Archives of Physical Medicine and Rehabilitation
journal homepage: www.archives-pmr.org
Archives of Physical Medicine and Rehabilitation 2017;98:137-50

REVIEW ARTICLE (META-ANALYSIS)

Gait Retraining With Real-Time Biofeedback to Reduce Knee Adduction Moment: Systematic Review of Effects and Methods Used

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Abstract

Objective: To review the current literature regarding methods and effects of real-time biofeedback used as a method for gait retraining to reduce knee adduction moment (KAM), with intended application for patients with knee osteoarthritis (KOA).

Data Sources: Searches were conducted in MEDLINE, Embase, CINAHL, SPORTDiscus, Web of Science, and Cochrane Central Register of Controlled Trials with the keywords *gait*, *feedback*, and *knee osteoarthritis* from inception to May 2015.

Study Selection: Titles and abstracts were screened by 1 individual for studies aiming to reduce KAM. Full-text articles were assessed by 2 individuals against predefined criteria.

Data Extraction: Data were extracted by 1 individual according to a predefined list, including participant demographics and training methods and effects.

Data Synthesis: Electronic searches resulted in 190 potentially eligible studies, from which 12 met all inclusion criteria. Within-group standardized mean differences (SMDs) for reduction of KAM in healthy controls ranged from .44 to 2.47 and from .29 to .37 in patients with KOA. In patients with KOA, improvements were reported in pain and function, with SMDs ranging from .55 to 1.16. Methods of implementation of biofeedback training varied between studies, but in healthy controls increased KAM reduction was noted with implicit, rather than explicit, instructions.

Conclusions: This review suggests that biofeedback gait training is effective primarily for reducing KAM but also for reducing pain and improving function in patients with KOA. The review was limited by the small number of studies featuring patients with KOA and the lack of controlled studies. The results suggest there is value and a need in further researching biofeedback training for reducing KAM. Future studies should include larger cohorts of patients, long-term follow-up, and controlled trials.

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Knee osteoarthritis (KOA) is one of the most common causes of chronic disability in the developed world,[1] with symptoms including knee pain, reduced function, and loss of mobility. Conservative treatment interventions for KOA include strengthening, orthotics, or assistive devices (eg, walking sticks). In recent years, gait modifications have been investigated as an alternative strategy for reducing knee joint loading and overcoming knee pain.[2-4] Knee joint forces cannot be measured directly; therefore, the knee adduction moment (KAM) is often used as a representation of the loading on the medial compartment of the knee, based on a clear biomechanical rationale and also demonstrated with a moderate to strong correlation reported between the 2 parameters.[5] Increased KAM, as observed in patients with KOA,[6,7] has been linked with the presence, severity, and progression of medial KOA.[8,9] Furthermore, a positive correlation between KAM impulse and loss of cartilage volume, assessed using magnetic resonance imaging, was reported in a longitudinal study of 144

Presented to the Osteoarthritis Research Society International, March 3−4, 2016, Amsterdam, The Netherlands.

Supported by the European Union Marie Curie Actions-Initial Training Networks (FP7-PEOPLE-2013-ITN) (grant no. 607510).

Disclosures: none.

0003-9993/16/$36 - see front matter © 2016 by the American Congress of Rehabilitation Medicine
http://dx.doi.org/10.1016/j.apmr.2016.07.006

patients.[10] For this reason, gait modifications are developed to reduce KAM. Reductions in KAM can be obtained either through reducing the total ground reaction force (eg, through weight loss or use of a walking stick) or through modifying the frontal plane moment arm from the knee joint center to the line of action of the force. A recent systematic review reported that modifying the foot progression angle (FPA) and increasing medial knee thrust and trunk lean were effective gait modifications for reducing KAM.[4] The biomechanical rationale behind the modifications is as follows. First, increasing the internal rotation of the foot with respect to the direction of travel (walking with toes in) has the effect of shifting the center of pressure laterally because the heel of the foot is now externally rotated, thereby reducing the moment arm from the center of pressure to the knee joint center during the first double support period.[11] Conversely, a toe-out modification shifts the center of pressure laterally during the second half of the stance phase, thereby reducing the lever arm and forcing the ground reaction force vector to pass closer to the knee joint center.[4,11,12] Increasing medial knee thrust reduces the knee varus angle and hence decreases the frontal plane moment arm. Finally, increasing the trunk lean over the support leg causes the center of mass to shift laterally, modifying the direction of the ground reaction force vector.[4,11]

More recently, there have been efforts to train these gait patterns using real-time biofeedback.[13-15] Biofeedback as a treatment intervention for gait training is not a new concept and has been researched in patients with stroke, cerebral palsy, and Parkinson disease for >20 years,[16-24] with more recent developments in amputee rehabilitation.[25,26] Outside of the clinical environment, biofeedback training has used extensively in sports, including running.[27,28]

A systematic review of 7 articles using biofeedback for gait retraining,[29] with only 2 studies featuring orthopedic populations,[26,30] concluded that biofeedback for gait retraining provides medium to large treatment effects in the short term, whereas longer-term effectiveness was inconclusive.[29] Research into use of real-time biofeedback for gait retraining in patients with KOA is at present rather limited with little consensus on the optimal methods. This review addressed the methods used and effects of gait retraining with biofeedback on the KAM. We aimed to first summarize the current use of biofeedback to accomplish reduced KAM through gait modifications and second to evaluate the current use of and potential for this type of training for use in patients with KOA. The specific aims of the review are therefore as follows: (1) to evaluate the methods used and effects of biofeedback for reducing KAM through gait modifications in persons without KOA (otherwise healthy subjects), with a specific focus on the methods used to implement the biofeedback; and (2) to evaluate the translation of results reported in healthy subjects to the clinical cohort, in terms of the reduction in KAM and the improvement in patient-reported outcome measures (PROMs), namely pain and function.

List of abbreviations:

FPA	**foot progression angle**
KAM	**knee adduction moment**
KOA	**knee osteoarthritis**
PROM	**patient-reported outcome measure**
RCT	**randomized controlled trial**
SMD	**standardized mean difference**

Methods

Details of the original protocol for this systematic review were registered on PROSPERO and can be accessed online (available at: http://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42015023488#.VYwbBxvtlBc).

Data sources and searches

On August 14, 2015, 6 databases were searched from inception to May 2015 to identify articles for this review: MEDLINE, CINAHL, Embase, Web of Science, SPORTDiscus, and Cochrane Central Register of Controlled Trials. The search strategy was developed iteratively with group discussions and preliminary searches to inform the strategy. The final search strategy used with database specific truncation was as follows: (gait OR walk* OR amulat* OR locomotion) AND (biofeedback OR bio-feedback OR retraining OR re-training OR feedback) AND (knee osteoarthritis OR Gonarthritis OR arthrosis of knee OR knee OA OR Degenerative joint disease of knee OR knee DJD).

Language of the search was not restricted at this stage, but during screening it was limited to English language. Gray literature was not searched outside of the aforementioned databases.

Study selection

Titles and abstracts were screened by 1 reviewer (R.R.) to identify potentially eligible studies. The results of the screening process were discussed with another reviewer (J.C.N.) to ensure no abstracts had been unnecessarily excluded. The full text of these studies were retrieved and independently assessed by 2 reviewers (J.C.N. and R.R.) against predetermined criteria (table 1). Where the full text was not available through the university resources, the corresponding author of the article was contacted. Ambiguities or disagreements in the independent reviews of the articles were resolved through discussion. A third member of the team (J.H.) was included as required to arrive at a consensus. Reference lists for each article retrieved in full were also manually searched by 1 author (R.R.) to identify other relevant articles. Where conference abstracts were retrieved, a further manual search was undertaken for a similar journal article by the same group.

Assessment of methodologic bias

Methodologic quality and bias at the study level was assessed first using the Downs and Black quality index[31] (table 2), a validated index consisting of 27 items used to assess reporting quality, methodologic design, external validity, and internal validity. The final item, power of the study, was omitted because of ambiguity in its interpretation.[40] Each item in the checklist scores either 1 or no point, with the exception of item 5 where 1 or 2 points can be scored depending on the level of detail. Therefore, the maximum possible score for an article (after excluding the final item) is 27. However, in some studies, particularly those featuring healthy controls, questions relating to follow-up measurements (ie, items 9, 17, and 26) were not considered applicable; hence, the maximum score for such articles was 24. Two independent reviewers (R.R. and J.C.N.) assessed all articles. Disagreements were resolved through discussion. Articles scoring <13 out of 27 or <12 out of 24 were excluded from further analysis.

Furthermore, each study was assessed for issues specific to the use of biofeedback using an in-house custom-defined