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Analytical Review: Meta-Analysis

# Knee Kinematics and Joint Moments During Stair Negotiation in Participants With Anterior Cruciate Ligament Deficiency and Reconstruction: A Systematic Review and Meta-Analysis

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**Abstract**

**Objective:** Biomechanical changes have been reported for patients with anterior cruciate ligament deficiency (ACLD) and anterior cruciate ligament (ACL reconstruction) (ACLR), likely due to loss of stability and changes in proprioception and neuromotor control. This review evaluated kinematics and kinetics of ACLD and ACLR knees, compared with those on the contralateral uninjured sides, as well as and those in asymptomatic controls during stair navigation.
**Design:** This is a systematic review and meta-analysis.
**Literature Survey:** Electronic database searches were conducted from their original available dates to January 2015. Studies that included participants with ACLD or ACLR and reported knee joint angles or moments during stair ascent or descent were included.
**Methodology:** Nine studies met the inclusion criteria, and the methodological quality of these was assessed with a modified Downs and Black checklist. Effect sizes for differences between injured leg and uninjured contralateral leg or controls were calculated, and meta-analyses were performed if two or more studies considered the same variable.
**Synthesis:** Quality assessment showed an average ($\pm$ standard deviation) of 70.3% $\pm$ 7.2%. Meta-analysis showed less knee flexion at initial contact for ACLR knees compared with that in contralateral knees during stair ascent, with a moderate effect size and minimal heterogeneity. Knees with ACLD showed less peak knee flexion compared with that on contralateral sides during stair ascent, with minimal heterogeneity. External knee flexion moments were lower for ACLR compared with those in controls and contralateral sides during ascent and descent, whereas these moments were decreased for the ACLD compared with controls only during ascent. Meta-analysis results exhibited moderate/high heterogeneity or small/trivial effect sizes.
**Conclusions:** Differences for kinematics and kinetics for the ACL-injured knees indicate long-term compensatory and asymmetric movement patterns while ascending and descending stairs. Due to the heterogeneity as well as the small numbers of available studies, the consequences of these differences in terms of long-term function or posttraumatic osteoarthritis need further exploration.

## Introduction

Anterior cruciate ligament (ACL) rupture is one of the most costly knee injuries, usually occurring in young athletes [1,2], often leading to functional instability [2-4] and inability to return to previous levels of physical activity [5]. The instability is likely due to a combination of the loss of the mechanical function of the ligament [6,7] and neurophysiological consequences [8-11]. Individuals with ACL deficiency (ACLD) may undergo ACL reconstruction (ACLR) surgery to address the instability and to retain functional ability.

Although ACL injury occurs mainly during high-level activities, repetitive daily activities can contribute toward subsequent cartilage damage that may be associated with posttraumatic osteoarthritis (OA) [12]. Higher knee joint loading is evident during ascending or descending stairs compared with level walking [1,13,14]. Thus, compensatory mechanisms and forces applied to the lower extremity may be more evident during stair navigation than during walking [15]. Knee injury outcomes questionnaires, such as the Knee Osteoarthritis and Injury Outcome Score (KOOS) [16], and the Lysholm questionnaire [17] include questions

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relating to the ability to ascend and descend stairs [18,19]. This highlights the significance of stair negotiation as a functional assessment after ACL injury. Furthermore, ascending stairs can be included in rehabilitation programs for patients with ACLDs and with ACLRs as an example of a closed kinetic chain exercise [20,21].

An understanding of gait pattern and compensatory mechanisms adopted by patients with ACLD and ACLR would contribute toward planning of relevant rehabilitation exercises and assessment of residual impairments [22,23]. The contralateral leg is usually used in clinical assessment as a comparator for the injured leg to progress the rehabilitation exercises [24-26].

Comparisons of 3-dimensional peak rotations and peak moments between healthy control participants and participants with ACL injury (between-group), and ACL-injured knee with the contralateral uninvolved knees (within-subject) have been considered in some studies during stair negotiation, as reviewed by Hart et al [27]. Decreased knee flexion angles and external flexion moments appear to be associated with quadriceps weakness [28-30], whereas knee varus and external varus moment estimate the medial and lateral knee load distribution [31]. Quadriceps weakness, mediolateral knee loading, and transverse plane rotations have direct effects on articular contact loading and may be associated with development of posttraumatic OA [30-33]. These variables can also be helpful in determining optimal rehabilitation exercises applied before and after operation, as well as reconsidering reconstructive surgery approaches. Although Hart et al [27] reviewed biomechanics of the knee after ACL injury during stair navigation, only the sagittal plane was considered, and a meta-analysis was not included. Therefore, this review evaluated the current knowledge of kinematic and kinetic deficits of participants with ACLD and ACLR during stair walking compared with asymptomatic controls and with the uninjured contralateral knees.

## Methods

### *Search Strategy*

An electronic search was conducted using Medline, Scopus, PubMed, and CENTRAL databases from their original available dates to January 2015. A combination of keywords was used by 2 reviewers (M.H., G.S.) for the search procedure (Table 1). Two assessors (M.H., A.H.O.) independently reviewed all papers by title and abstract after blinding of the authors' names, journal titles, and dates of publication. If insufficient information was provided by the title and abstract, the full paper was reviewed. Any disagreement between the assessors was resolved by discussion and consensus.

**Table 1**
Search strategy

| Search No. | Terminology |
|---|---|
| 1 | Gait disorders |
| 2 | Kinetics |
| 3 | Biomechanics |
| 4 | Locomotion |
| 5 | Kinematics |
| 6 | 1 OR 2 OR 3 OR 4 OR 5 |
| 7 | Anterior cruciate ligament |
| 8 | 6 AND 7 |

Manual searches were performed of the reference lists of all included papers.

### *Inclusion Criteria*

The following inclusion criteria were applied for the studies: peer-reviewed and published papers; papers in the English language; studies in human participants with ACLD or ACLR, regardless of gender, surgical approach, or type and period of rehabilitation exercises; cross-sectional or prospective studies (randomized clinical trials were included if the injured leg was compared with the contralateral uninjured or healthy control knees, either at baseline or as final outcome); main outcome measures that included 3-dimensional knee kinematic and kinetic components being compared between ACL injured leg and either healthy control leg or uninjured contralateral leg (papers with kinematic and kinetic variables calculated based on radiographic or fluoroscopic images and finite element analysis were excluded); and papers including stair ascent or descent. Papers with multiple subsequent activities, such as pivoting, after stair descent, were excluded.

### *Methodological Quality Assessment*

Two independent reviewers (M.H. and A.H.O.) assessed the methodological quality of the included papers using a 17-question modified Downs and Black checklist for nonrandomized trials [34]. The original checklist [32] was modified as relevant for cross-sectional studies and as used in previously published reviews [35,36]. The modified checklist included 7 questions for reporting, 2 for external validity, 4 for internal validity (bias), 3 for internal validity (confounding), and 1 question for power (Supplementary Table 1). The items were scored as 0 ("no" or "unable to determine") or 1 ("yes"), except item 5 for the principal confounders, scored as 0, 1, 2, or unable to determine. Body height, weight, and speed of movement were considered as principal confounders. The total quality score for each study was calculated as a percentage of the maximum score (18). Papers with quality scores of 75% or greater were classified as high quality, those with 60%-74% as moderate quality, and those 60% or less as low quality [37].