Journal of Research in
Orthopedic Science

May 2021. Volume 8. Number 2

# Review Paper: Knee Muscle Activity During Jump Landing Tasks Following Anterior Cruciate Ligament Reconstruction: A Review Study

**Maedeh Taghizadeh Kerman[1], Ali Yalfani[1*], Ahmad Ebrahimi Atri[2], Seyyed Hamed Mousavi[3]**

*1. Department of Corrective Exercises and Sport Injuries, Faculty of Physical Education and Sport Sciences, Bu-Ali Sina University, Hamedan, Iran.*
*2. Department of Exercise Physiology, Faculty of Sport Sciences, Ferdowsi University of Mashhad, Iran.*
*3. Department of Health and Sport Medicine, Faculty of Physical Education and Sport Sciences, University of Tehran, Iran.*

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**Citation** Taghizadeh Kerman M, Yalfani A, Ebrahimi Atri A, Mousavi SH. Knee Muscle Activity During Jump Landing Tasks Following Anterior Cruciate Ligament Reconstruction: A Review Study. Journal of Research in Orthopedic Science. 2021; 8(2):57-64. http://dx.doi.org/10.32598/JROSJ.8.2.755.1

**doi:** http://dx.doi.org/10.32598/JROSJ.8.2.755.1



**Article info:**
**Received:** 19 Jan 2021
**Revised:** 29 Feb 2021
**Accepted:** 24 Apr 2021
**Available Online:** 01 May 2021

**Keywords:**
Anterior Cruciate Ligament, Electromyography, Reconstruction, Muscle

## ABSTRACT

**Background:** Changes in knee muscle activity remain years after Anterior Cruciate Ligament (ACL) surgery. However, the literature on the successful or unsuccessful recovery of lower limb muscle activation during jump landing is controversial.

**Objectives:** The present review intended to compare the surface Electromyography (EMG) of knee muscle activity in healthy and Anterior Cruciate Ligament Reconstruction (ACLR) groups in jump landing tasks.

**Methods:** PubMed, Embase, and Web of Science databases were searched papers from 1990 to 2020 using the keywords "anterior cruciate ligament or ACL, EMG or Electromyography or Muscle activation, Landing or Jumping or Hopping". After screening the titles, abstracts, and full text of the collected articles, 7 studies met the inclusion criteria of this review. The Critical Appraisal Skills Program tool was used for the quality assessment of the included papers.

**Results:** The present research results suggested earlier onset muscle activity for quadriceps and hamstring in ACLR subjects, compared to healthy subjects. Furthermore, the ratio of activation of quadriceps/hamstring in the ACLR group was higher than that in the healthy individuals considering the type of rehabilitation, the time elapsed from surgery, and gender. The methodological quality of the observational studies ranged from 6 to 8 out of 12 that reflects the overall quality of the methodology.

**Conclusion:** According to this review, we can conclude that the ACLR group exhibited different neuromuscular strategies in the pre-landing phase that might increase the recurrent risk of ACL injury.

*** Corresponding Author:**
*Ali Yalfani, PhD.*
***Address:*** *Department of Corrective Exercises and Sport Injuries, Faculty of Physical Education and Sport Sciences, Bu-Ali Sina University, Hamedan, Iran.*
***Phone:*** *+98 (918) 3155478*
***E-mail:*** *ali_yalfani@yahoo.com*

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## 1. Context

The most common Anterior Cruciate Ligament (ACL) injuries occur during single-leg landing, sudden pivoting, or cutting maneuvers in sports activities. These movements can cause the loss of balance control and lead to abnormal loading on the knee joint [1]. Most non-contact ACL tears were knee angle <30° and lack of alignment occurred in the ankle, knee, and hip joints [2, 3], i.e., the valgus collapse [4]. An ACL injury causes improper performance, i.e., often associated with a prolonged absence of the athlete and the prevalence of arthritis development [5]. Therefore, ACL injury prevention exercises were provided for athletes [6]. More than 100000 individuals experience the reconstruction of ACL in the United States, annually [7].

More ACL surgeries are performed with the autograft and allograft tissues. Furthermore, there was no significant difference in the achieved results by using allograft and autograft in the ACL reconstruction method [8]. Most orthopedic surgeons favor reconstruction in an athlete with ACL deficiency who expects to return to sports participation after ACL injury [9]. It is estimated that young athletes who successfully return to sports are approximately 30-40 times more prone to predispose secondary knee injuries. Despite the improvement in ACLR rehabilitation protocols, muscle weakness, movement deficits, abnormal neuromuscular control, and difficulty in returning to activity are common for numerous years after surgery. These characteristics predispose athletes to recurrent ACL injuries [10]. Return to acceptable physical performance to pre-injury level depends on the rehabilitation process. Besides, it requires a serious focus on quadriceps and hamstring muscle contraction [11, 12]. Athletes who fail to meet the minimum criteria for returning to sports may experience a neuromuscular malfunction and incorrect movement patterns [13]. Neuromuscular control is essential and defined as the unconscious activation of muscles for joint stability [14].

Deficits in neuromuscular control can enhance the extra burden on the knee joint during daily living activities and generate cartilage damage over time [15]. To avoid the anterior tibia shear force, impaired movement patterns are observed as a protective mechanism in the patient with ACL defect and reconstruction [16]. One aspect that requires evaluation is the mechanical stability of the knee. This condition may be restored; however, the neurosensory defect remains constant [17]. The increased sensitivity of muscle spindles induced by proper muscle activity significantly impacts joint stiffness and stability [18]. The onset of muscle activity can be assessed using Electromyography (EMG) by identifying the first action potential of the motor units, i.e., continuously generated before touchdown [19].

A recent case study signified a risk factor for an ACL injury to be the delayed onset of muscle activity after initial contact during landing. The indicator of muscle activation, as onset time, has been evaluated to compare injured ACL with healthy controls. This factor can be a key aspect in defining an injury profile or decision to return to play [20]. Changes in the activity of the quadriceps, hamstrings, and both heads of the gastrocnemius muscles are the post-surgery risk factors for injury and re-injury [21, 22]. Studies revealed that women exhibit higher quadriceps/hamstring muscle activity. In other words, hamstring muscle activity is not increased to compensate for elevated quadriceps muscle activity in females [23]. Some discrepancies have been raised between patients with ACL and healthy individuals; however, the relevant evidence is scarce and unclear. Therefore, the present review article aimed to compare knee muscle activity in healthy and ACLR groups during landing tasks.

## 2. Methods

This systematic review has been reported using Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [24] (Figure 1).

### Search strategy

Electronic databases, such as PubMed, Web of Science, and Embase were searched. The following keywords were combined to the search: “Anterior cruciate ligament or ACL, EMG or Electromyography, Muscle activation, Landing, Jumping, hopping”. The search was limited to articles published from 1990-2020 in English.

### Eligibility criteria

The research designs of the cohort, case-control, and cross-sectional were entered the systematic review. Studies were qualified if they compared healthy male and/or female subjects to reconstructed samples related to ACL. Studies using superficial EMG to evaluate activity (mean muscle activity/peak) or timing (onset/duration) before landing jump activities were included in our study. All studies that considered ACLD patients and activities other than jump and landing were excluded.

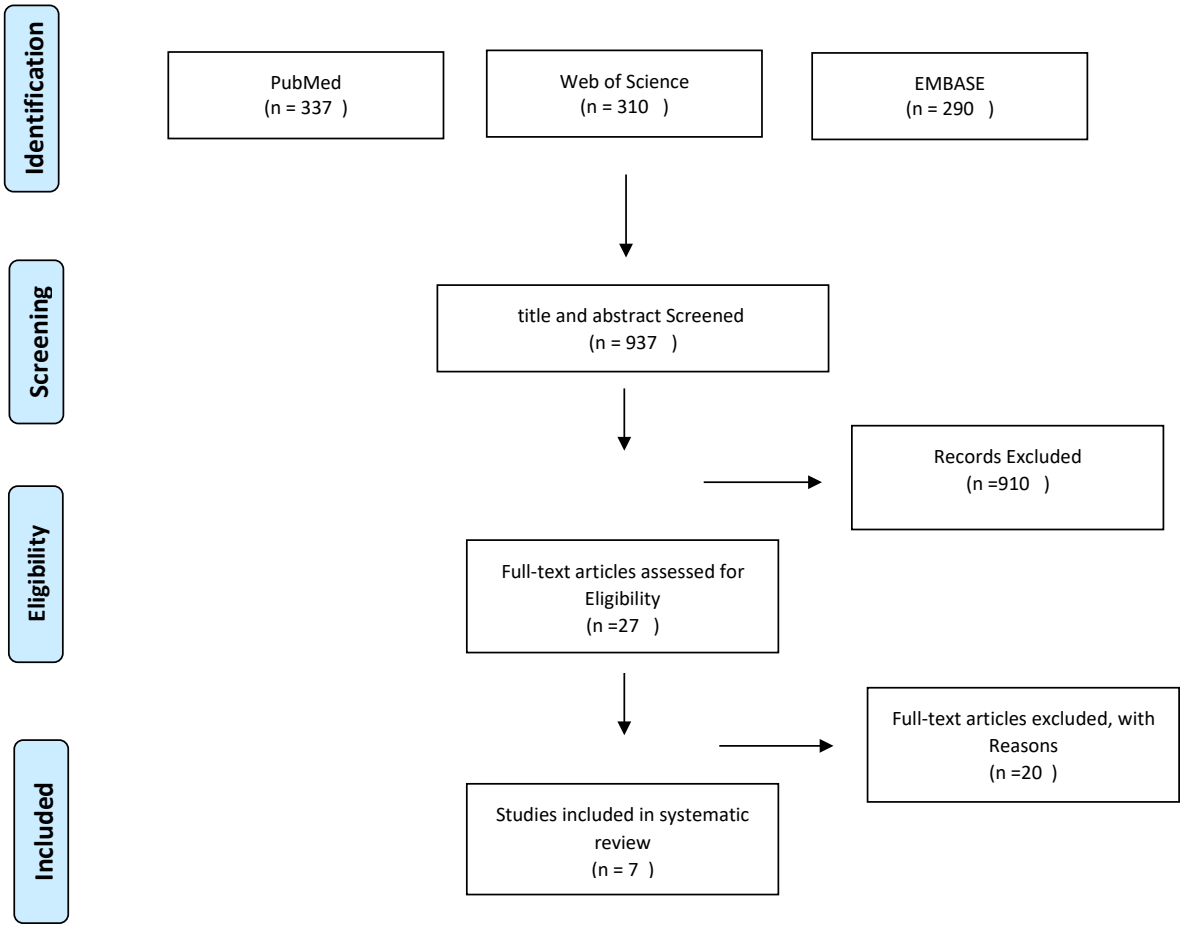


**Figure 1.** PRISMA flowchart

### Study selection

Two reviewers (MT, SHM) independently examined the abstracts and titles according to the inclusion criteria. Moreover, they mentioned the relevant reason in case they were rejected. A third reviewer (AY) did the arbitration in case of disagreements. In the initial search, 937 articles were found. After reviewing the titles, abstracts, and full text of the articles, 7 articles were included in the present review study.

### Quality evaluation

The Critical Appraisal Skills Program (CASP) is recommended by the National Health Service (NHS) Public Health Resource Unit to evaluate observational studies [25]. This 12-item checklist assesses the validity, methodological quality, and generalizability of the studies. We investigated the existing articles using this tool. Based on the 12-key criteria, the maximum score equals 12. Methodological quality was categorized into 3 levels of high (9≥), moderate (8≤5), or weak to help interpret the quality of the study.

## 3. Results

Using the above-mentioned search method, we obtained 7 articles according to the inclusion criteria. The methodological quality of the observational studies ranged from 6 to 8 out of 12 that reflected the moderate quality of the methodology. Table 1 displays the scores of the included papers based on the CASP scale. The details of the included articles have been presented in Table 2.

## 4. Discussion

The feed-forward mechanism plays an essential role in producing force for the correct alignment of the lower limb during landing. In other words, the onset of muscle activity increases the stiffness or stability of the joints before landing. However, improper timing may cause the non-alignment of the knee, increasing recurrent ACL injury [26]. The result of this systematic review suggested that the ACLR group presented different muscle activities during landing tasks, compared to the healthy subject, regardless of graft type, at the time of return to

**Table 1.** Study evaluation based on the CASP Scale

| CASP Scale | Gokeler et al. [27] | Rocchi et al. [26] | Thomas et al. [31] | Demont et al. [29] | Nyland et al. [17] | Ortiz et al. [28] | Ortiz et al. [30] |
|---|---|---|---|---|---|---|---|
| 1 | + | + | + | + | + | + | + |
| 2 | + | + | + | + | + | + | + |
| 3 | - | - | - | - | - | - | - |
| 4 | - | + | - | + | - | - | - |
| 5 | + | + | - | - | + | + | + |
| 6 | + | + | + | + | + | + | - |
| 7 | - | + | - | - | - | - | - |
| 8 | - | - | - | - | - | - | + |
| 9 | + | + | - | - | + | + | + |
| 10 | + | - | + | + | - | - | - |
| 11 | - | - | - | - | + | - | - |
| 12 | + | + | + | + | + | + | + |
| Total score | 7 | 8 | 8 | 6 | 7 | 6 | 6 |

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exercise. Rocchi et al. indicated earlier muscle activity for all muscles considered (VM, VL, RF, BF, & ST) in 4 tasks in the ACLR group, compared to the controls [26]. This result is consistent with those of Gokeler and associates [27]. They signified the earlier onset of muscle activation in the involved limbs of male and female ACLR groups, compared to the groups with non-involved limbs and the controls [27]. Thus, patients who unconsciously or consciously employ feedforward control strategies for joint stiffness also reported decreased knee flexion angels in the involved limb [27].

The pre-tension of muscles increases the sensitivity of the spindle and joint perturbation identified immediately. Rocchi et al. detected no significant difference in pre-impact EMG duration between the two ACLR groups. The choice of graft type seems not to affect neuromuscular abnormalities in landing tasks upon returning to sports activities [26]. Ortiz et al. found a significant difference in the neuromuscular activity of quadriceps and the rate of quadriceps/hamstring co-contraction between ACLR and uninjured females [28].

The study participants in the ACLR group may require further contraction and activation of quadriceps, i.e., a problem in eccentric control than healthy individuals. Additionally, increased co-contraction between agonists and antagonists was associated with facilitating the process of learning new tasks and improving the stability of the lower limbs. Thus, the increased muscle activity observed in patients with ACL reconstruction may be a sign of such strategies to perform a successful landing [29].

Ortiz et al. also investigated the lower limb muscle activity in two tasks among ACLR and healthy women. Accordingly, they found no significant difference in the hamstring, quadriceps amplitude EMG, and quadriceps/hamstring contraction rate between the research groups. These data indicated the anterior-posterior dynamic stability of the knee in the ACLR group [30]. Such a condition was induced by the time lapsed from surgery (1 to 16 years), i.e., considerably different. Thomas et al. identified no significant difference between the before phase quad/ham activity ratios of ACL intact and ACL reconstructed subjects, or between those of males and females [31]. These differences could be attributed to the time lapsed surgery and the type of jump task, as well as the gender of the subjects.

Other researchers reported that ACLR individuals presented a sensory defect in the reconstructed knee. Such sensory deficits are assumed to be caused by impaired proprioception [32] or more specifically, damaged ACL mechanoreceptors [33, 34]. The studies indicated that the

**Table 2.** Study characteristics

| Results | Muscles | Tasks | Subjects | Study |
|---|---|---|---|---|
| Gokeler et al. (2010) [27] | 9 ACLR<br>11 control | Single leg hop | BF, VM<br>ST, SM,<br>VL, RF,<br>MG, LG, SO | There were significant differences in onset times between patient group and healthy subjects, except for the ST, VL, and VM. |
| Rocchi et al. (2017) [26] | 26 ACLR (15 B-PT-B, 11 ST GR)<br>15 control | Single-leg hop | VM, RF, VL, BF, ST | EMG duration (before landing) was earlier in the ACL-R group, compared to the healthy participants. |
| Thomas et al. (2013) [31] | 10 ACL intact<br>10 ACLR | Jump-cut maneuver | RF, VM<br>ST,BF, MG LG | There was no significant gender-wise difference in agonist/antagonist muscle of the knee joint. |
| Demont et al. (1999) [29] | 24 female subjects<br>ACLD= 6,<br>ACLr=12,<br>Con=6 | Hopping, landing from a step | VMO, VL, MH,<br>LH, MG, LG | Group differences were observed in the dominant limb during the hop for VL muscle. |
| Nyland et al. (2010) [17] | 70 ACLR | Single-leg counter-movement jump | VM, MH, G | There was increased gluteus maximus EMG at the involved lower limb. |
| Ortiz et al. (2007) [28] | 15 non-injured women and 13 women with ACLR | Single-leg 40-cm drop jump and 20-cm up-down hop task | RF, LH, MH | Significant differences were detected in neuromuscular activity in women with ACLR compared with non-injured females in the drop jump task. |
| Ortiz et al. (2011) [30] | 15 control<br>13 ACLR | Side hopping and crossover hopping maneuvers | RF, LH, MH | There was no significant difference between the study groups. |

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B-PT-B: Bone-Patellar Tendon; ST GR: Semitendinosus and Gracilis; BF: Biceps Femoris; LH and MH: Lateral and Medial Hamstring; VM: Vastus Medialis; VL: Vastus Lateralis; RF: Rectus Femoris; MG and LG: Gastrocnemius Medial and Lateral Head; EMG: Electromyography

rate of gastrocnemius/hamstring activation was not significantly different between ACL intact individuals and ACLR individuals, and between males and females [31].

## 5. Conclusion

Based on the literature, this review concluded that ACLR individuals exhibit different neuromuscular activity strategies during jump landing. Furthermore, patients manifested earlier onset muscle activity out of the healthy values as demonstrated in controls. In addition to the earlier onset of the quadriceps muscles activation than that of the hamstring muscle during the jump, the landing was a risk for the recurrent ACL injury. Specialists are suggested to analyze onset EMG duration in landing tasks at the time of return to sports. Moreover, the neuromuscular motor program can be an effective tool for deciding whether to return to sports or not in athletes. However, relevant evidence is scarce; thus, further studies are recommended to focus on whether and how the asymmetries of muscle activity and muscle timing may modify over time and whether rehabilitation exercises can improve them.

## Ethical Considerations

### Compliance with ethical guidelines

The study is a review article and there is no need for ethical approve.

### Funding

This research did not receive any grant from funding agencies in the public, commercial, or non-profit sectors.

### Authors' contributions

Investigation and draft preparation: Maedeh Taghizadeh Kerman; Review and edit: Ali Yalfani, Ahmad Ebrahimi Atri; Supervision: Maedeh Taghizadeh Kerman and Seyyed Hamed Mousavi.

### Conflict of interest

The authors declared no conflict of interest.

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