# Investigating Behavioral Modes of Postural Control and Coordination

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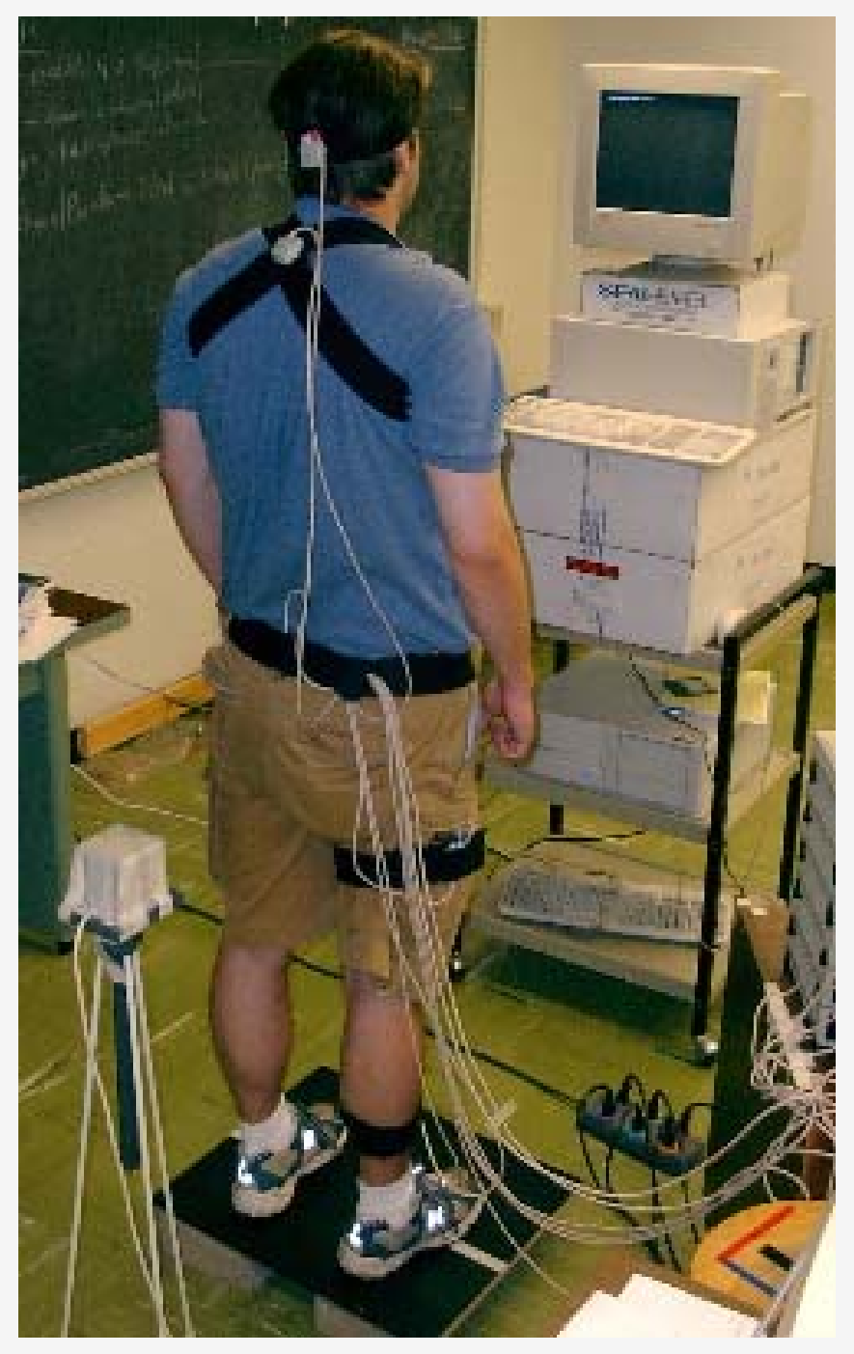
## Problem

Dynamic systems research typically examines postural control by disturbing posture and then observing how the system returns to its original state. The current study examines how people control their posture in the absence of such externally generated disturbances. Previous studies have examined postural coordination and have shown that postural sway is modulated in a task specific manner (Bardy, Marin, Stoffregen, and Bootsma, 1999; Marin, Bardy, and Bootsma, 1999; Bardy, Oullier, Bootsma, and Stoffregen (2002). However, this research has not examined postural coordination modes amidst multiple simultaneous constraints (e.g., task, environment). Our previous research has demonstrated that different coordination strategies, as measured by hip-ankle ratios, emerge as a function of support surface during quiet stance. In this study we manipulated both the surface of support (hard surface vs. foam roller) and suprapostural task (tracking frequency) in a *continuous* manner by ramping frequency up or down within a trial. In this experiment, we sought to determine the dynamical nature of coordinative strategies based on changing suprapostural task together with support surface.

## Method

***Participants:*** The participants were 12 right-handed Miami University undergraduate and graduate students (5 male, 7 female) from multiple disciplines. All participants had normal or corrected to normal vision and reported no history of musculoskeletal disorders.

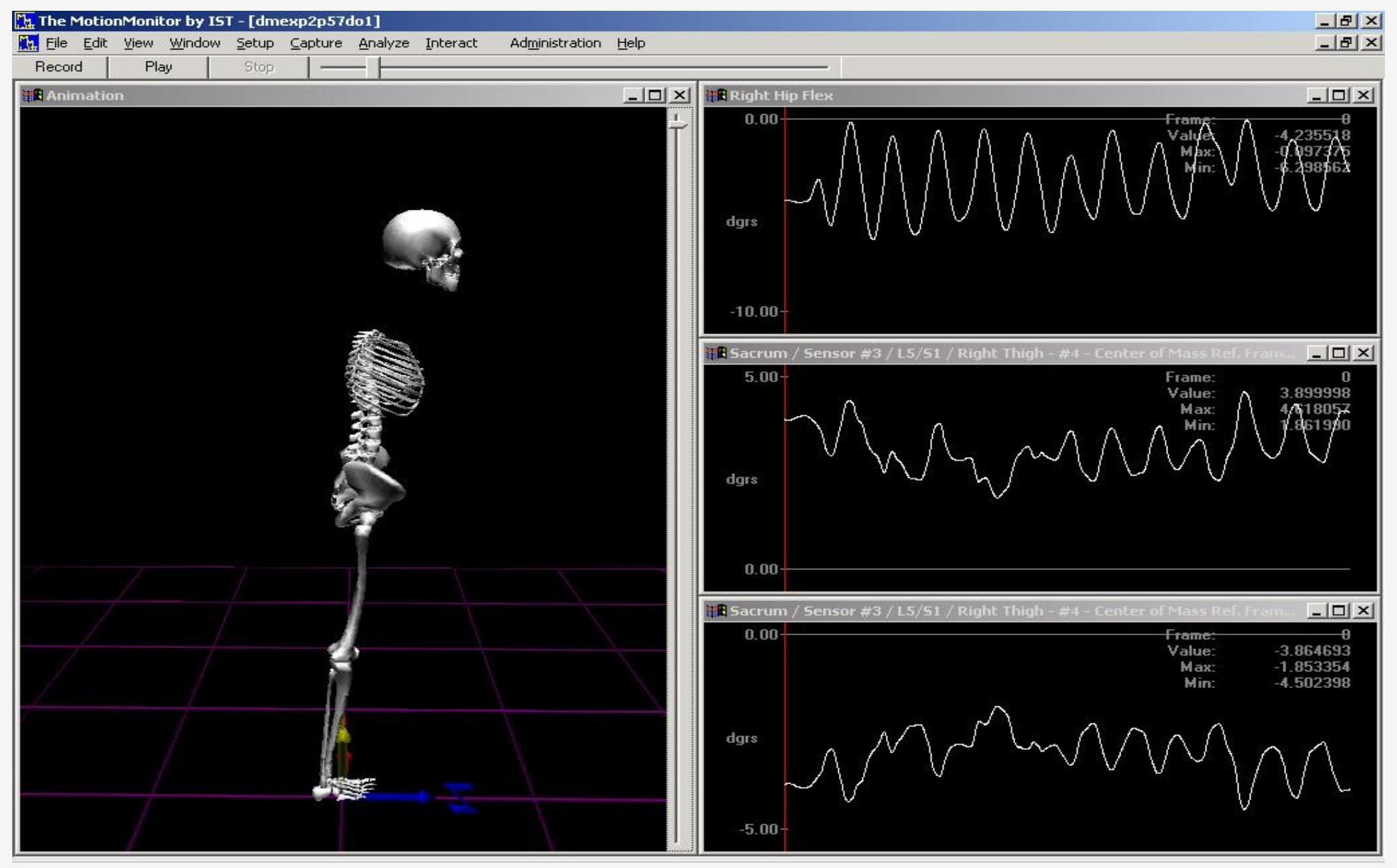
***Motion Tracker and* Software:** The body motion of the participants was obtained using a magnetic tracking system (Flock of Birds: Ascension, Inc.) recorded at 75 Hz. Six sensors were used: occiput, T1, S1 tubercle, right thigh, right tibia, right foot. The following points were digitized using a stylus; T12, hip joints, right knee, right ankle and the right second phalanx (foot).



***Task and Apparatus:*** Participants stood with their hands behind their back on one of two surfaces at a 1 m viewing distance from a computer monitor (15") at eye height (Figure 1, right). Participants were asked to track the fore-aft oscillations of a target that appeared on the computer monitor with their head. Room lights were left on. Displays depicted 200 randomly presented opaque dots (1x1 pixel) in a coronal plane that oscillated in projected space with a suggested peak-to-peak amplitude of 20cm. Two surfaces were employed in this study: a wide hard surface, (.56m x .46m x .11m), and a standard rehabilitation half-biofoam roller (.92m x .15m x 0.8m).

***Design/Procedure:*** The design/procedure was modified from Bardy et al. (2002). The frequency of target oscillation varied in two stepwise conditions (up or down). In the up condition, frequency increased in the following order, 0.16 Hz, 0.23 Hz, 0.31 Hz, 0.47 Hz, 0.54 Hz, 0.63 Hz and 0.75 Hz. All frequencies were viewed in a single trial. In the down condition, the order was reversed. Each frequency lasted 12 oscillation cycles. There were two trials per condition and participants were allowed a 5-min rest between trials. Participants performed both conditions on each of the 2 surfaces. Support surface and condition were counterbalanced.

***Data Acquisition and Analysis:*** Linear displacement in centimeters and angular displacement in degrees were recorded with Motion Monitor software. The software allowed for the reconstruction of a 3-D representation of participants kinematics.



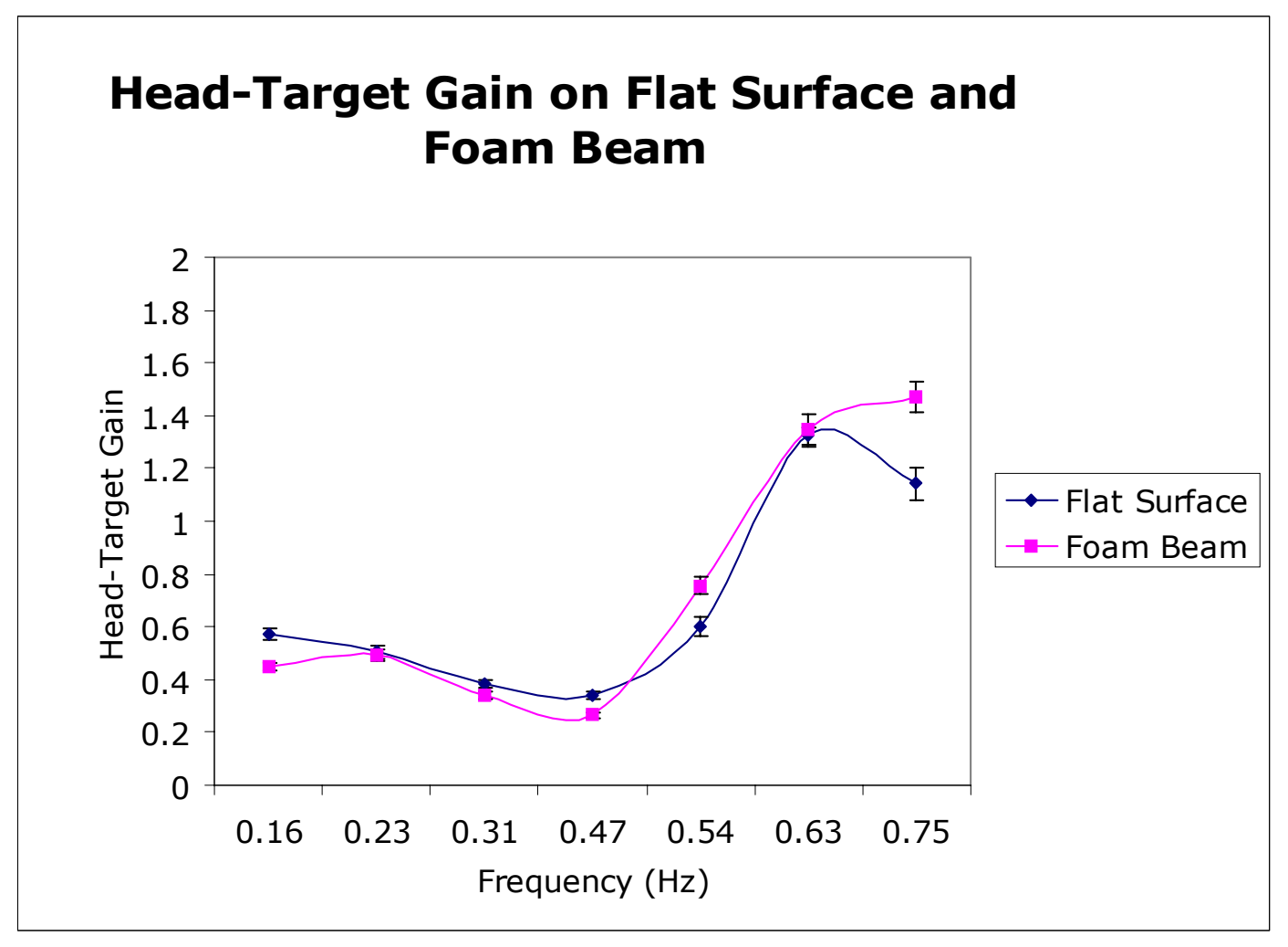
A custom built switch triggered the initiation of both the target and recording of postural movements to allow for the analysis of the tracking task performance (gain and phase angle). Angular measurements were formed based on projection angles and correspond to standard goniometric measurements as described in Norkin & White (1995). Only angular measures in the sagittal plane were analyzed.

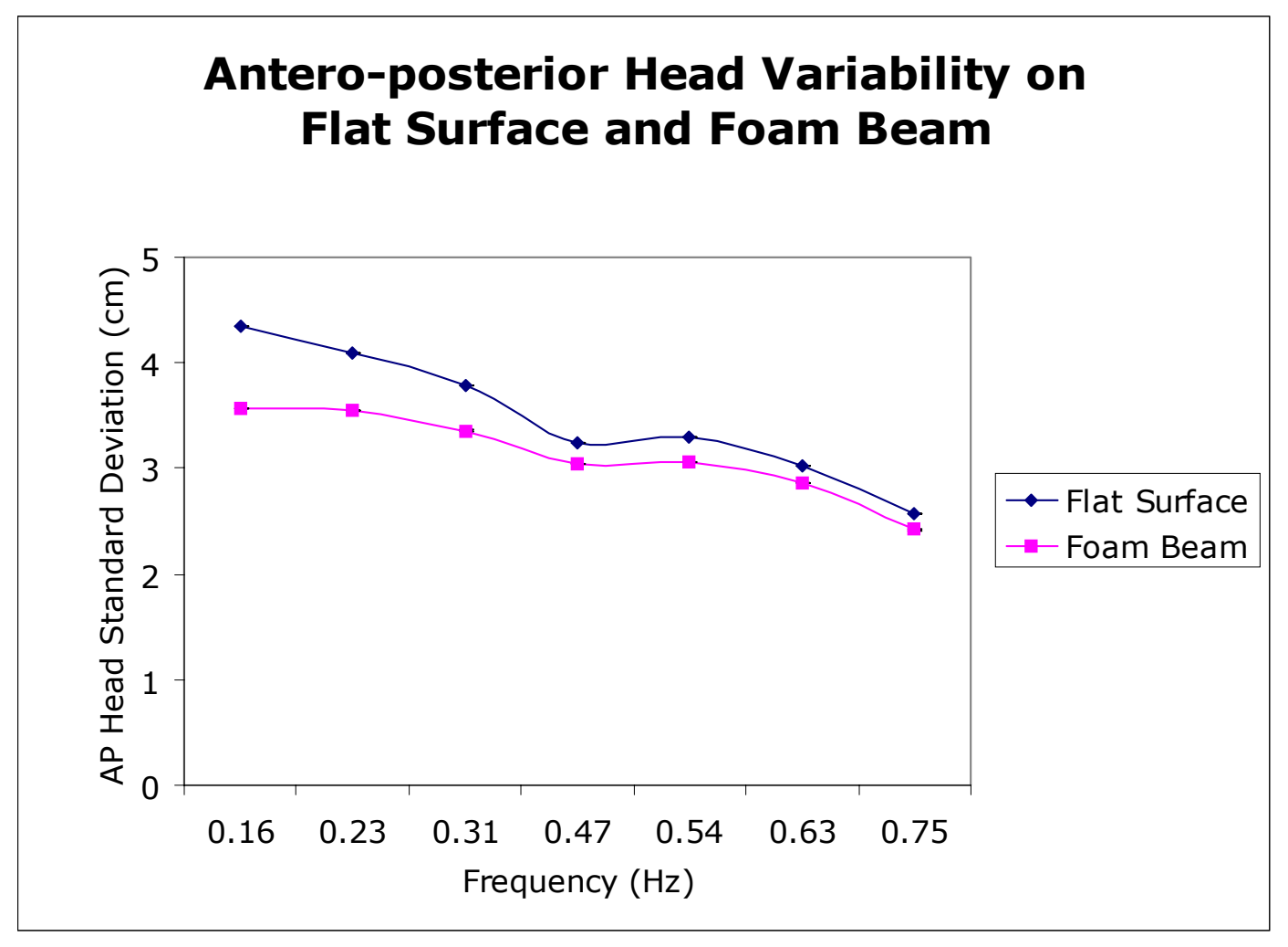
The following dependent variables were analyzed:

1) mean head-target gain at each frequency;
2) relative phase angle between the person's head movement and the target oscillation along the antero-posterior axis;
3) the hip-ankle angle variability ratio (a measure of coordination obtained by dividing hip sagittal angle standard deviation by ankle angle sagittal standard deviation);
4) the cervical-trunk angle variability ratio (procedure same as that for hip-ankle ratio);
5) the trunk-knee angle variability ratio;
6) the antero-posterior head movement variability.

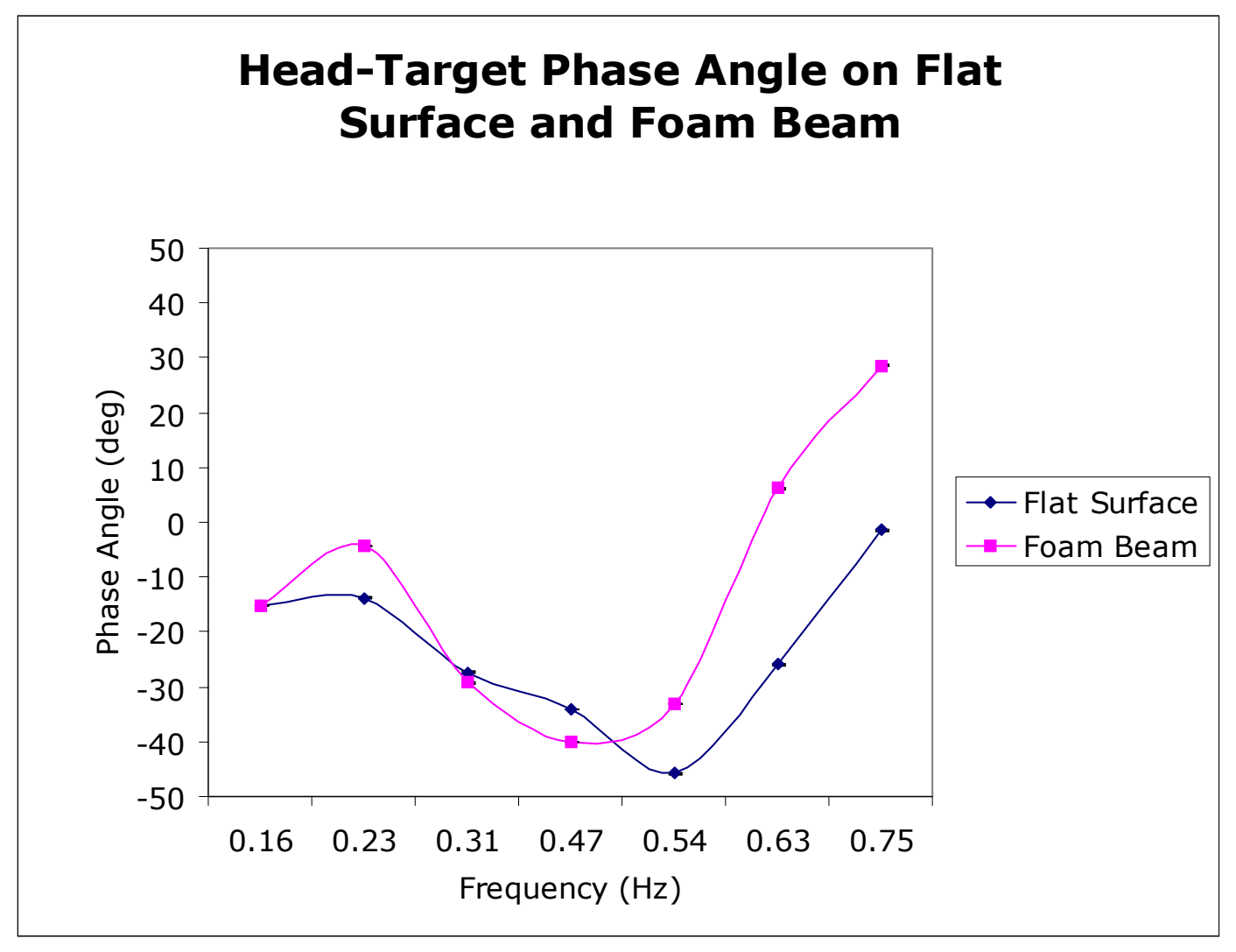
## Results

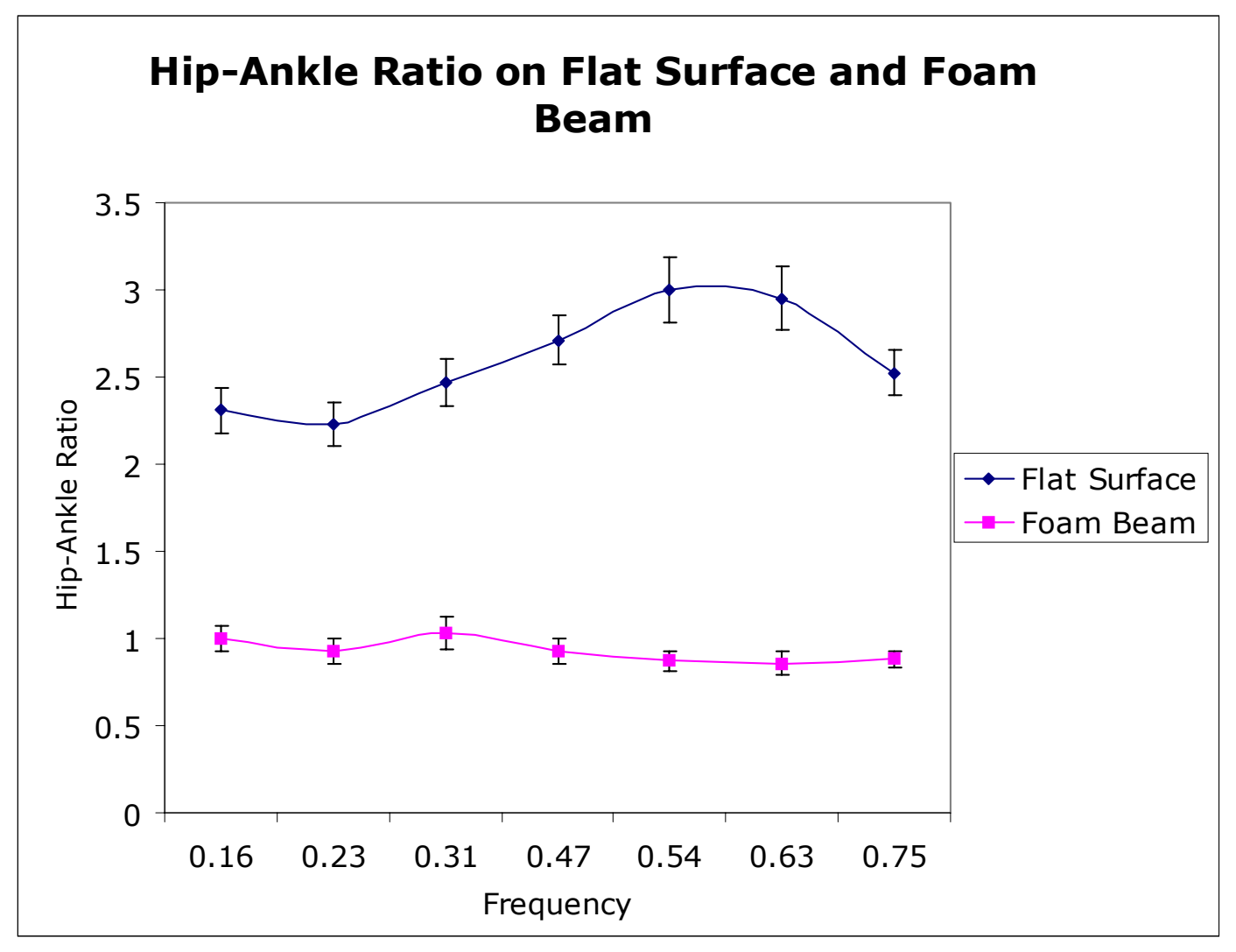
Task performance was measured by head AP movement gain and phase, along with AP head movement variability. Participants modulated the amplitude and variability of their AP head movements to the target frequency (Figures 2 & 3, below, left and right), with larger gain occurring at higher frequencies [F(6, 132) = 91, p<.05)] along with reduced head variability [F(6, 132) = 105, p<.05)] at higher frequencies. The mean head-target gain across frequencies for the flat surface was 0.70 and the average gain for the foam beam surface was 0.74.



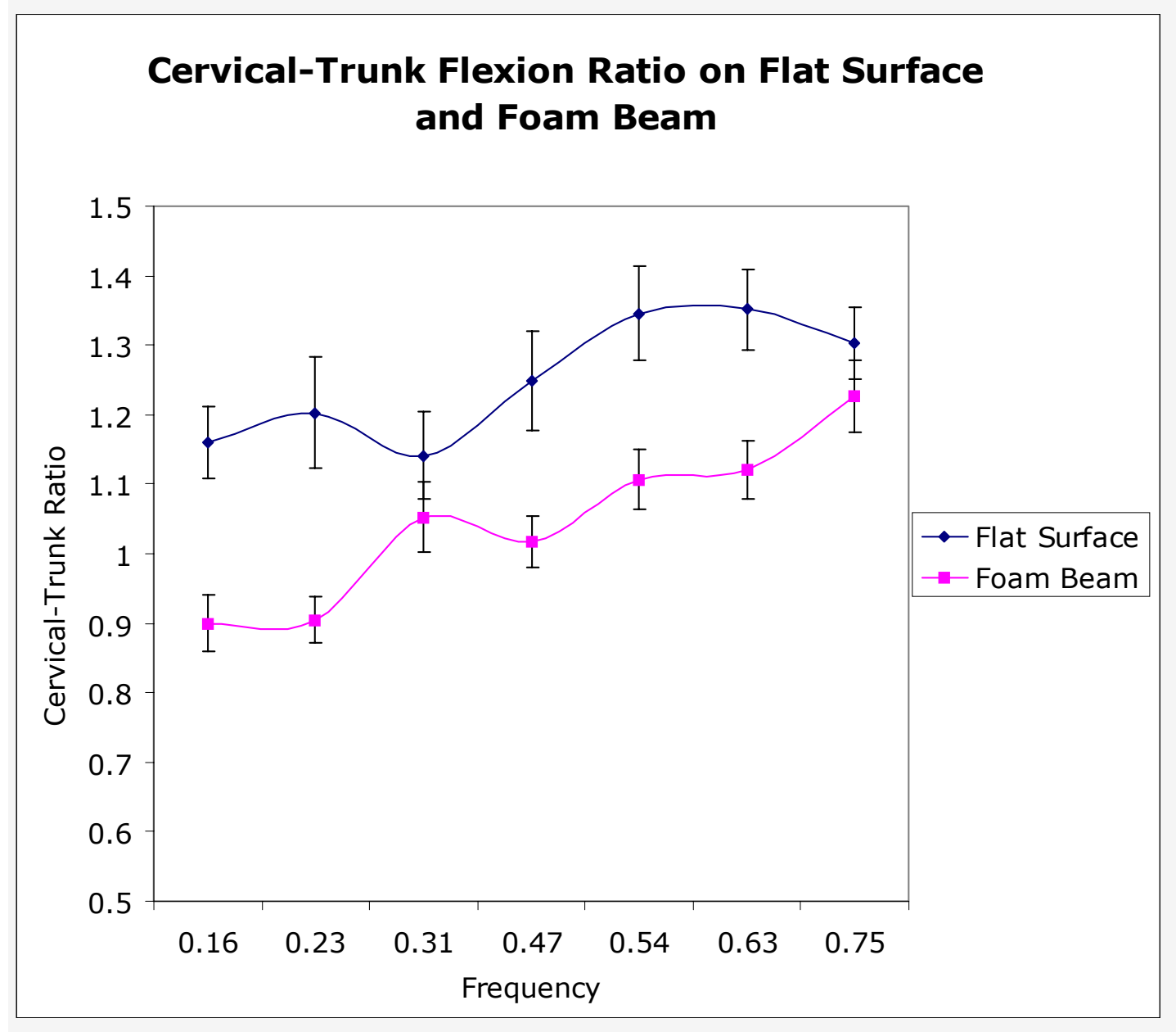


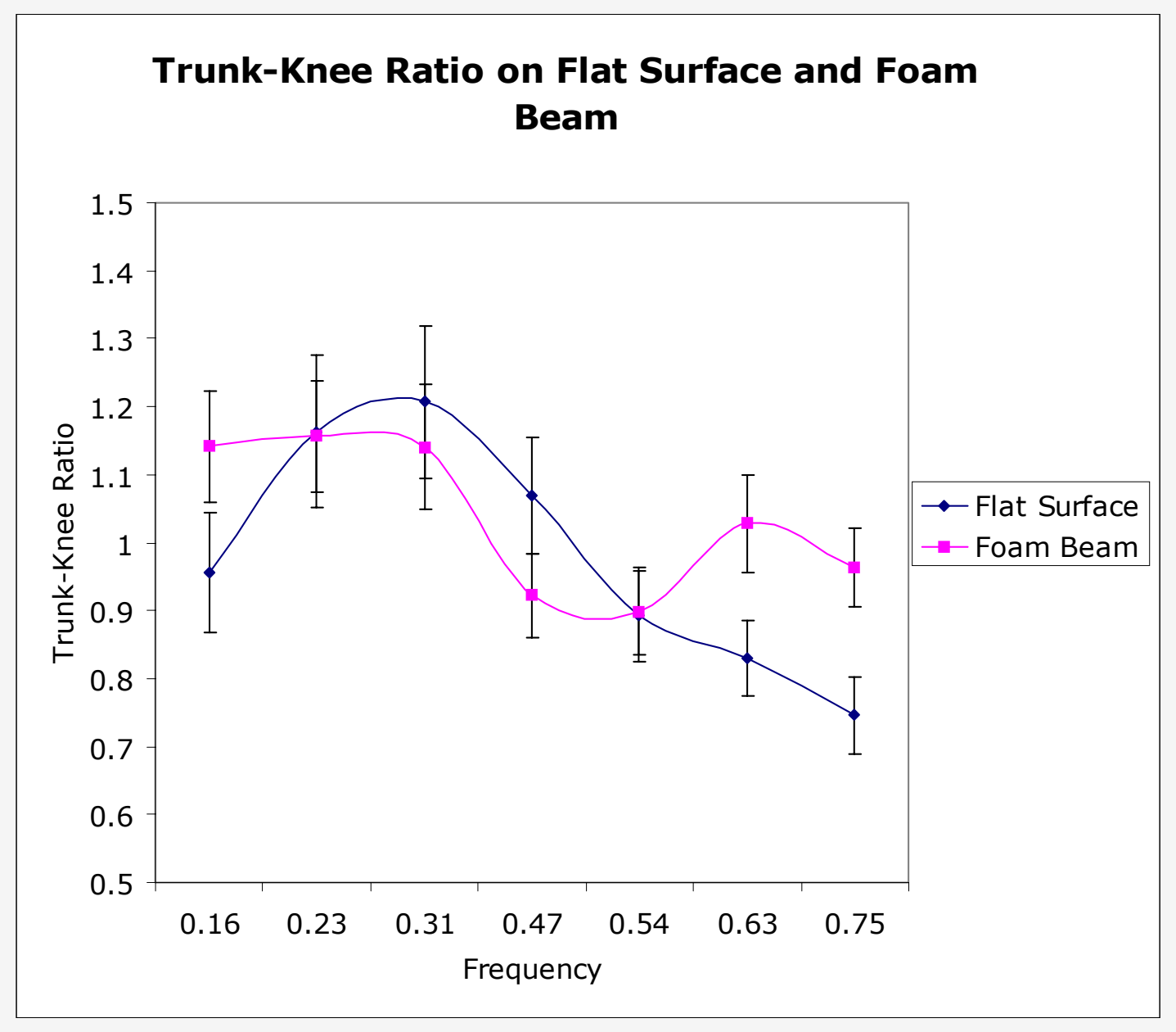
Both surface [F(1, 22) = 4.99, p<.05] and frequency [F(6, 132) = 5.4, p<.05] main effects existed for head-target relative phase angle (Figure 4, below left) indicating a phase lag for low to mid-range frequencies on both surfaces and a phase lead for the 0.75 Hz frequency on the foam beam. Inter-joint coordination was assessed by joint angle variability ratios. These ratios allowed for the computation of a unit-less measure of coordination between the respective joints. Hip-ankle angle ratios (Figure 5, below right) discriminated performance across surfaces [F(1, 22) = 59.9, p<.05)] with the foam beam exhibiting steady low ratios (mean = 0.93, indicating slight ankle strategy) and the flat surface exhibiting high ratios (mean = 2.6, indicating hip strategy).





Cervical flexion-trunk flexion ratios (Figure 6, below left) were modulated according to both surface [F (1,22) = 4.84, p<.05] and frequency [F(6, 132) = 4.13, p<.05] with increasing ratios corresponding to higher frequencies and the foam beam having lower ratios than the flat surface at every frequency. Finally, trunk flexion-knee flexion ratios (Figure 7, below right) were modulated according to frequency [F (6, 132) = 3.86, p<.05] with lower ratios occurring at higher frequencies.





## Conclusion

Participants in this study accomplished the head tracking task with varying degrees of precision. Overall low head movement gain was realized at low frequencies with higher gain at higher frequencies. The pattern of AP head movement was similar for both surfaces providing converging evidence that people completed the task in the same manner despite dissimilar constraints. Although the pattern of AP head movement is similar across surfaces, inter-joint coordination modes were vastly different. It appears that to accomplish the task of AP head tracking, different degrees of freedom were mobilized specific to the imposed constraints. Further, in order to understand how the body can accomplish the global behavior (e.g., head tracking) during a postural task, it appears necessary to examine the flexibility of its apparently softly-assembled degrees of freedom. These degrees of freedom can be characterized for example by inter-joint coordination (behavioral modes). Interestingly, participants in this study seemed to employ an 'ankle' strategy on the narrow beam, and a 'hip' strategy on the flat surface. This is contrary to predictions made by Nashner and McCollum (1985). This also seems to contradict the finding of Bardy and his colleagues (1999), however, the hip-ankle ratio presented here and the relative phase analysis performed by Bardy et al. (1999) may be reflecting different aspects of the same coordinative structure. Further analysis will hopefully reveal the relation between these measures as well as reconcile our results with the existent literature.

## Acknowledgment

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