Passive vs. active wearable technology monitoring trunk flexion in elementary teachers

Bailey Jose
Mississippi State University, baileyrjose@gmail.com

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Passive vs. active wearable technology monitoring trunk flexion in elementary teachers

By

Bailey Jose

Approved by:
Lesley Strawderman, P.E. (Major Professor)
Reuben F. Burch V
David Saucier
Mohammad Marufuzzaman (Graduate Coordinator)
Jason M. Keith (Dean, Bagley College of Engineering)

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Mississippi State University
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for the Degree of Master of Science
in Industrial Engineering
in the Bagley College of Engineering

Mississippi State, Mississippi

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The objective of this study was to assess the biomechanical and subjective measures of elementary school teachers while wearing active and/or passive wearable devices during the average workday. Five elementary school teachers wore a harness that held an Upright GO 2 posture tracking device and a Vicon Blue Trident sensor on the participant's upper back for two school days. Haptic feedback was on for one day and off for the other. Data from the Vicon wearable was analyzed to determine participants’ trunk flexion severity, frequency, and duration. Surveys were used to determine perceived exertion and perception of wearable technology. This study proved that teachers are undergoing severe trunk flexion throughout the day; however, there was not consistent improvement in trunk flexion when haptic feedback was applied. Results also indicated that perceived exertion levels of teachers did not always correlate to the frequency of trunk flexion measured through the wearable device.
ACKNOWLEDGEMENTS

Thanks to Dr. Kari Babski-Reeves and the Industrial and Systems Engineering department at Mississippi State University for providing me with the opportunity to complete this study.

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CHAPTER I
INTRODUCTION

In 2020 alone, there were a total of 1,170 occupational trunk injuries and illnesses resulting in days away from work for educational service workers, with 830 of those being back injuries, more than the number of injuries of any other single body part. Elementary and secondary school teachers made up over 27% of the trunk injuries in educational workers (U.S. Bureau of Labor Statistics, 2021). Many factors contribute to back injuries including poor posture, improper lifting, and frequent bending. This study aims to explore the frequency and duration of trunk flexion in elementary teachers and whether introducing wearables with haptic feedback can reduce the severity of trunk flexion in comparison to teacher’s perceptions of exertion.
CHAPTER II
BACKGROUND

To create a landscape page, you just rotate the page using the “Orientation” option in the Layout Tab. This will put your page number at the bottom of the page. If you would like to print a hard copy and have the page number similar to the portrait pages, we can help you make those changes.

Ergonomics of Teachers

The ergonomics of teachers, elementary and otherwise, have been studied by many. Because there is no standard amount of physical activity teachers undergo, there is a lot of variability in teachers’ actions throughout the day. Even so, back, neck, and shoulder pain are seen in all methods of teaching, whether that be mainly sitting, standing, or constant movement. One study focused on sitting computer workstations of teachers and found that a majority of 265 participants suffered from musculoskeletal disorders (MSDs), particularly in the neck and lower back (Golam Kibria & Rafiquzzaman, 2019). A different study, focused on teachers’ postures while standing and speaking, found that 55% of participants had a hunched upper back posture, 46% had raised shoulders, and 60% kept their heads in an unergonomic position (Rantala et al., 2018). Another study compared chalkboard use in secondary teachers and found that teaching for multiple hours in a day and standing for long periods with a bent back may be harmful (Bogaert et al., 2016). A literature review identifying risk factors among educators found a high prevalence of low back pain (33.3–72.9%), upper back pain (33.33–56.4%), and neck/shoulder
pain (40.4–80.1%) in twenty-two articles (Tai et al., 2019). A cross-sectional study in Bolivia found that the prevalence of MSDs across 60 schools and 517 participants was 47% in the back within the last twelve months (Solis-Soto et al., 2017).

While most educators can choose how active they want to be in their class, elementary teachers can be more adequately compared to those who teach physical education or those who are special education aides, because they tend to have a more active day than administrators or those who teach higher education. When researching work-related MSDs in special education teachers and aides, one study found that 86% of the 388 participants experienced MSDs, with the back, shoulder, and wrist being the most affected areas (Cheng et al., 2016). Another study, focused on special education teachers, administered a survey to early intervention educators and found that 94% of the 323 suffered from MSDs. They also found that work-related ergonomic factors were highly associated with MSD symptoms in the lower back, shoulder, and neck (Kathy Cheng et al., 2013). An additional study surveyed 769 primary and secondary physical education teachers and found that 43% experienced an injury at work at some point, with the most common injuries affecting the knee (18.65%), back (18.35%), and ankle (14.98%) (Montón & Lopez Del Amo, 2019).

Studies focused solely on elementary teachers also found high levels of back pain. One study found that MSDs occurred in 80% of participants across fifteen different primary schools during a six-month period (Ng et al., 2019). Another study on 104 elementary school teachers found that the most common regions of musculoskeletal pain or discomfort came from the neck (39%) and lower back (38%) (Karakaya et al., 2015). While there is research on primary school teachers already, there has not been research that applies the use of wearable technology to measure and improve the trunk flexion in teachers.
**Environment Fit for Children**

As stated previously, research shows that many teachers experience back pain and MSDs. Elementary teachers are not only typically more active than those in higher education, but also work in an environment that is tailored towards small children. With the average height being 69” for men and 64” for women, bending, leaning, or squatting would be required to reach the height of the furniture used in elementary classrooms, including desks, chairs, bookshelves, pencil sharpeners, and more. While there is no set standard for the height of classroom chairs and tables, recommended guidelines for each age group are shown in Table 1.

<table>
<thead>
<tr>
<th>Age Range (yrs.)</th>
<th>Chair Seat Height</th>
<th>Table Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-4</td>
<td>10-12”</td>
<td>20-22”</td>
</tr>
<tr>
<td>5-7</td>
<td>12-14”</td>
<td>22-25”</td>
</tr>
<tr>
<td>8-10</td>
<td>13-17”</td>
<td>24-29”</td>
</tr>
</tbody>
</table>

(SF Gate, 2022)

**Acceptance of Wearable Technology in Educators**

When it comes to acceptance of wearable technology or the barriers that prevent it, research has been conducted on the attitudes of workers in manufacturing, construction, government, healthcare, safety, and technology (Ferrone, Napier, et al., 2021; Schall et al., 2018; Strawderman et al., 2022), but there is a lack of research on the acceptance of wearable technology for teachers.

Literature that does exist on teachers’ perception of wearable technology is focused on children’s use of wearable technology. One study found that primary school teachers were open to the integration of wearable technology when measuring the activity of kids in physical education. Teachers spoke positively about the benefits of the technology and were able to use
and interpret the data produced by the wearable (Wort et al., 2021). Another study on physical education students found that teachers were willing to integrate wearable technology if it did not change the curriculum or preferred practices already in place (Marttinen et al., 2020). Almusawi et al. created a model of readiness for wearable technology integration in education, seen in Figure 1, after interviewing physical education teachers on their perception of wearables (Almusawi et al., 2021). Although this model was based on children’s use of wearable technology, it could also be applied to the use of wearables for improving teacher ergonomics, and the barriers that would prevent integration.

Figure 1  Model of readiness for wearable integration in education.

(Almusawi et al., 2021)
Active vs. Passive Wearable Technology

This paper categorizes wearable technology into two categories: active and passive. Passive wearable technology is that which does not give any active feedback while the user is wearing it, while active wearable technology implements haptic feedback. Haptic feedback refers to the use of touch to communicate with users. Past studies have shown that users have had a positive experience with haptic feedback and an increase in helping correct behavior. One study measuring customer responses to haptic feedback found that it improved performance and demonstrated an increased sense of “social presence” rather than an impersonal exchange of technology (Hadi & Valenzuela, 2021). Another study found that the use of haptic feedback significantly reduced the time in unfavorable postures for the upper arm when training and was effective when learning proper posture and ergonomic body movements (Lind et al., 2020). A study looking at correcting back postures to reduce lower back pain in nurses found a 40% improvement in forward/backward bending posture when haptic feedback was applied, alongside a 7% improvement for trunk twist (Ferrone, García Patiño, et al., 2021). This study aims to determine whether teachers enjoy using a wearable that gives haptic feedback through vibration and if it provides similar benefits to those found in past research.
CHAPTER III
RESEARCH OBJECTIVES

The objective of this study was to assess the biomechanical and subjective measures of elementary school teachers while wearing both active and passive wearable devices compared to wearing only passive wearables during the average workday. The results will attempt to establish if elementary teachers are undergoing unsafe trunk flexion during the average workday and if introducing haptic feedback improves this. The following hypotheses were investigated:

1. Elementary school teachers are currently bending an unsafe amount during the average workday.

2. Elementary teachers who bend over more frequently during the day will have higher scores of perceived exertion.

3. When haptic feedback is introduced, elementary teachers will bend over less frequently.
CHAPTER IV

METHODS

Participants

Participants for this study were recruited on a volunteer basis through social media, word of mouth, and outreach through emails found on Oktibbeha County School websites. Recruitment materials can be found in Appendix A. To participate in this study, participants had to meet the following criteria:

- Be at least 18 years old
- Be a teacher at one of the following Oktibbeha County Schools:
  - Emerson Preschool (PreK)
  - Sudduth Elementary (PreK-1)
  - West Elementary (K-5)
  - Henderson Ward Stewart Elementary (2-4)
  - Overstreet Elementary (5)
- Be the primary teacher of their classroom
- Have NO history of musculoskeletal disorders
- Have NO history of trunk or back injuries
- Have NO history of back surgeries

Five participants were recruited from Oktibbeha County Schools. Four participants taught 3rd grade and one taught 1st grade. All participants were female between the ages of 24 and 28.
Experimental Design

For this study, five participants were asked to wear a backpack-like harness that held both the Upright GO 2 posture tracking device and the Vicon Blue Trident sensor on the participant's upper back. This study took place on two separate days, with the only difference being that the haptic feedback of the Upright device was on for one day and off for the other. To counteract order effects, the day which haptic feedback was presented was alternated, with half of the participants having haptic feedback on during day one of data collection, and the other half having haptic feedback on during day two. The days which participants had haptic feedback on can be seen in Table 2.

<table>
<thead>
<tr>
<th>Participant No.</th>
<th>Haptic Feedback On</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Day 2</td>
</tr>
<tr>
<td>2</td>
<td>Day 1</td>
</tr>
<tr>
<td>3</td>
<td>Day 2</td>
</tr>
<tr>
<td>4</td>
<td>Day 1</td>
</tr>
<tr>
<td>5</td>
<td>Day 2</td>
</tr>
</tbody>
</table>

Wearable Devices

Two wearable devices were worn for this study: Vicon Blue Trident and Upright GO 2. Pictures and dimensions of each device can be seen in Figure 2. The Vicon wearable is a small Dual-g Inertial Measurement Unit (IMU) that captures accelerometer, gyroscope, and magnetometer data. For this study, the Global Angles feature was used to capture data, at a sample rate of 225 Hz. The Upright wearable is a posture trainer worn on the upper back that can notify the user when experiencing poor posture through vibrations.
Both wearables were placed inside a thin backpack-like harness, shown in Figure 4, to collect trunk flexion data throughout the day. The harness is made of felt and elastic straps to allow for a light weight and adjustable fit. There are straps that go across the upper and lower chest, as well as clasps on each pocket to ensure the wearable devices do not move around the back during the day. Elastic extenders were also provided to participants who needed more room than the harness allowed.
Both devices were calibrated using corresponding mobile apps on the researcher’s phone, following each manufacturer’s instructions. To calibrate the Upright device, the participant stood upright to allow the device to get a baseline posture measurement for the day. The device was turned on, placed in the upper pocket of the harness, and then calibrated to the participant’s posture. For days when haptic feedback was applied, the Upright device was programmed to vibrate on a “knock-knock” vibration pattern with medium strength when participants were slouched or bending past a level 4, denoted by the Upright app and seen in Figure 5, for more than five seconds.
Figure 4  Vibration and range settings used from the Upright mobile app

The Vicon device was calibrated by following instructions given in the Capture.U app. First, the device was moved in a figure eight that rotated in all three dimensions for ten seconds. Then the device was set on a flat surface for five seconds and then rotated fully twice about the z-axis. Once calibrated the device was set into the bottom pocket of the harness.

Figure 5  Calibration instructions from the Capture.U mobile app
Pre-Testing

As stated previously, participants for this study were recruited on a volunteer basis through social media, word of mouth, and outreach through emails found on Oktibbeha County School websites. Once participants responded to the recruitment email, a researcher scheduled and met with the participant to try on the harness and fill out a pre-screening survey, shown in Appendix C. The participant was then asked to read and sign a consent form. In total, this took approximately 10 minutes. If the participant met the inclusion criteria, they were then scheduled for two days of data collection. This included finding a time and place before and after school that the participant and researcher agreed upon. All interactions with the researcher took place outside of school hours, so there was no interference with students or classroom activities.

Protocol

On days of data collection, the researcher met with the participant before school to calibrate the wearable devices according to each manufacturer’s directions and help the participant put on and adjust the harness. The participants were then reminded to not take the wearable off until the researcher returned to collect it. If haptic feedback was applied, participants would also be reminded that the wearable would vibrate throughout the day if they bent over or slouched for a significant period. A fact sheet, seen in Appendix B, with the researcher’s email and phone number was left with participants if any questions or concerns arose. Data was then collected via the wearables during the participants’ workdays, approximately 8 hours. During the day, the researcher did not contact the participant or interfere with data collection to ensure the data portrayed a normal workday.

After the school day finished, the researcher and participant met once again to return the harness and devices. Both devices were turned off to stop data collection. The participant was
then asked to complete a survey with six questions if haptic feedback was not applied. If haptic feedback was used, four additional questions were added. The survey covered participants’ perceived intensity of effort and perception of wearable technology. In total, this took approximately 15 minutes. Participants were compensated $100 for their participation upon the completion of data collection. Failure to complete the study resulted in no incentive.
CHAPTER V
ANALYSIS

After all data was collected, data from the Vicon wearable was uploaded to Capture.U desktop software and then analyzed in Python to determine participants’ frequency and time spent in trunk flexion throughout both days. The severity of trunk flexion was determined by comparing angles measured by the Vicon device with trunk positions found on the Rapid Upper Limit Assessment (RULA) worksheet. Data from the Upright app was also observed and taken into consideration. The wearable data from each day (with/without haptic feedback) was compared for each participant to determine if their behavior was altered when wearable devices gave feedback. The survey results were analyzed to see how teachers perceived their exertion levels each day and how they perceived the wearable device with and without the haptic feedback.

Surveys

The surveys, found in Appendix C, were comprised of short, clear statements made up of both questions to be rated using a five-point Likert scale, as well as open response questions. There were ten questions total when haptic feedback was applied and six without. Three of the questions, asked in both post-data collection surveys, pertained to the participant’s perceived exertion and how it related to their average day. The remaining open-ended questions asked about the participant’s perception of the harness and vibrational feedback, if applied.
Surveys were distributed at the end of each day in the agreed upon meeting location after the harness and wearables were returned to the researcher. Once the survey was completed on the second day of data collection, the participant was given the gift card incentive. After all testing was completed and data was collected, surveys were used to determine the effect that vibrational feedback had on the perception of the wearable device, as well as if the data collected represented an average day for the participant.

**Upright GO 2**

The Upright GO 2 device was primarily used for haptic feedback but did provide some data through the Upright mobile app. The app provided an “Upright vs. Slouch” percentage, showing how much of the day participants had good posture, as well as a graph to display the levels of posture throughout the day. Examples of each are shown in Figure 6. While the charts presented a big picture of posture throughout the day, they did not provide raw data and therefore the specific angles were not captured through this device.

![Figure 6](image)

*Figure 6  Percentages shown in Upright mobile app*
**Vicon Blue Trident**

After all data was collected from the Vicon devices and uploaded through Capture.U computer software application, Python script was used to measure the angle of trunk flexion of teachers throughout the day. This included the frequency of trunk flexion, as well as the total duration of each angle range. To measure the severity of trunk flexion, angles found from the Vicon blue trident and python code were compared to the Rapid Upper Limb Assessment (RULA) tool for trunk bending, shown in Figure 7. A slight bend measured between 0°-20°, a moderate bend measured between 21°-60°, and a severe bend measured above 60°.

Figure 7  Trunk posture angles from Rapid Upper Limb Assessment tool (RULA Employee Assessment Worksheet)
CHAPTER VI
RESULTS

Surveys

The surveys, shown in Appendix C, asked participants how they perceived the wearable device, how it affected the participant, and how it affected their way of working. These questions were open ended to allow participants to give their unbiased opinion on the wearable device. One participant stated the wearable “wasn’t noticeable at all” and “I think it made me sit up straight.” Another stated it was “comfortable and easy to wear. Didn’t bother me at all or affect my day at all.” A third participant said the wearable was “comfortable” and “made me notice my posture more.” Another participant said the harness “did not affect my way of working. I honestly forgot I was wearing it!” The only negative feedback received was from a teacher that stated the wearable “got trapped a time or two on my lanyard, but that’s all.” Even so, this participant stated the wearable was “very comfortable, hardly noticeable.”

When haptic feedback was introduced, additional open-ended questions were asked: how participants perceived the vibrational feedback, how it affected the participant, and how it affected their way of working. One participant stated the haptic feedback “made me more cautious of bending down and getting up” and “I noticed how often I move or sit with bad posture.” Another said it “helped me notice when I was straining my back.” Three participants stated the vibration “made me aware of my posture.” One participant stated the vibration “made me sit/stand straighter and notice I hunch more than I realize.” While all participants stated the
feedback made them notice their posture or bending more, some also noted that the feedback was irritating. One participant stated the haptic feedback “was a little annoying because I had to bend down to help students.” Another said it was “slightly annoying and made me become a little irritable.” However, other participants stated the vibration “wasn’t as strong as I thought it would be” and the vibration “just tickled.”

The surveys also had participants report their average and peak exertion during the day and compare it to their typical exertion. The average and peak exertion were measured on a 5-point Likert scale from very light to very hard, with descriptions given for each of the options so participants could compare their day to each type of physical exertion. Relative exertion, how the day of data collection could be compared to an average workday, was measured on a 5-point Likert scale from much easier than normal to much harder than normal. Participants’ responses can be seen in Table 2. All participants stated the workday was light or very light. In comparison to an average workday, all participants said it was either normal or slightly easier than normal.

Table 3 Perceived exertion levels from post-data collection surveys

<table>
<thead>
<tr>
<th>Participant</th>
<th>Haptic</th>
<th>Average</th>
<th>Peak</th>
<th>Relative</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Y</td>
<td>Light</td>
<td>Light</td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>Light</td>
<td>Light</td>
<td>Normal</td>
</tr>
<tr>
<td>2</td>
<td>Y</td>
<td>Light</td>
<td>Light</td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>Very Light</td>
<td>Light</td>
<td>Normal</td>
</tr>
<tr>
<td>3</td>
<td>Y</td>
<td>Very Light</td>
<td>Very Light</td>
<td>Slightly Easier</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>Light</td>
<td>Light</td>
<td>Normal</td>
</tr>
<tr>
<td>4</td>
<td>Y</td>
<td>Light</td>
<td>Light</td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>Light</td>
<td>Light</td>
<td>Slightly Easier</td>
</tr>
<tr>
<td>5</td>
<td>Y</td>
<td>Light</td>
<td>Light</td>
<td>Slightly Easier</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>Light</td>
<td>Light</td>
<td>Normal</td>
</tr>
</tbody>
</table>
Upright GO 2

As stated previously, the Upright mobile app did not provide raw data and therefore the specific angles were not captured through this device. However, the app did present a percentage for each day that shows when participants are in a “healthy range of 70-95% upright posture” (Upright Help Center). The percentages given to each participant are shown in Table 3. Comparing these percentages, two participants had an increase in their upright posture, while one had a decrease in posture on the day that haptic feedback was applied.

Table 4  Upright percentages given in the Upright mobile app

<table>
<thead>
<tr>
<th>Participant</th>
<th>Haptic On</th>
<th>Haptic Off</th>
<th>Change with Haptics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>80%</td>
<td>90%</td>
<td>-10%</td>
</tr>
<tr>
<td>2</td>
<td>76%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>-</td>
<td>78%</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>100%</td>
<td>52%</td>
<td>48%</td>
</tr>
<tr>
<td>5</td>
<td>93%</td>
<td>92%</td>
<td>1%</td>
</tr>
<tr>
<td>Average</td>
<td>87.25%</td>
<td>78%</td>
<td>13%</td>
</tr>
</tbody>
</table>

There were a couple of data collection days where the app recorded little data or none at all; therefore, the percentages and graphs provided by the app were not used to evaluate trunk flexion in teachers. Although no data was given for two days through the app, the vibrational feedback was active and detected by participants on all days when haptic feedback was turned on.

Vicon Blue Trident

The Vicon device was worn by each participant for two full workdays to measure trunk flexion. Graphs that display the trunk flexion angles for each participant for the full day can be
seen in Appendix D. Using the trunk bending category on the RULA tool, severity of trunk flexion was categorized into three groups: slight bend (0°-20°), moderate bend (21°-60°), and severe bend (60°+). Flexion frequency measured the number of times a participant bent over in each angle range. This was determined by counting the number of peaks in the data that maximized in the specified angle range. Table 4 shows each participant’s number of bends for each day of data collection in each angle range, as well the difference between number of bends when haptic feedback was introduced. A positive number denotes that haptic feedback improved trunk flexion, while a negative number denotes that there was not any improvement.

Table 5   Frequency of trunk flexion measured by Vicon wearable

<table>
<thead>
<tr>
<th>Participant</th>
<th>Haptic</th>
<th>Flexion Frequency</th>
<th>Change with Haptics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0°-20° 21°-60° 60°+</td>
<td>0°-20° 21°-60° 60°+</td>
</tr>
<tr>
<td>1</td>
<td>Y</td>
<td>91 272 1,474</td>
<td>-3 101 -260</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>88 373 1,214</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Y</td>
<td>77 326 454</td>
<td>42 224 391</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>119 550 845</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Y</td>
<td>87 273 599</td>
<td>33 48 239</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>120 321 838</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Y</td>
<td>78 358 1,208</td>
<td>-20 -104 -174</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>58 254 1,034</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Y</td>
<td>9 466 917</td>
<td>-2 -105 -186</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>7 361 731</td>
<td></td>
</tr>
</tbody>
</table>

| Average     | 73.5   | 355.7 932   | 10 32.8 2       |

All participants bent over most frequently in the severe angle range, and least in the slight angle range. Two participants bent over more frequently in every angle range when haptic feedback was off. However, two other participants bent over more frequently when haptic feedback was introduced. The remaining participant bent over more frequently in the 21°-60°
range with no haptic feedback, but with haptic feedback on bent more frequently other two ranges. On average, introducing haptic feedback slightly improved trunk flexion frequency in the 0°-20° and 60°+ ranges, and moderately improved frequency in the 21°-60° range. Table 6 shows the descriptive statistics for each participant and each day. These were measured using the peak values used to calculate flexion frequency.

Table 6  Descriptive statistics for trunk flexion

<table>
<thead>
<tr>
<th>Participant</th>
<th>Haptic</th>
<th>Max.</th>
<th>Min.</th>
<th>Median</th>
<th>Mean</th>
<th>Std. Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Y</td>
<td>153.9°</td>
<td>1.5°</td>
<td>94.3°</td>
<td>83.1°</td>
<td>30.1°</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>171.0°</td>
<td>6.3°</td>
<td>94.5°</td>
<td>82.6°</td>
<td>29.9°</td>
</tr>
<tr>
<td>2</td>
<td>Y</td>
<td>125.1°</td>
<td>5.2°</td>
<td>64.0°</td>
<td>59.2°</td>
<td>26.7°</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>129.2°</td>
<td>2.2°</td>
<td>72.2°</td>
<td>63.6°</td>
<td>28.8°</td>
</tr>
<tr>
<td>3</td>
<td>Y</td>
<td>139.9°</td>
<td>1.3°</td>
<td>73.4°</td>
<td>63.0°</td>
<td>25.8°</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>142.4°</td>
<td>1.6°</td>
<td>74.7°</td>
<td>64.6°</td>
<td>27.1°</td>
</tr>
<tr>
<td>4</td>
<td>Y</td>
<td>157.4°</td>
<td>2.8°</td>
<td>89.7°</td>
<td>84.3°</td>
<td>36.4°</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>176.4°</td>
<td>3.5°</td>
<td>81.8°</td>
<td>74.2°</td>
<td>25.6°</td>
</tr>
<tr>
<td>5</td>
<td>Y</td>
<td>159.9°</td>
<td>3.8°</td>
<td>82.7°</td>
<td>74.1°</td>
<td>28.4°</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>138.2°</td>
<td>2.9°</td>
<td>81.3°</td>
<td>74.5°</td>
<td>27.7°</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>149.3°</td>
<td>3.1°</td>
<td>72.3°</td>
<td>80.9°</td>
<td>28.7°</td>
</tr>
</tbody>
</table>

Duration was measured by cumulating all the time spent in the specified angle range during the workday. The number of seconds spent in each angle range was then divided by the total number of seconds for each participant’s data collection day to get the flexion duration percentage. Table 5 shows the percentage of the day that participants spent in each angle range for both haptic and non-haptic days, as well as the percentage difference when haptic feedback was applied. A positive number denotes that haptic feedback improved trunk flexion, while a negative number denotes that there was not improvement.
Table 7  Percentages of trunk flexion measured by Vicon wearable

<table>
<thead>
<tr>
<th>Participant</th>
<th>Haptic</th>
<th>Flexion Duration Percentage</th>
<th>Change with Haptics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>≤0°</td>
<td>0°-20°</td>
</tr>
<tr>
<td>1</td>
<td>Y</td>
<td>14.6%</td>
<td>13.6%</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>11.1%</td>
<td>15.7%</td>
</tr>
<tr>
<td>2</td>
<td>Y</td>
<td>18.2%</td>
<td>24.4%</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>31.4%</td>
<td>29.6%</td>
</tr>
<tr>
<td>3</td>
<td>Y</td>
<td>21.7%</td>
<td>25.2%</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>25.6%</td>
<td>17.0%</td>
</tr>
<tr>
<td>4</td>
<td>Y</td>
<td>14.5%</td>
<td>15.9%</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>10.0%</td>
<td>10.6%</td>
</tr>
<tr>
<td>5</td>
<td>Y</td>
<td>5.6%</td>
<td>46.0%</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>8.1%</td>
<td>41.8%</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>16.1%</td>
<td>24.0%</td>
</tr>
</tbody>
</table>

While participants bent over most frequently in the 60°+ degree range, the duration of flexion in that range was hardly ever the highest. For seven out of the ten days of data collection, the most time was spent in the 21°-60° range. This shows that participants bent over further more often but did not remain in that position for as long as they did in the lower ranges. When haptic feedback was introduced improvements in duration of trunk flexion were made in the 0°-20° range for two participants, only one participant in the 21°-60° range, and three participants in the 60°+ range. On average, participants’ trunk flexion duration did not improve for the slight and moderate ranges when haptic feedback was on but did improve in the most severe angle range.

Four of the participants had variations in their exertion survey answers, having lighter average exertion, peak exertion, and/or relative exertion scores on one day in comparison to their scores for the other day. The remaining participant did not report any differences in exertion levels between both days. Table 6 shows the correlation between lighter perceived exertion and
lower flexion frequency and duration of the two days of data collection. Two participants’ data showed less flexion frequency in all angle ranges in correlation to lighter perceived exertion levels. This may contribute to the smaller numbers experienced for this day. The remaining two participants, however, only showed differences in one of the three categories of flexion duration and had more frequent trunk flexion in all angle ranges on what they perceived to be a day with less activity.

Table 8  Comparison of exertion survey results and Vicon wearable data

<table>
<thead>
<tr>
<th>Participant</th>
<th>Less Exertion</th>
<th>Flexion Frequency</th>
<th>Flexion Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Day</td>
<td>0°-20°</td>
</tr>
<tr>
<td>2</td>
<td>Average</td>
<td>2</td>
<td>✓</td>
</tr>
<tr>
<td>3</td>
<td>Average Peak</td>
<td>2</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Relative</td>
<td>1</td>
<td>✓</td>
</tr>
<tr>
<td>4</td>
<td>Relative</td>
<td>2</td>
<td>✓</td>
</tr>
<tr>
<td>5</td>
<td>Relative</td>
<td>2</td>
<td>✓</td>
</tr>
</tbody>
</table>
CHAPTER VII
DISCUSSION

The following hypotheses were investigated in this study:

*Elementary school teachers are currently bending an unsafe amount during the average workday:* Similar to past studies researching posture or trunk/back movement of teachers, (Bogaert et al., 2016; Cheng et al., 2016; Golam Kibria & Rafiquzzaman, 2019; Karakaya et al., 2015; Kathy Cheng et al., 2013; Montón & Lopez Del Amo, 2019; Ng et al., 2019; Rantala et al., 2018; Solis-Soto et al., 2017) the results from this study prove that teachers are undergoing severe trunk flexion throughout the day. For all participants, the most severe bending angles (60⁰+) occurred more frequently than those in both lower angle ranges. These results align with already existing elementary teacher ergonomic research that demonstrates teachers’ experience with back pain and MSDs. This data also aligns with the assumption that teachers are bending over often due to the small furniture options and height of the students being taught. All teachers in this study also perceived data collection days to be either average or slightly easier than normal, so data collected on a more demanding day would provide even more trunk flexion activity.

* Elementary teachers who bend over more frequently during the day will have higher scores of perceived exertion:* When comparing the data from the Vicon wearable to the perceived exertion levels on the survey, it was expected that elementary teachers that bend over more frequently would have higher scores on the exertion survey. This was not proven through
the data provided. While there were two participants whose data did correlate to their perceived exertion, one teacher did not report any higher exertion on one day over another, and the remaining two reported the opposite effect. Comparing trunk flexion on days where teachers have greater differences in perceived exertion may lead to more conclusive results.

Another thing to consider when discussing participants’ perceived exertion is how they define an easy versus a difficult workday. Teachers may consider many other factors when thinking about the activity level they experienced during the day, such as repetitive movements, more walking, increased stress/heart rate, or other factors that would not show when measuring trunk flexion alone. It is also important to note that all teachers were young. Older teachers may perceive the trunk flexion they experience as more difficult.

**When haptic feedback is introduced, elementary teachers will bend over less**

*frequently*: Unlike in the study conducted by Ferrone et al. that found a 40% improvement in forward/backward bending posture when haptic feedback was applied with nurses (Ferrone, García Patiño, et al., 2021), the introduction of haptic feedback did not improve all teachers’ trunk flexion, therefore this hypothesis was not proven. Although the average change when haptic feedback was applied was positive for all angle ranges, only two of the five participants’ flexion frequency was improved overall when haptic feedback was applied. Of the remaining three participants, two showed no improvement in flexion frequency and one only showed improvements in the 21°-60° range.

Teachers did, however, state in the surveys that they were more aware of their posture, even on days where haptic feedback was not applied, which may have affected their trunk flexion. One concern is that haptic feedback may not be improving trunk flexion because there it is difficult for elementary teachers to avoiding bending over or leaning. Teachers stated they
were aware of their poor posture, but that does not mean they can completely disregard students’ needs or their duties to improve it.

While the frequency of trunk flexion did not improve when haptic feedback was applied for all participants, the Vicon wearable did provide data that was otherwise unknown about the severity of trunk flexion in elementary teachers. Teachers also perceived the wearable devices to be helpful in noticing their posture and bending throughout the day. Implementing more wearable technology in classrooms in the future will allow for more research on elementary teacher ergonomics and hopefully improve their overall wellbeing.
CHAPTER VIII
CONCLUSION

This study sought to examine the effects of applying haptic feedback via a wearable device on elementary school teachers’ frequency, duration, and severity of trunk flexion. This study also sought to explore whether teachers’ perceptions of exertion levels aligned with their measured trunk flexion and how they perceived a wearable device with and without haptic feedback. The results indicated that although teachers are experiencing the most trunk flexion in severe angles, there was no consistency in improving that trunk flexion when haptic feedback was applied. Results also indicated that the perceived exertion levels of teachers did not always correlate to the frequency of trunk flexion measured through the wearable device.

Limitations

A major limitation for this study was the sample size. A larger sample size may have resulted in more conclusive data. Another limitation of this survey is that participants were aware of observation for both days of data collection. Some participants stated that even without haptic feedback applied, they were more aware of their posture and movement simply from wearing the harness. This may have inadvertently improved their trunk flexion on days where no haptic feedback was introduced.
Future Work

For future work, a larger sample size should be considered. It is also recommended that height of teachers is measured and compared to the severity of trunk flexion. Teachers who are taller may be bending or leaning over further to interact with students during the day. An additional consideration would be to have teachers use the Upright app throughout the day. While the data given from the Upright app’s “Upright vs. Slouch” percentage was not received every day, it may be due to the phone being taken away from data collection site. If teachers were to use the app on their personal devices, it may have given more consistent or reliable data that could be compared directly to the Vicon data for future studies.

Another consideration would be to add another wearable device, such as a Fitbit or Apple watch to capture more data alongside the external load captured through the Vicon wearable. These wearables could capture heart rate to learn more information about teachers’ activity levels and see if trunk flexion correlates to other measures of exertion. Wearables could also count steps, which could see how much teachers are walking around during the day, compared to sitting. The data from the Vicon wearable just showed trunk flexion, no other body movement, so it is unclear whether trunk flexion was caused by teachers bending over while standing, leaning in their chair, or simply just having poor posture. Adding another wearable to data collection could give more insight into the specifics of teachers’ trunk flexion. Lastly, having a longer period of data collection may produce more accurate results. While this study collected a total of 80 hours of trunk flexion data, there may be more conclusive data drawn if data is collected from teachers for a full week, rather than two days.
REFERENCES


APPENDIX A

RECRUITMENT MATERIALS AND INFORMED CONSENT
Teachers,

My name is Bailey Jose, and I am a graduate student at Mississippi State University. I am currently recruiting elementary teachers to take part in a study for my thesis to measure posture and bending of teachers.

The study includes wearing two small wearable technology devices on the upper back for two school days, as well as filling out a couple surveys. **Participants will be compensated with a $100 gift card upon the study’s completion.** Participants must be at least 18 years of age and serve as the primary teacher in the classroom, as well as have no history of musculoskeletal disorders, back injuries, or back surgeries. For more information, see the attached file*.

If you are interested in participating or would like additional information, please reach out to me via text at 662-579-9467 or email brj135@msstate.edu.

Thank you,

Bailey Jose

*File attached will be the consent form that notes the project procedures

Figure 8   Recruitment email sent to potential participants
Mississippi State University
Informed Consent Form for Participation in Research

IRB Approval Number: IRB-23-565

Title of Research Study: Passive vs. Active Wearables Monitoring Trunk Flexion in Elementary Teachers

Study Site: Sudduth Elementary, West Elementary, Henderson Ward Stewart Elementary

Researchers: Bailey Jose, Mississippi State University; Dr. Lesley Strawderman, Mississippi State University

Purpose
The purpose of this research is to investigate the biomechanical and subjective measures of elementary school teachers while wearing both active (Upright GO 2) and passive wearable devices (Vicon Blue Trident) compared to the measures while wearing only passive wearables during the average workday.

Procedures
For this study, you are being asked to wear a backpack-like harness that will hold the Upright GO 2 posture tracking device and Vicon Blue Trident sensor (images and dimensions for both devices are shown below) on your upper back on two separate school days. All interactions with the researcher will be outside of school hours, so there will be no interference with students or classroom activities.

Upon meeting the study’s inclusionary criteria, you will be asked to meet with a researcher off school campus in an agreed-upon location to complete a pre-screening survey, consisting of seven questions regarding daily activity, schedule, and demographic information. You will also be asked to sign a consent form. In total, this will take approximately 10 minutes. Then, the researcher will work with you to schedule two days of data collection in the following weeks. Procedures will be the exact same for both days of data collection, aside from the addition of vibrational feedback on one day.

Both days of data collection will be scheduled as follows:

Before the school day begins, a researcher will meet with you in the previously agreed upon location off school campus to calibrate the devices, assist in putting on the

Figure 9  Informed consent, page 1/3
harness, and help with set up. This will take approximately 15 minutes. You will be asked to keep the harness on for the entire school day (7-8 hrs.), until meeting with the researcher again. During one of the data collection days the wearable device will vibrate occasionally. If there are any questions or concerns, you may reach out to the researcher via phone or email during the day. After the school day is over, you will meet with the researcher to return the harness and wearable devices. You will also be asked to complete a survey with seven (if no vibration used) or eleven (if vibration was used) questions on comfort, perceived intensity of effort, and your perception of wearable technology. In total, this will take approximately 15 minutes. You will be given your incentive for participation at the end of the second day of data collection once all surveys have been completed.

**Risks or Discomforts**
You may experience minimal discomfort from wearing the harness during the day.

**Benefits**
There are no direct benefits to participating in this study.

**Incentive to Participate**
You will be compensated with a $100 gift card at the end of data collection. Failure to complete the study will result in no incentive.

**Confidentiality**
Identifiable information, such as name and email, will not be linked to your data and will only be on consent forms. Once you have met with a researcher, you will be assigned a number that will not be linked with any identifiable information.

Please note that these records will be held by a state entity and therefore are subject to disclosure if required by law. Research information may be shared with the MSU Institutional Review Board (IRB) and the Office for Human Research Protections (OHRP) and others who are responsible for ensuring compliance with laws and regulations related to research. The information from the research may be published for scientific purposes; however, your identity will not be given out.

**Questions**
If you have any questions about this research project or want to provide input, please feel free to contact Bailey Jose at 662-579-9457 or bjo135@mssstate.edu or Lesley Strawderman at 662-722-0738 or strawderman@lise.mssstate.edu.

For questions regarding your rights as a research participant or to request information, please feel free to contact the MSU Human Research Protection Program (HRPP) by e-mail at irb@research.mssstate.edu, or visit our participant page on the website at https://www.orc.mssstate.edu/human-subjects/participant-information.

To report problems, concerns, or complaints pertaining to your involvement in this research study, you may do so anonymously by contacting the MSU Ethics Line at http://www.msstate.ethicpoint.com.
Voluntary Participation
Please understand that your participation is voluntary. Your refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled. You may discontinue your participation at any time without penalty or loss of benefits.

Please take all the time you need to read through this document and decide whether you would like to participate in this research study.

If you agree to participate in this research study, please sign below. You will be given a copy of this form for your records.

<table>
<thead>
<tr>
<th>Participant Signature</th>
<th>Date</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Investigator Signature</th>
<th>Date</th>
</tr>
</thead>
</table>

Research Participant Satisfaction Survey
To make sure that your rights as a research participant have been protected, after your participation in the research study, the MSU HRPP would like for you to complete this survey. Your answers will help us make sure that research participants are protected.

https://msstate.co1.qualtrics.com/jfe/form/SV_5dMg4uHnw8tU5D0

MSU HRPP

Approved: Expires:
2/16/23 2/15/28

IRB # 23-565

Figure 11  Informed consent, page 3/3
APPENDIX B

FACT SHEET FOR PARTICIPANTS
Fact Sheet for Wearables

- Keep harness on at all times.

- You may adjust the harness to be tighter or looser if experiencing discomfort but always allow the wearables to stay placed on the upper back.

- If a wearable happens to fall out of the harness, immediately place back inside the correct pouch, in the correct orientation, as shown in the diagram below.

- If a wearable happens to fall out, please take note of the time and report it to the researcher at the end of the day.

- If any questions or concerns arise, do not hesitate to contact Bailey Jose at brj135@msstate.edu or 662-579-9467.

Figure 12  Fact sheet for wearables
APPENDIX C

PRE- AND POST-SURVEYS
PRE-SCREENING SURVEY

1. Please enter your contact information.

Name______________________________
Birthday
(mm/dd/yyyy) _______________________
Race/Ethnicity________________________
Gender____________________________
Name of School_______________________
Grade ______________________________
Email Address________________________
Phone Number________________________

2. Are you the primary teacher of your classroom?

☐ Yes
☐ No

3. Do you have any history of back injuries or surgeries?

☐ Yes
☐ No

4. Do you have any history of musculoskeletal disorders?

☐ Yes
☐ No
5. How much does your physical activity at work vary throughout the week?

- A great deal
- A lot
- A moderate amount
- A little
- None at all

6. Are there certain days of the week you are exerting more energy at work? If so, select which day(s).

- Monday
- Tuesday
- Wednesday
- Thursday
- Friday
- I exert the same amount of energy each workday.

7. Are there any days you would not be able to undergo data collection?

- No
- Yes (please specify when)

---

Figure 14  Pre-screening survey, page 2/2
POST DATA COLLECTION SURVEY

1. Please enter your contact information.

Name ____________________________
Name of School ______________________
Grade ____________________________
Email Address __________________________
Phone Number __________________________

2. What level of physical exertion on average did you experience today? ☐ o
   □ Very light activity: hardly any exertion
   □ Light activity: Feels like you can maintain for hours, easy to breathe and carry conversation.
   □ Moderate activity: Breathing heavily, but can hold short conversation. Still somewhat comfortable but becoming more challenging.
   □ Hard activity: Borderline uncomfortable. Short of breath, can speak a sentence.
   □ Very hard activity: Very difficult to maintain exercise intensity, can barely breath and speak.

3. During the most physically demanding point in your day, what level of physical exertion did you experience today? ☐ o
   □ Very light activity: hardly any exertion
   □ Light activity: Feels like you can maintain for hours, easy to breathe and carry conversation.
   □ Moderate activity: Breathing heavily, but can hold short conversation. Still somewhat comfortable but becoming more challenging.
   □ Hard activity: Borderline uncomfortable. Short of breath, can speak a sentence.
   □ Very hard activity: Very difficult to maintain exercise intensity, can barely breath and speak.

Figure 15  Post data collection survey, page 1/2
4. How typical was your workday today? 🌟 0

☐ Much easier than normal
☐ Slightly easier than normal
☐ Normal
☐ Slightly harder than normal
☐ Much harder than normal

5. How did you perceive the wearable device? 🌟 0

6. How did the wearable device affect you? 🌟 0

7. How did the wearable device affect your way of working? 🌟 0

---

**Haptic Feedback Applied**

5. How did you perceive the vibration feedback? 🌟 0

6. How did the vibration feedback affect you? 🌟 0

7. How did the vibration feedback affect your way of working? 🌟 0

8. What did you learn from the vibration feedback? 🌟 0

---

Figure 16   Post data collection survey, page 2/2
APPENDIX D

TIME VS. TRUNK FLEXION ANGLE GRAPHS
Participant 1:

Day 1 (Haptic Off):

Day 2 (Haptic On):

Figure 17  Time vs. Trunk Flexion Angle graphs, Participant 1

Participant 2:

Day 1 (Haptic On):

Day 2 (Haptic Off):

Figure 18  Time vs. Trunk Flexion Angle graphs, Participant 2
Participant 3:

Day 1 (Haptic Off):  

Day 2 (Haptic On):

Figure 19  Time vs. Trunk Flexion Angle graphs, Participant 3

Participant 4:

Day 1 (Haptic On):  

Day 2 (Haptic Off):

Figure 20  Time vs. Trunk Flexion Angle graphs, Participant 4
Participant 5

Day 1 (Haptic Off):

Day 2 (Haptic On):

Figure 21  Time vs. Trunk Flexion Angle graphs, Participant 5