



Review

Biomechanical characteristics of stair ambulation in patients with knee OA: A systematic review with meta-analysis toward a better definition of clinical hallmarks



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ABSTRACT

Background: Stair climbing was suggested to be the first affected task in individuals with knee osteoarthritis (OA).

Research question: This review aimed to identify consistent kinematic, kinetic, and spatiotemporal alterations of stair climbing exhibited by individuals with knee OA.

Methods: A literature search published until September 2017 was conducted in PubMed, PEDro, CINAHL, and Cochrane CENTRAL. Reviewer extracted data in accordance with the Cochrane Handbook. Where possible, data were combined into a meta-analysis; the pooled standardized mean differences between individuals with knee OA and healthy adults were calculated using the random-effect model.

Results: In total, 585 potentially relevant articles were selected, of which 12 (695 participants, mean age: 58.4 years) met the inclusion criteria. Meta-analysis revealed that kinematic and kinetic alterations during stair climbing associated with knee OA were lower external knee flexion moment in conjunction with a larger trunk/hip flexion angles and smaller knee flexion/ankle dorsiflexion angles. Individuals with knee OA showed a delayed quadriceps activation during stair ascent. A lack of evidence was detected for alterations in external knee adduction moment during stair climbing. Effect estimate in each meta-analysis was judged “very low” on the GRADE approach.

Significance: No strong conclusion can be drawn because of the low quality of evidence; however, individuals with knee OA may exhibit altered kinematics and kinetics changes in sagittal plane during stair climbing, and have delayed quadriceps muscle activity. Further studies with adequate adjustment for confounders are warranted to facilitate clinical hallmarks of the knee OA, particularly in early stages of the disease.

1. Introduction

Knee osteoarthritis (OA) is a common, chronic joint disease resulting in knee pain and disability. Many cross-sectional observational studies investigated the alterations in level walking biomechanics and demonstrated that individuals with knee OA exhibit an adaptive walking pattern [1,2]. However, stair climbing is also a common and frequent dynamic activity that is biomechanically and physiologically more challenging than level walking [3,4]. Recently, stair climbing was suggested to be the first affected task in individuals with knee OA [5], which may cause ambulatory physical activity limitation [6]. Thus, better understanding of alteration in ambulatory biomechanics during stair climbing could provide unique insights into the pathomechanics of

knee OA, particularly in the early stages of the disease.

This systematic review of cross-sectional observational studies aimed to identify consistent kinematic, kinetic, and spatiotemporal alterations of stair climbing exhibited by individuals with knee OA. This information would be particularly important to facilitate clinical hallmarks of early knee OA and establish an effective management for preventing the progression of knee OA.

2. Methods

This study was conducted in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement [7], PRISMA protocols (PRISMA-P) [8], Meta-analysis of

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Observational Studies in Epidemiology (MOOSE) checklist [9], and Cochrane Handbook for Systematic Reviews of Interventions [10]. A detailed protocol of this systematic review has not been previously published and registered.

2.1. Literature search and study selection

The electronic databases of PubMed, Physiotherapy Evidence Database (PEDro), Cumulative Index to Nursing and Allied Health Literature (CINAHL), and Cochrane Central Register of Controlled Trials (CENTRAL) were used. Searches in the PubMed used combined key terms, including “osteoarthritis,” “knee,” “biomechanical phenomena,” “walking,” “stair climbing,” “kinetics,” and “kinematics,” using Medical Subject Headings terms. A database search strategy is provided in the eMethod 1 in the Supplement. Google Scholar was also used as a complementary search engine. In addition, a manual search of the reference lists of past systematic reviews was performed. Furthermore, citation searching was performed on the original record by using the Web of Science. These citation indices are recommended by the Cochrane Handbook [10].

The studies that were included were those (i) published in a peer review journal, (ii) written in English, (iii) that had a control group of age-matched healthy adults, (iv) that included patients diagnosed as having radiographic OA in tibiofemoral or patellofemoral joints, and (v) whose outcomes included kinematic and/or kinetic parameters, electromyographic (EMG) activity, and/or performance-based physical function. Knee OA was defined either radiographically or clinically by using some established existing criteria for OA, such as the American College of Rheumatology criteria [11]. Since biomechanical and spatiotemporal alterations during stair climbing would occur as part of the normal aging process, this review included only studies with an age-matched control group. No restrictions were imposed on study dates, follow-up duration, disease severity, involved compartment, or lower limb alignment. Studies that included participants who had undergone total joint arthroplasty were excluded. For each electronic database, the end point was September 2017.

2.2. Determining inclusion

One reviewer who was also a content expert assessed eligibility in accordance with the Cochrane Handbook [10]. The reviewer screened the title and abstracts yielded by the search. The full manuscripts of the articles that met the eligibility criteria were then obtained and reviewed. During these processes, the reviewer prepared and used simple predesigned Google spreadsheets to assess eligibility by extracting study features.

2.3. Outcome measures and data extraction

The primary outcomes in this review were (i) kinematic parameters during stair climbing, (ii) kinetic parameters during stair climbing, (iii) EMG activity of the skeletal muscle during stair climbing, and (iv) performance-based physical function during stair climbing. Where possible, data from early stance phase of stair ambulation were extracted based on clinical judgment. The same reviewer collected the data using standardized data extraction form regarding authors, years, subject population, Kellgren/Lawrence (K/L) grade, outcome measures, stair task (ascending and/or descending), device for evaluation of kinematic and kinetics parameters, and funding sources.

2.4. Risk of bias assessment of included studies

The same reviewer evaluated the risk of bias of each study by using the Downs and Black scale [12] that was modified to include only 6 variables (bias: four items [items 15, 16, 18, and 20]; confounding: two items [items 22 and 25]) to assess internal validity (minimum: 0 point,

maximum: 6 points) in accordance with previous meta-analysis[1]. A difference from that study is that we maintained item 15 related to blinding of the assessor to the main outcome of stair ambulation, as we believed that this was possible for some measures. Unlike the adaptation used by Mills et al. [1], modified version does not include items related to patients' recruitment site, as nature of the included study would be impossible for OA and control patients. All items were scored 1 for fulfilling the criterion or 0 if the criterion was not filled. Publication that did not provide sufficient details to fulfill the criterion were also given a 0 for unable to be determined. Rewarding a pre-defined criterion with 1 point suggests that this criterion has a low risk of bias. This scale is a useful tool for assessing the risk of bias in observational studies [13] and the methodological quality of both randomized controlled trial (RCT) and non-RCT of treatment [10]. We previously reported fair to good [14] inter-rater reliability between two independent examiners ($\kappa = 0.593$, 95% confidence interval [CI]: 0.515–0.670). Furthermore, to assess intra-rater reliability in the current data set, the same examiner was rescored more than 1 month after the first assessment. The intra-rater reliability was excellent [14] for all 6 items ($\kappa = 0.974$, 95% CI: 0.852–1.000), which included 4 bias-related items ($\kappa = 0.917$, 95% CI: 0.804–1.000), and 2 confounding-related items ($\kappa = 1.000$, 95% CI: 1.000–1.000).

2.5. Data analysis

For the meta-analysis, pooled estimates and 95% CIs for standardized mean differences (SMDs) were calculated using the DerSimonian-Laird method [15] (eMethod 2 in the Supplement). The SMDs were calculated for paired samples by using the mean difference between the groups (knee OA and health adults) divided by the pooled standard deviation (SD). The formulae for calculating the pooled SD and pooled SMD are shown in eMethod 2 in the Supplement. The meta-analyses were performed using Review Manager (RevMan) Version 5.3 (Nordic Cochrane Centre, Cochrane Collaboration, Copenhagen, Denmark). We used a forest plot to represent the meta-analysis results in accordance with a previous study [16]. The size of the SMD was interpreted using Cohen's *d* [17] (< 0.5: small effect size, 0.5–0.8: moderate effect size, and ≥ 0.8 : large effect size). When mean and SD values were not directly reported in an article, they were calculated from other available data, if possible; for example, mean and SD values were estimated from the figure in each article. When individual SD data were missing and interquartile ranges were reported, we calculated the SD by using a previously described method [18]; the width of the interquartile of a standard normal distribution is 1.35 SD, therefore, dividing by 1.35 estimates the SD. When individual SD data were missed and upper and lower maximum ranges were reported, we calculated the SD using the RevMan calculator.

To test for publication bias, we used a funnel plot. Since relatively few studies were found (< 10 studies) for each outcome and the power of the test was too low to distinguish chance from real asymmetry [10], we did not perform statistical tests such as Egger's test [19] in this meta-analysis. Study heterogeneity was assessed using I^2 and Q statistics[20]. If I^2 was $\geq 50\%$, a univariate, random-effects meta-regression was performed using certain parameters selected *a priori* as follows: i) age (per year), ii) % female (per percent), iii) body mass (per kg), iv) year of publication (per year), v) knee pain intensity in patients with knee OA (per point), vi) study sample size (per subject), vii) Downs and Black scale score (per point), and viii) funding source (0: no, 1: yes). To standardize the pain outcomes of different studies, all pain scales were converted into a scale of 0–100 points and the pain scores were recalculated as done in the previous meta-analysis[21]. These factors were chosen because of their potential association with effects estimate of the difference between patients with knee OA and healthy adults, and would not be associated on the causal pathway. All other statistical analyses were performed using JMP Pro 12.2 (SAS Institute, Cary, NC, USA). *p* values of < 0.05 were considered statistically significant.

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