Energy Expenditure and Muscular Activation Patterns through Active Sitting on Compliant Surfaces
Rachel Surowiec, Henry Wang, Andrea Hite and D. Clark Dickin
Biomechanics Laboratory – Ball State University, Muncie, IN, USA
email: rksurowiec@bsu.edu

INTRODUCTION
Modifications to various sitting surfaces have been made as a means to influence muscle recruitment levels and potentially influence energy expenditure through increased instability [1]. Replacing an office chair with an exercise ball or an air cushion may be helpful in increasing activity in the workplace [2]. However, the effects of sitting on an air cushion on energy expenditure and levels of muscle activation have not been quantified.

Active sitting is a concept that applies primarily to sitting surfaces that allow movement. The premise of active sitting is to permit or encourage the seated occupant to move [3]. Although active sitting can be performed on a stability ball or on an air cushion placed on a chair, it is not generally considered suitable to use a stability ball as a seating surface in many situations (e.g., at the office, in waiting areas). As such the purpose of the study is twofold, first to determine the levels of caloric expenditure using a direct measure of metabolic function and secondly to compare levels of muscle activity between an active sitting cushion, a stability ball and a firm sitting surface.

METHODS
Eleven healthy female subjects (age= 20 ± 1.8 yrs; height=167.27 ± 6.48 cm; weight=67.14 ± 9.22 kg) were recruited for the study. All subjects had a body mass index (BMI) of less than 30 kg/m². All subjects were able to sit for three, 10-minute sessions while maintaining an upright posture. Additionally, each participant completed an informed consent document outlining the experiment that was approved by a university Institutional Review Board.

To determine the level of muscular activity and metabolic cost of active sitting, three different task conditions were measured. The three tasks included 1) sitting on a flat surface, 2) sitting on an Automatic Abs air cushion (Licensing Services International, Philadelphia, Pennsylvania) and 3) sitting on a stability ball (Power Systems Inc, Knoxville, Tennessee). The three conditions were assigned in random order and each lasted 10-minutes with a 5-minute break between conditions to permit a rest period and to prepare for the next sitting condition. All conditions were performed within the same day with the entire session lasting approximately 90 minutes.

Muscle activity was measured at one minute intervals throughout each 10-minute condition for a period of 10 seconds using a Delsys EMG system (Delsys Bagnoli Desktop EMG System, Boston, Massachusetts). Each subject had 6 pairs of surface EMG electrodes (Delsys DE-2.1 Single Differential EMG Electrode, Boston, Massachusetts) (inter-electrode distance: 1cm) attached to the external oblique, rectus abdominus, erector spinae, adductor longus, soleous, and tibialis anterior on both the right and left side of the body. The EMG signals were amplified (gain=1000, CMRR >92dB) and were collected at 2400 Hz. VICON Workstation 5.0 (Vicon, Denver, Colorado) was used to capture the raw EMG signals. Root-mean-square (RMS) was calculated for each muscle for the 10, 10-second trials taken during each 10-minute sitting condition using a custom C++ program.

Energy expenditure was measured via open-circuit direct calorimetry using a Parvomedics (Sandy, Utah) metabolic cart. Heart rate was measured using a heart rate monitor (Polar Electro Inc. Lake Success, New York) and transmitted to a receiver on the metabolic cart. Average energy expenditure was calculated based on the rates of oxygen consumption and carbon dioxide production during the three, 10-minute sitting tasks with sampling occurring every 30 seconds.

Using measures of direct calorimetry the effect of sitting surface (i.e. stability ball, cushion, flat) on energy expenditure, a one-way RM-ANOVA was
performed. To assess the effect of sitting surface on muscular activity a $6 \times 3$ (Muscle $\times$ Surface) RM-ANOVA was used. Follow-up pairwise comparisons were performed, where appropriate. For all tests the significance level was set at $P \leq 0.05$.

RESULTS AND DISCUSSION

Energy Expenditure: Mean values for the measure of energy expenditure (collected at 30 second intervals over the course of ten minutes of sitting) were $12.64 \pm 1.69; 12.55 \pm 2.11; 11.45 \pm 2.42$ kcal for the ball, cushion and flat surface, respectively, which resulted in significant differences between the three surfaces ($P=0.02$). Follow-up comparisons revealed that caloric expenditure on the flat surface was less than either the ball ($P=0.01$) or the cushion ($P=0.03$) with no significant difference between the ball and cushion ($P=0.84$).

Muscle activation: Measures of muscle activation revealed a significant effect for surface ($P=0.001$) and muscle ($P<0.001$). However, the higher-order interaction effect of surface and muscle was also significant ($P=0.001$), indicating that the individual muscles were impacted differently by the various sitting surfaces. Figure 1 illustrates the interactive effect in that the upper body musculature (i.e. rectus abdominus, external obliques, erector spinae) were not impacted differently by the three sitting surfaces, while, lower body musculature (i.e. adductor longus, soleous, tibialis anterior) demonstrated differential effects across the three sitting surfaces.

The cushion demonstrated increased levels of activation for the adductor when compared to the ball and flat conditions while the soleus resulted in higher activation levels for the ball over either the cushion or the firm surface. Finally, both the ball and cushion demonstrated increased activation over the flat surface for the tibialis anterior muscle.

The findings from this study demonstrated an increase in caloric expenditure as well as increased muscle activation in certain muscles when sitting on an exercise ball or an air cushion over that of a flat non-compliant surface. This finding suggests that sitting on a stability ball or air cushion does promote “active” sitting involving frequent postural adjustments that increase caloric expenditure likely through the measured increases in muscular activity. Although sitting on an exercise ball or an air cushion expended more calories than the non-compliant flat surface, there was difference between the two compliant surfaces tested.

CONCLUSIONS

The findings from this study demonstrated increased energy expenditure and increased levels of muscle activation when sitting on a compliant surface over a firm and stationary surface. These results extend findings from studies using an exercise ball to suggest that similar results can be achieved using a more discreet sitting alternative to a large air-filled ball. Although the difference in caloric expenditure was relatively small over the course of the 10 minutes of sitting, the cumulative level becomes considerable when extrapolated over the course of the average work day and beyond.

REFERENCES