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Male subjects with early-stage knee osteoarthritis do not present biomechanical alterations in the sagittal plane during stair descent

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ABSTRACT

Patients with osteoarthritis (OA) of the knee show a loss of functional independence due to difficulty performing tasks that require high demand of the knee joint, such as descending stairs. However, it is unclear how muscular and biomechanical changes were present in patients with OA in the early stages. Thus, the purpose of this study was to analyze the kinetics, kinematics and muscle activation of men with early-stage knee OA during stair descent and compare them with a healthy control group. We evaluated 31 volunteers who were divided into two groups. The Osteoarthritis Group (OAG) included 17 men with grade I or II knee OA (53 ± 6 years) and the Control Group (CG) included 14 healthy men (50 ± 6 years). We performed a kinematic evaluation of stair descent in the sagittal plane in order to analyze knee flexion angles. Electromyography (EMG) of the vastus lateralis muscle was also performed and the vertical ground reaction force was measured. The WOMAC questionnaire was administered to all volunteers. Statistical analysis consisted of the nonparametric Mann-Whitney *U* test for intergroup comparisons of all variables ($p > 0.05$). There were no significant kinematic, kinetic or EMG differences between groups. For the WOMAC, the intergroup differences were significant in all three sections (pain: $p = 0.001$, stiffness: $p = 0.008$ and function: $p = 0.0005$). In men with knee OA grade I or II, the stair decent is preserved in the sagittal plane, indicating that at these stages of the disease the functional adaptations are not expressed.

1. Introduction

Patients with knee osteoarthritis (OA) show great impairment of the musculoskeletal system, including pain, stiffness and decreased range of motion (ROM) [1,2], which leads to progressive loss of functional. Kinematic and kinetic studies have shown that, compared with level walking, greater knee ROM is required for climbing stairs [3]. Thus, for subjects with knee OA, stair ascent and descent are more difficult and demanding tasks than level walking [1,4,5]. Neuromuscular impairment of the quadriceps has been identified as a contributing factor to altered joint kinematics in subjects with knee OA and includes muscle weakness, delayed activation and inhibition of the quadriceps and even proprioceptive deficits [6–8].

Since the quadriceps muscle is essential for walking and descending stairs, especially for ROM control and shock absorption [7], impairment in quadriceps function can lead to limitations in range of knee flexion and increased vertical ground reaction force during locomotion [9,10]. Some studies have assessed stair descent in patients with OA, although including subjects with different degrees of OA in the same group for analysis [1,5,6,11]. Moreover, the literature does not give information on biomechanical changes in early degrees of the disease. This knowledge can help to identify possible compensatory strategies in this population.

Therefore, alterations in neuromuscular strategy associated with knee OA may change the quadriceps strength, leading to abnormalities in knee biomechanics, which would increase joint loading and result in progression of the disease. Mechanical factors contribute to articular cartilage injury [12], but exactly how these alterations influence the progression of the disease has not yet been identified.

Thus, to identify possible changes in the early stages of the disease and to know compensatory strategies used by this population would be relevant to the development of an appropriate rehabilitation program. This knowledge would contribute to improve quality of life and monitor the progression of the OA, since this is a chronic degenerative and debilitating disease. Therefore, the purpose of this study was to analyze the kinetics, kinematics and muscle activation of men with early-stage knee OA during stair descent in sagittal plane and compare the results with those of a healthy control group.

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2. Methods

2.1. Participants

This study involved 31 sedentary males, aged between 40 and 65, who were divided into two groups: the Control Group (CG), which included 14 subjects with no dysfunction or joint disease, and the Osteoarthritis Group (OAG), which included 17 subjects with grade I or II OA of the knee (Table 1). All subjects underwent an initial evaluation and a radiological examination of both knees to determine the OA diagnosis, according to the criteria of Kellgren & Lawrence [13], and were placed in the appropriate group.

For inclusion in OAG each subject had to present signs of OA in at least one knee joint compartment (tibiofemoral or patellofemoral) that could be classified as grade I or II [14] and to have had no history of trauma, ligament injury or lower limb fracture. For inclusion in the CG, the subjects had to show no radiographic alterations, as well as to have had no history of lower limb pain, illness, injury, trauma, surgery or fracture. Exclusion criteria included knee physiotherapy in the previous 12 months, knee surgery in the previous 3 months, systemic arthritis, steroid injections in the previous 6 months and any medical condition that might preclude safe testing [1,15]. Subjects with decreased knee ROM were also excluded.

The knee compartment affected by OA for the OAG subjects was identified through radiological examination. Eight subjects presented OA in the patellofemoral (PF) compartment, one in the medial tibiofemoral (MTF) compartment, and one in the lateral tibiofemoral (LTF) compartment. Combined affected compartments were found in seven subjects: PF plus MTF was found in 5 subjects, PF plus LTF in one subject, and PF plus MTF and LTF in another subject.

The study was approved by the Federal University of São Carlos Human Research Ethics Committee (295/2009). All participants provided written informed consent.

2.2. Procedures

A three-step wooden staircase (20.5 cm high and 27.5 cm deep) was used to evaluate stair descent [16]. The most symptomatic limb of the OAG was assessed and the right or left limb of the CG was randomly tested [1]. To carry out the descent, the volunteers, barefoot, always initiated with the evaluated limb, so that the assessed limb was the first to hit the ground. For each subject five valid trials were considered, being defined as trials in which the subject descended the stairs by placing one foot on each step while his hands remained positioned at his waist (Fig. 1). The subjects performed stair descent at a self-selected speed. Additionally, three warm-up trials were allowed to familiarize the subject with the task prior to data collection.

2.2.1. Kinematic analysis

To carry out the kinematic analysis, a passive reflective marker was affixed to each of the following three locations: the skin over the greater trochanter, laterally on the knee joint and the lateral malleolus (Fig. 1). The task was recorded at 60 Hz with two digital video cameras (NV-Panasonic GS180PL) that were placed in the frontal and sagittal plane perpendicular to each other.

Table 1
Mean and standard deviation of anthropometric data of subjects.

	CG	OAG
Age (years)	50.1 (± 6.3)	52.9 (±6.1)
Height (m)	1.75 (±0.1)	1.73 (±0.1)
Weight (Kg)	81.3 (±13.1)	88.0 (±10.2)
BMI (Kg/m²)	26.5 (±2.7)	29.7 (±4.7)

BMI = body mass index; CG: control group; OAG: osteoarthritis group.

Calibration was performed using a 40 × 145 × 150cm object that was positioned where the subjects would perform the tests (orientation X = latero-lateral; Y = vertical ; Z = antero- posterior) and contained 24 markers with known absolute positions in Cartesian Coordinates. The Kinematic data were digitized, filtered and reconstructed using Ariel Performance Analysis System software (APAS, Ariel Dynamics, Inc., Trabuco Canyon, USA). Data were low-pass filtered at 10 Hz using a digital filter algorithm. The reconstruction of real coordinates was performed using the direct linear transformation (DLT) procedure. Complete knee extension was considered to be 180°.

2.2.2. Kinetic analysis

For kinetic analysis, a force platform (Bertec® model 4060–08, Bertec Corp., Ohio, USA) was placed on the ground at the end of the stair case (Fig. 1) to capture the vertical component of ground reaction force (GRFz) at a sampling frequency of 1000 Hz.

2.2.3. Electromyography (EMG)

Surface EMG activity of the vastus lateralis (VL) muscle was recorded during stair descent. The data were collected with an eight-channel signal conditioning module (EMG-800 C, EMG System do Brasil®, São José dos Campos, SP, Brazil) featuring an analogue-to-digital converter with 12-bit resolution and an acquisition frequency of 1000 Hz per channel and with Dataq data acquisition software (EMG System do Brasil®). Each channel had a 100x gain, a Butterworth filter at a bandwidth of 20 to 500 Hz and common-mode rejection of 100 dB.

After skin preparation, two disposable self-adhesive 20x gain Ag/AgCl preamplified surface electrodes (Medi-Trace™, Kendall, Mansfield, MA, USA) were attached over the muscle belly 20 mm apart, according to SENIAM recommendations (i.e., placed 2/3 of the way from the superior anterior iliac spine to the lateral side of the patella) [17]. The reference electrode was placed on the opposing wrist. Electrodes were also secured with hypoallergenic adhesive tape to reduce movement artifact.

The kinetic, kinematic and EMG data were synchronized with a light emitting diode (LED) that sent two signals, one luminous, recorded by the cameras and another electric, recorded by the force platform and EMG.

2.2.4. Knee pain and disability

For the assessment of knee pain and disability the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) was used. The WOMAC is a self-report questionnaire for subjects with knee OA. This questionnaire has three dimensions pain, stiffness, and physical function. Each item was scored on a 5-point Likert scale [15,18], and the maximum score in each section was considered as a percentage.

2.2.5. Data analysis

Data were processed using MatLab® (version 7.0.1, MathWorks Inc., Natick, USA). A sliding window (with duration of 13 s and 50% overlap) was used with the kinematic data to identify the start of the task. The beginning of the task was defined as when the average of two consecutive windows (k and k + 1) was smaller than the average of the previous window (k-1) minus 2 standard deviations of that mean. The end of the task was determined by foot contact with the force platform. Foot contact time was defined as when GRFz reached 2 N [19]. By identifying the events that determined the beginning and end of the stair descent, we calculated the time it took to perform the task or task time (TT).

The EMG signals were band-pass filtered using a fourth-order zero-lag Butterworth filter at 20 to 400 Hz, and were full-wave rectified and normalized according to the average signal obtained during the task [20]. The integral of the signal was calculated after being low-pass filtered at 8 Hz to obtain the linear envelope. It was also determined the onset of VL activation (VL onset) that preceded