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Original Article

Relationship between Kinesiophobia and Vertical Ground Reaction Force in Anterior Cruciate Ligament Reconstructed and Deficient Patients during Landing Task

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ABSTRACT

Background: The effect of kinesiophobia (fear of movement) following an anterior cruciate ligament injury (ACL) has recently received great attention. However, the relationship between kinesiophobia and peak vertical ground reaction force (VGRF) in ACL reconstructed (ACLR) and deficient (ACLD) individuals has not been investigated.

Methods: Forty male patients (20 ACLR and 20 ACLD), 24 months post-ACL injury, who had completed post-injury/operative rehabilitation, participated in this cross-sectional study. Participants completed a drop vertical landing task on force plate while the VGRF was recorded. Participants also completed the TSK-11 (kinesiophobia) questionnaire.

Results: Associations between peak VGRF and the TSK scale were made with Pearson correlation coefficients; significant relationships were defined as $p \leq 0.05$. The average peak VGRF was 2.67±0.28 and 2.68±0.17 (mean±SD) %bodyweight and the TSK value was 33.45±4.6 and 31.60±3.40 (mean±SD) for ACLD and ACLR groups, respectively. There was a significant negative association between poorer responses on the TSK scale and peak VGRF in the ACLD group (r=-0.58, P=0.007) but not in the ACLR group (r=-0.31, P=0.17).

Conclusion: This study found greater kinesiophobia to be associated with a lower peak VGRF in the ACLD group during the landing task. It seems that ACLD individuals unload their injured limb because of fear of movement. These results suggest that in ACLD individuals with high kinesiophobia, cognitive training should be incorporated into their rehabilitation program to improve landing mechanics. Future studies are needed to assess whether these relationships play a role in developing osteoarthritis over time.

Introduction

Anterior cruciate ligament (ACL) rupture is a common injury in many sports [1]. ACL rupture frequently causes disability in athletes and usually occurs following sudden turning, jumping, or pivoting movements during sports activities [2, 3]. Reconstruction surgery is the standard treatment for ACL rupture. It stabilizes the knee joint and helps prevent further injuries and returning to previous levels of activity [4]. Nonetheless, more than 50% of highly active individuals with an ACL injury choose conservative treatment (active rehabilitation alone) [5]. The rehabilitation of an ACL injury can restore range of motion, strength, movement control, and knee function [6]. During the rehabilitation process, not only physical but also psychological factors can be indicators of success

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in outcomes. However, some performance deficiency remains after a rehabilitation program. Research findings have revealed that while rehabilitation programs have been successful on ACL injuries, a considerable number of athletes, about 47%, do not return to the pre-injury level; in fact, 24% of them report fear of re-injury as the reason for not returning to sports [7]. Accordingly, other studies have demonstrated that 44% of athletes do not returned to sports with no cause [8] and about 30% [9] and 7% [10] state fear of re-injury as the main cause.

In recent years, the biopsychosocial model in the rehabilitation process has received more attention in clinical research. Implementing the assessment and management of psychological factors in rehabilitation programs for individuals with musculoskeletal injuries/ pain can aid in the decision-making process and improve outcomes. Therefore, it is important to know which psychological factors are related to the rehabilitation process and can contribute to a good recovery [11, 12].

Kinesiophobia is the fear of movement or fear of re-injury before or after returning to activity or sports. It is also the most extreme form of fear of movement and is defined as irrational and debilitating fear of physical movement or activity resulting from a feeling of vulnerability to painful re-injury [13]. As measured on the Tampa Scale of Kinesiophobia (TSK), pain-related fear is a psychological construct associated with poor short- and long-term outcomes that are frequently documented at the completion of rehabilitation after ACLR [7, 14-16]. High kinesiophobia has been associated with lower self-reported knee function [7, 17, 18], weak performance in hop tests [18, 19], lower quadriceps [16] and hamstring [18] strength, stiffened movement patterns [20], and greater risk of re-injury [19, 21] in ACLR individuals.

A previous systematic review demonstrated reductions in injured-limb knee-extension moments and vertical ground reaction forces (VGRF) in individuals after ACLR [22]. Lower peak VGRF has also been demonstrated in ACLD individuals compared to the healthy control group [23, 24]. These findings indicate that the potential unloading of the injured limb may have significant implications for secondary ACL injury and long-term joint health [22]. The incidence of early knee osteoarthritis after ACL injury and reconstruction has been associated with unloading of the knee joint, including decreased medial and lateral contact forces during gait [24, 25]. Reductions in VGRF and knee contact forces in ACLR and ACLD individuals have been attributed to muscle activation patterns and kinematic adaptations [25-27]; however, the association between kinesiophobia and the magnitude of VGRF in ACLR and ACLD individuals remains unknown. Establishing the relationship between kinesiophobia and VGRF during a drop landing task may result in the development of a specific rehabilitation program to reduce fear of movement and improve jump landing mechanics after ACL injury, resulting in a diminished risk of re-injury. Therefore, the current study purposed to define the relationship between peak VGRF and TSK score in individuals 24 months after ACL injury and reconstruction during the drop landing task. It was hypothesized that greater kinesiophobia is associated with lower peak VGRF in ACL-injured individuals. Secondly, it was hypothesized that kinesiophobia is greater in ACLD compared to ACLR individuals.

Methods

Participants

Forty male participants (20 ACLR and 20 ACLD), 24 months post-ACL injury, who had completed post injury/operative rehabilitation and were cleared by their physician to begin the return to sports drills, took part in this cross-sectional study (Table 1). Sample size was estimated using G-power software, based on the standard deviation of the main variable (kinesiophobia) and assumed moderate association (r=0.50), which indicated that 20 participants would be necessary for each group to attain an a priori power of 0.80 with a 95% confidence interval [28]. Inclusion criteria required that all participants be male; recreationally active (exercised for at least three sessions per week for 30 min per session) according to ACSM guidelines [29]; and between 18 and 40 years of age. Individuals were excluded from participation if they were not medically cleared by their physician to participate in exercise; had a history of bilateral ACL injury or injury to the medial collateral ligament, posterior cruciate ligament, lateral collateral ligament, or meniscus in either knee; had any lower extremity injury episodes in the prior 6 months that left them unable to par+ticipate in physical activity for more than 3 consecutive days; had a history of more than one ACL injury; or sustained a contact ACL injury. This study was approved by the university institutional review board (IR.SSRI.REC.1396.138), and all participants provided informed written consent before testing.

Peak Vertical Ground Reaction Force

The peak VGRF values of the operated leg of ACLR and deficit leg of ACLD individuals during the single leg vertical drop-landing task (Figure 1) were analyzed. A force plate (Advanced Medical Technology, Inc., Watertown, MA, USA) was used for VGRF data collection. VGRF data was low pass filtered using a zero-lag fourth-order Butterworth filter at 50 Hz [30].

Table 1: Participant characteristics

	ACLD (n=20)		ACLR (n=20)		t	P
	Mean	SD	Mean	SD		
Age (y)	27.54	2.89	25.83	5.49	0.16	0.78
Height (cm)	172.41	4.62	174.25	4.78	0.34	0.62
Mass (kg)	75.25	7.13	76.45	5.93	0.55	0.63
BMI	25.43	3.58	25.25	5.14	0.47	0.66
Months since surgery or initial injury	28.42	7.95	25.75	6.3		

BMI: Body Mass Index

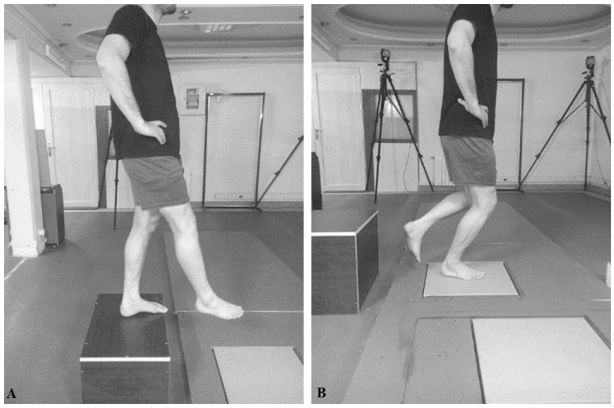

Figure 1: Single-leg drop landing. (A) Preparation phase. (B) Landing phase.

VGRFs were normalized to body mass (N/kg), and the mean of the three trials of landing was used for statistical analysis. Intraclass correlation coefficients of VGRFs in three trials for ACLR and ACLD groups were 0.967 and 0.953, respectively.

Assessment of Kinesiophobia

Kinesiophobia was assessed with the shortened version of the Tampa Scale of Kinesiophobia (TSK-11). TSK-11 is an 11-item questionnaire that eliminates psychometrically poor items from the original version of the TSK to create a shorter questionnaire with comparable internal consistency [31, 32]. The TSK-11 includes 11 items which relate to somatic sensations (e.g., "Pain always means I have injured my body") or activity avoidance (e.g., "I cannot do all the things normal people do, because it is too easy to get injured"). Each item on the questionnaire is scored from 1 ("strongly disagree") to 4 ("strongly agree"). The item scores are summed to create a total score ranging from 11 to 44 points; higher scores indicate greater pain-related kinesiophobia [14].

Statistical Analysis

Correlations between the kinesiophobia scale and VGRFs during the single drop-landing task were assessed using simple Pearson's correlational analyses. Standard Cohen's r effect sizes were calculated to assess the strength of relationship between variables. The strength of the effect sizes was interpreted using the guidelines described by Cohen [33] with values less than 0.1 interpreted as weak, those ranging from 0.1 to 0.36 interpreted as medium, those ranging from 0.36 to 0.51 interpreted as moderate, and values greater than 0.51 interpreted as strong. The independent t test was used to compare VGRF and kinesiophobia scores between the ACLR and ACLD groups. Statistical analyses were performed with SPSS software (version 20).

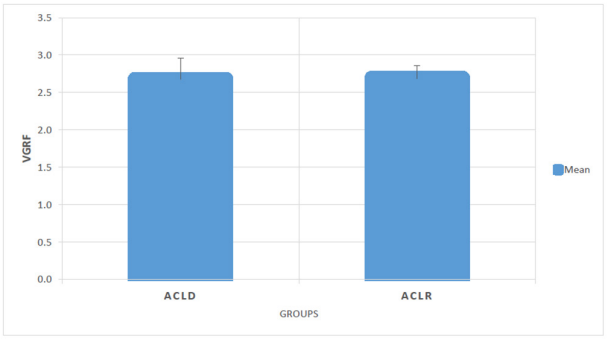

Figure 2: Comparison of vertical ground reaction force between anterior cruciate ligament deficit (ACLD) and anterior cruciate ligament reconstructed (ACLR) groups (Mean±SD)

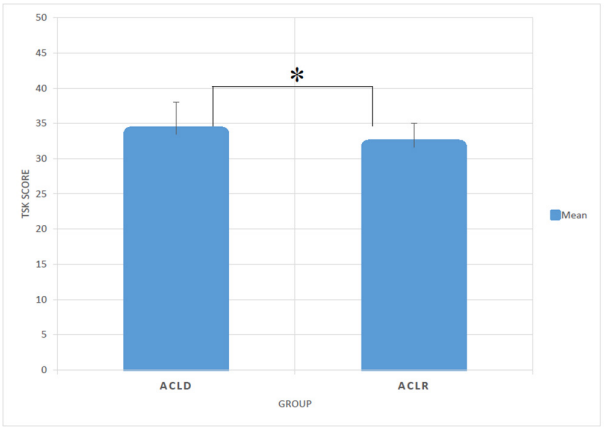

Figure 3: Comparison of kinesiophobia Tampa scale of kinesiophobia (TKS) between anterior cruciate ligament deficit (ACLD) and anterior cruciate ligament reconstructed (ACLR) groups (mean±SD). ACLD patients had significantly higher kinesiophobia scores than ACLR. *P<0.01

Results

There was no significant difference *(*t=0.08, P≥0.05*)* in peak VGRF between ACLR and ACLD groups (Figure 2); however, kinesiophobia (TSK) was significantly higher in ACLD compared to ACLR individuals *(*t=2.74, P≤0.05*)* (Figure 3).

There was a significant negative association between the TSK scale and peak VGRF in the ACLD group (r=-0.58, P=0.007) but not in the ACLR group (r=-0.31, P=0.17). Specifically, an increased score (poorer response) on TSK was associated with lower VGRF in ACLD individuals (Table 2).

Discussion

The current study examined the association between kinesiophobia levels and VGRF in ACLD and ACLR individuals. It was hypothesized that greater kinesiophobia is associated with lower peak VGRF in ACL injured individuals. The findings support the hypothesis in

Table 2: Correlations between TSK and VGRF in ACLD and ACLR groups.

Groups	ACLD		ACLR	
	VGRF		VGRF	
	r	P	r	P
TSK total score	-0.58	0.007 *	-0.31	0.17

P≤0.05, Effect size (Cohen r): <0.1 weak, 0.1 to 0.36 medium, 0.36 to 0.51 moderate and >0.51 strong correlation. TSK: Tampa scale of kinesiophobia, VGRF: vertical ground reaction force, ACLD: anterior cruciate ligament deficit, ACLR: anterior cruciate ligament reconstructed

ACLD but not in ACLR individuals. Specifically, greater kinesiophobia was found to be associated with a lower VGRF in the ACLD individuals during the vertical drop landing task. Furthermore, it should be noted that kinesiophobia levels were significantly higher in ACLD individuals than in those with ACLR.

The fear avoidance model could explain the influence of kinesiophobia on knee function, which has an important role in patient behavior. Among individuals with fewer fear-avoidance beliefs, fear usually dissipated as the musculoskeletal condition resolved. Those individuals interpret pain as non-threatening and are likely to maintain their activities of daily living despite pain as a result of this facilitated recovery. When individuals experience a recurrent painful stimulus, an exaggerated negative psychological response to pain or the anticipation of pain (pain catastrophizing) results in an active avoidance of movement out of fear of recurrent pain or injury (kinesiophobia) [34].

In the present study, a significant negative association was noted between kinesiophobia and VGRF in ACLD individuals. To the best of our knowledge, this is the first study to evaluate the association between kinesiophobia and VGRF in ACLD individuals. In previous studies, lower VGRF force [23, 24] and knee flexion moment [35] have been demonstrated in ACLD individuals during gait and single leg hop tests compared to healthy individuals and the non-involved leg. Previous studies have suggested that compensatory mechanisms in ACLD individuals, including reduced VGRF and peak knee flexion moment, are related to quadriceps avoidance strategies associated with decreased quadriceps activity, a problem that can persist for years following ACL injury and successful rehabilitation [26, 36]. However, quadriceps activation alone does not account for similar compensation strategies utilized by individuals who have torn their ACL but have not had ACL reconstruction [23, 37]. In the present study, a higher score in TSK (kinesiophobia) was associated with lower VGRF in ACLD individuals; thus, it seems that the fear avoidance model may help explain compensatory movement patterns in ACLD individuals. Fear of movement or re-injury has been suggested to be a factor contributing to the adoption of a biomechanical strategy that reduces loading on the ACL reconstructed or injured limb when completing discrete, non-repetitive tasks such as single-leg hopping [38]. It seems that the association between VGRF and kinesiophobia in ACLD individuals is a protective strategy to prevent further injury in their knees. Future studies should determine whether unloading of the injured limb due to kinesiophobia plays a role in the development of osteoarthritis among ACL-deficient individuals.

There was no significant association between TSK and VGRF in ACLR individuals during the drop landing task. In a previous gait study, no significant association was seen between the level of kinesiophobia and gait speed, peak VGRF, instantaneous VGRF loading rate, peak knee extension moment or knee flexion excursion on the ACLR limb, or the magnitude of inter-limb asymmetry for these same biomechanical variables compared to the uninjured limb [38]. However, Stephanie et al. [20] demonstrated that a greater fear of re-injury is associated with stiffened movement patterns (including less trunk, hip, and knee flexion) during the jump landing task. Although the current study did not measure kinematic variables, it should be noted that the participants of the Stephanie et al. study were females with a history of ACLR, and this difference between subject populations (males vs. females) may help explain the conflicting results between the present study and the study of Stephanie et al.

ACLD individuals had significantly higher TSK scores than ACLR individuals, which supports the second hypothesis of this study. Kinesiophobia levels have been shown to be elevated prior to ACL reconstruction, especially in those with poorer dynamic knee stability (i.e. noncopers). After ACL reconstruction, kinesiophobia levels were reduced the most in noncopers, and the reductions in kinesiophobia were significantly related to improvements in self-reported knee function during activities of daily living [39]. Moreover, it has been demonstrated that the timing of ACL reconstruction after injury is a good predictor for high kinesiophobia. In fact, prolonged injury to surgery time could increase the level of kinesiophobia [21]. It seems that restoration of mechanical knee stability with surgery might contribute to decreased kinesiophobia levels in ACLR individuals. Another possible explanation for higher kinesiophobia levels in the ACLD group could be the number of instances of giving way during functional activities. Previous studies have proven the association between knee instability and high levels of kinesiophobia [16, 21].

The current study has provided new information about the relationship between kinesiophobia and VGRF in ACLD and ACLR individuals, and rehabilitation specialists can use this information for both prevention and rehabilitation of ACL injuries. Based on statistical power, the sample size was enough to achieve meaningful results. This study was conducted in a laboratory setting, and researchers tried to control the effects of confounding variables; however, it had several limitations. Because the study design was a cross-sectional, it cannot be determined whether kinesiophobia was present before the injury or occurred due to the injury. The participants were recreationally active male athletes with 3 periods of activity weekly [29]; thus, the results cannot be generalized to females or professional or elite athletes. Future studies should compare levels of kinesiophobia between males and females after ACL injury and the association between kinesiophobia and landing mechanics. The current study did not measure the uninjured leg of the participants; future studies could consider both legs in ACL-injured individuals. Different graft types in the ACLR group, patellar tendon (n=6), semitendinosus/gracilis (n=10), and allograft (n=4), were included in this study and may have affected the results. While this increases the generalizability of the current findings, future investigations are warranted to determine the potential relationship between kinesiophobia and landing biomechanics in different graft types.

Conclusion

The current study found greater kinesiophobia to be

associated with a lower peak VGRF in the ACLD group during landing tasks. It seems that ACLD individuals unload their injured limb because of fear of movement. The lack of relationship to peak VGRF in the ACLR group suggests kinesiophobia does not affect the magnitude of impact forces in this group of individuals. These results suggest that for ACLD individuals with high kinesiophobia, cognitive training should be incorporated into their rehabilitation program before initiating other exercises to improve landing mechanics. Additional studies are needed to assess whether these relationships could play a role in the development of osteoarthritis over time.

The current study indicates that self-reported kinesiophobia (fear of movement) may be an important factor for some biomechanical adaptations in ACLD individuals during landing tasks. Clinicians may also need to be aware of the high level of kinesiophobia in individuals with ACL injury and address it as a criterion for returning to sports.

Conflict of Interests: None declared.

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