Abstract

Background: Over 50% of the body's mass is concentrated within the head, arms and trunk. Thus, small deviations in the orientation of the trunk, during normal walking, could influence the position of the centre of mass relative to the lower limb joint centres and impact on lower limb biomechanics. However, there are minimal data available on sagittal kinematics of the trunk in people with knee osteoarthritis (OA) during walking.

Research question: Do people with knee OA have altered kinematic patterns of the trunk, pelvis or hip compared with healthy control participants during walking?

Methods: Statistical parametric mapping was used to compare sagittal and frontal plane kinematic patterns, during walking, between a healthy group and cohort of people with knee OA.

Results: Individuals with knee OA walked with a mean increase in trunk flexion of 2.6°. Although this difference was more pronounced during early stance, it was maintained across the whole of stance phase. There were no differences, between the groups, in sagittal plane pelvic or hip kinematics. There were also no differences in trunk, pelvic or hip kinematics in the frontal plane.

Significance: Most previous gait research investigating trunk motion in people with knee OA has focused on the frontal plane. However, our data suggest that an increase in sagittal trunk flexion may be a clinical hallmark of people with this disease. Altered trunk flexion could affect joint moments and muscle patterns and therefore our results motivate further research in this area.

Keywords:

Knee OA; osteoarthritis; trunk flexion; thorax, pelvis, trunk inclination, kinematics;

Introduction

Over 50% of the body's mass is concentrated within the head, arms and trunk. Therefore, small deviations in the orientation of the trunk, during normal walking, could influence the position of the centre of mass relative to the lower limb joint centres. Such deviations may lead to corresponding changes in sagittal [1] and frontal plane moments [2] and muscle activation patterns. Interestingly, people with knee osteoarthritis (OA) are known to walk with altered lower limb moments [3, 4] and increased hamstring-quadriceps co-contraction [5]. Although, it is possible that these differences are localised responses to the disease, it is also possible that they may result from altered trunk kinematics. It is therefore important that we have a comprehensive description of trunk motion in individuals with knee OA.

Previous research investigating lateral trunk lean has produced mixed results [6, 7]. Whereas some authors have found clear increases in trunk lean [6] in people with knee OA, others have shown subtle, hard to detect, alterations [7]. To date, three papers have reported data on sagittal plane trunk flexion during walking in people with knee OA [8-10]. However, these studies have either focused on relatively young people, who had developed OA following anterior cruciate ligament injury [8], used a marker set which may not be optimal for measuring trunk kinematics [10, 11] or compared OA and healthy groups at different walking speeds [9]. Importantly, a recent systematic review identified the need for further research to clarify whether sagittal plane kinematic alterations of the trunk/pelvis are a clinical hallmark associated with knee OA. Therefore, this study sought to understand if people with knee OA have altered kinematic patterns of the trunk during normal walking. A secondary aim was to compare pelvis and hip kinematics between healthy participants and people with knee OA.

Methods

A total of 27 people with knee OA (17 males) and 19 healthy control participants (13 males) took part in the study. Participants with knee OA were included if they had radiologically diagnosed OA of the tibiofemoral joint (medial or lateral), satisfied the ACR criteria [12] and had knee pain for at least 6 months duration. We also required participants with knee OA to report difficulty rising from sitting or ascending stairs to ensure that their knee pain affected their ability to perform challenging activities of daily living. Participants were excluded if they suffered with rheumatoid arthritis or other metabolic disease or if they suffered with pain/OA in any other joint of the lower limb, including the patellofemoral joint.

Healthy subjects were required to be free from any musculoskeletal disorders of the lower limb or spine. The mean (SD) age of the participants was 56 (9) years old (OA group) and 54 (11) years old (healthy group) and the mean (SD) BMI of the participants was 28(3) Kg/m^2 (OA group) and 27(3) Kg/m^2 (healthy group). The mean (SD) total WOMAC score across the group with OA was 41(11) with 16 of the individuals with OA suffering with bilateral OA and the remaining 11 suffering with unilateral OA. Before testing, all subjects provided written informed consent to participate in the study and ethical approval was obtained from the local UK NHS ethics committee.

Each participant underwent a three-dimensional gait analysis in a standard Oxford shoe. Whereas participants with knee OA were instructed to walk at their self-selected speed, the healthy group were instructed to walk slightly slower than normal. Optical timing gates were used to measure walking speed for each individual and trials, not within ±5% of the median speed for that participant,

rejected. These data showed minimal differences in the mean (SD) walking speed between the two groups, OA=1.10 (0.13) m/s and healthy =1.09 (0.13) m/s.

Motion data were collected with a Oqus system, Qualysis (100Hz) and motions of the lower limb and foot segments tracked using a previously published protocol [13]. The pelvis was defined using markers on the anterior superior iliac spines (ASISs) and the posterior superior iliac spines (PSISs) and tracked with a rigid cluster plate mounted on the sacrum. In order to track thorax motions, we adopted a protocol similar that used by Leteneur *et al.* [1] in which this segment is defined using markers on the greater trochanters and the acromions and tracked using markers on the jugular notch and 2^{nd} and 8^{th} thoracic vertebrae [11]. A 6DOF model was used in Visual 3D to calculate pelvic and thorax orientation in the laboratory coordinate system as well as hip angle. For each subject, an ensemble average was calculated, across a minimum of seven trials, for each joint/segmental angle in both the sagittal and frontal planes. Data for hip kinematics are presented for the side most affected by pain in the group with OA and a matched side for the control group.

An independent t-test statistical parametric mapping (SPM) approach was used to investigate potential differences in joint angles, across stance phase, between the two groups. With this approach, a scalar output statistic (SPM{t}) is calculated across the trajectory. If this statistic exceeds the critical threshold (shown as a horizontal dotted line in Figures 1-3) at any time node, the null hypothesis is rejected. Regions in which this threshold is exceeded are termed, “supra-threshold clusters” and cluster-specific p-values derived. All SPM analyses were implemented using the open-source spm1d code (v.M0.1, www.spm1d.org) in Matlab [14].

Results

On average, trunk flexion in the sagittal plane was 2.5-3° larger in the people with knee OA compared to the healthy control group (Figure 1). Although differences were most pronounced during early stance, the SPM analysis identified a single supra-threshold cluster (p=0.002) over the whole of stance phase (Figure 1). There were no other statistically significant differences in the sagittal plane (Figures 2 & 3). We did not observe any differences between the two groups in frontal plane kinematics for either the trunk, pelvis or hip (Figures 1-3).

FIGURES 1-3 HERE

Discussion

Our data showed that people with knee OA walk with an average of 2.6° more trunk flexion when compared to healthy individuals. The magnitude of this difference is consistent with the data of Turcot *et al.* [10], who observed an average of 2.2° more trunk flexion in their two OA groups (valgus and varus) in comparison to healthy controls, and the data of Hart et al. [8], who observed 3.4° more trunk flexion in their OA group. However, neither Hart *et al.* [8] nor Turcot *et al.* [10] found a significant difference, presumably because of a the large variability in trunk flexion across their participants. For example, Turcot et al. [10] observed an SD of 7-8° across their two groups with knee OA which is considerably higher than the corresponding variability in our data (Figure 1). It is possible that this increased variability could have been the result of the marker set used. While Turcot et al. [10] used a Vicon Plug-in-Gait model, we used a marker set found to be optimal for tracking the thorax [11].

Our finding of a difference in trunk flexion appears to contrast with the findings of Naili *et al.* [9] who observed no differences between people with knee OA and healthy controls. However, they reported on range of movement rather than mean across the gait cycle and their control group walked approximately 20% faster than their OA group. As trunk flexion is likely to be influenced by

gait speed [15], this may have masked a true difference between the groups. Following their systematic review, Iijima et al. [16] concluded that biomechanical alterations of the trunk in the sagittal plane in people with knee OA were not evident from previous research. In contrast, our data support the idea that increased trunk flexion in walking could be a clinical hallmark of people with knee OA, provided that walking speed is appropriately matched between groups and an appropriate marker set used.

In a previous study, Leteneur *et al.* [1] divided healthy individuals into two groups based on their trunk flexion angle during walking. Interestingly, the forward-lean group, who walked with 4.6° higher trunk flexion, exhibited a prolonged hip extensor moment throughout stance. This finding, of a prolonged hip moment, was also observed by Liu et al. [4] in a cohort of people with knee OA. In a recent study, we observed a decrease in hamstring activity following neuromuscular re-education in people with knee OA [5]. It is possible that these differences in hip moments [4] and changes in muscle activity [5] were related to alterations in trunk flexion during walking. As such, our findings motivate further research investigating the links between trunk flexion and lower limb moments/muscle activity in people with knee OA.

The inclusion criteria adopted for this study did not differentiate between medial/lateral knee OA or between different grades of radiographic severity. Therefore, it is not clear whether trunk flexion is consistently increased across different subgroups of people with knee OA. Further work is required to understand whether such differences may exist.

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Figure 1

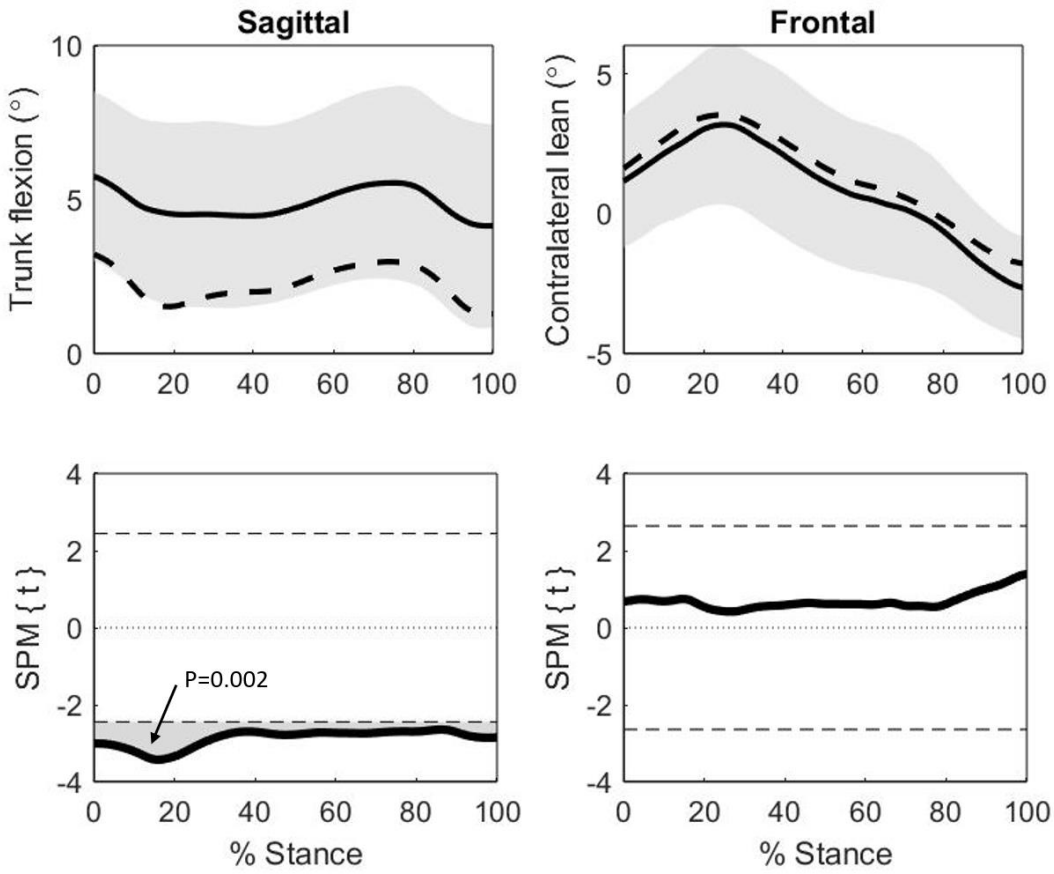

Figure 1: Mean trunk flexion (sagittal plane) and contralateral trunk lean (frontal plane) across the participants with knee OA (solid) and healthy group (dotted). The shaded area in the upper panels indicates one SD in the group with knee OA. The bottom panels show the statistical parametric maps for the corresponding trunk data with shaded areas indicating a difference between the two groups. The critical threshold (horizontal dotted line) in the bottom panels was set with an $\alpha = 0.05$.

Figure 2

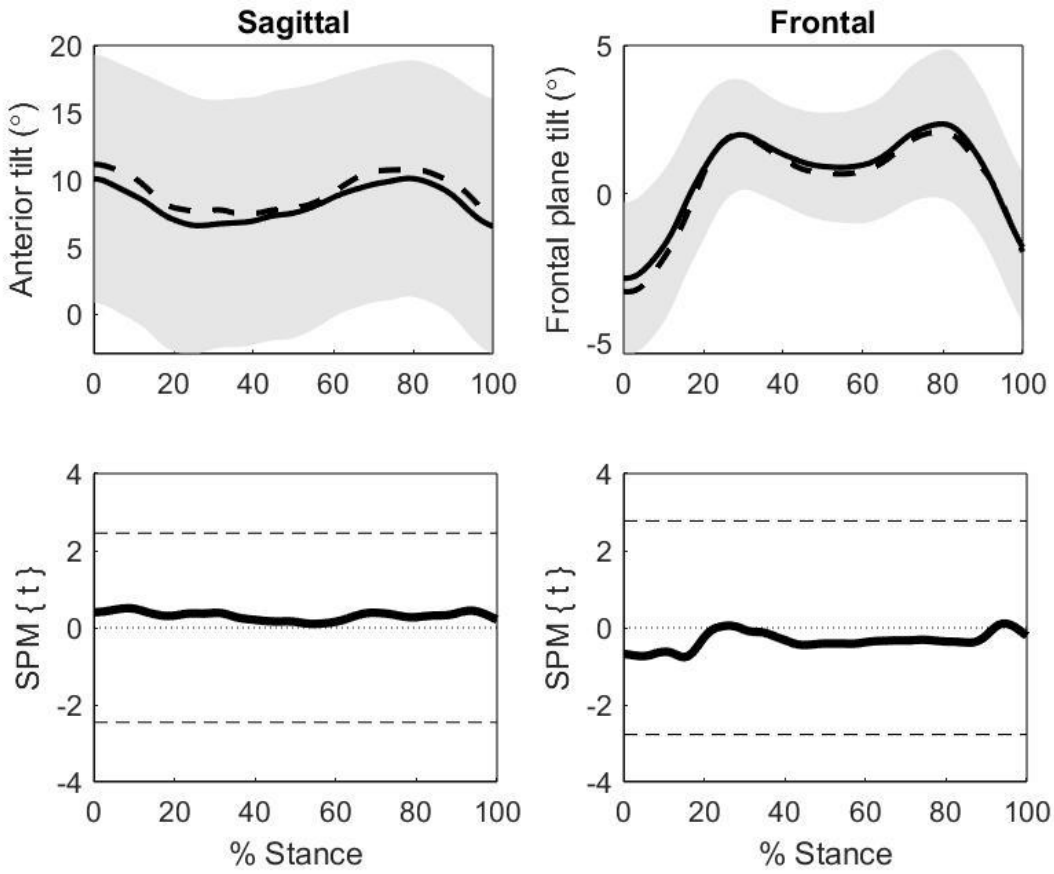

Figure 2: Mean anterior pelvic tilt (sagittal plane) and frontal plane pelvic tilt (up = positive) across the participants with knee OA (solid) and healthy group (dotted). The shaded area in the upper panels indicates one SD in the group with knee OA. The bottom panels show the statistical parametric maps for the corresponding pelvic data. The critical threshold (horizontal dotted line) in the bottom panels was set with an $\alpha = 0.05$.

Figure 3

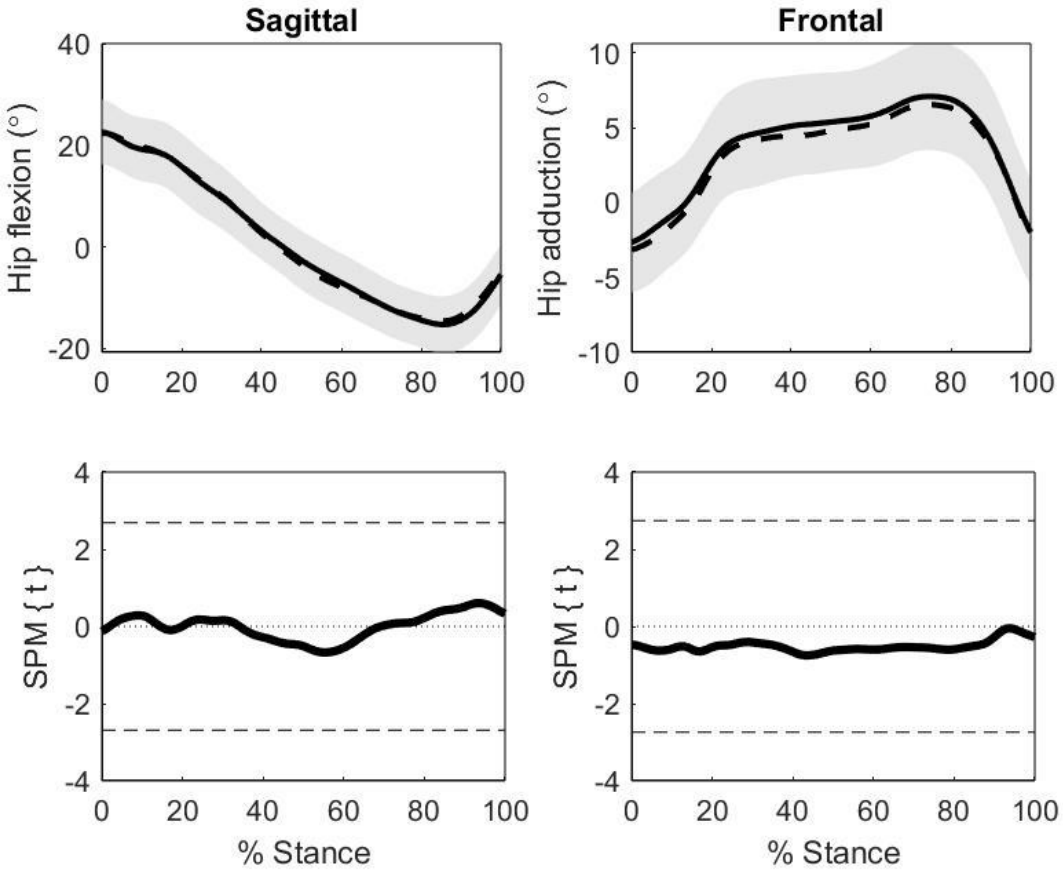

Figure 3: Mean hip flexion (sagittal plane) and hip adduction (frontal plane) across the participants with knee OA (solid) and healthy group (dotted). The shaded area in the upper panels indicates one SD in the group with knee OA. The bottom panels show the statistical parametric maps for the corresponding hip data. The critical thresholwd (horizontal dotted line) in the bottom panels was set with an $\alpha = 0.05$.