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Biomechanical balance response during induced falls under dual task conditions in people with knee osteoarthritis

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ABSTRACT

Objective: People with knee osteoarthritis (OA) are at twice the risk of falling compared to older people without knee OA, however the mechanism for this is poorly understood. This study investigated the biomechanical response of the trunk and lower limb joints during a forward induced fall under different task conditions in people with and without knee OA.

Method: Twenty-four participants with OA (68.6 ± 6.2 years) and 15 asymptomatic controls (72.4 ± 4.8 years) participated in the study. Forward fall was induced by releasing participants from a static forward leaning position. Participants were required to recover balance during three conditions: normal, physical (obstacle clearance) and cognitive dual tasks (counting backwards). Spatiotemporal parameters, lower limb joint kinematics and kinetics of the recovery limb were compared between the two groups and across the three task conditions.

Results: The OA group demonstrated slower spatio-temporal characteristics and reduced hip and knee flexion angles, joint moments/powers and reduced muscle negative work at the knee and ankle ($p < 0.05$). Cognitive dual task resulted in reduced centre of mass velocity and step length ($p = 0.03$) compared to the physical dual task condition. Reduced knee ($p = 0.02$) and hip joint powers ($p = 0.03$) were demonstrated in the OA group in the physical task condition.

Conclusion: When simulating a forward fall, participants with OA demonstrated difficulty in absorbing the impact and slowing down the forward momentum of the body during a recovery step. Moreover, poor dynamic postural control was demonstrated as task complexity increased.

1. Introduction

Falling is the leading cause of death and disability among older adults [1,2]. Falls are prevalent in older adults 65 years and over with 30% falling each year [3–6]. Falls rates are even higher for older adults with knee osteoarthritis (OA) [7–9]. However, despite the high prevalence of falls in people with knee OA, the mechanism of falling in this group is unclear.

Older adults demonstrate less capacity to recover balance during imbalance episodes compared to young adults and tend to employ multiple compensatory steps [10,11] which has been shown to predict future falls [12]. Successful balance recovery during induced falls might necessitate effective stepping reaction to prevent falling [13,14], where a single step response is linked to a low risk of falling due to the ability to fully arrest the forward momentum of the body [12]. Most daily activities require the simultaneous performance of cognitive and motor tasks, thus attending to a secondary task while performing a balance recovery task [15] can have a more deleterious effect on postural control [16]. As dual task represents the interaction between cognition and mobility, balance impairment may be exacerbated by impaired attention dynamics in older adults (dividing attention during dual tasks) [17], thereby increasing the risk of falls under these challenging circumstances.

Increased neuromuscular deficits are common in people with OA such as impaired balance and proprioception, muscle weakness, reduced power and joint pain [18,19]. Pain may impair executive function, as reduced cognitive factors have been found to

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be associated with the presence and deterioration/worsening of knee pain [20]. It is therefore possible that people with knee OA have impaired capacity to re-allocate attention due to the presence of pain, and this may further increase their risk of experiencing a fall. These deficits may further impact on postural control mechanisms and the ability to defend against a fall. However, no studies to date have investigated the characteristics of balance recovery response among people with knee OA and the stepping strategies used during balance loss. The aims of this study were, therefore, twofold. First, to investigate the biomechanical response of the lower limb joints during a forward induced fall under different task conditions (normal, physical and cognitive dual tasks) in people with knee OA. Second, to determine how the balance recovery step responses (single vs multi steps) would be affected due to the presence of knee OA while undertaking the three task conditions. We hypothesised that people with knee OA would demonstrate impaired knee function during balance recovery tasks with greater impairment during dual task conditions and that pain associated with knee OA may affect balance responses when simultaneously undertaking an attention demanding cognitive task.

2. Material and method

Two groups participated in the study: a knee OA group ($n = 24$) and an age-matched asymptomatic control group ($n = 15$). The demographic characteristics are summarised in Table 1. Knee OA was classified according to the American College of Rheumatology criteria [21]. The OA participants were under the following conditions (1) knee pain persisting longer than six months with stiffness and limited movement, (2) a minimum average pain score of 4 on an 11-point numerical rating scale in the past week (where 0 is 'no pain' and 10 is 'worst pain possible') and (3) capable of walking at least 45 m independently. The control group did not have self-reported clinical symptoms of OA, rheumatoid arthritis or history of knee trauma or pain and were capable of self-ambulation. Participants were recruited via advertisement in a local newsletter. All participants were fully informed about the nature of the study and signed a consent form prior to participation. The study protocol was approved by the Human Research Ethics Committee of Victoria University.

3. Procedure

All participants underwent balance recovery tasks. The OA group also completed questionnaire to assess pain, function and stiffness. Height and mass were measured for all participants. Information about previous falls in the preceding 12 months was also collected from both groups. A commonly used standardised definition of falls was used: 'in-advertently coming to rest on the ground, floor or other lower level,' (WHO Global Report on Falls Prevention in Older Age, 2007).

Reflective markers (14 mm in diameter) were attached to the participants' upper and lower body according to the full body Plug In Gait model (Oxford Metrics Group, Oxford, England) as detailed in Nagano et al. [22]. Three dimensional (3D) motion analysis system (VICON, Oxford Metrics) with 10 Cameras (MX-T 40S, 100 Hz) and three AMTI force plates (Watertown, MA, USA; 1000 Hz) were used to capture the balance recovery tasks as detailed in Nagano et al. [22].

3.1. Balance recovery from a forward induced fall

A previously described Tether-Release apparatus was used to induce a forward fall as detailed in Nagano et al. [22], see Fig. 1. Participants were instructed to relax while leaning forward and to regain balance with a single step using the recovery limb of their choice once the restraining cable was released. One practice

Table 1
Participants' characteristics.

Parameters	Control ($n = 15$)	OA ($n = 24$)	p value
Age (yr)	72.5 ± 4.8	68.6 ± 6.2	0.05
Gender % (n)	73% (4) female	50% (12) females	0.2
Height (m)	1.7 ± 0.1	1.7 ± 0.1	0.7
Body mass (kg)	76.0 ± 12.3	80.7 ± 14.5	0.2
Body mass index (kg/height^2)	26.1 ± 3.0	27.7 ± 4.1	0.2
Falls in previous 12 months % (n)	40% (6)	50% (12)	0.38
Pain, function and stiffness			
WOMAC pain	–	217.2 ± 298.8	–
WOMAC stiffness	–	55.4 ± 39.7	–
WOMAC function	–	318.2 ± 250.8	–
WOMAC total	–	590.9 ± 518.8	–

Abbreviation: WOMAC – Western Ontario and McMasters University Osteoarthritis Index.

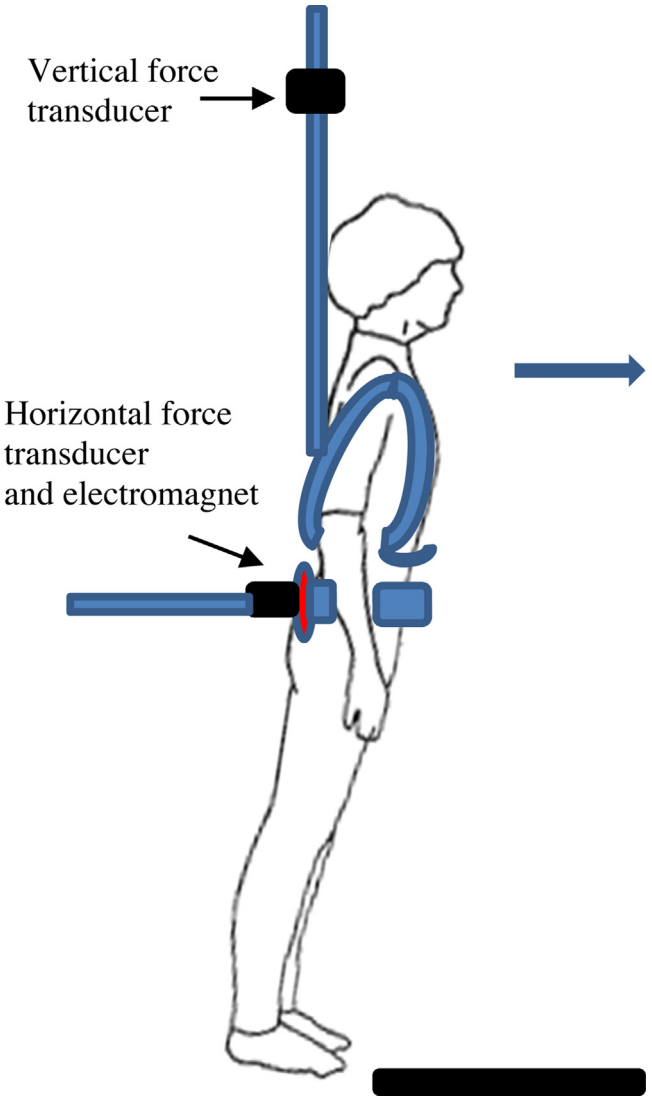

Fig. 1. The Tether-Release method of balance recovery from an induced forward fall. Participants were placed in a forward lean angle with overhead and horizontal force transducers. An electromagnet was connected to a restraining cable which was randomly disconnected once forward perturbation was initiated.