moderate-to-strong positive relationships for both knee extension and flexion PT/BW with single leg vertical jump height ($p <= 0.004$) (Tables 4 & 5). Similar positive relation-

**Table 4.** *Relationships between involved knee extension strength and jump tests among ACL-R participants expressed as r-value (p-value)*

| Jump test | Knee Extension at 180°/sec | | Knee Extension at 300°/sec | |
|---|---|---|---|---|
| | PT/BW | Bilat Diff | PT/BW | Bilat Diff |
| Single leg | 0.71 (0.001)* | 0.04 (0.81) | 0.74 (0.001)* | -0.02 (0.90) |
| Double leg | 0.64 (0.001)* | -0.23 (0.19) | 0.63 (0.001)* | -.23 (0.21) |
| 4-Jump | | | | |
| Ground Contact | 0.06 (0.73) | 0.11 (0.54) | 0.01 (0.63) | 0.10 (0.57) |
| Ratio | -0.17 (0.34) | 0.10 (0.59) | -0.21 (0.23) | 0.03 (0.88) |
| Vertical height | 0.63 (0.001)* | 0.16 (0.37) | 0.73 (0.001)* | 0.15 (0.41) |

*Statistically significant relationship (p<0.05).
ACL-R = anterior cruciate ligament reconstruction, PT/BW = peak torque-to-body weight, Bilat Diff = bilateral difference.

**Table 5.** *Relationships between involved knee flexion strength and jump tests among ACL-R participants expressed as r-value (p- value).*

| Jump test | Knee Flexion at 180°/sec | | Knee Flexion at 300°/sec | |
|---|---|---|---|---|
| | PT/BW | Bilat Diff | PT/BW | Bilat Diff |
| Single leg | 0.53 (0.002)* | -0.29 (0.11) | 0.49 (0.004)* | -0.09 (0.62) |
| Double leg | 0.58 (0.001)* | -0.39 (0.02)* | 0.45 (0.009)* | -0.16 (0.37) |
| 4-Jump | | | | |
| Ground Contact | 0.16 (0.39) | 0.06 (0.72) | 0.24 (0.18) | 0.37 (0.03)* |
| Ratio | -0.05 (0.79) | 0.01 (0.99) | -0.13 (0.49) | 0.02 (0.92) |
| Vertical height | 0.39 (0.02)* | -0.24 (0.18) | 0.56 (0.001)* | -0.07 (0.70) |

*Statistically significant relationship (p<0.05).
ACL-R = anterior cruciate ligament reconstruction, PT/BW = peak torque-to-body weight, Bilat Diff = bilateral difference.

ships were found between knee extension and flexion PT/BW with double leg vertical jump ($p < 0.009$) (Tables 4 & 5). The same positive relationships were found between knee extension and flexion PT/BW with the single leg vertical jump during the 4-jump test ($p = < 0.02$) (Tables 4 & 5). Only two significant relationships were found between bilateral difference in knee strength and jump characteristics. Bilateral difference in knee flexion strength at 180°/sec had a moderate negative relationship with the double leg jump ($r = -0.39$, $p = 0.02$). Also, the bilateral difference in knee flexion strength at 300°/sec had a moderate positive relationship with ground contact time during the 4-jump test ($r = 0.37$, $p = 0.03$).

## DISCUSSION

Jump and isokinetic strength testing are commonly utilized during therapeutic rehabilitation programs and used to determine functional capabilities among ACL-R patients.[2, 3, 22, 26, 27] Although isokinetic knee strength testing is often viewed as an effective standard for determining various stage progressions during ACL-R rehabilitation,[3, 10, 26, 28] many clinicians do not have access to these expensive and bulky devices. Because of this, jump training and the use of electronic jump mat systems have become increasingly popular as an assessment tool.[22] This study was the first to investigate the usefulness of a jump assessment system among athletes who had completed an ACL-R rehabilitation program and had been cleared to return-to-play by an orthopedic physician. The results of this study show that ACL-R patients have less vertical jump capabilities and some bilateral knee strength differences when compared to matched controls. The ACL-R group also showed several moderate-to-strong positive relationships for both knee extension and flexion strength with several jump performance characteristics.

Numerous studies have shown diminished knee strength during various periods following ACL-R. Mattacola et al,[29] reported that at 18 months post-surgery the involved knee extension isokinetic strength is not within the normal limits of the contralateral knee. Similarly, Giampietro[30] reported several strength deficits among ACL-R patients approximately 25 months post-surgery when compared to a control group. Several investigations have also shown strength deviations around the time of return-to-play clearance. Thomas et al,[8] showed that during this time period (approximately 212.5 days post-surgery), ACL-R patients had greater bilateral strength differences compared to a control group. Hsiao et al,[31] reported that ACL-R patients had excessive weakness at six months post-surgery when compared to the contralateral knee. Similarly, Xergia et al,[32] stated that knee extension deficits persist six to nine months following ACL-R. The isokinetic extension strength results of the current study support these previous findings and provide further insight into deficiencies that occur at faster testing speeds such as 300°/sec. Conversely, the current results demonstrate that ACL-R patients actually have more knee flexion strength compared to a control group at speeds of 180°/sec and 300°/sec. As such, strength testing at speeds which more closely mimic functional activities should also be addressed in ACL-R rehabilitation programs.

Much of the previous research that has investigated jump characteristics among ACL-R patients has focused on hop tests for distance[17-20, 34-36] with limited research on vertical jump performance.[22, 27, 37] In one of the few studies that assessed a single one-legged jump for height among ACL-R patients, the investigators reported less jump height in the involved side compared to the contralateral side.[22] In another study investigating jump height, Myer et al[27] found that repeated single leg jumps for height over a ten second span were less in an ACL-R group compared to controls. Based on these findings, Myer et al suggested that persistent side to side differences may increase risk of injury and that jump height should be considered in the return-to-play decision. The results of the current study support those of Petschnig et al and Myer et al and demonstrate that other jump characteristic deficiencies exist, such as the inter-limb difference during single leg vertical jumps, as well as the vertical jump height and air time-to-ground time ratio during the 4-jump test when compared to a matched control group. Characteristics such as single leg vertical jump height and bilateral difference in vertical jump height, as well as air time-to-ground time ratio and vertical height during the repeated jump task differ when compared to a matched control group. These findings emphasize the need for vertical jump training and testing during ACL-R rehabilitation.

Although isokinetic testing has been proven to be beneficial when assessing ACL-R patients' progress following rehabilitation,[38] some clinicians may not have access to such equipment. Several studies have investigated the relationship between isokinetic knee strength testing and various jump for distance tests. Greenberger and Paterno[16] reported that isokinetic knee extension strength had a significant correlation with a single leg hop for distance among an asymptomatic group. Paasuke et al[39] showed a relationship between jump height and knee extension strength at 0°/sec and 60°/sec among asymptomatic participants. However, Wilk et al,[15] conducted one of the only studies to investigate and show a relationship between knee strength and hop tests among ACL-R patients. These investigators showed that knee extension peak torque correlated positively with three hop tests (hop for distance, timed hop, cross-over triple hop). The results of the current study are the first to show that a similar relationship exists among ACL-R patients during various jump tests for height. Thus, the use of these inexpensive and easily portable and storable electronic jump mats may be an effective alternative to isokinetic testing as a means of determining functional performance.

There are a few limitations to the current study worth mentioning. First, the jump tests used in this study do not take into consideration side-to-side movements or rotation, which must also be considered during ACL-R rehabilitation. Second, the participants in this study were athletes which make comparison to non-athletes who sustain an ACL injury difficult. Also, the ACL-R participants were placed into a single group rather than separated by gender. Due to the known physical differences between genders, especially among incidence of ACL injuries, future research should investigate potential gender differences in the same parameters. Lastly, although relatively fast speeds of isokinetic testing were chosen in an attempt to replicate athletic functional movements the authors understand that creating similar speeds and forces in a clinic is not possible.

## CONCLUSION

The results of this study indicate that ACL-R patient's performance (e.g. jump height during single leg, double leg, and 4-jump tasks) assessed using an electronic jump mat system have a moderate-to-strong positive relationship with isokinetic knee strength measures. Thus, jump height performance may be considered a partial predictor of knee strength. The ACL-R participants in this study also presented with several knee strength and vertical jump differences compared to a matched control group, suggesting that even at the time of return-to-play ACL-R athletes may not have full restoration of strength and vertical jump capabilities. The findings of this study may prove useful throughout an ACL-R rehabilitation protocol and when making return-to-play decisions.

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