ORIGINAL ARTICLE

Enhancing Ergonomics: Assessing the Effect of Vibrating Insole Prototype on Female School Teachers' Muscle Activity

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ABSTRACT

Introduction: Throughout the school day, teachers often endure extended periods of standing, resulting in frequent experiences of pain and muscle fatigue by day's end. The purpose of this study was to identify the effectiveness of a prototype of vibrating insole on muscular activity on teachers. **Materials and methods:** A total of 124 female school teachers participated in this study. During a one-hour classroom teaching session, school teachers were randomly assigned to either the experimental group or the control group. Throughout the hour-long session, wireless surface electromyography (sEMG) sensors were used to continually monitor the muscles in the right and left legs. **Results:** During the one-hour prototype testing, compared to control group, participants in the experimental group showed a reduction in muscle activity exertion ranging from 13% to 16% in both the tibialis anterior and peroneus longus muscles of the right and left legs. Moreover, there were significant changes of muscle activity exertion among school teachers, X^2 (15) = 289.94, p<0.001 within testing period. **Conclusion:** The study revealed a significant decrease in muscle activities, especially the feet, demonstrating a gradual adaptation to the vibration effects from the insole prototype. This contributed significantly to lower leg comfort during teaching sessions. As a result, the vibrating insole prototype was well-received by school teachers and had a positive impact on their feet comfort throughout the experimental testing session.
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INTRODUCTION

Musculoskeletal disorders (MSDs) are prevalent occupational hazards that significantly impact the workforce, particularly those in physically demanding jobs (1). This subset includes long-term work-related difficulties that cause pain or dysfunction in the musculoskeletal systems, which include the bones, joints, and soft tissues that support and protect the human body. Any discomfort, pain, or ailment that extends from fingertips to shoulders or the neck, mainly affecting the upper limb, falls under one category of MSDs. On the other hand, another kind adds to the range of MSDs by involving conditions affecting the lower limbs or hip-toe disorders (2). When considering the context of comfort, ergonomics aims to enhance the interaction between teachers and the equipment or supporting elements, especially in the classroom, with a particular focus on the teachers' posture and physical health. The principal aim of ergonomics is to alleviate pain sensations, which frequently result in reduced work performance, limiting the scope of tasks that can be performed efficiently and possibly resulting in long-term impairments (3).

Occupations that include high demands and multiple health risks can expose workers of different occupational groups to discomfort or pain related to musculoskeletal disorders at work. School teachers stand out among these groups in particular (4). With 455,904 teachers, 237,317 of whom are employed as primary school teachers, teaching is a significant occupation in Malaysia (5). School teachers are particularly vulnerable to MSDs due to prolonged standing, uncomfortable postures, and repetitive movements during teaching (6). Aside from physical obligations, teachers encounter psychological as well as social obstacles primarily between and after school hours. They frequently lament the lack of time they have for rest because of their increased responsibilities. These variables may lead to long-term musculoskeletal issues (7;8).

"Prolonged standing" refers to teachers who stand for more than half of the school day (9). This extended standing usually results in pain and tired muscles at the end of the day, which raises the risk of musculoskeletal disorders that gradually worsen over time. Standing all the time might lead to a progressive decline in posture. To lessen strain, teachers typically carefully shift their body weight from one foot to the other while standing in the classroom. However, prolonged use of this uncomfortable posture may result in circulation issues, including edema in the legs and feet. Long durations of standing can also cause the knee, foot, and back joints to become stiff or partially immobile (4).

Researchers have advised using insoles to address health issues that school teachers face because they can be utilised with a range of footwear designs (10;11). Furthermore, research on the use of vibration therapy to reduce pain has demonstrated encouraging efficacy (12). According to the Ohio State University Medical Centre (13), vibration stimulation is recognised for a therapy for relieving tension by producing numb in the affected areas. According to Hijmans et al. (14), vibration also helps to relax the muscles surrounding uncomfortable spots, which lessens pains and discomfort in the muscles. Even with this information, there are few studies especially in Malaysia that apply these types of interventions with teachers. According to Alias et al. (10), teachers should be aided with ergonomic footwear or inserts, particularly when engaging in activities in the classroom that require extended standing and repeated leg movements. The goal of providing teachers with ergonomic shoes is to reduce lower limb pain or discomfort while they are in the classroom, especially during teaching sessions. Thus, in this regard, the effectiveness of a prototype vibrating insole on the electromyography muscle activity of female teachers was examined.

MATERIALS AND METHODS

Participants Selection

A total of 124 school teachers from six different elementary schools in Terengganu, Malaysia, participated in this study, meeting the specified requirements: i) they were female teachers, ii) their ages ranged between 20 and 35 years old, and iii) they had a normal BMI falling between 18.5 and 24.9 kg/m2. The participants were divided into two groups at random (the experimental group and the control group) using simple random sampling. The Malaysian Ministry of Education (MOE) and the Universiti Putra Malaysia Ethics Committee (UPM) were both approved the study technique ethically. Prior to participating in this research study, all teachers were provided with an extensive description of the study's objectives and asked to sign an informed consent form.

Questionnaire Survey

A self-administered survey was distributed among school teachers from six selected schools that met specific inclusion and exclusion criteria. The questionnaire was self-modified and comprised two distinct sections aimed at collecting information related to socio-demographic and work-related aspects. Section A focused on gathering general participant information, encompassing socio-demographic characteristics such as age, height, weight, sleeping habits, household income, and type of footwear used. Section B examined variables connected to the workplace, such as years of teaching experience, hours taught on average each day, physical activities performed, and hours spent in standing and sitting positions. All female teachers selected for participation in this study consented to be respondents, resulting in a 100% response rate.

The questionnaire went through a thorough content validity procedure, beginning with a review and validation by a panel of experts related to this field of research. These experts scored each item using the I-CVI index computation, with scores ranging from 0.75 to 1.0, indicating a high level of content validity. Furthermore, the reliability of the questionnaire was evaluated using the Kappa statistics test, which yielded an overall Kappa coefficient of 0.81 for the questionnaire.

Electromyography Muscle Recording.

Wireless electromyography (EMG) equipment allowed for non-invasive muscle activity recording and assessment while allowing school teachers to move freely without being distracted by EMG equipment. Surface electrodes were attached on skin to collect EMG data from the left and right peroneus longus and tibialis anterior muscles. Each teacher wore wireless surface electromyography (sEMG) devices on both legs for an hour to continuously measure their muscle activity. Teachers' both legs were prepped by using an alcohol swab to clean the surrounding region of the skin surface and an abrasive pad to remove non-conductor materials between electrodes and skin. Throughout the experiment, the sEMG activity of the tibialis anterior and peroneus longus muscles in each leg was measured using the medial malleolus as the reference electrode site. Each electrode was securely placed on the skin, maintaining constant pressure on selected muscles and minimising movement of electrode while teachers in teaching session. The Konrad (15) handbook principles served as the foundation for recording and capturing EMG data of muscle activity. Participants were reminded to engage in regular work-related tasks and movement such as sitting, standing, and walking while the experimental prototype was being tested.

Experimental Testing Procedure

A cohort of 124 school teachers participated in this research. Among them, 62 teachers were assigned to the experimental group, tasked with wearing shoes equipped with a vibrating insole prototype (Figure 1) and the remaining 62 teachers were instructed to wear regular shoes with no vibrating insole prototype for control group by randomisation. This vibrating insole were designed with three different sizes and before the trial began, teachers may select the best insole size for their foot. They might have adjusted the insoles further before the session without disrupting the flow of the classroom. During the experimental prototype testing, teachers were permitted to engage in typical activities such as sitting, standing, and walking during learning session in classroom. Each testing session lasted one hour, as this duration aligned with the maximum length of a teaching session of primary school before teachers transitioned to˜their next class or took a break. The sessions were held during a classroom teaching period, notably the first morning session. Every individual took part in two distinct experimental sessions, separated by at least three days (16;17). The control box's potentiometer was used to measure each participant's sensitivity to vibrations. The noise level of the insole was determined such that both feet could feel the prototype's vibrations. The vibration amplitude has been set to 90% of every teacher based on their sensory threshold to tactile sensitivity for vibration. Before the experimental began, teachers were instructed to perform a maximum voluntary contraction (MVC) of the plantarflexion and dorsiflexion of the foot about 10 seconds prior to the onset of signal recording with wireless surface electromyography (sEMG). The method was developed to assess teachers' muscular strength using MVC data while providing an appropriate comparison point of muscle exertion of the prototype's experimental session (18).

Figure 1: Shoe Attached with Vibrating Insole Prototype.

Ethical Consideration
The study was approved by the Ethical Committee Members of Universiti Putra Malaysia (JKEUPM) (JKEUPM-2019-078) and the Ministry of Education Malaysia (KPM.600-3/2/3-eras-4403).

RESULTS

Background Population
According to the data provided in Table I, teachers' average age was 31 years old, and their average salary ranged from RM 2,000 to RM 4,000. Within both study groups, there was a marginally greater percentage of teachers who liked to wear heels compared to those who chose flat shoes. The study's teachers fell into the category of young adults, with an age range of 20 to 35. The majority of teachers in both the experimental and control groups managed to attain sufficient sleep, averaging between 7 to 9 hours per day, a duration deemed optimal for adults according to the National Sleep Foundation (19).

Table I also illustrated that most teachers in both studied groups have teaching experience ranging from 2 to 10 years (88.7% vs. 91.9%). Most school teachers in both groups spent 1 to 4 hours teaching, sitting and standing, and participating in sports during the school day.

Table I: Background information

Variables	Experimental Group (n=62)		Control Group (n=62)		z-Value	p-value
	Mean ±SD	Frequency (%)	Mean ±SD	Frequency (%)		
Age (years)	31±3.14		31±2.62		-0.295	0.768
Household Income						
<RM 2,000		1(1.6)		0(0)		
RM 2,000 – RM 4,000		38(61.3)		36(58.1)		
>RM 4,000		21(37.1)		26(41.9)		
Sleeping hour (daily)						
<7 hours		2 (3.2)		1(1.6)		
7-9 hours		55(88.7)		58(93.5)		
>9 hours		5(8.1)		2(4.9)		
Shoe type						
Flat		27(43.5)		30(48.4)		
With heel		35(56.5)		32(51.6)		
Teaching experience (years)						
2 – 10 years		55(88.7)		57(91.9)		
11 – 20 years		7(11.3)		5(8.1)		
Teaching hours (daily)						
1 – 4 hours		46(74.2)		50(80.6)		
5 – 8 hours		16(25.8)		12(19.4)		
Sitting hours (daily)						
1 – 4 hours		59(95.2)		60(96.8)		
5 – 8 hours		3(4.8)		2(3.2)		
Standing hours (daily)						
1 – 4 hours		53(85.5)		51(82.3)		
5 – 8 hours		9(14.5)		11(17.7)		
Sport activity (daily)						
Yes		54(87.1)		52(83.9)		
No		8(12.9)		10(16.1)		

Muscle Activity (EMG) Rate among School Teachers

The electromyography test that was performed on teachers primarily examined two muscle groups: tibialis anterior and peroneus longus muscles for right and left legs. Figure 2 through 5 show the distribution of electromyography (electromyography) data for these analysed muscles among teachers. Essentially, the recorded muscle activity over a one-hour period was captured using surface electromyography (sEMG) facilitated by wireless EMG sensors in a time series format. The exertion frequency, represented as a percentage of exertion (%) and a higher percentage of exertion indicated an increase in muscle activity for the specified muscles. During the one-hour prototype testing, experimental group in Figure 2 to Figure 5 showed a reduction in muscle activity exertion (%) for both leg muscles compared to the control group, ranging from 13% to 16%. Among the muscles examined in the experimental group versus the control group, the peroneus longus muscle in the left leg showed the largest reduction in muscular activity exertion, measuring at 16%.

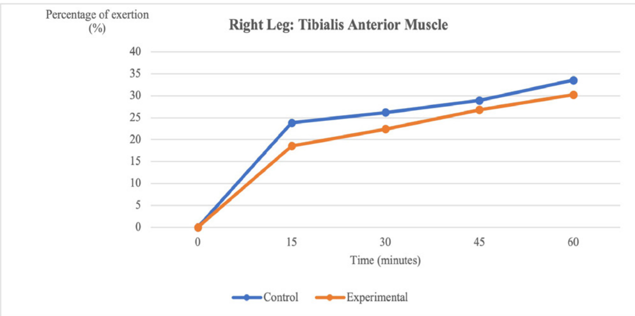

Figure 2: Changes of exertion of muscle activity (tibialis anterior) during one-hour teaching duration.

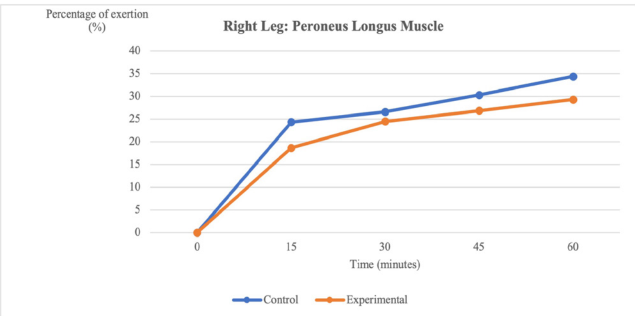

Figure 3: Changes of exertion of muscle activity (peroneus longus) during one-hour teaching duration

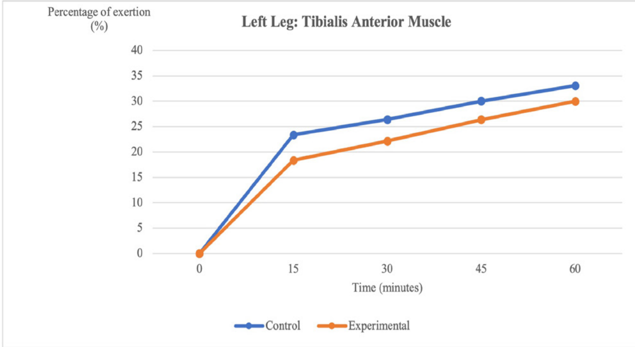

Figure 4: Changes of exertion of muscle activity (tibialis anterior) during one-hour teaching duration

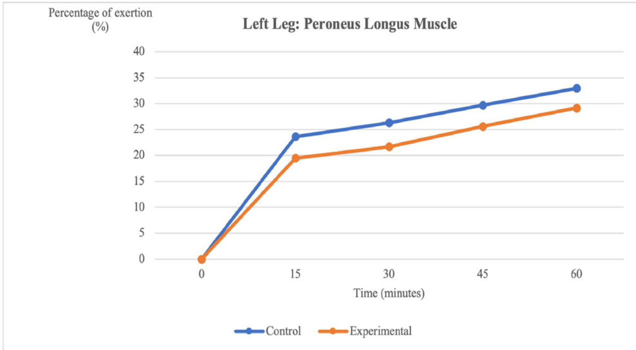

Figure 5: Changes of exertion of muscle activity (peroneus longus) during one-hour teaching duration

The percentage of exertion (%) values for the tibialis anterior and peroneus longus muscles on the left and right were displayed in Table II. The outcomes were derived from a statistical analysis utilizing the Friedman test, chosen as an alternative to the One-way repeated measure ANOVA due to its independence from the requirement of the dependent variable adhering to a normal distribution. This specific test was used to determine within-subject effects as well as changes in effects between groups. In essence, three or more time points or different underlying conditions were used to assess the sample of subjects (female school teachers) using the Friedman test. The outcomes of this test unveiled notable exertion changes (%) during the one-hour experimental testing, X^2 (15) = 289.94, p<0.001. Subsequent to this, a Post Hoc analysis utilizing the Wilcoxon signed-rank test was executed, incorporating a Bonferroni correction, which revealed significant mean differences across all pair.

Table II: Exertion of muscle activity (electromyography) of tibialis anterior and peroneus longus muscles among female school teachers

Time (minutes)	Median (IQR)				Median (IQR)				X^2-value	p-value
	Experimental Group (n=62)				Control Group (n=62)					
	Right (Tibialis Anterior)	Right (Peroneus Longus)	Left (Tibialis Anterior)	Left (Peroneus Longus)	Right (Tibialis Anterior)	Right (Peroneus Longus)	Left (Tibialis Anterior)	Left (Peroneus Longus)		
15	18.53 (18.14, 23.57)	18.66 (13.21, 26.61)	18.35 (14.52, 25.63)	19.46 (18.47, 24.15)	23.84 (21.98, 34.35)	24.32 (21.98, 29.32)	23.38 (21.75, 29.93)	23.62 (17.34, 35.57)	289.94 (15)	<0.001*
30	22.39 (24.27, 19.21)	24.48 (19.87, 30.31)	22.14 (17.82, 28.99)	21.69 (18.49, 23.57)	26.18 (18.12, 32.00)	26.58 (28.86, 38.29)	26.39 (23.70, 28.35)	26.3 (16.73, 32.55)		
45	26.8 (20.32, 28.99)	26.84 (20.64, 30.46)	26.37 (19.65, 29.49)	25.61 (15.62, 31.10)	28.93 (23.01, 27.42)	30.28 (26.54, 31.31)	30.01 (19.78, 39.32)	29.7 (16.42, 37.05)		
60	30.23 (25.4, 34.02)	29.31 (21.48, 33.86)	29.98 (25.21, 30.44)	29.15 (26.75, 34.21)	33.55 (19.54,36.63)	34.37 (17.41, 38.32)	33.08 (19.71, 39.69)	32.95 (21.34, 39.64)		

DISCUSSION

We described the clinical manifestations and risk factors The assessment of human comfort levels through the use of objective measurement such as electromyography (EMG) entails the study of human physiology, namely muscles and bodily functions (20). The principal objective of this study was to discover if a prototype vibrating insole had any influence on muscular activation in the tibialis anterior and peroneus longus muscles. Statistical analysis using the Friedman test revealed that most female school teachers showed significant changes in muscle exertion (%), X^2 (15) = 289.94, p<0.001, for both muscles when comparing the experimental and control groups during the one-hour experimental assessment. Teachers in the experimental group demonstrated reductions in muscular activity exertion during the hour-long prototype testing period with electromyography (EMG) values in the left and right leg muscles were 13% to 16% lower than teachers in the control group. Additionally, when compared to other investigated muscles, the peroneus longus muscle in the left leg among teachers in experimental group revealed the highest reduction in muscle activity exertion when compared to the control group, at 16%.

According to other studies that explored the use of insoles, muscular activities in the anterior tibialis were higher during the standing period when the soles touched the ground (21), as was the function of the peroneus longus muscles, which included stabilising and pulling the base of the first metatarsal downward to maintain the longitudinal arch, as well as assisting in the plantarflexion of the foot (22-24). The effort variations caused by the vibrating insole prototype lowered muscular tension, potentially minimizing muscle stiffness and leg discomfort in school teachers, particularly in the ankle and foot. This decrease meant that the tibialis anterior and peroneus longus muscles did not have to contract for as long (25), making the insoles more comfortable for teachers in the classroom.

Recent study had found a significant occurrence of musculoskeletal conditions (MSDs) (40.1%) among Terengganu primary schools teachers. For the period of 12-months, the feet (32.5%) were found to be the most severely affected area among school teachers while engaging with work-related activities in school. Factors associated with this, including age, BMI, engagement in sports activities, footwear type, teaching duration, and hours spent standing, were scrutinized among the school teachers (26). There is a chance that teachers will have even greater rates of MSDs if efforts to reduce MSD prevalence are not implemented. The increased frequency of foot-related MSDs emphasises how important it is for teachers to have access to footwear that is ergonomically designed, particularly during class times when standing and repetitive foot motions are required (10). Comfort should be the top priority when it comes to these ergonomic footwear options, especially for the lower limbs. While lower limb conditions are crucial for teachers to maintain neutral posture during class and the entire day in school, there has been little attention paid to them in recent scholarly endeavours (10;26).

Furthermore, integrating vibrating insoles or shoe designs represents one facet of ergonomic interventions, wherein elements like vibrating tactors, control boxes, and noise generators can be incorporated into their structure. Vibration tactors can be activated with minimal power supply, presenting cost-effectiveness and suitability for prolonged usage in intricate conditions (27). Ergonomic solutions, such as vibrating insoles, can help teachers who stand for extended periods of time by reducing lower leg muscle fatigue and discomfort. Supportive insoles reduce force transmission when standing on hard surfaces, which improves general muscular health (28).

This study highlights the benefits of vibrating insole prototype for female teachers, showing this vibrating insole reduce physical discomfort and improve effectiveness with minimal impact on muscle activity.

These insoles aid to minimize muscular pain and tiredness, potentially decreasing the prevalence of musculoskeletal sickness among Malaysian primary school teachers. The study also provides useful insights into shoe comfort, which may inspire future ergonomic footbed designs to improve foot comfort during extended teaching hours.

CONCLUSION

The results obtained from the study are encouraging. The vibration tactors' precise size, frequency range, and amplitude of vibration seem to offer a practical solution for improving teacher comfort. The insoles' flexible design makes it simple to attach them to conventional shoes without interfering with teachers' work during school hours, especially in classroom settings. One potential intervention for addressing dynamic balance requirements is the vibrating insole, which can help equalise pressure distribution across the foot. Interventions involving footwear, particularly insoles, ought to be designed to promote postural dynamics that mitigate undue strain on the muscles of the foot and lower limb. With individually adjusted vibrations, the prototype vibrating insoles softly massage the feet, ease muscle tension, and reduce pain and suffering in every part of the foot, from the toes to the heels. The observed significant decrease in muscle activity in teachers points to a gradual response in the lower limb, especially the feet, to the vibrations from the prototype insole, which helps to improve lower limb comfort during teaching sessions. In turn, the vibrating insole prototype garnered positive acceptance from school teachers and exhibited a beneficial impact on their musculoskeletal systems throughout the experimental testing period.

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