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Multi-joint postural behavior in patients with knee osteoarthritis

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ABSTRACT

Background: Previous studies have demonstrated balance impairment in patients with knee osteoarthritis (OA). Although it is currently accepted that postural control depends on multi-joint coordination, no study has previously considered this postural strategy in patients suffering from knee OA. The objectives of this study were to investigate the multi-joint postural behavior in patients with knee OA and to evaluate the association with clinical outcomes.

Methods: Eighty-seven patients with knee OA and twenty-five healthy elderly were recruited to the study. A motion analysis system and two force plates were used to investigate the joint kinematics (trunk and lower body segments), the lower body joint moments, the vertical ground reaction force ratio and the center of pressure (COP) during a quiet standing task. Pain, functional capacity and quality of life status were also recorded.

Results: Patients with symptomatic and severe knee OA adopt a more flexed posture at all joint levels in comparison with the control group. A significant difference in the mean ratio was found between groups, showing an asymmetric weight distribution in patients with knee OA. A significant decrease in the COP range in the anterior–posterior direction was also observed in the group of patients. Only small associations were observed between postural impairments and clinical outcomes.

Conclusion: This study brings new insights regarding the postural behavior of patients with severe knee OA during a quiet standing task. The results confirm the multi-joint asymmetric posture adopted by this population.

1. Introduction

Knee osteoarthritis (OA) is associated with many factors leading to a decrease in functional capacity and postural control [1]. The main recognized factors are pain, muscle weakness, obesity, loss of proprioception, joint instability and lower limb malalignment [2]. Each factor or a combination of them may compromise the postural stability of patients affected by knee OA. Additionally, as the decline in postural control may be related to an increased risk of falling, individuals with knee OA should be monitored closely to prevent fall injuries [3].

On the basis of previous studies, it is well known that individuals with knee OA exhibit impaired postural control in comparison with age-matched controls [1,4–9]. Significant higher sway was found in patients with knee OA during both eyes open and eyes closed conditions [5,8]. In another study, Kim et al. investigated the relation between the balance control and the severity of knee OA disease [3]. They reported that balance impairments were positively correlated with knee OA severity [3]. The authors associated the increased balance impairments with a decrease in muscle strength and proprioception and an increase in knee pain [3]. This is in agreement with previous studies [1,4,6]. Indeed, a recent study conducted by Sanchez-Ramirez et al. confirmed significant associations between decrease in postural control and muscle weakness, proprioceptive inaccuracy and performance-based activity limitations [1].

Considering that patients with knee OA experience knee pain and are affected by many other factors, as mentioned previously (i.e., muscle weakness, obesity, loss of proprioception, joint instability, malalignment), we hypothesise that patients with knee OA will adopt a postural behavior that compensates for their limitations and unloads their affected knee.

Nowadays, it is increasingly accepted that postural control depends on multi-joint coordination [10]. Hsu et al. identified four hypothetical postural control modes that may be adopted by an individual to maintain his or her equilibrium: single inverted pendulum, double inverted pendulum, multi-joint coordination, and stiffening strategy [10]. Multi-joint coordination has already been investigated in healthy and pathological populations, its relevance has been shown in postural control analysis [11–14]. However, it has not been investigated in the knee OA

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population. The investigation of complex postural control modes, especially the multi-joint coordination strategy, necessitates a full-body analysis.

Although previous studies have demonstrated balance impairments in individuals with knee OA and have also confirmed their association with clinical outcomes, no study has previously considered the possible multi-joint movement strategies adopted by this population. Therefore, the main objective of this study was to investigate the multi-joint postural behavior in patients with severe knee OA. It was hypothesized that patients with knee OA would show impaired balance and would adopt different multi-joint postural behaviors in comparison with a healthy elderly population. The second objective was to evaluate the association among the most important balance and postural impairments and pain, functional limitation, and quality of life.

2. Methods

2.1. Participants

A total of 87 patients (41 men and 46 women) with symptomatic knee OA and scheduled for a total knee arthroplasty (TKA) were recruited from the orthopedic service of the Geneva University Hospitals from April 2010 to December 2012. The exclusion criteria were joint prosthesis, a history of lower limb or back surgery, and neurological or orthopedic disorders other than the presence of knee OA that could affect patients' gait or balance. Patients were also excluded if they could not walk for a short distance without the use of technical aids. The mean and standard deviation (SD) of age and body mass index (BMI) were 69 (seven) years and 31.4 (5.7) kg/m^2, respectively.

A total of 25 healthy elderly individuals (12 men and 13 women) were recruited from the Geneva community as the control group. Individuals were included if they were free from knee pain, had no recent history of lower limb or back surgery, and had no neurological or orthopedic disorders that could affect their gait or balance. The mean and SD of age and BMI were 68 (six) years and 24.8 (3.6) kg/m^2, respectively. The ethical committee of the University Geneva Hospitals approved this study, and written informed consent was obtained from all the participants.

2.2. Postural assessment

A 12-camera motion analysis system (Vicon Peak, Oxford, UK) was used to capture the three-dimensional (3D) body kinematics during a quiet standing task. Reflective markers were positioned on the pelvis and on lower limb landmarks according to the Davis protocol [15] and on the trunk according to Gutierrez-Farewik et al. [16]. Two force plates (AMTI, Watertown, NY, USA) were used to measure the ground reaction forces under each leg as well as the center of pressure (COP). The motion and force plate data were synchronized and sampled at 100 and 1000 Hz, respectively. Marker trajectories were filtered using a generalized cross-validation (GCV) spline. The joint kinematics and kinetics were generated using the dynamic model (Vicon Plug-in-Gait). The joint moments were normalized for body weight (Nm/kg).

To realize the quiet standing task, the participants were asked to rise from a chair at their self-selected pace and were then instructed to stand as still as possible with their arms on each side for a period of 10 s. The position of their feet was not imposed but maintained during the trial. Each participant completed the task four times. The first three well-executed trials were kept for data analysis.

The mean position of the trunk, the pelvis in addition to the mean position of the hip, the knee, and the ankle for the affected (i.e., knee OA joint) and contralateral sides were calculated in sagittal and frontal planes. The average moment of the hip, the knee, and the ankle for the affected and contralateral sides were also calculated in both sagittal and frontal planes. The range of the COP in the anterior–posterior (AP) and medical–lateral (ML) directions and the average speed of the COP were calculated. Each COP parameter was calculated for the affected and contralateral sides as well as considering both sides (i.e., COP net).

Finally, the mean ratio of the vertical ground reaction force (GRF) was calculated using the affected side divided by the contralateral side. For the control group, the ratio was calculated using the right and left sides in a randomized manner.

2.3. Clinical measurements

The self-reported quality of life was evaluated using the SF-12 questionnaire [17]. The SF-12 is a generic instrument for measuring the health-related quality of life for two specific components: physical component summary (PCS) and mental component summary (MCS). The PCS and MCS scores were designed to have a mean score of 50 and a SD of 10 for a healthy population. A score > 50 represents an above-average health status, and a score < 50 represents a below-average health status.

The pain and functional levels were evaluated using the reduced version of the Western Ontario and McMaster Universities Arthritis Index (WOMAC) [18]. The reduced WOMAC pain and function scores range between 0 and 100 (lower numbers indicate a worse score and higher numbers indicate a better score). Hence, if a patient does not experience any pain or any functional limitation, the score would be 100. By contrast, a score of 0 indicates extreme pain or extreme functional deficit. A specific question related to the pain while standing and part of the WOMAC questionnaire was also investigated. For this question, the patients had to choose among none, slight, moderate, severe or extreme pain while standing (score 0 to four).

2.4. Data analysis

The mean values for the above-listed postural variables were obtained by averaging the discrete values across the three trials. All the computations were performed using MATLAB R2012 (MathWorks, USA) and the open-source Biomechanical ToolKit package for MATLAB (http://code.google.com/p/b-tk).

2.5. Statistical analysis

Unpaired Student's *t*-tests were used to assess the difference between the groups' characteristics. The parameters extracted from the kinematics and kinetics data and averaged from the three trials were compared between the groups (OA affected side (OA-A) vs. control group (C); OA contralateral side (OA-C) vs. control group (C)) using a one-way analysis of variance (ANOVA). When significant differences existed, Tukey's post hoc tests were performed. In addition, we also assessed the effect size (d) which was interpreted as trivial (<0.20), small (≥0.2 to < 0.5), moderate (≥0.5 to < 0.8), or large (≥0.8) [19]. Considering the non-normal distribution of COP parameters, the nonparametric Mann–Whitney U tests were used for these data. A significant difference was defined as $p < 0.05$.

For patients with knee OA, multiple forward stepwise linear regressions were also conducted to explore the relationships between the clinical (i.e., pain, function, and quality of life) and relevant postural behavior variables (i.e., trunk and knee mean positions in the sagittal plane). We fixed the F to enter value to its minimum (0.0001), and the F to remove value to its minimum.

3. Results

All results are presented using mean ± SD. Significant group effects were obtained between the control group and patient group for the affected side (OA-A; $p < 0.001$; $d = 0.472$) and contralateral side (OA-C; $p < 0.001$; $d = 0.376$). When comparing the control group with the group of patients for their affected side (OA-A group) we found that patients with knee OA adopt a more flexed posture in all joints in comparison with the control group (Fig. 1). Significant differences were obtained in the sagittal plane for the trunk (OA: 1.4° ± 6.3°; control: −1.5° ± 4.7°; $p = 0.034$; d = 0.485), the pelvis (OA: