BREAKING SEDENTARY BEHAVIOR: ACOUSTIC VS. VIBRATIONAL STIMULATION

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ABSTRACT

This study objectively assessed the differences in physical activity responses to acoustic stimuli, vibrational stimuli and both (acoustic and vibrational) stimuli. Seven participants (average age: 47.9 ± 9.5 years, average Body Mass Index (BMI) 27.9 ± 5.3 kg/m²) completed the 4-stage (12 work-day) study that examined their physical activity response to various stimuli. Participants completed a control stage, acoustic stage, vibrational stage, and combination (acoustic and vibration) stage, each consisting of 3 work-days wearing an activity tracking device and a stimulus administering device for a minimum of 8 hours. During each stage participants wore two wrist-worn devices, an Actigraph GT9X (Actigraph GT9X Link, Pensacola, Florida, USA) which is a triaxial accelerometer used to measure steps, and a VibraLITE watch (VibraLITE Mini, Oakland Park, Florida, USA) used to administer the stimuli. The Actigraph was worn on the non-dominant wrist and the VibraLITE watch on the dominant wrist continuously during the work-day. Participants also received a daily activity log to record whether they sensed the stimulus as well as if they responded to it. A repeated measures ANOVA test with post-hoc comparisons was completed with the IBM SPSS statistical software to analyze any significance among the control stage, vibrational stage, acoustic stage, and combination stage. No statistical significance was observed for steps during the work-day for any of the stages as presented in control vs. vibration (18,289 ± 6497 vs. 17,982 ± 7007 steps/work-day, p=1.00), control vs. acoustic (18,289 ± 6497 vs. 15,927 ± 4548 steps/work-day, p=1.00), and control vs. combination (18,289 ± 6497 vs. 15,275 ± 5173 steps/work-day, p=.721). The results indicate that no stimuli or combination of stimuli significantly increased physical activity response. However, subjects noted feeling more aware of one stimulus over another during
specific activities. Therefore, specific stimuli may be better on a subject to subject basis or for certain activities/events.
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Chapter 1

Introduction

The purpose of the study was to objectively assess the differences in physical activity responses to acoustic stimuli, vibrational stimuli, and both (acoustic and vibrational) stimuli, in hopes of finding an effective stimulus to interrupt bouts of prolonged sitting. We hypothesized that the stage that incorporated the vibrational stimulus, whether only vibrational or vibrational with acoustic stimulation, would have the largest activity response. The vibrational stimulus was hypothesized to create the largest activity response because conditioning to noises from technologies such as cellphones, smart watches, smart TV’s, and interactive devices (Siri, Alexa) are abundant in daily life. Furthermore, the stimuli from these devices was what led the researchers to question if one stimulus would produce a larger response in physical activity compared to others.

We aimed to assess the benefit of acoustic and vibrational stimuli reminders on disrupting bouts of prolonged sitting among university employees during the workday. The stimuli were chosen for this study because of the lack of information on them in relation to their effects on sedentary time, physical activity and for their easy incorporation into everyday life. Sedentary time, and, more importantly, periods of prolonged sitting have been observed in most working adults daily schedule.\textsuperscript{[1]} Sitting time at work has increased in jobs involving desk work and is likely to be a larger contributor to overall sitting time for the day than sitting time during leisure activities.\textsuperscript{[5]}
Prolonged Sitting

Sedentary lifestyles incorporate low levels of physical activity with high levels of prolonged sitting. Prolonged sitting has been defined as bouts of sitting 30 minutes or more resulting in up to eight or more hours of the day.\(^\text{[1]}\) Multiple studies have focused on researching the negative effects of prolonged sitting and leading a sedentary lifestyle.\(^\text{[9]}\) Prolonged sitting has been identified as an intermediate cause of many health concerns and chronic diseases such as hypertension, diabetes, and obesity.\(^\text{[8]}\) Owen, et al, conducted a meta-analysis which observed the effects on metabolic health due to prolonged sitting.\(^\text{[1]}\)

Owen, et al, hypothesized that prolonged sitting in the context of daily leisure activities such as watching TV, sitting in automobiles, sitting at work, and general sitting time would be underestimated in studies that used self-reported measures (questionnaires).\(^\text{[1]}\) Based on the results from Owen, et al, the physiological changes that were observed to occur from too much sitting and not enough physical activity include: loss of contractile stimulation leading to a decrease in the amounts of skeletal muscle lipoprotein lipase (LPL) as well as chronic and metabolic diseases.\(^\text{[1]}\) LPL was used as a marker because of its importance in the proper uptake of triglycerides as well as its role in maintaining high-density lipoprotein (HDL) cholesterol production.\(^\text{[1]}\) Proper uptake of triglycerides allows for creating and maintaining energy as well as keeping a moderate low-density lipoprotein (LDL) profile. Furthermore, being able to maintain high levels of HDL allows the body to clear away the LDL from the arteries and prevent it from causing clots.\(^\text{[1]}\)

In a separate study, Cabanas-Sánchez, et al, focused on the elderly population and the effects of sitting time on cardiovascular mortality.\(^\text{[9]}\) They used self-reporting questionnaires to assess the physical activity of 2,657 participants from the age of 60 years old to 80 years old. The
participants were followed over a two-year span to observe changes in sitting time and the subsequent cardiovascular disease mortality. The results showed that 27.14% of the cohort were consistently sedentary while 30.71% were consistently not sedentary, meanwhile the other 42.15% showed no consistency in sedentary or activity time in their schedule. The active behavior was associated with reduced cardiovascular disease mortality as compared to the participants who were consistently sedentary. The findings of Cabanas-Sánchez, et al, were reported to be consistent with those in the literature. The findings from Owen, et al, and Cabanas-Sánchez, et al, aid in identifying the dangers of prolonged sitting and a sedentary lifestyle, while also encouraging the public to disrupt bouts of prolonged sitting.

**Physical Activity Interventions**

Studies such as those mentioned above have focused on how to measure the metabolic effects of sitting, however, the second half of the issue is to eliminate or at least disperse these bouts of prolonged sitting and reverse negative effects on the body. Rutten, et al, looked at how breaking long bouts of sitting into short bouts affected health. They found that by breaking long bouts of sitting into shorter portions by standing up and stretching, walking around, or other means of physical activity, the negative health effects were significantly lessened. Based on the lessened negative effects from the shortened sitting times, they created the acronym STUFF, meaning “Stand Up For Fitness”. STUFF is meant to remind people that bouts of sitting shouldn’t occur for longer than 30-minutes. After 30-minutes, people should incorporate some type of physical activity such as those that Rutten, et al, identified, or another which better suits
that person’s preference, for example, someone who was once a gymnast may prefer stretching over going for a walk.

Withagen and Caljouw\textsuperscript{[4]} took this idea of interrupting prolonged bouts of sitting by attempting to end the culture of sitting in the office by changing an office space to include fewer seats. The study focused on a conventional office space with chairs and desk the participants must sit in as well as a redesigned office space with standing desks and no chairs.\textsuperscript{[4]} The exclusion of these chairs and sitting areas in the redesigned office space forced the participants to stand more frequently. They found that the participants who used the nonconventional office space reported the workplace to feel more enjoyable and they felt more energetic, as compared to the participants who used the conventional space.\textsuperscript{[4]} On the post-intervention questionnaire, the participants in the nonconventional space also reported a significant increase in productivity, although subjects also reported their legs felt more tired at the end of the day.

**Actigraph Validation**

The activity monitoring device used in our study was an Actigraph GT9X triaxle accelerometer (Actigraph GT9X Link, Pensacola, Florida, USA). Triaxle accelerometers identify accelerations in all three planes of motion and can convert those accelerations into step counts. Therefore, these accelerometers are able to measure any changes in step count in response to a preset stimulus. The Actigraph GT9X devices have been previously validated to measure significantly accurate accelerations as shown by Shiroma, et al.\textsuperscript{[2]} Shiroma, et al, measured the accuracy of the Actigraph GT3X (the previous model) in three wear locations, each wrist (left and right) and the right hip.\textsuperscript{[2]} In general, they found that the counts were higher for the dominant wrist compared to the non-dominant wrist; however, both devices remained in the
same interquartile ranges. Interquartile ranges refers to the state of activity, meaning they registered the participant as running when they were running, and not running while they were walking. [2] Also the wrist worn devices measured increased counts compared to the hip worn device, but all devices measured the same activity curve once analyzed. Furthermore, they found no significant differences between men and women during the study, eliminating any gender bias. [2] Therefore, Shiroma, et al, recommended the use of wrist worn devices to be on the non-dominant wrist and to be worn for a minimum of six consecutive hours to observe the accurate accelerometer measured activity. [2]
Chapter 2

Methods

Participants

Eleven participants, aged 32 – 64 years old were recruited via email flyer and word of mouth for the study at Penn State University, Berks Campus. The target population were university employees, including faculty, and staff. This population was of interest because of the regularity of their work schedule as well as similarity to office workers who demonstrate sedentary behavior. When a participant responded to the email flyer or in-person meeting, he/she scheduled a testing session in order to obtain baseline measurements, receive the full briefing of the study, and collect the activity tracking devices. Prior to all recruitment and testing, institutional review board (IRB) approval was obtained: the identification for the present study is STUDY00003772.

Inclusion criteria to participate in the study included: participants being able to wear two wrist activity monitors (one on each wrist), being able to respond to each stimulus with physical activity, and participants had to be able to receive both acoustic and vibration stimuli. Therefore, any participants who had musculoskeletal disorders, hearing disorders, or other similar disorders were eliminated from the study. One participant was unable to participate in the study due to the duration of the study, while three others were excluded due to not following the schedule correctly resulting in incomplete data collection.
During the first meeting, study protocol was explained, informed consent was obtained, and baseline measurements were taken. Seven participants completed the full 12 work-day protocol. There were more female participants who completed the study than males (2 males and 5 females). The average age of participants was $49.3 \pm 9.5$ years. Furthermore, the average Body Mass Index (BMI) of participants was $27.9 \pm 5.3$ kg/m$^2$.

**Procedures**

Upon arrival at the scheduled session at the Human Movement Research Center (HMRC), the participants were informed of all aspects relating to the study, including what measurements would be taken, why the study is being performed, and what is expected of them. After discussing the study as well as their expectations, they were asked to read and sign an informed consent form as well as complete a medical questionnaire.

Next, baseline measurements were collected such as an assessment of cardiometabolic risk factors, pulse, blood pressure (BP), height, weight, body mass index (BMI), waist circumference, hip circumference, visceral fat percent, body fat percent, muscle percent, resting metabolic rate (RMR), and a glucose/cholesterol profile. The participant’s body height was measured by a wall-mounted stadiometer and body weight, visceral fat percent, body fat percent, muscle percent, resting metabolic rate was measured by the Omron HBF-516B bioimpedance device. BMI was calculated as body weight divided by body height squared. Waist circumference was measured after exhalation at mid-distance between the bottom of the rib cage and the top of the iliac crest. Hip circumference was measured at the maximal girth of the hips at the gluteal region. BP was digitally measured using Welch Allyn Connex ProBP 3400 Digital
Blood Pressure Device. The BP measurement was assessed after a rest of five minutes, with three measurements taken in the sitting position at 2-minute intervals. The mean of all three values was used for pulse, systolic and diastolic blood pressure. Glucose and cholesterol was assessed after an 8–10 hours fast, the participant’s profile was assessed by inserting a cartridge with a small sample of blood from the finger of the participant into the Cholestech LDX Analyzer.

After baseline measurements were collected, participants were given their wrist worn activity monitor (Actigraph GT9X), which was calibrated to their measurements (height, weight, age, arm dominance). Participants wore an Actigraph GT9X for all 12 days of intervention. Participants wore the activity monitor (Actigraph GT9X) on their non-dominant wrist and the VibraLITE stimulus watch on their dominant wrist for a minimum of 8 hours continuously during the workday for the duration of the study. Participants also had an hourly activity log to record whether they sensed the stimulus or not (Yes/No), and whether they responded with physical activity to the stimulus (Yes/No).

**Protocol**

Participants completed a 4-stage (12 work-day) protocol consisting of a control stage (stage 1), acoustic stage (stage 2 or 3), vibrational stage (stage 2 or 3), and combination (acoustic and vibration) stage (stage 4). Each stage consisted of 3 work-days wearing the devices for a minimum of 8 hours. During stage 1 the participants wore the Actigraph without the VibraLITE. During stage 2, the participants wore the VibraLITE with either acoustic stimulation (3 continuous days) or vibrational stimulation (3 continuous days). Then stage 3 was the stimulation
that was not used during stage 2. For example, if the participants received the vibrational stimulus for stage 2, they would have acoustic stimulus for stage 3. Finally, they received both acoustic and vibration stimuli for the final stage. See Figure 1. Stimuli Schedule for a visual representation of the study schedule.

During the study protocol, participants met with investigators on day 7 to change the VibraLITE settings and change Actigraph devices. They met again on day 10 to change the VibraLITE settings, then ended the study on day 12 when the investigators collected all devices. Supplemental meetings happened if needed. When researchers and participants met for supplemental meetings it was because the batteries on the devices were low. At each meeting, both regular and supplemental, the data from the Actigraph was downloaded using the ActiLife software and then converted into Microsoft Excel CSV files for future analysis.

**Figure 1. Stimuli Schedule**

<table>
<thead>
<tr>
<th>Week</th>
<th>M</th>
<th>T</th>
<th>W</th>
<th>Th</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pre-test</td>
<td>Pre-test</td>
<td>Pre-test</td>
<td>Vibralite</td>
<td>Vibralite</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>Control</td>
<td>Control</td>
<td>(A/V)</td>
<td>(A/V)</td>
</tr>
<tr>
<td>2</td>
<td>Vibralite</td>
<td>Vibralite</td>
<td>Vibralite</td>
<td>Vibralite</td>
<td>Vibralite</td>
</tr>
<tr>
<td></td>
<td>(A/V)</td>
<td>(A/V)</td>
<td>(A/V)</td>
<td>(A/V)</td>
<td>(A+V)</td>
</tr>
<tr>
<td>3</td>
<td>Vibralite</td>
<td>Vibralite</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(A+V)</td>
<td>(A+V)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(A = acoustic; V = vibration; A/V = acoustic or vibration; A+V = acoustic & vibration)
**Instruments**

**Stadiometer:** Health-O-Meter Professional (Model: 500KL; Healthometer, Neosho, MO). The stadiometer was used to measure the participant’s height and weight. The measurement was taken with the participant standing on the base, facing away from the device. A member of the research team lowered the horizontal bar onto the participant’s head. Height was read on the vertical ruler. Weight was read from the digital display on the device. Both measurements were recorded in inches and pounds respectively.

**Actigraph GT9X Tri-axial Accelerometer:** (Actigraph GT9X Link, Pensacola, Florida, USA) The tri-axial accelerometer works by detecting accelerations in the three planes of motion (x, y, z). These accelerations are then used for calculations such as steps and counts per minute. The GT9X is capable of continuously recording for long durations of time such as 1 – 2 weeks. The Actigraph hardware and software have been supported as scientifically validated instruments. [10]

**Actigraph ActiLife 3.2.2:** (Actigraph, Pensacola, Florida, USA) The ActiLife software collects the data obtained from the Actigraph GT9X and creates files for calculations based on the subjects characteristics and the protocol being used.

**VibraLITE Mini Watch:** (VibraLITE Mini, Oakland Park, Florida, USA) The VibraLITE Mini Watch is capable of producing 12 alarms that use vibration, acoustic, or vibration and acoustic settings. This device was used to produce the daily alarms to encourage the participants to move.

**Gulick Tape:** Gulick Measurement Tape is used to collect accurate measurements of body circumferences. The tape has a built-in tension spring at the beginning to allow for it to not tightly press against the skin during application. The tape also has a push-button style
mechanism to retract the tape or lock in place. The tape offers readings in both inches and centimeters measuring 5 feet long.

**Cholestech – LDX Analyzer:** The cholestech – LDX analyzer uses blood collected from a finger-prick to analyze cholesterol (HDL, LDL) glucose, 10 year CHD risk, and tryglycerides. The prick is performed with a medical grade finger stick, the blood is then collected by a capillary and deposited into a cassette which is inserted into the machine for analysis.

**Omoron HBF-516B Bioimpedance Scale:** Bioimpedance devices use a small wave of electricity to measure body composition. The model at Penn State Berks is both a foot contact and hand contact scale. Initial measurements such as height, sex, and age are entered into the scale, then participants remove footwear and stand on the scale while holding the handles. The machine then calculates their weight, BMI, muscle percentage, body fat percentage, visceral fat percentage, body age, and resting metabolic rate. This device may not be used if the participant has a pacemaker or is pregnant.

**Welch-Allyn Connex ProBP 3400 Digital Blood Pressure Device:** This device is a validated automated blood pressure cuff which measure systolic blood pressure, diastolic blood pressure, and heart rate. The cuff is placed on the arm over the bicep aligning with the brachial artery. The investigator then presses the button to start the device and it auto-inflates and then auto-deflates to calculate blood pressure.
Chapter 3

Results

Subjects

Seven human subjects were used in this study of varying ages, body mass indexes, and other descriptive measurements. There were two males and five females in the study with a mean age of 50 years old. Some important statistics derived from the subjects include body fat percentage (33.9 ± 10.6 %), visceral fat percentage (9.1 ± 4.6 %), BMI (27.9 ± 5.3 kg/m²) and high-density lipoproteins (HDL) (59.4 ± 20.5 mg/dL). These statistics are of interest because body fat and visceral fat percentages are both within the risk ranges, body fat being over 32% and visceral fat being at or above 9%. The subjects can be identified as having extra body fat, which correlates with the mean BMI value of 27.9 kg/m², placing the cohort in the overweight category. However, paired with the increased fat percentage is a high level of HDL. HDL levels at or above 60 mg/dL are considered protective against heart disease. Though the mean HDL present in the subjects is not at 60 mg/dL, the mean HDL level is very close, which is interesting given the high mean fat percentage would imply more of a risk of heart disease. \[12\]
Table 1. Descriptive Statistics

Table 1. lists all descriptive statistics with presented means and standard deviations.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>49.7</td>
<td>9.5</td>
</tr>
<tr>
<td>Sex</td>
<td>2 Male</td>
<td>5 Female</td>
</tr>
<tr>
<td>Height (ins)</td>
<td>64.9</td>
<td>3.1</td>
</tr>
<tr>
<td>Weight (lbs)</td>
<td>165.7</td>
<td>24.5</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>27.9</td>
<td>5.3</td>
</tr>
<tr>
<td>Waist Circumference (cm)</td>
<td>88.4</td>
<td>12.8</td>
</tr>
<tr>
<td>Hip Circumference (cm)</td>
<td>101.6</td>
<td>11.1</td>
</tr>
<tr>
<td>WHR</td>
<td>0.87</td>
<td>0.08</td>
</tr>
<tr>
<td>Average Systolic BP (mmHg)</td>
<td>112.7</td>
<td>8.4</td>
</tr>
<tr>
<td>Average Diastolic BP (mmHg)</td>
<td>72.7</td>
<td>6.1</td>
</tr>
<tr>
<td>Average Pulse</td>
<td>70.1</td>
<td>9.4</td>
</tr>
<tr>
<td>Body Fat Percentage</td>
<td>33.9</td>
<td>10.6</td>
</tr>
<tr>
<td>Muscle Percentage</td>
<td>29.4</td>
<td>5.3</td>
</tr>
<tr>
<td>RMR (kcals)</td>
<td>1530.4</td>
<td>177.8</td>
</tr>
<tr>
<td>Visceral Fat Percentage</td>
<td>9.1</td>
<td>4.5</td>
</tr>
<tr>
<td>Total Cholesterol</td>
<td>176.4</td>
<td>35.1</td>
</tr>
<tr>
<td>HDL (mg/dL)</td>
<td>59.4</td>
<td>20.5</td>
</tr>
<tr>
<td>Triglycerides</td>
<td>116.7</td>
<td>68.7</td>
</tr>
<tr>
<td>LDL (mg/dL)</td>
<td>92.7</td>
<td>24.5</td>
</tr>
<tr>
<td>Glucose</td>
<td>96.7</td>
<td>10.4</td>
</tr>
</tbody>
</table>

Figure 2. Scatter Plot of Age and BMI separated by Sex
Figure 3. Scatter Plot of Body Fat % and HDL separated by Sex

Figure 4. Scatter Plot of Waist-Hip Ratio and Systolic BP separated by Sex
Steps

Table 2. Means and Standard Deviations of Steps Taken per Stage

<table>
<thead>
<tr>
<th>Stage</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>18,289</td>
<td>6,497</td>
</tr>
<tr>
<td>Vibration</td>
<td>17,982</td>
<td>7,007</td>
</tr>
<tr>
<td>Acoustic</td>
<td>15,927</td>
<td>4,548</td>
</tr>
<tr>
<td>Combination</td>
<td>15,275</td>
<td>5,173</td>
</tr>
</tbody>
</table>

Figure 5. Steps Taken by Participants Across All Stages

Statistical Analysis

A repeated measures ANOVA statistical test was used to identify significance among the stages for change in steps. There was no significance in steps found between any of the stages as
identified from the post-hoc analysis. Direct significance values with mean and standard
development for each stage versus the control is as follows (mean ± standard deviation): control vs.
vibration (18,289 ± 6497 vs. 17,982 ± 7007 steps/work-day, p=1.00), control vs. acoustic
(18,289 ± 6497 vs. 15,927 ± 4548 steps/work-day, p=1.00), and control vs. combination (18,289
± 6497 vs. 15,275 ± 5173 steps/work-day, p=.721). The results indicate that no stimuli or
combination of stimuli significantly increased physical activity response.

Table 3. ANOVA with Post-hoc Analysis

<table>
<thead>
<tr>
<th>Steps</th>
<th>Steps</th>
<th>Mean Difference</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Vibration</td>
<td>306.857</td>
<td>928.645</td>
<td>1.000</td>
<td>-3280.49</td>
<td>3894.204</td>
</tr>
<tr>
<td>Acoustic</td>
<td></td>
<td>2362</td>
<td>1715.039</td>
<td>1.000</td>
<td>-4263.18</td>
<td>8987.18</td>
</tr>
<tr>
<td>Both</td>
<td></td>
<td>3014.143</td>
<td>1664.99</td>
<td>0.721</td>
<td>-317.697</td>
<td>9445.982</td>
</tr>
<tr>
<td>Vibration</td>
<td>Control</td>
<td>-306.857</td>
<td>928.645</td>
<td>1.000</td>
<td>-3894.204</td>
<td>3280.49</td>
</tr>
<tr>
<td>Acoustic</td>
<td></td>
<td>2055.143</td>
<td>2379.854</td>
<td>1.000</td>
<td>-7138.21</td>
<td>11248.496</td>
</tr>
<tr>
<td>Both</td>
<td></td>
<td>2707.286</td>
<td>2222.804</td>
<td>1.000</td>
<td>-5879.385</td>
<td>11293.957</td>
</tr>
<tr>
<td>Acoustic</td>
<td>Control</td>
<td>-2362</td>
<td>1715.039</td>
<td>1.000</td>
<td>-8987.18</td>
<td>4263.18</td>
</tr>
<tr>
<td>Vibration</td>
<td></td>
<td>-2055.143</td>
<td>2379.854</td>
<td>1.000</td>
<td>-11248.496</td>
<td>7138.21</td>
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<tr>
<td>Both</td>
<td></td>
<td>652.143</td>
<td>1317.054</td>
<td>1.000</td>
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<td>5739.909</td>
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<tr>
<td>Both</td>
<td>Control</td>
<td>-3014.143</td>
<td>1664.99</td>
<td>0.721</td>
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</tr>
<tr>
<td>Vibration</td>
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<td>2222.804</td>
<td>1.000</td>
<td>-11293.957</td>
<td>5879.385</td>
</tr>
<tr>
<td>Acoustic</td>
<td></td>
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<td>1317.054</td>
<td>1.000</td>
<td>-5739.909</td>
<td>4435.624</td>
</tr>
</tbody>
</table>
Figure 6. Box and Whisker Plot of Average Steps Taken Across the 4 Stages
Chapter 4

Discussion and Conclusion

The purpose of the study was to objectively assess the differences in physical activity responses to acoustic stimuli, vibrational stimuli, and both (acoustic and vibrational) stimuli. We were also interested in determining if one stimulus produced a larger response in physical activity compared to another. As depicted in the results there were no significant differences among any of the stimuli and the control stage. Therefore, our hypothesis as stated was not supported, the stimuli stage that incorporated the vibrational stimulus did not have the largest activity response.

However, the aim of the study was to assess the benefit of stimulus reminders on disrupting bouts of prolonged sitting among university employees during the workday. Though the steps were not significantly increased from the stimuli, the participants sedentary bouts were disrupted throughout the day as recorded by their activity logs: a majority of participants moved when they sensed the stimulus, they just did not move enough to create a significant difference in steps. Therefore, the study showed no significant difference in step count throughout the various stages but did show fewer bouts of prolonged sitting.

The study presented many strengths and limitations. The strengths include the supported validity of the activity monitor used, the regularity of stimulation, and ease of the protocol. The Actigraph GT9X used for tracking steps throughout the day was previously validated as discussed in the introduction. It also has a long-lasting battery life, allowing the device to be used over several days if not weeks. The VibraLITE Mini’s capability of producing 12 stimuli-based alarms through the day allowed for the stimuli to be administered on a regular and consistent basis. Lastly, participants having to respond to stimuli by getting up and moving around allowed
for ease of adhering to the protocol during the 12 work-days. This ease of protocol made the 12 work-day study duration possible and kept participants from dropping out of the study.

There are also limitations to the study, including: a small sample size, breaks in the study, and faculty having different class schedules on Monday, Wednesday, and Friday (MWF) as compared to Tuesday and Thursday (TR). The small sample size made determining statistical significance more difficult. A sample size of 30 or more would allow for greater chance of a standardized bell curve to analyze true significance. With a larger sample size, we would expect the results to change, possibly to the point of significance. Also, various participants took a break during the study, for example, between stages two and three a participant went on vacation for a long weekend. This break both made the study longer in duration but also did not allow for continuous recording of data that may have affected daily activity movement patterns. Lastly, faculty who participated in the study had different class teaching schedule for MWF as compared to TR which also may have an effect on the amount of movement completed during a workday. We knew of the discrepancy in class teaching schedule beforehand, so we made each stage consist of 2 days from MWF and one day from TR. This way if there were a difference in the class teaching schedule, it would be standardized within each stage.

As for how these results support or refute previous studies on the effects of stimuli on physical activity, we have not been able to find any studies that examine the effects of differing stimuli on physical activity and bouts of prolonged sitting. The study does, however, incorporate some key features from other studies such as the physical activity intervention STUFF [3] mentioned in the introduction, except we used stimuli-based alarms to remind subjects to move, not the acronym STUFF. Future studies looking to improve on these results should add more stimuli to the procedure such as a voice reminder either pre-recorded or from a device like
Apple’s Siri or Amazon’s Alexa. Also, extending the duration of each stage to a week would allow for a more accurate average of movement, and eliminate the issue of schedule conflict for professors. Improvements such as more devices and longer duration may make the study protocol more difficult but could improve the results and the potential impact of the study.

In conclusion, the study presented no significant differences among any of the stimuli stages and the control stage in terms of step count. Participants did note sensing one of the stimulus more often than another, which means that though there is not a stimulus which elicits a greater activity response for everyone, differing stimuli may be helpful on an interpersonal level. For example, one participant preferred the vibrational stimulus, but another preferred the acoustic. Overall, wearable technologies should incorporate these stimuli to aid their users in noticing reminders and daily goals. Also, the more stimuli that are able to be incorporated into a device, the better, because the user can make customizations to their preference of stimulation.


Dear Colleagues,

Interested in Cholesterol/Glucose testing?
Kinesiology is currently recruiting volunteers to participate in a student research project 'Breaking Sedentary Behavior with Serial Prompts' during which cholesterol/glucose testing will be performed. Please read below.

---------------------------------------

Breaking Sedentary Behavior with Serial Prompts

√Accurate assessment of sedentary behavior
√Fingerstick cholesterol and glucose
√Body fat percentage analysis

Feel like you are sitting too much at work?

If Yes, we can accurately measure using state-of-the-art device in wearable technology. The Department of Kinesiology is currently seeking volunteers (Berks Faculty & Staff) for a research study to assess the sedentary behavior among PSU-Berks workforce.

All Penn State Berks employees are eligible

Screening/Initial Assessment (~45min):
What?
Eligibility will be confirmed, consent will be taken and you will be asked to fill the medical history questionnaire.
Measurements: Height, weight, body mass index, waist/hip circumference, blood pressure, pulse and fasting fingerstick blood cholesterol and glucose.
Sedentary behavior assessment: Activity monitor wristband (to be worn like a wristwatch) & Vibralite (wrist watch like device for serial acoustic & vibrational reminders) for 3 weeks.
When?
Scheduled appointments on Mon-Fri (8am – 10am)
Where?
HMRC, Gaige 229

Questions? and to schedule for initial visit, please email or call Praveen Veerabhadrappa pmv5057@psu.edu
Penn State Berks, Kinesiology, 114D Beaver
P. O. Box 7009, Tulpehocken Road
Reading, PA 19610-6009, Office: (610) 396-6009
or Matthew Duffy Moran (Senior, Kinesiology) mdm5788@psu.edu
## Appendix B (Daily Activity Log)

<table>
<thead>
<tr>
<th>Time</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
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<th>Friday</th>
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<tbody>
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<td>No</td>
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<td>9:00 AM</td>
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</table>
Appendix C (Instruments)

Actigraph GT9X

VibraLITE Mini
Health-O-Meter Stadiometer

Cholestech LDX
## Appendix D (Weekly Meeting Schedule)

<table>
<thead>
<tr>
<th></th>
<th>M</th>
<th>T</th>
<th>W</th>
<th>Th</th>
<th>F</th>
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<tbody>
<tr>
<td>Week 1</td>
<td>Pre-test Control</td>
<td>Pre-test Control</td>
<td>Pre-test Control</td>
<td>Vibralite (A/V)</td>
<td>Vibralite (A/V)</td>
</tr>
<tr>
<td>Week 2</td>
<td>Vibralite (A/V)</td>
<td>Vibralite (A/V)</td>
<td>Vibralite (A/V)</td>
<td>Vibralite (A/V)</td>
<td>Vibralite (A+V)</td>
</tr>
<tr>
<td>Week 3</td>
<td>Vibralite (A+V)</td>
<td>Vibralite (A+V)</td>
<td>Post-test</td>
<td>Post-test</td>
<td>Post-test</td>
</tr>
</tbody>
</table>
Appendix E (Medical Questionnaire)

Medical Questionnaire: Health Screening Form

Age _______ Year of Birth _______ Gender _______ Occupation _______

Date __________

Known Diseases (Medical Conditions)

1. List the medications you take on a regular basis.
   (Include aspirin, vitamins & minerals, prescription and non-prescription)

2. Do you have diabetes?
   a. If yes, please indicate if it is insulin dependent diabetes mellitus (IDDM) or non-insulin dependent diabetes mellitus (NIDDM).
   No  Yes

3. Have you had a stroke?
   No  Yes

4. Have you ever had a heart attack or heart trouble?
   No  Yes

5. Do you take asthma medication?
   No  Yes

6. Are you, or do you have reason to believe, you may be pregnant?
   No  Yes

7. Is there any other physical reason that prevents you from participating in an exercise program (e.g. cancer, osteoporosis, severe arthritis, mental illness, thyroid, kidney or liver disease)?
   No  Yes

Signs and Symptoms of Disease

8. Do you often have pains in your heart, chest, neck, jaw, arms or other areas, especially during exercise?
   No  Yes

9. Do you often feel faint or have spells of severe dizziness during exercise?
   No  Yes

10. Do you experience unusual fatigue or shortness of breath at rest or with mild exertion?
    No  Yes

11. Have you had an attack of shortness of breath that came on after you stopped exercising?
    No  Yes

12. Have you been awakened at night by an attack of shortness of breath?
    No  Yes

13. Do you experience swelling or accumulation of fluid in or around your ankles?
    No  Yes

14. Do you often get the feeling that your heart is beating faster, racing, or skipping beats, either at rest or during exercise?
    No  Yes

15. Do you regularly get pains in your calves or lower legs during exercise which are not due to soreness or stiffness?
    No  Yes

16. Has your doctor ever told you that you have a heart murmur?
    No  Yes

Cardiac Risk Factors
17. Do you or did you smoke cigarettes on a daily basis?  
   a. If you did smoke when did you quit? (mm/dd/yy)  

<table>
<thead>
<tr>
<th>Relative</th>
<th>Age</th>
<th>Did they pass away?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

18. Has your doctor ever told you that you have high blood pressure?  

19. Has a first degree relative (e.g. father, mother, sister, brother, or child) suffered from a heart attack or diagnosed cardiovascular disease?  

<table>
<thead>
<tr>
<th>Relative</th>
<th>Age</th>
<th>Did they pass away?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

20. What is your systolic blood pressure?  
   mmHg

21. What is your diastolic blood pressure?  
   mmHg

---

**Current Physical Activity Patterns and Future Intentions**

1. Does your job involve sitting for a large part of the day?  
   How much __________  

2. What are your current physical activity patterns?  
   a) Frequency: ______ activity sessions per week  
   b) Intensity:  
   - Sedentary  
   - Moderate  
   - Vigorous  
   c) Duration: ______ minutes per session (on the average)  
   d) How long have you been following this routine (circle one)?  
   - Less than 3 months  
   - 3-6 months  
   - 6-12 months  
   - More than a year  

3. What types of exercises do you regularly do? Please check all that apply.  
   - [ ] Walking  
   - [ ] Running  
   - [ ] Stair-stepping  
   - [ ] Brisk Walking  
   - [ ] Elliptical machine  
   - [ ] Weight-lifting  
   - [ ] Swimming  
   - [ ] Cycling  
   - [ ] Pilates  
   - [ ] Yoga  
   - [ ] Racquet sports  
   - [ ] Basketball/Volleyball  
   Other: ____________________________  

4. Are you interested in changing your activity routine? If so, please explain.  

5. What are your fitness goals?  
6. How committed are you to improving your fitness at this time?
Official Use: Physical Exam

Height

Weight

BMI

Waist Circumference

Hip Circumference

Body Fat %

BP
1. _________
2. _________
3. _________

Average BP: _________

Pulse
1. _________
2. _________
3. _________

Average Pulse: _________
Appendix F (Consent Form)

Version Date:

CONSENT FOR RESEARCH
The Pennsylvania State University

Title of Project: Physical activity patterns and cardiometabolic profile among University workforce

Principal Investigator: Praveen Veerabhadrapa

Address: Penn State Berks I Kinesiology I 114D Beaver
P. O. Box 70091 Tulpehocken Road
Reading, PA 19610-6009

Telephone Numbers: Weekdays: 8:00 a.m. to 5:00 p.m. 610-396-6091

Subject’s Printed Name: __________________________

We are asking you to be in a research study.
Whether or not you take part is up to you. You can choose not to take part. You can agree to take part and later change your mind. Your decision will not be held against you.

This form gives you information about the research. Please ask questions about anything that is unclear to you and take your time to make your choice.

1. Why is this research study being done?

The purpose of this study will be to assess the differences in physical activity responses to acoustic stimuli, vibrational stimuli and both (acoustic and vibrational) stimuli, within the work context for a duration of 15 days. Approximately 100 subjects will participate in this study.

Actigraph, a tool to measure your activity levels and vibralite, a tool to induce stimuli-sound (acoustic) and/or vibration will be used in this study.

2. What will happen in this research study?

The study will consist of:
- Measuring physical activity and physical inactivity
- Measuring cardiometabolic profile

Once you fill the medical history questionnaire and your recruitment is confirmed, your height, weight, body mass index, waist and hip circumference, body fat percentage pulse and blood pressure will be assessed.
Next, your fasting blood glucose and cholesterol levels will be measured using fingerstick technique and analyzed by the LDX-Cholestec machine within 5-10 min. Actigraph accelerometer will be applied to your wrist (to be worn like a watch) for 15 days. You will wear only actigraph without the vibralite for the first 3 days during which time we will assess your baseline physical activity levels. Next, you will wear vibralite with either the acoustic (3 days) or vibration (3 days) stimuli - the sequence will be determined and explained when the vibralites are deployed. You will be instructed to move (be active) when you sense the preset stimuli (either acoustic or vibration). Following which you will wear vibralite with both acoustic & vibration stimuli for the next 3 days. Finally, you will wear only the actigraph for the final 3 days to note a change in physical activity behavior. You will have to log in your hourly activities with the time frames for the entire study period using the provided activity log sheet. At the end of 15 days, we will collect the actigraphs to retrieve the data. During the study you will meet us on day 7 to change the vibralite setting & swap actigraph and again day 10 to change the vibralite setting.

After the data collection is done the hard copies of the data will be stored and secured at Penn State University Berks in a locked office.

What are my responsibilities if I take part in this research?
Responsibilities include- to wear Actigraph link & Vibralite on the wrist (similar to a wrist watch) for a minimum of 8 hours during the workday for 15 days, to move/be active if & when you sense the acoustic or vibration stimuli and to maintain a daily activity log for the entire week using the provided activity log sheet.

3. What are the risks and possible discomforts from being in this research study?
There are no risks associated with participating in this research beyond those experienced in everyday life. However, if you feel uncomfortable at any time please inform the researcher. You are free to not participate if you do not feel comfortable.

The following risks, although low, are related to your participation in this research study. There is a small risk of bruising and rarely infection during the time of fingerstick blood sample collection. These risks will be lowered by using sterile procedures and by having trained research students take all blood samples. There is also some pain associated with needle sticks and sometimes, people have been known to faint during needle sticks and blood drawing. This will be minimized by the procedure being performed in a seated posture.

There are no known risks related to measuring your BP except for some occasional discomfort experienced when the BP cuff is inflated and squeezes your arm.

There is a risk of loss of confidentiality if your information or your identity is obtained by someone other than the investigators, but precautions will be taken to prevent this from happening.
4. What are the possible benefits from being in this research study?

4a. What are the possible benefits to me?
   
   You will gain insight into your activity and inactivity patterns and cardiovascular risk based on your cardiometabolic profile. Additionally, you will have a better understanding of the current state of your health and the possibilities of improving your health status.

4b. What are the possible benefits to others?

   This research will help us better understand the physical activity and inactivity behaviors of the PSU Berks workforce and map the University workforce sedentary behaviors. This will enable us to design workplace wellness programs to improve the lifestyle of employees in the workplace setting.

5. What other options are available instead of being in this research study?

   You may decide not to participate in this research.

6. How long will I take part in this research study?

   Your participation will take approximately 15 days.

7. How will you protect my privacy and confidentiality if I decide to take part in this research study?

   Your participation in this research is confidential. No names or identifying information will be placed on any research materials. Hard copies of the data will be labeled with assigned numbers that are not tied to you in any way, and will be stored and secured at Penn State University Berks in a locked office.

   Your data will be stored securely, indefinitely without any identifiable information and encrypted using Box at Penn State with password protection.

   Efforts will be made to limit the use and sharing of your personal research information to people who have a need to review this information.

   In the event of any publication or presentation resulting from the research, no personally identifiable information will be shared.

   We will do our best to keep your participation in this research study confidential to the extent permitted by law. However, it is possible that other people may find out about your participation in this research study. For example, the following people/groups may check and copy records about this research.

   - The Office for Human Research Protections in the U.S. Department of Health and Human Services
   - The Institutional Review Board (a committee that reviews and approves research studies) and
   - The Office for Research Protections.
Some of these records could contain information that personally identifies you. Reasonable efforts will be made to keep the personal information in your research record private. However, absolute confidentiality cannot be guaranteed.

8. What are the costs of taking part in this research study?  
There are no costs associated in taking part in this study for you.

9. Will I be paid to take part in this research study?  
There will no monetary compensation for participating in this study.

10. Who is paying for this research study?  
The institution and the investigators are not receiving any funds to support this research study.

11. What are my rights if I take part in this research study?  
Taking part in this research study is voluntary.  
* You do not have to be in this research.  
* If you choose to be in this research, you have the right to stop at any time.  
* If you decide not to be in this research or if you decide to stop at a later date, there will be no penalty or loss of benefits to which you are entitled.

12. If I have questions or concerns about this research study, whom should I call?  
Please call the head of the research study Dr. Praveen Veerabadrappa (principal investigator) at 610-396-6009 if you:  
* Have questions, complaints or concerns about the research.  
* Believe you may have been harmed by being in the research study.

You may also contact the Office for Research Protections at (814) 865-1775, ORP@psu.edu if you:  
* Have questions regarding your rights as a person in a research study.  
* Have concerns or general questions about the research.  
* You may also call this number if you cannot reach the research team or wish to offer input or to talk to someone else about any concerns related to the research.
INFORMED CONSENT AND AUTHORIZATION TO TAKE PART IN RESEARCH

Signature of Person Obtaining Informed Consent

Your signature below means that you have explained the research to the subject or subject representative and have answered any questions he/she has about the research.

________________________________________________________________________
Signature of person who explained this research       Date       Time       Printed Name
(Only approved investigators for this research may explain the research and obtain informed consent.)

Signature of Person Giving Informed Consent and Authorization

Before making the decision about being in this research you should have:
  • Discussed this research study with an investigator,
  • Read the information in this form, and
  • Had the opportunity to ask any questions you may have.

Your signature below means that you have received this information, have asked the questions you currently have about the research and those questions have been answered. You will receive a copy of the signed and dated form to keep for future reference.

Signature of Subject

By signing this consent form, you indicate that you voluntarily choose to be in this research and agree to allow your information to be used and shared as described above.

________________________________________________________________________
Signature of Subject       Date       Time       Printed Name
Academic Vita

MATTHEW DUFFY MORAN
mdm5788@psu.edu

Education:
The Pennsylvania State University, Berks (Reading, PA) Graduation: May 2018
B.S. Kinesiology, Exercise Science Option, Honors in Kinesiology

Thesis Supervisor: Dr. Praveen Veerabhadrappa

Publications:
Veerabhadrappa, P., Moran, M., Renninger, M., Rhudy, M., Dreisbach, S., Gift, K. Tracking Steps on Apple Watch at Different Walking Speeds. Journal of General Internal Medicine (Accepted for Publication)

Moran, M., Dreisbach, S., Rhudy, M., Veerabhadrappa, P. Breaking Sedentary Behavior among Faculty and Staff: Are Acoustic and/or Vibrational Stimuli Effective? International Journal of Exercise Science: Conference Proceedings (Accepted for Publication)


Presentations:


Posters:


Honors & Awards:
Dean’s List (Fall 2014-Spring 2018)
Science Division Undergraduate Research Award (2017-18)
Boscow Honors Program Scholarship (Fall 2016, Spring 2017, Fall 2017, Spring 2018)
Schreyer Honors College Grant (2017)
Campus Life Award (2017)
Science Division Undergraduate Research Award (2016-17)
Frank Franco Undergraduate Research Grant (2016)
Anatomy & Physiology Peer Tutoring Award (2016)
Nominated for Eric A. and Josephine S. Walker Award (2017)

Service:
Resident Assistant, of Healthy Living and Health Sciences Special Living Option (Spring 2015-Spring 2018)
Student Government Association, Secretary (Fall 2017-Spring 2018)
Lion Ambassador, Member (Spring 2016-Spring 2018), Historian (Fall 2017-Spring 2018)
Peer Academic Leader for
  Kines203 (Medical Terminology) (Spring 2018- Spring 2018)
  Bio129 (Mammalian Anatomy with lab) (Fall 2015- Spring 2018)
  Bio141 (Introduction to Physiology) (Fall 2015- Spring 2018)
  Bio142 (Physiology lab) (Fall 2015-Fall 2017)
  Kines 350 (Exercise Physiology) (Spring 2017)
  Kines456 (Exercise Physiology), (Fall 2017)
International Society of Hypertension May Monthly BP Measurement (Summer 2017)
Invited to presented wearable technologies on campus to Reading High School (Fall 2017)
Kinesiology Club, Member (Fall 2014- Spring 2018), President (Fall 2015-Spring 2017)
FITT Youth, Volunteer (Spring 2017)
Guts & Glory Expo, Volunteer (Fall 2015, Fall 2016)
I’m Able Duathlon, Volunteer (Fall 2015)

Professional Memberships:
Student member of American College of Sports Medicine
Student member of American Heart Association