



Full length article

The influence of continuous versus interval walking exercise on knee joint loading and pain in patients with knee osteoarthritis[☆]



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ABSTRACT

Objective: To evaluate whether knee contact force and knee pain are different between continuous and interval walking exercise in patients with knee osteoarthritis (OA).

Methods: Twenty seven patients with unilateral symptomatic knee OA completed two separate walking exercise sessions on a treadmill at 1.3 m/s on two different days: 1) a continuous 45 min walking exercise session, and 2) three 15 min bouts of walking exercise separated by 1 h rest periods for a total of 45 min of exercise in an interval format. Estimated knee contact forces using the OpenSim software and knee pain were evaluated at baseline (1st minute of walking) and after every 15 min between the continuous and interval walking conditions. **Results:** A significant increase from baseline was observed in peak knee contact force during the weight-acceptance phase of gait after 30 and 45 min of walking, irrespective of the walking exercise condition. Additionally, whereas continuous walking resulted in an increase in knee pain, interval walking did not lead to increased knee pain.

Conclusion: Walking exercise durations of 30 min or greater may lead to undesirable knee joint loading in patients with knee OA, while performing the same volume of exercise in multiple bouts as opposed to one continuous bout may be beneficial for limiting knee pain.

1. Introduction

General aerobic exercise is advocated by most international clinical guidelines as an effective treatment for management of patients with knee osteoarthritis (OA) [1–3]. Randomized clinical trials of aerobic walking exercise, in particular, have shown significant short-term improvements in pain, functional status and quality of life in patients with knee OA [4,5]. However, high exercise attrition and low long-term compliance rates with walking exercise programs are major barriers for achieving sustained clinical improvements in patients with knee OA. For instance, a recent systematic review reported significant dropout rates of 20–30% in as many as 12 randomized controlled trials of walking exercise in patients with knee OA, indicating patients' reluctance to adopt walking as a form of exercise [3]. Additionally, sustained

compliance with maintaining a regular walking exercise program has been reported to be as low as 50% in patients with knee OA, resulting in loss of therapeutic benefits observed immediately after completing a walking exercise program [5,6]. To this end, evidence suggests that exercise-induced increases in symptoms, beliefs that exercise could be damaging to the knee, and reduced physical capacity to perform exercises at intensities and durations recommended for cardiovascular fitness gains appear to influence why patients with knee OA stop exercising [6,7].

The current recommendations for walking exercise by the Ottawa Panel suggest that aerobic walking for obtaining cardiovascular fitness in patients with knee OA should be performed for at least 30 min, at a level of exercise intensity above normal daily activities and at a minimal frequency of 3 to 4 times a week [3]. This recommendation

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is similar to that of the American Geriatric Society which advocates 20–30 min of aerobic exercise for patients with knee OA at low to moderate intensity (40–60% of heart rate reserve), two to five times per week [8]. According to the recommendations from the American College of Sports Medicine and the American Heart Association, further participation in aerobic activities above the minimum recommended amounts can provide additional health benefits [9]. However, prolonged aerobic exercise may also increase symptoms and lead to non-compliance in patients with knee OA. Evidence from a randomized clinical trial comparing aerobic and resistance exercise with a health education program suggests that the benefits gained from a walking program may be negated by exercising for extended periods of greater than 35 min [6]. Similarly, findings from a clinical trial of combined effects of diet and exercise suggest that prolonged walking exercise appeared to lead to more knee symptoms and blunting of clinical benefits compared to a non-weightbearing exercise program [10]. As such, long duration walking in patients with knee OA has been hypothesized to lead to quadriceps muscle fatigue, loss of effective shock absorption, and higher rates of knee joint loading, which can lead to increased pain and greater cartilage damage [11]. As very few studies have evaluated the effects of increasing walking exercise duration on symptoms and other clinical benefits, the optimal walking exercise duration for patients with knee OA remains unknown.

While a single prolonged continuous bout of exercise could have unintended negative effects, completing the same volume of aerobic exercise through an interval training program of shorter daily bouts may be an effective alternative. Evidence suggests that an interval walking exercise program provides comparable and in some cases greater health and fitness benefits compared to a traditional continuous walking exercise program in middle aged men and women [12] as well as in post-menopausal women [13]. Interval walking exercise programs may also reduce attrition within the first 24 weeks of an exercise program [14] and increase compliance [15] compared to a continuous walking program. Evidence from a randomized clinical trial of aerobic and resistance exercise compared to a health education program in patients with knee OA also suggests that participants who either exceeded or worked at the upper end of their prescribed duration per session did not appear to benefit as much from their exercise program as those who elected to take brief timeouts approximately half-way through their exercise therapy [6]. Currently, whether an interval walking program could lead to greater joint protection and less symptoms compared to a continuous walking program has not been evaluated.

The purpose of this repeated-measures, cross-sectional, laboratory study was to compare the acute changes in knee joint contact loading and knee pain between a continuous 45 min bout of walking exercise compared to performing the same volume of exercise as three shorter 15 min bouts of walking, with a 1 h rest break between each bout. We hypothesized that knee contact force (KCF) and knee pain will be higher during a continuous 45 min bout of walking exercise compared to completing the same volume of exercise in an interval format.

2. Materials and methods

2.1. Subjects

A total of 27 older adults who met the American College of Rheumatology (ACR) clinical criteria (sensitivity = 95% & specificity = 69%) were recruited from the local research registries and through community advertisements to participate in this study [16]. The ACR clinical criteria for knee OA include knee pain on most days plus 3 of the following 6 criteria: age > 50 years, morning stiffness of < 30 min, crepitus on active movement, tenderness of the bony margins of the joint, bony enlargement of the joint, and lack of palpable warmth of the synovium. For all participants, radiographic knee OA (grade II or greater) was confirmed according to the Kellgren and

Table 1
Patient demographics and characteristics.

Age (years)	63.7 (7.7)
Female, n (%)	20 (74.1%)
Height (cm)	168.0 (8.7)
Weight (kg)	77.4 (14.7)
Body Mass Index (kg/m ²)	27.3 (3.7)
Tibiofemoral Compartment Radiographic Severity, n (%) ^a	
Grade 2	10 (37%)
Grade 3	8 (30%)
Grade 4	9 (33%)
Patellofemoral Compartment Radiographic Severity, n (%)	
Grade 0	4 (15%)
Grade 1	10 (37%)
Grade 2	7 (26%)
Grade 3	2 (7%)
Grade 4	4 (15%)
Knee injury and Osteoarthritis Outcome Score (KOOS) ^b	
Pain (Range: 0–100)	64.4 (17.7)
Symptoms (Range: 0–100)	63.2 (17.3)
Function in Daily Living (Range: 0–100)	72.5 (18.3)
Function in Sport and Recreation (Range: 0–100)	46.2 (26.2)
Knee Related Quality of Life (Range: 0–100)	53.6 (18.7)
Heart Rate Response to Walking Exercise	
Baseline (Beats Per Minute)	75.7 (10.3)
15 min of Walking (Beats Per Minute)	100.8 (14.4)
30 min of Walking (Beats Per Minute)	105.1 (15.6)
45 min of Walking (Beats Per Minute)	105.5 (16.2)

^a All patients had to have at least a grade 2 evidence of radiographic tibiofemoral joint OA to be included in the study.

^b KOOS scoring: 100 indicates no problems and 0 indicates extreme problems.

Lawrence rating scale [17] for their painful knee (Table 1). Participants were excluded if they had contralateral knee pain, had a past history of traumatic knee injury, total joint arthroplasty, hip or spine pain, cardiovascular disease or uncontrolled hypertension, were taking beta blockers, had a neurological disorder that affected their gait, required an assistive device for ambulation or had a history of two or more falls within the previous year.

All subjects were also screened prior to inclusion into the study to ensure that they are capable of maintaining a continuous 45 min bout of walking exercise on a treadmill at a speed of 1.3 m/s. This walking speed was selected as the average self-selected walking speed previously reported in patients with knee OA [18] and to ensure that all participants completed similar volumes of exercise over a 45 min bout of walking by covering the same distance, while minimizing the influence of variable gait speed on knee joint contact forces [19]. All participants wore a heart rate monitor (Polar Electro Inc., Lake Success, NY, USA) during the walking exercise screening to ensure that walking at the speed of 1.3 m/s coincides with 40–60% of their heart rate reserve (Table 1), which is the recommended intensity of aerobic exercise by the American Geriatric society for patients with knee OA [8]. All participants signed an informed consent form approved by the institutional review board of the University of Pittsburgh prior to any testing.

2.2. Data collection

Participants meeting the inclusion criteria were invited to attend two separate testing sessions. For the continuous walking exercise session, participants completed a single 45 min bout of walking exercise at a speed of 1.3 m/s on an instrumented, split-belt treadmill (Bertec Corp., Columbus, OH, USA). For the interval walking exercise session, subjects performed three separate 15 min bouts of walking exercise for a total of 45 min, with each bout separated by a 1 h rest period. A 1 h rest period was chosen to simulate performing multiple short bouts of exercise per day, which has been previously recommended in the literature for enhancing exercise adherence and weight loss, while

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