The Effects of Gender, Speed and Target Height on the Coupling of Spine and Hip Motions During Full Body Reaching Tasks.

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Introduction

Every day we perform reaching tasks that can be completed by combining an infinite number of movement patterns. When there are greater degrees of freedom (DOF) available than are required to complete a task, the problem of kinematic redundancy is introduced (Hasan, 1999). Our central nervous system (CNS) attempts to control for this abundancy of options by imposing rules to simplify complex multi-joint tasks (Bernstein, 1967). One possible control strategy addressed thoroughly in the literature involves the scaling of torques produced by upper extremity segments while completing a multi-joint reaching task. Multi-joint tasks have more torques that must be factored into the planning of the movement, and the CNS coordinates shoulder and elbow movements so that control is simplified and redundant DOF are reduced. Coupling of spine and hip motions is thought to occur in a similar manner and kinematic patterns have been described during forward bend and forward reaching tasks. Although movement patterns of the spine and hip have been identified, conclusive evidence explaining how the CNS simplifies the redundant DOF available during unconstrained tasks is lacking in the spine and hip literature.

The purpose of this study was to investigate the effects of specific variables on the S/H ratio during forward reaching tasks. In this study we hypothesize that gender and target height will have an effect on the S/H ratio, however the S/H ratio will be invariant relative to the speed of movement.

Methods

Sixteen healthy individuals, 8 men (M= 25.25 $\pm$ 3.99) and 8 women (M= 23.63 $\pm$ 3.54), were recruited to participate. Experimenters used trunk length, hip height, and arm length to determine the target locations for each subject. In theory, the high target could be reached by flexing the hips 40 degrees with the shoulder flexed at 90 degrees, the elbow extended and no motion about the knees and ankles. The middle and low target heights could be reached in a similar manner by flexing the hips 60 and 80 degrees respectively. The Motion Monitor™ (MM™) was used to record motion of the lumbar spine and hip during full-body reaching tasks in the para-sagittal plane. Sensors were attached to the seventh cervical vertebra (C7), sacrum, and mid-thigh of the right leg by Velcro® straps. Lumbar spine motion was defined as the difference between the orientations recorded (for each instance in time) at the C7 and sacral sensors. Hip motion was defined as the sum of the orientations recorded at the mid-thigh and sacral sensors (Figure 1B).

Participants performed reaching tasks to three targets in the para-sagittal plane at comfortable and fast speeds. For each speed, subjects performed three trials at each target height and were given no instructions regarding the limb segment geometry to be used to complete the task. During the fast paced trials subjects were instructed to reach the targets in half the time of their comfortable paced trials.

Kinematic data was collected at 100 Hz for a total of 5 seconds. The initial joint angles were determined by averaging the data over a 100 ms window prior to the beginning of a movement trial. The final joint angles were determined by averaging the data over a 100 ms window following target contact. The change in joint angles from initial posture to target contact was the difference between initial and final angles. The spine/hip ratio was defined as the change in joint angle of the lumbar spine divided by the change in joint angle of the hip. The spine/hip ratios were analyzed with a mixed model ANOVA in which target height (40°, 60°, and 80°) and movement speed (comfortable and fast) were the within subject variables and gender was the between subjects variable.

Results

There was a main effect of movement speed on the spine/hip ratio ($F_{(1,14)}$=8.36, p<.05). As the speed of movement increased, the spine/hip ratio decreased (Fig. 5). Across all targets the mean spine/hip ratio was 1.51 for comfortable speeds and .95 for fast speeds. Figure 5 also illustrates that while target height was not a significant factor, there was a trend for the spine/hip ratio to decrease as the target height was lowered ($F_{(2,13)}$=3.14, p=.077). There were no main effects of gender on the spine/hip ratio.

A B

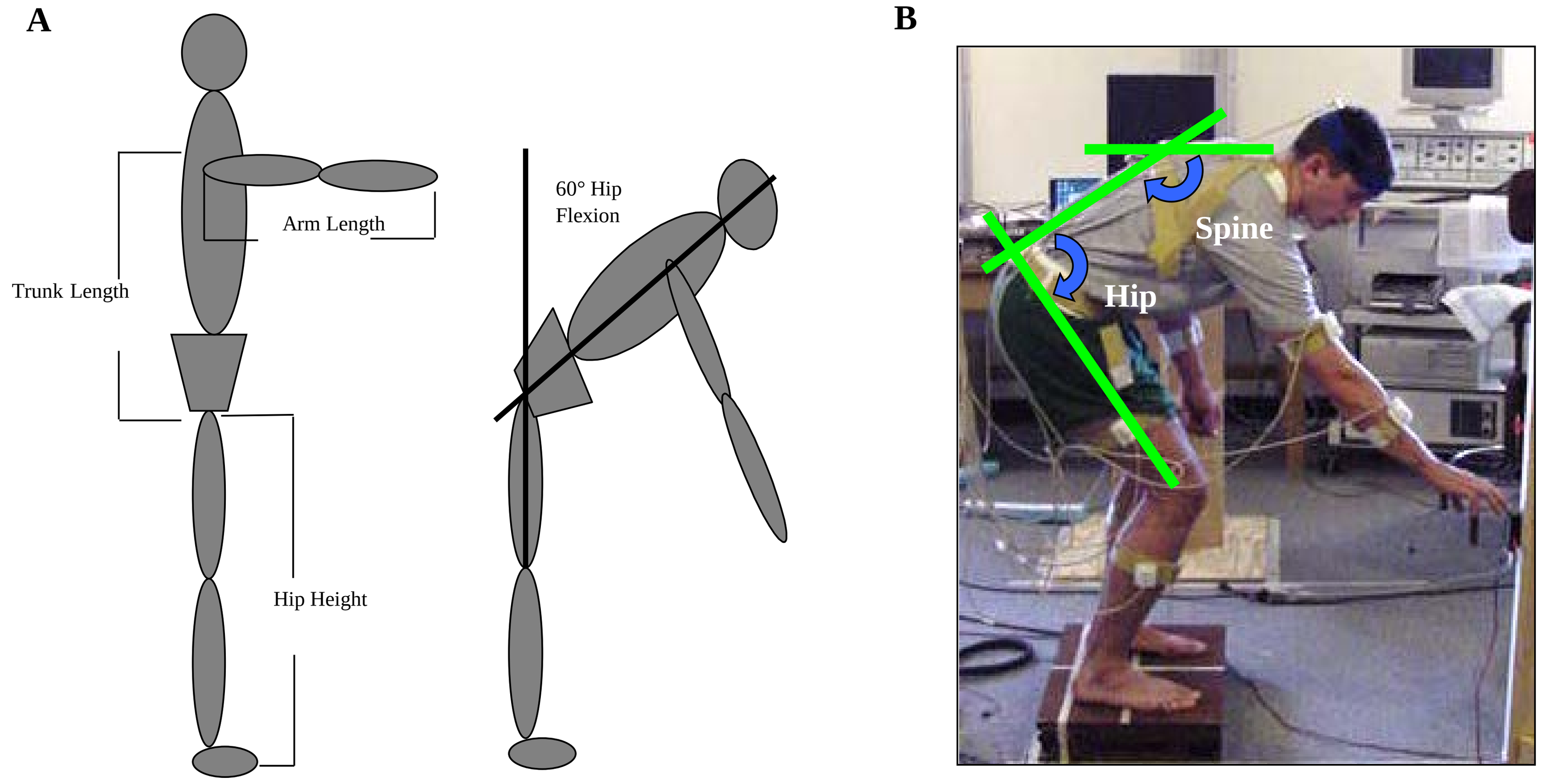

Figure 1. A) Target locations were determined from the subject's trunk length, arm length, and hip height. Subjects could reach Target 2, in theory, by flexing their hips 60° (with the elbow extended and the shoulder flexed 90°) without any motion of the ankle, knee, or spine. **B)** An individual subject reaching for Target 2 at a comfortable pace.

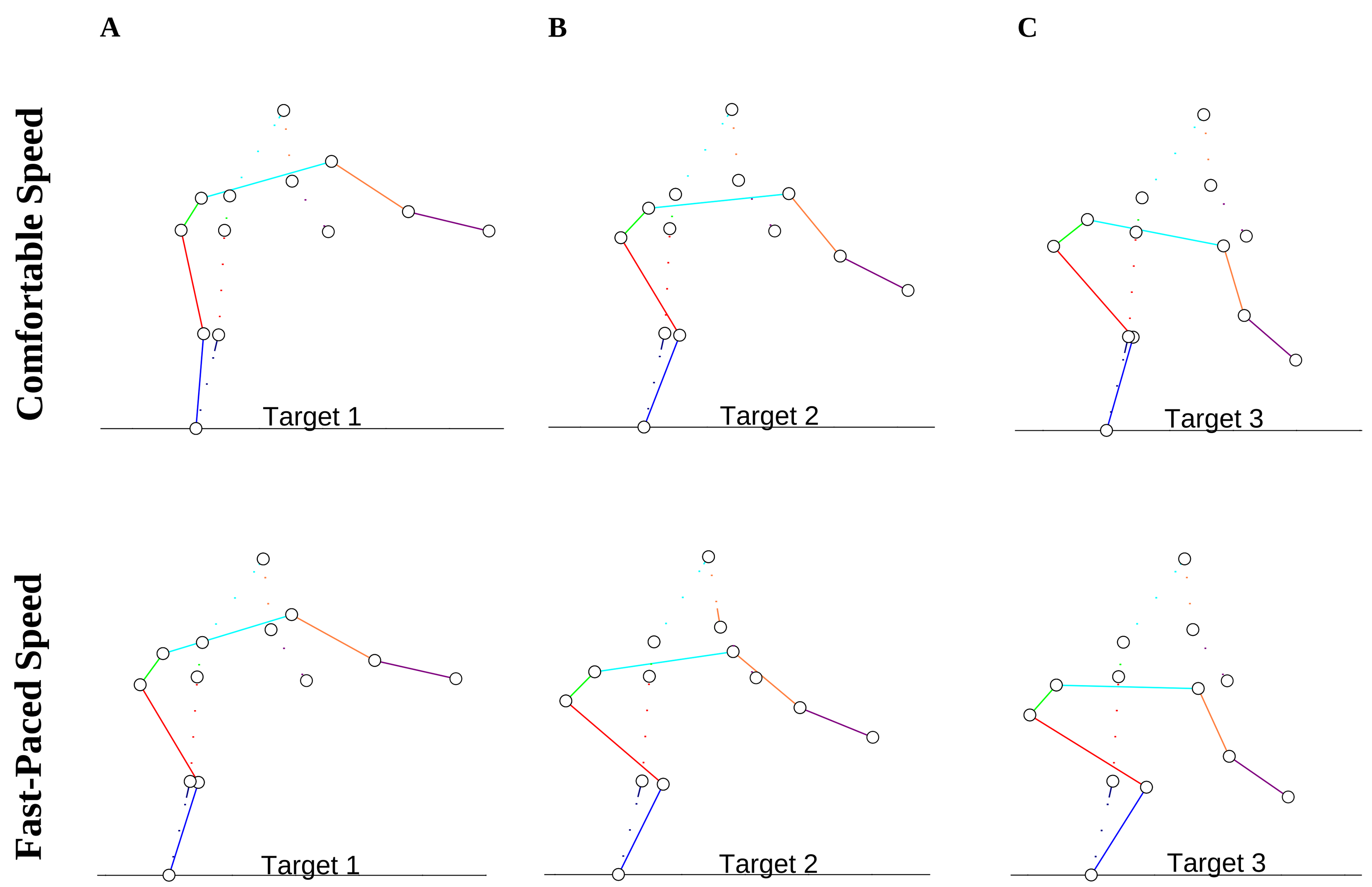

Figure 2. The effect of movement speed on segment excursions of the forearm, humerus, trunk, pelvis, thigh, and shank are illustrated by stick figures derived from the anthropometrics and time series segment orientation data from four individual subjects performing reaching tasks to each of the target locations at comfortable (top row) and fast-paced (bottom row) speeds. A) Target 1: 40° hip flexion B) Target 2: 60° hip flexion C)Target 3: 80° hip flexion.

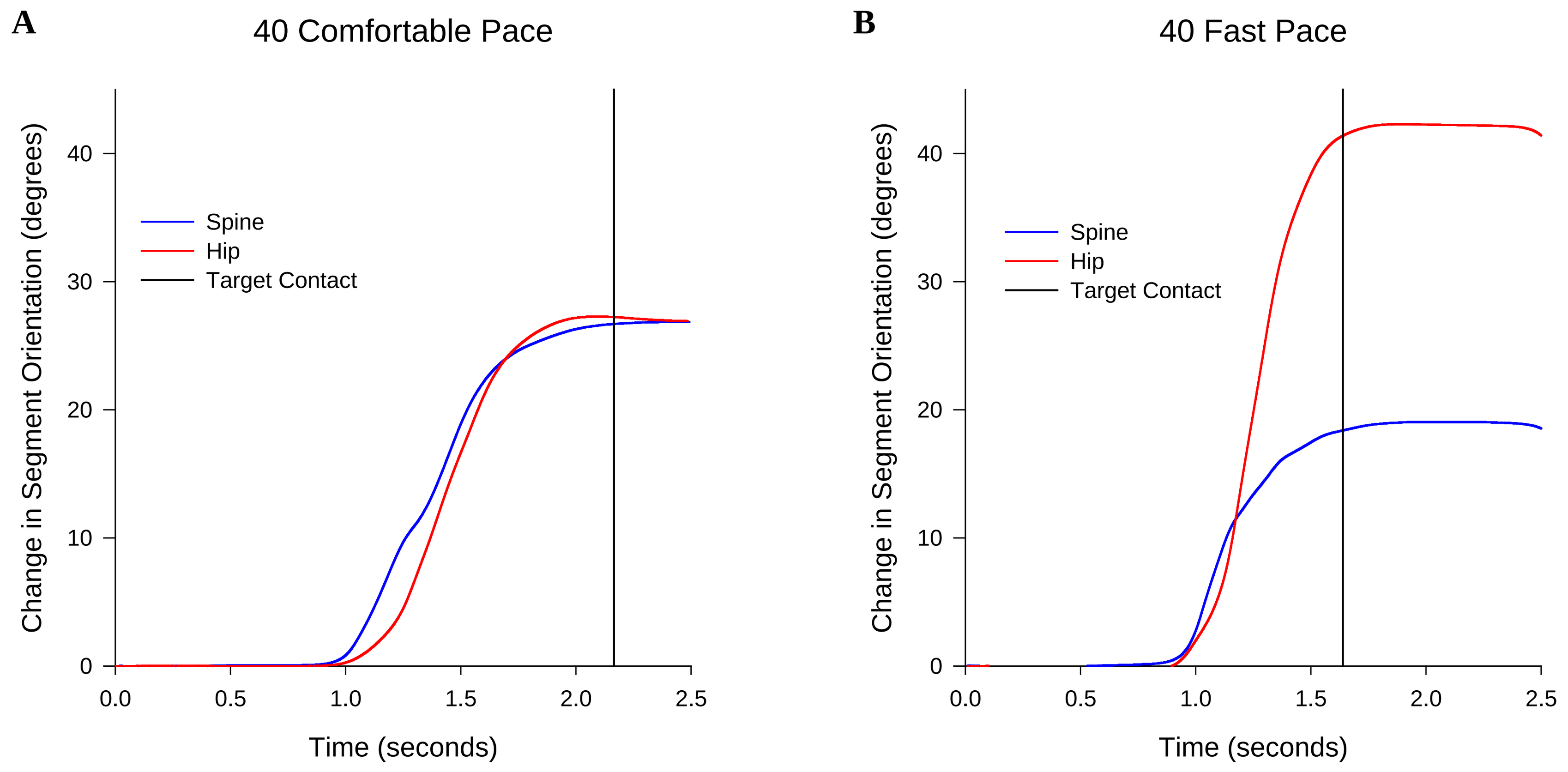

Figure 3. Time series data display the changes in the spine and hip orientations for an individual subject's reach to Target 2. A) At a comfortable pace. B) At a fast pace.

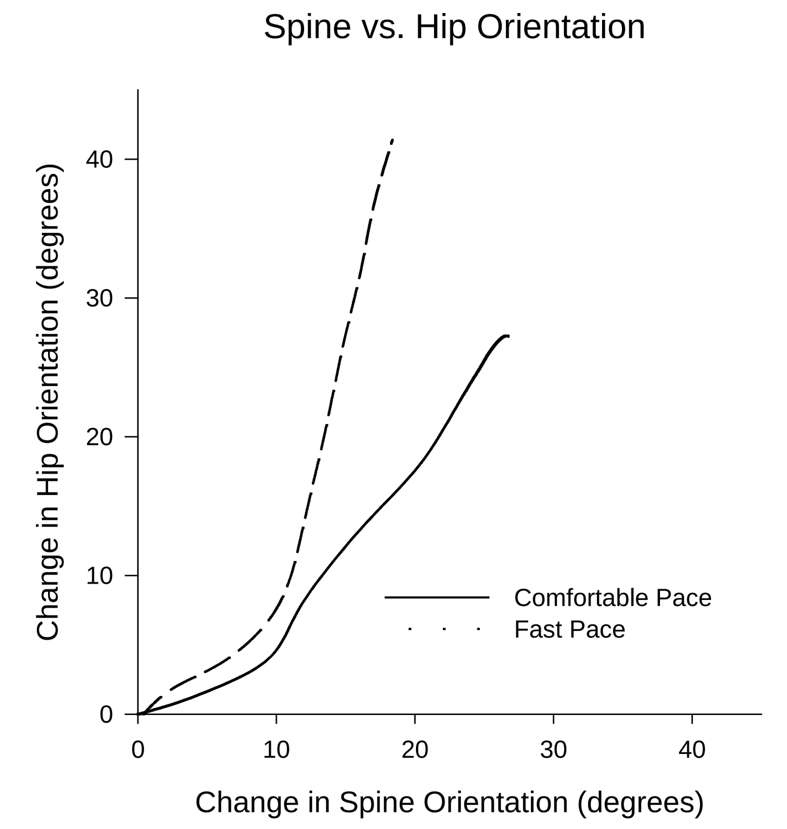

Figure 4. Changes in hip orientation plotted against changes in spine orientation for an individual reaching for target 2 at comfortable and fast-paced speeds.

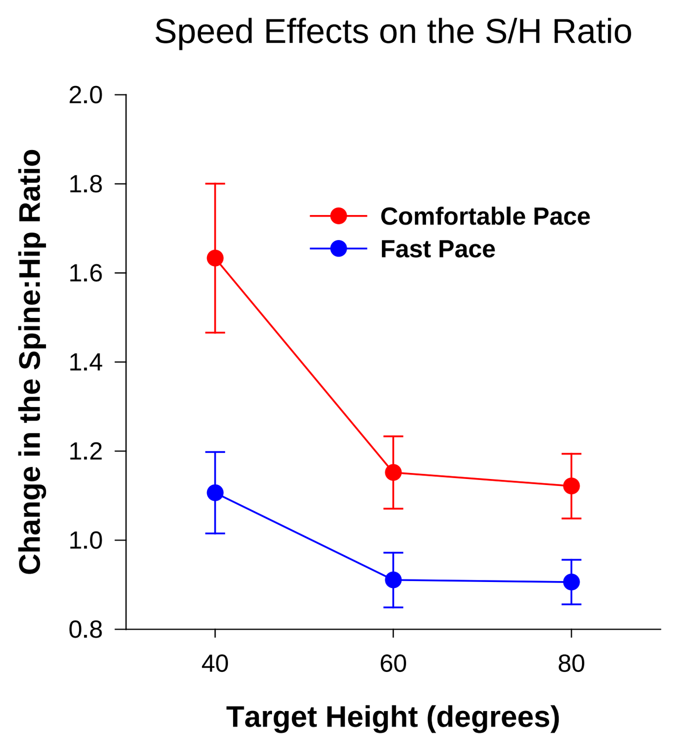

Figure 5. The change in the S/H ratio is displayed for all subjects at each target height for both comfortable and fast-paced speeds.

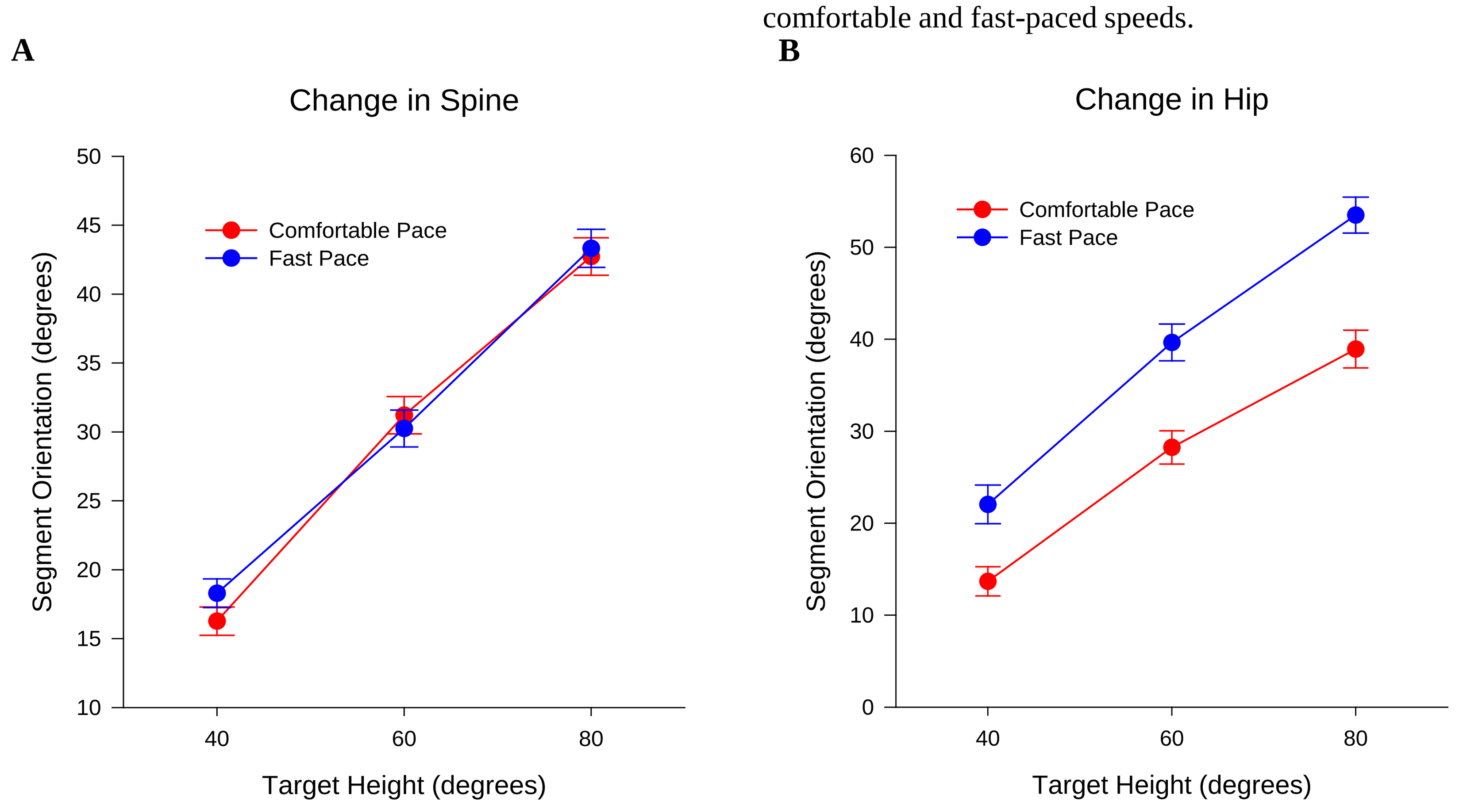

Figure 6. The mean contributions of individual segments that make up the S/H ratio are illustrated for for all three target heights and both comfortable and fast-paced speeds. A) The mean changes in spine orintation for all subjects. The mean changes in hip orientation for all subjects.

Conclusions

The results clearly indicate that the coupling of spine and hip motions change as movement speed varies. It may be the case that individuals with low back pain have altered coupling of the spine and hip that is only revealed when the task parameter of movement speed is varied. Additionally, it appears from these data that there is considerable variability in the coupling of the spine and hip motions for reaches to various target heights. This study provides baseline data for investigations of movement patterns of individuals with impairments of the lumbar spine.

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