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Changes in proprioceptive weighting during quiet standing in women with early and established knee osteoarthritis compared to healthy controls

Armaghan Mahmoudian [a], Jaap H. van Dieen [b], Isabel A.C. Baert [c], Ilse Jonkers [d], Sjoerd M. Bruijn [b,e], Frank P. Luyten [f], Gert S. Faber [b], Sabine M.P. Verschueren [a,*]

[a] Department of Rehabilitation Sciences, Faculty of Kinesiology and Rehabilitation Sciences, KU Leuven, Belgium
[b] MOVE Research Institute Amsterdam, Faculty of Human Movement Sciences, VU University Amsterdam, The Netherlands
[c] Department of Health Care, Artesis University College of Antwerp, Belgium
[d] Department of Kinesiology, Faculty of Kinesiology and Rehabilitation Sciences, KU Leuven, Belgium
[e] Department of Orthopedics, First Affiliated Hospital of Fujian Medical University, Fuzhou, Fujian, China
[f] Department of Development & Regeneration, Skeletal Biology and Engineering Research Center, KU Leuven, Leuven, Belgium

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ABSTRACT

Objectives: Knee osteoarthritis (OA) is highly prevalent in people above the age of 60, and is typically associated with pain, stiffness, muscle weakness and proprioceptive deficits. Muscle-tendon vibration has been used to assess the spatial reweighting of proprioceptive input during standing. The current study aimed to investigate whether weighting of proprioceptive input is altered in patients with early and established knee OA compared to asymptomatic controls.
Methods: The upright posture of 27 participants with early OA, 26 with established OA, and 27 asymptomatic controls was perturbed by vibrating (frequency: 70 Hz and amplitude: approximately 0.5 mm) ankle muscles (i.e. tibialis anterior and triceps surae) and knee muscles (vastus medialis). Center of pressure displacements of the participants were recorded using a force plate.
Results: Both patients with early and established OA were more sensitive to triceps surae vibration compared to their healthy peers ($P < 0.01$ for both). No such difference was found for the vibration of tibialis anterior or vastus medialis muscles between patients with knee OA and healthy controls.
Conclusions: These results suggest that the early stages of knee OA may already lead to reweighting of proprioceptive information, suggesting more reliance on ankle proprioceptive input for postural control.

1. Introduction

Maintaining upright posture requires the central nervous system (CNS) to accurately observe the instantaneous state of the body relative to the environment. The body state is observable through a range of sensory inputs arising from vestibular, visual, and somatosensory systems [1]. The proprioceptive input from the lower limb muscles is crucial in preserving postural stability [2], which implies that impoverished afferent signals from these muscles might compromise postural stability. As an example, subjects with dorsal root ganglionopathy show severe balance impairments, due to absence of lower limb proprioception [3]. Certain conditions such as injury, disease, or aging may negatively affect the quality of input from affected body parts [4]. In such cases, the CNS needs to substitute for the impaired source by using more information from other available sources such as vision or proprioceptive information from other body parts, to maintain a stable posture [5].

Knee osteoarthritis (OA) is highly prevalent in people above the age of 60 and has been associated with proprioceptive deficits [6–8] and postural control deficits [9,10]. However, reports of impaired proprioception in knee OA populations have thus far mostly been based on testing conscious perception of posture or movement [6–8],

* Corresponding author at: Department of Rehabilitation Sciences, KU Leuven., Tervuursevest 101, 3001 Heverlee, Belgium. Tel.: +32 16 32 91 70; fax: +32 16 32 91 92.
E-mail addresses: armaghan.mahmoudian@gmail.com (A. Mahmoudian), j.van.dieen@vu.nl (J.H. van Dieen), isabel.baert@uantwerpen.be (Isabel A.C. Baert), ilse.jonkers@faber.kuleuven.be (I. Jonkers), s.m.bruijn@gmail.com (S.M. Bruijn), frank.luyten@uzleuven.be (F.P. Luyten), gertfaber.sci@gmail.com (G.S. Faber), sabine.verschueren@faber.kuleuven.be (Sabine M.P. Verschueren).

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while a better understanding of the role of a specific sensory system in postural control might be achieved through bypassing the role of conscious perception in testing [11]. Muscle-tendon vibration has been used to assess the weight allocated to proprioceptive inputs from different body parts [4]. Muscle vibration stimulates the primary afferents of muscle spindles [12] and results in an illusory perception of muscle lengthening [13]. The vibrated muscle is perceived to lengthen, and as a result of this distorted sensory information, a corrective movement is made. The direction of this corrective postural response differs depending on the origin of the distorted information, and the magnitude depends on the weight that the CNS allocates to input from this body part compared to the other sources of information [4]. For instance, in a study on postural weighting of patients with low back pain by Brumagne et al., persons with low back pain showed larger CoP shifts towards posterior direction compared to the healthy individuals when vibration was applied bilaterally on the triceps surae, suggesting more reliance on ankle input [4]. Only one recent study by Shanahan et al. used muscle vibration to assess the proprioceptive weighting (PW) in a group of subjects with severe knee OA (Kellgren and Lawrence grade 3 or 4) [11]. Participants with knee OA were initially perturbed more by triceps surae (TS) than vastus medialis (VM) vibration compared to control subjects [11], from which it was concluded that these participants were unable to compensate the induced and non-veridical sensory signals from the TS by using the information from the VM [11]. To the best of our knowledge, proprioceptive weighting has not yet been studied in the early stage of knee OA. Such understanding might be helpful for development of more purposive preventive or therapeutic strategies.

Proprioceptive deficits associated with knee OA have been considered as a potential cause for observed changes in proprioceptive weighting in this population [11], however, there are no studies on the relationship between PW and proprioceptive accuracy in the population of subjects with knee OA. In the current study we also investigated this relationship by including the proprioceptive accuracy of subjects with early and established knee OA [8].

Consequently, to better understand the progression of proprioceptive impairments with the progression of knee OA, the aim of this study was: (1) to investigate proprioceptive weighting in a group of patients with early knee OA, patients with established knee OA and to compare them with healthy peers; (2) to explore whether the sensitivity of the knee muscle to vibration decreases with increasing severity of knee OA; (3) to explore if there is a relationship between proprioceptive weighting and proprioceptive accuracy in subjects with knee OA.

2. Materials and methods

Fifty-two women with medial knee OA and 27 asymptomatic women participated in this study. Participants with knee OA were recruited during their regular visit to a rheumatologist or orthopedic surgeon at the University Hospitals Leuven. Participants in the healthy control group were recruited through social organizations. All participants were informed about the study procedure and signed informed consent forms. The study was approved by the ethical committee for Biomedical Sciences of the KU Leuven in Belgium prior to testing and was conducted in agreement with the principles of Declaration of Helsinki.

Each participant was referred for a physical exam and bilateral standard anterior–posterior weight-bearing radiographs in fixed flexed position were obtained (Siemens, Siregraph CF, Agfa CR HD5.0 detector 24*30). Diagnosis and categorization of knee OA were based on the K&L grading system [14] and a single experienced observer (FPL) graded each radiograph. A magnetic resonance image (MRI) was taken from the (most) affected side of the OA patients, based on radiography, and a random side in the control group, as described by Baert et al. [15].

The standardized Boston–Leeds Osteoarthritis Knee Score (BLOKS) scoring system was used by two separate readers (NN, GVDS) to score structural features in the tibiofemoral joint [16]. On 91% of all scored items, the two readers had full agreement and disagreements were resolved by consensus.

Participants with knee OA were further sub-classified, into early ($n = 27$) and established ($n = 26$) medial knee OA groups [17]. The inclusion criteria for the early OA group were: presence of knee pain, a K&L grade 0, 1 or 2− for the medial compartment, and presence of two of four MRI criteria: (1) ≥BLOKS grade 2 for size cartilage loss, (2) ≥BLOKS grade 2 for percentage full-thickness cartilage loss, (3) signs of meniscal degeneration and (4) ≥BLOKS grade 2 for size of bone marrow lesions (BMLs) in any one compartment.

The classification of participants in the established knee OA group was based on the slightly adjusted American College of Rheumatology (ACR) classification criteria [18], which includes knee pain, age above 50, stiffness less than 30 min and crepitus, combined with structural changes defined as presence of minimum K&L grade 2+, indicating a moderate to severe disease severity.

The inclusion criteria for the control group were as follows, K&L grade 0 or 1 on the radiography of either knee, asymptomatic, no history of knee OA or other pathology involving any lower extremity joints.

2.1. Clinical assessment

To assess knee symptoms and function, the Knee Injury and Osteoarthritis Outcome Score (KOOS) (Dutch version) was filled in by all participants. Validity and reliability of the KOOS has been verified for evaluation of short- and long-term symptoms and function in knee OA patients [19,20].

2.2. Proprioceptive weighting and postural control assessment

Postural control was assessed using a six-channel force plate (Bertec, Corporation, Ohio, USA). Force plate data were sampled at 1000 samples/s. Participants were asked to comfortably stand barefoot on the force platform with arms crossed in front of the chest and the feet slightly separated. In all trials, vision was occluded by means of a blindfold. Each participant underwent three experimental conditions during which they were instructed to stand still and relaxed. The three conditions were: (1) bilateral vibration of the TS tendons; (2) bilateral vibration of the tibialis anterior (TA) muscle bellies; and (3) bilateral vibration of the VM muscle bellies. Two muscle vibrators (VB100, Dynatronic, Valence, France) were attached over the most proximal part of the tendon of the triceps surae muscles, and vastus medialis muscle belly using straps. The tightness of these straps was subjectively checked with the subject. The activation (frequency of 70 Hz, amplitude of approximately 0.5 mm) and deactivation of the vibrators was controlled manually. These characteristics of vibration were chosen to induce the maximal illusory joint movement [21]. Each trial lasted 45 s, during which muscle-tendon vibration was applied for 15 s, initiated 15 s after the start of the trial. Data collection continued for 15 s after the vibration was stopped.

All participants were asked to stop the test whenever they felt discomfort or pain during the test procedure. In case a participant lost her balance and tended to fall, the trial was excluded and repeated. As all subjects participated in the current study fulfilled every test trial without difficulty, we do assume that they did not experience pain related to the test procedures.