Gait & Posture 49 (2016) 315–328

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Review

Gender differences in knee abduction during weight-bearing activities: A systematic review and meta-analysis

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ARTICLE INFO

Article history:
Received 19 October 2015
Received in revised form 20 July 2016
Accepted 22 July 2016

Keywords:
Knee abduction
Knee valgus
Functional performance
ACL injury
Patellofemoral pain
Prevention

ABSTRACT

Background: Increased knee abduction during weight-bearing activities is suggested to be a contributing factor for the high knee injury risk reported in women. However, studies investigating gender difference in knee abduction are inconclusive.
Objective: To systematically review gender-differences in knee abduction during weight-bearing activities in individuals with or without knee injury.
Methods: A systematic review and meta-analysis were conducted according to the PRISMA guidelines. A search in the databases Medline, CINAHL and EMBASE was performed until September 2015. Inclusion criteria were studies that reported (1) gender differences, (2) healthy individuals and/or those with anterior cruciate ligament (ACL) deficiency or reconstruction or patellofemoral pain PFP, and (3) knee abduction assessed with either motion analysis or visual observation during weight-bearing activity.
Results: Fifty-eight articles met the inclusion criteria. Women with PFP had greater peak knee abduction compared to men (Std diff in mean; −1.34, 95%CI; −1.83 to −0.84). In healthy individuals, women performed weight-bearing tasks with greater knee abduction throughout the movement (initial contact, peak abduction, excursion) (Std diff in mean; −0.68 to −0.79, 95%CI; −1.04 to −0.37). In subgroup analyses by task, differences in knee abduction between genders were present for most tasks, including running, jump landings and cutting movements. There were too few studies in individuals with ACL injury to perform meta-analysis.
Conclusion: The gender difference in knee abduction during weight-bearing activities should be considered in training programs aimed at preventing or treating knee injury.

1. Background

Anterior cruciate ligament (ACL) injury and patellofemoral pain (PFP) are common sports-related injuries [1,2]. Such injuries are more frequent in women than in men [1,2]. Although the evidence is limited, it is suggested that increased knee abduction may be a contributing factor for this gender difference [3]. Indeed, greater knee abduction is consistently reported to form part of the mechanism of non-contact ACL injury [4–7], and is associated with greater strain on the ACL [8–12]. Similarly, with respect to PFP, greater knee abduction has been demonstrated to increase contact forces within the lateral patellofemoral joint [13]. Knowledge of the presence, or absence, of a gender difference in knee abduction is essential in understanding the role it may play in the higher knee injury incidence in females, and subsequently in the development of appropriate prevention and treatment strategies in female and male athletes.

Knee abduction is the frontal plane angle between the thigh and shank, and can be assessed quantitatively with either 2-dimensional (2-D) or 3-dimensional (3-D) motion analysis or qualitatively by visual observation. Qualitative visual observation is typically performed by a trained clinician who may use one of various different methods to evaluate whether an individual exhibits neutral, varus or valgus alignment of the limb during the task. Whether these differences in movement patterns are due to structural influences and/or sensorimotor mechanisms is yet to be determined [14–16]. Irrespective of the underlying cause, increased knee abduction, or a knee medial to foot position (KMFP), is commonly considered to be an inappropriate movement pattern, whereas a more neutrally aligned knee, positioned over the foot (knee-over-foot position, KOFP) is considered a more appropriate movement pattern [17]. Supporting this, an "inappropriate"

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http://dx.doi.org/10.1016/j.gaitpost.2016.07.107
0966-6362/

movement pattern incorporating greater knee valgus, is reported to be more common in patients with ACL injury or PFP than in uninjured controls [18–21], and some evidence indicates elevated risk of knee injury in individuals that exhibit greater knee valgus during weight-bearing activities [22–24].

In recent years, there has been an increased focus on the quality of movements during the performance of functional tasks in athletes [18–20,25]. The theory that women have a greater magnitude of knee abduction during activity than men is widely spread in the research and clinical sport setting [26,27], however, empirical support for this theory is inconsistent [27–30]. These differences may relate to the different tasks in which knee abduction is assessed, and to the different methodological approaches used to measure knee abduction.

The aims of the present study therefore, were to: (1) quantify possible gender-differences in knee abduction across weight-bearing tasks, with the three different measurement methods (2-D, 3-D, and visual observation) and (2) quantify possible gender differences in knee abduction for each individual weight-bearing task; this was undertaken separately in patients with a history of PFP or ACL injury and in healthy individuals.

2. Methods

A systematic review and meta-analyses were conducted according to the PRISMA guidelines. The study protocol was pre-registered (PROSPERO 2013: CRD42013005415).

2.1. Literature search and study selection

2.1.1. Search strategy

A search in the following databases was performed in August 2013 and updated in September 2015: Medline (PubMed), CINAHL and EMBASE (OVID) using the terms as follows:

(((((((((((((healthy[Title/Abstract]) OR non-injured[Title/Abstract]) OR ACL reconstruct*[Title/Abstract]) OR ACL injur*[Title/Abstract]) OR anterior cruciate ligament injur*[Title/Abstract]) OR anterior cruciate ligament reconstruct*[Title/Abstract]) OR patellofemoral pain[Title/Abstract]) OR “Anterior Cruciate Ligament”[-Mesh]) OR “Anterior Cruciate Ligament Reconstruction”[Mesh]) OR “Patellofemoral Pain Syndrome”[Mesh])) OR uninjured[Title/Abstract])) AND (((((((((((((((((“joint position sense”[Title/Abstract]) OR propriocept*[Title/Abstract]) OR kinesthesia[Title/Abstract]) OR proprioception[MeSH Terms]) OR Muscle activation[Title/Abstract]) OR Muscle strength[Title/Abstract]) OR muscle strength[MeSH Terms]) OR muscle strength dynamometer [MeSH Terms]) OR range of motion[Title/Abstract]) OR ROM[Title/Abstract]) OR range of motion, articular[MeSH Terms]) OR gender [Title/Abstract]) OR sex[Title/Abstract]) OR females[Title/Abstract]) OR males[Title/Abstract]) OR sex characteristic[MeSH Terms])) OR “Sex Factors”[Mesh])) AND ((((((biomechanic*[Title/Abstract]) OR kinematic*[Title/Abstract]) OR valgus[Title/Abstract]) OR “postural orientation”[Title/Abstract]) OR alignment [Title/Abstract]) OR “movement quality”[Title/Abstract]).

In EMBASE and CIHNAL the search was performed without MeSH terms. In addition, all reference lists of relevant articles were searched for additional studies. No language or publication date restrictions were imposed.

2.1.2. Eligibility criteria

All original research studies investigating gender-differences in knee abduction/medio-lateral knee position were considered for inclusion; case studies, review papers, editorials and letters were excluded. Studies including healthy men and women of all ages and/or those with ACL deficiency/reconstruction or PFP were included. Knee abduction angle in degrees assessed with either a 2-D or 3-D motion analysis system, and/or medio-lateral knee position assessed by visual observation during weight-bearing activities, had to be reported in the studies. Weight-bearing activities were defined as any functional task that required weight to be supported by the lower extremity, resembling conditions in daily life and/or sport participation.

2.1.3. Data extraction and synthesis

Two researchers (JN and AC) independently screened the titles, abstracts and full papers against the inclusion/exclusion criteria. Any disagreements were resolved by a consensus discussion between JN and AC and if not resolved with a third researcher (EA). The following data were extracted from the studies: Study year, type of subjects (healthy, ACL injury or PFP), number of participants, gender, outcome measure (visual observation or knee abduction in degrees), time point during the movement at which an assessment was made (e.g. on contact with the ground or the peak angle during the movement), functional task and effect size. If relevant data were not reported in the studies, study authors were contacted and additional data were requested.

Comprehensive Meta-Analysis software (version 2.2.064, Biostat, Englewood, USA) was used for meta-analyses. The effect size was calculated on standardized mean difference (Std diff in mean) in knee abduction between men and women. If mean data were not provided in the publication, the Std diff in mean was calculated from p-value and sample size [31]. When data from more than one leg was reported, i.e. left and right or dominant and non-dominant legs, the right and dominant legs, respectively, were used in the analyses. If a study reported data from more than one functional task, the number of subjects included in the primary analysis was divided by the number of tasks reported, and each task was then treated as an independent study [32]. A random effect model was used due to expected heterogeneity between studies, such as the use of different functional tasks and different outcomes, i.e. 2-D or 3-D analysis. Between-studies heterogeneity in effect size was calculated with the Q-test and expressed as I^2-statistics. Subgroup analyses for healthy individuals were also performed on all tasks that were included in more than one study, to evaluate in which specific tasks differences between men and women were present. Meta-analyses were performed separately for healthy individuals, individuals with ACL-injury and individuals with PFP. All data assessed with motion analysis equipment and visual observation was analyzed separately. For the Std diff in mean, the following thresholds were used: 0.2 = small, 0.5 = moderate, 0.7 = large and >0.7 = very large effect [33]. Studies that were not eligible for meta-analysis were reported descriptively.

2.1.4. Quality assessment and publication bias

A modified version of the checklist used by Munn et al. [34] from the original checklist by Downs and Black [35] was used for assessment of methodological quality of the included studies. Our modified checklist included item 27 from Downs and Black: If the study had adequate power to detect any differences. Furthermore, opposite to Munn et al. [34], who gave maximum one point for item 20: “If the main outcomes were valid and reliable”, we gave two points if the answer was yes and one point if “accuracy not reported but method clearly described” (Online resource 1). If an author reported on the same subjects in multiple articles, the article that included more outcomes, i.e. more functional tasks, was included. If the same number of outcomes were included in both articles, the article with the highest quality score was included. Studies meeting the inclusion criteria were assessed for methodological quality by two independent reviewers (JN and AC). Any disagreements were solved by a consensus discussion between these two reviewers, and if not resolved with a third