Feet Plantar Pressure Distribution Among Female School Teachers

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Research Article

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Abstract

Background: Plantar pressure distribution has been recognized as a significant finding to associate with various feet conditions. Objectives: To determine the feet plantar pressure distribution among female school teachers;

Methods: This research consisted of 124 female school teachers. Respondents was asked to walk at a regular pace for 10 seconds from a fixed starting point while using footwear pressure insole device and pressure measurement was recorded.

Results: The findings show that lateral heel exerted the most pressure in the right and left foot (94 kPa vs 85 kPa). The second highest average of plantar pressure distribution for right foot among female school teachers was medial forefoot (67 kPa), followed by central forefoot (55 kPa), lateral forefoot (52 kPa) and lateral midfoot with 49 kPa. For the left foot, the second highest for average of plantar pressure distribution was medial forefoot (58 kPa), followed by lateral forefoot (48 kPa), and central forefoot (47 kPa) and lateral midfoot (33 kPa). The result was significant differences as the right foot often exerted greater pressure on any part of the foot than the left foot;

Conclusions: The pressure plantar distribution of foot reflects the conditions of school teachers with various posture and movement.

Introduction

The roles of teachers had changed due to advanced technology, globalization and change of education exposure. In the stage of rapid technology development, well-evolved and sophisticated, the roles and duties of teachers are quite challenging and demanding. Skilled teachers should creatively blend the knowledge with learning and teaching methodologies so that the concepts of contents are well understood by the students during learning process [1]. Studies state that MSD is most likely influenced by psychosocial factors among school teachers such as excessive workload or requirements, high psychological distress, poor job satisfaction and lack of job quality [2,3]. Teacher spends most of the school hours standing in the classroom, working between desks in small spaces, educating students, writing on the chalkboard, planning lessons, assessing assignments and performing extra school administrative work, that can develop mental and physical health problems [4].

Postural pain in the classroom, uncomfortable sitting and standing, because of long teaching hours, repetitive and uncomfortable bend, MSDs on the lower extremities may suffer from impairments among school teachers [5]. Even so, school teachers are faced with social and psychological difficulties both within and after school hours every day and have reported less time to relax after teaching, due to extra work that could lead to chronic musculoskeletal problems [6,7]. Basically, a teacher is expected to uphold a standing position when he or she gives lesson in a classroom by putting one foot up, often trying to adjust the position and keeping the posture at pleasant height even from wearing shoe with heel. A
teacher is considered to be subject to prolonged standing if he or she spends more than half of the school hours every day in a standing position [8].

Eventually, when teachers have spent a long time of energy in a standing posture throughout their school hours, at the end of the working day they may experience discomfort and muscle fatigue. For a long period of time, they may have suffered musculoskeletal injuries. Slow posture degradation can be caused by long standing or standing for long periods of time. Teachers usually slowly move their weight from one foot to the next when standing in the classroom in order to ease the strain. Slouching facilitates a standing posture that makes it possible for teachers to be less alert and passive. When this uncomfortable pose is maintained for long-standing teachers, it may lead to problems of circulation such as swollen legs and feet. Long standing also renders the joints in the back, knee and feet partially immobilized or stiff [9].

Plantar pressure distribution is often used in foot clinical assessment and offers a view of plantar load characteristics during practical tasks such as running and walking. The assessment, evaluation and enhancement of the function of the foot and lower limb can be combined with these data [10]. Many commercially available clinicians and researchers are currently using them to evaluate plantar processing [11]. The reliability of equipment commonly used for plantar pressure evaluation method has been improved in the normal adult population [12-14] and recent study on the reliability of plantar pressure measurements for adults has been published by Gurney, Kersting and Rosenbaum [15]. The results showed that areas with usually high loading characteristics, such as the central of forefoot, showed a higher degree of reliability (>0.9).

In order to identify and treat individuals with a diverse range of lower limbs disorders linked with musculoskeletal and neurological conditions that can affect both adult and young patients, data collected from a plantar pressure assessment may be used. If plantar pressure levels are found to be anomalous, the insight can be used footwear adjustments, foot custom insoles, fitness routine and weight bearing restrictions to modify the patient’s treatment regimen. Information derived from pressure processes is often valuable from a theoretical viewpoint to address a range of aspects related to the relationship between plantar and lower limb posture [10]. In addition to relevant literature on plantar pressure distribution, none of these studies was performed among school teachers. The workplace of teachers in school included all the risk factors such as heavy physical loads, prolonged static postures and lifting may associated with the findings on distribution of plantar pressure among teachers and made it necessary to carry out research to determine the distribution of feet plantar pressure in primary schools among female teachers.

**Methods**

**a) Participants Selection**

The aim of this cross-sectional study was to determine the feet plantar pressure distribution among female teachers in primary school. The subjects of study included 124 female school teachers in 6
different primary schools in Terengganu, Malaysia with the criteria listed: i) female teachers, ii) between 20 and 35 years of age, iii) normal Body Mass Index (between 18.5 and 24.9), iv) with a minimum of 1 year of teaching experience, v) no history of foot injury in the last one year. Criteria for exclusion: i) pregnancy, ii) Operations or prior procedures on some of the parts of body were done.

The research was carried out on the basis of the principles of Helsinki Declarations 1964 and Ministry of Education, Malaysia (KPM.600-3/2/3-erars-4403) and The Ethics Committee for Research involving Human Subject of Universiti Putra Malaysia (JKEUPM-2019-078) ethically endorsed the study protocol. After receiving a comprehensive summary of the study objectives and agreeing to take part as respondents, all teachers were received written informed consent for study participation.

b) Questionnaire

In 6 different schools, questionnaires were administered to all school teachers who matched the selection requirements of the study. For all teachers, the overall response score was 100%. The instrument was a self-modified questionnaire made up of 2 parts to gather information on socio-demographic and work-related characteristics. Section A: Socio-demographic variables were used to collect information on participants such as age, weight, height and average salary. Section B: Work-related characteristics, including length of teaching experience (years), average teaching hours, physical activity, and duration of standing and sitting work during school hours. The questionnaires were collected from participants that met inclusion and exclusion criteria.

c) Plantar pressure measurement

Foot is categorized in 3 regions which are forefoot, midfoot and hindfoot. Every part of foot produces different value of pressure. The foot pressure mapping system was therefore used to calculate and evaluate the pressure distribution on the teacher's foot. It captured and visualized measurable, responsive pressure data in real time over a wireless interface for minimal invasive measurements obtained between teachers. In order to identify the location of high point pressure, foot was divided into 9 areas to allow an experimental recording of pressure which were Hallux (HA), Lesser Toes (LT), Medial Forefoot (MF), Central Forefoot (CF), Lateral Forefoot (LF), Medial Midfoot (MF), Lateral Midfoot (LM), Medial Heel (MH) and Lateral Heel (LH) [15-17] (Figure1).

The wireless foot mapping sensor device was used to quantify plantar the distribution of plantar foot pressure in real time. Wireless sensors have demonstrated their high precision and reliability in calculating high foot pressure distribution in field settings without any disruption [18]. The sensed data was obtained wirelessly from the base station (BS). This will show the pressure distribution data on the Graphical User Interface (GUI) in real time. In accordance with the protocol for documenting the distribution of plantar foot pressure, respondents were asked to walk at a regular pace for 10 seconds from a set starting point. They were advised to look straight ahead while walking a shoe pressure insole system. Until the final set of readings was taken, it was assured that respondents walked comfortably.
The general benefit of the insole technique was that multiple steps data can be generated in a single record of respondent [17].

d) Statistical Assessment

The data was generated and analysed using SPSS 19.0 version programme. The statistical data of the respondents were defined using descriptive statistics such as mean and standard deviation.

Results

a) Background Population

The study involved 124 female school teachers teaching in different of 6 primary schools in Terengganu, Malaysia with 100% of response score. The average teachers’ age was 31 years, according to Table 1. Teachers who were included in this study, from age 20 to 35 years old and classified as young adult. Muscle strength peaks at about 25 years of age, plateaus at 35 to 40 years of age, accompanied by an accelerated decline with a 25% reduction of peak strength at 65 years of age [19]. Therefore, it is important to choose the age between 20 until 35 years old to avoid factors as may affect the result of muscle activity during plantar pressure data recording. Additionally, average of BMI data reported was 22.8kg/m$^2$. Normal BMI was included in inclusion criteria in order of priority for teachers as respondents needed to be in a healthy state and did not influenced the plantar pressure distribution. A large number of teachers had an average salary of between RM 2,000 and RM 4,000 (91.1%). Most of them had adequate sleep, with range of 7 to 9 hours a day (54.8%). According to National Sleep Foundation [20], the best hour for sleeping in a day for adults are 7 to 9 hours in order to get a quality daily life. In spite of shoe preference, heel-selecting teachers (57.3%) is marginally higher than those who prefer to wear flat shoes (42.7%).

Table 1: Background Characteristics of the Female School Teachers
<table>
<thead>
<tr>
<th>Variables</th>
<th>Total (%)</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>(n=212)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>31</td>
<td>3.62</td>
<td></td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>22.8</td>
<td>2.19</td>
<td></td>
</tr>
<tr>
<td>Household income</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; RM2,000</td>
<td>9 (7.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RM 2,000 – RM 4,000</td>
<td>113 (91.1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;RM 4,000</td>
<td>2 (1.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleeping hours</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 7 hours</td>
<td>10 (8.1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 – 9 hours</td>
<td>68 (54.8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;9 hours</td>
<td>46 (37.1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat</td>
<td>57 (42.7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>With heel</td>
<td>67 (57.3)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### b) Work-related Characteristics

Table 2 displayed that school teachers in this study mostly had experience with teaching between 1 and 10 years of age (90.3%). Almost all the teachers said that during school hours, they spent 1 to 4 hours teaching (77.4%), sitting (96.0%), and standing (83.9%) in a day. As a result, 85.5% of teachers involved with sports activity in a day compared to other 14.5% of teachers.

**Table 2: Work-related Characteristics of the Female School Teachers**
<table>
<thead>
<tr>
<th>Variables</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n=212)</td>
</tr>
<tr>
<td><strong>Teaching experience (Years)</strong></td>
<td></td>
</tr>
<tr>
<td>1- 10 years</td>
<td>112 (90.3)</td>
</tr>
<tr>
<td>11- 20 years</td>
<td>12 (9.7)</td>
</tr>
<tr>
<td><strong>Teaching hours (daily)</strong></td>
<td></td>
</tr>
<tr>
<td>1- 4 hours</td>
<td>96 (77.4)</td>
</tr>
<tr>
<td>5 – 8 hours</td>
<td>28 (22.6)</td>
</tr>
<tr>
<td><strong>Sitting hours (daily)</strong></td>
<td></td>
</tr>
<tr>
<td>1- 4 hours</td>
<td>119 (96.0)</td>
</tr>
<tr>
<td>5 – 8 hours</td>
<td>5 (4.0)</td>
</tr>
<tr>
<td><strong>Standing hours (daily)</strong></td>
<td></td>
</tr>
<tr>
<td>1- 4 hours</td>
<td>104 (83.9)</td>
</tr>
<tr>
<td>5 – 8 hours</td>
<td>20 (16.1)</td>
</tr>
<tr>
<td><strong>Sports activity</strong></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>106 (85.5)</td>
</tr>
<tr>
<td>No</td>
<td>18 (14.5)</td>
</tr>
</tbody>
</table>

c) Plantar Pressure Distribution of feet

There were 5 significant areas chosen based on high pressure distribution of feet (the plantar side of Medial Forefoot (MF), Lateral Forefoot (LF), Central Forefoot (CF), Lateral Midfoot (LM), and Lateral Heel (LH). According to the figure below, lateral heel exerted the most pressure in the right and left foot (94 kPa vs 85 kPa). The second highest average of plantar pressure distribution for right foot among female school teachers was medial forefoot (67 kPa), followed by central forefoot (55 kPa) and lateral forefoot (52 kPa). The least pressure exerted on right foot among teachers was lateral midfoot with 49 kPa. For the left foot, the second highest for average of plantar pressure distribution was medial forefoot (58 kPa), followed by lateral forefoot (48 kPa), and central forefoot (47 kPa). Lastly, compare to the right foot, lateral midfoot had the least pressure left foot pressure of 33 kPa. The outcome showed significant differences as the right foot applied more strain on each section of the foot than the left foot, as seen in Figure 2.

Discussion
Therefore, the objective of this study was to create baseline data on the distribution of plantar pressure amongst female school teachers. The foot is the lowest region of the body that carries weight. The structure of bones, muscles and joints facilitates stability by sustaining and supporting vigorous strain or pressure during standing and walking. The physiological pattern of distribution of pressure on the sole is almost symmetrical and gives the foot, and hence our body, an optimum flexibility [21]. Most people comprise a significant part of their lives in a standing position. Walking is also known as a postural control and is one of human beings’ main locomotives, the most common in daily living. The ground surface and feet made contact with each other while we were standing. Upon landing on the ground, the sole of our foot had force. The force impact on foot sole or on the distribution of plantar pressure may be erratic and imbalanced, such impacts may exploit changes of stress, as results of severe applied to the foot, may trigger transient or long-lasting discomfort or foot pain and thus induce foot pressure. In the meantime, this can exacerbate foot disorders or negatively affect an individual’s overall health [17].

Prolonged standing for a significant period of time may lead to a gradual degradation of posture. In a standing lesson, teachers appear seems to be hunching and shifting their weight from one foot to the other in order to ease pain. Slouching promotes static posture that causes the person to become less conscious and therefore more passive. It will lead to poor circulation, along with swelling of the feet and legs, if this uncomfortable pose is maintained by long standing teachers. Prolonged standing often allows the joints to be partially immobilised or to stay in either the feet, knees or legs. Promptly, this disorientation may result to the degeneration of a rheumatic condition associated with tendons and ligaments. Long standing during the teaching process can allow blood to build up on the legs and feet without any relief when you walk. When extended standing with little or no rest during teaching time, this might lead to inflammatory response to the veins. Inflammation may prompt to a long-lasting, painful, persistent varicose vein [22].

Furthermore, feet have been detected as the highest MSD among all parts of the body, concerning 32.5% of female school teachers [23] as shown by latest observations in Terengganu. The research recently carried out in Kota Kinabalu confirmed this high prevalence of lower extremities among primary school teachers with 48.9% (hips, bottoms, legs and feet) [24]. Recent research has shown that knee (33.73%), ankle/foot (25.41%) and hip/thigh (7.01%) are experiencing discomfort as a result of long school standing for long hours without a break and repeated school stairs climbing among Indian teachers [19]. The prevalence of musculoskeletal pain affecting the knee was higher among teachers in Kenya who taught within 1 to 2 hours, was observed by Ndawa, Nyamari and Ireri study [25]. Besides that, study done by Leme and Maia [26] showed that at the end of working hours, 71% of the teachers did not showed disrupted productivity, however due to facilities they use and their posture at the time of the class, they do get discomfort and tired, specifically with the prevalence of pain in the legs (33%), tights (14%) and feet (43%).

The distribution of plantar pressure in various studies has generally been recognised as a critical evaluation for postures and movements of human. The variations and severity of plantar pressure would provide valuable analysis on musculoskeletal disorders especially on ankle and feet parts. Plantar
pressure evaluations of walking, standing and sitting may show irregular foot path mechanics and provide quantitative metrics to monitor impairments of foot [27]. Several studies [27-29] on foot anatomy and physiology have stated that differences in plantar pressure are useful in assessing irregular posture. The pathological gait can be classified into either neuromuscular or musculoskeletal on the basis of basic etiology [30]. Harm to foot tissue depends not only on high strain or pressure, but also on the involvement of physical activity and footwear used by individuals [31]. If plantar pressure levels are found to be anomalous, the knowledge can be used to reconfigure the individual care regimen by adjustments in shoes, foot custom soles, workout schedules and body mass limits. Evidence gained from pressure systems is also beneficial from a scientific point of view to discuss a number of issues related to the relationship between plantar pressure production and lower limb’s posture [10].

Important distinctions were shown in the outcome as the right foot usually imposed more pressure in each area of the foot compared with the left foot among female school teachers in the classroom. In regular walking, the heel was the first part of the foot to bear body weight followed by midfoot and forefoot, eventually the load moved to the toe for the raise. Heel hit the ground on the posterolateral part of the heel, and the highest peak pressure occurred at roughly 18 to 36% of the standing period where heel, midfoot and forefoot were in touch with the ground [31]. According to many reports, natural forefoot pressure patterns are strongest under the 2\textsuperscript{nd} and 3\textsuperscript{rd} metatarsal regions and offer useful information when determining abnormal forefoot conditions. Studies have indicated that toes do not play a major role in the movement of load and produce lower pressure patterns relative to other foot areas [27, 31-32].

The primary goal of researchers for plantar pressure measurements for discomfort of lower limb was to explore the effects of foot pain and footwear adjustment, shoe insoles and various products used to cushion the foot. Various types of insole materials and internal and external footwear modifications have been assessed by researchers using pressure measurement platforms. The results collected from these studies can be used to help clinicians assess the acceptable form and volume of posting needed for foot pain or discomfort, as well as the amount of pressure relief that can be anticipated by using different types of insole interventions [10, 33-34]. In comparison to an outsole that is in contact with the shoe and floor, the insole has a function as a substantial interface that has contact with the shoe and the plantar surface of the foot. While multiple insoles are used in everyday shoes, they are mostly used for foot comfort. A pair of insoles, inserted into the shoe, has the ability to influence the mobility of the whole body as well as the lower extremities by the movement of the foot. If this is actually the case, because an incorrect insole would have a negative influence on the foot [35].

The in-shoe pressure measurement device was used in this analysis and the pressure plantar distribution of the foot among female school teachers was observed. The in-shoe pressure sensor device contains sensing components in the insoles [10, 36] and has achieved an edge over platform applications due to their mobility. It has really enabled a wide variety of field studies and clinical trials. One of its biggest benefits when in-shoe devices are the capability of measuring and analyse consecutive movements, since the foot usually stays synchronised with the same sensors. Dependable pressure measurement can influence by both the movement of the soles and the movement of the feet inside the shoes. The
accessibility of in-shoe devices has enabled the evaluation of gait habits and also facilitated the assessment and enhancement of footwear and insole intervention [37-38]. There has also been a great deal of curiosity in implementing in-shoe plantar pressure delivery techniques to help in the development of custom footwear and insole for the discharge of elevated plantar foot pressure [39-40].

In fact, 35% of the plantar pressure differences during the gait is due to anatomical foot composition, including soft tissue thickness and arch height. Pressure below the heel and midfoot are frequently caused by heel strikes and centre bearings, while flexibility, muscle strength and muscle mobilisations are the primary factors of pressure [41]. The age-related deterioration of soft tissue and bone structure can also reduce the ability to endure plantar foot loads [42]. Essentially, the plantar pressure analysis depends primarily on the level of pressure detected to determine the presence of a foot pathology. In particular, in circumstances of pressure transfer to alleviate foot discomfort and decrease the likelihood of plantar fracture, the diagnostic mechanism involved in the foot assessment has been eased and the therapeutic potential for pathogenic foot has improved dramatically [39,43-45]. Although pressure evidence is so very critical for the diagnosis of foot disorders, generalised conclusions or decisions based merely on plantar pressure thresholds cannot be made [46].

The application of pressure footwear insoles at different locations does not reflect the “day work” of the foot, since people walk at different speeds in everyday activity and use several types of footwear. Changes observed at the stand are often due to foot anatomy, although the abnormal foot pressure can be caused during walking disruptions such as knee, hip or foot pain [47]. Several experiments have shown that the findings are the same or even nuanced as the measurement of the static posture, as antalgic gaits are useful when walking, meaning that the real pressure of the individuals’ soles can be defined correctly [48]. A variety of experiments have been performed on the basis of a person's foot. However, plantar pressure distribution is not evenly distributed in all foot regions. Researchers have their own field of interest in many studies. The foot was split into several regions and according to Gurney, Kersting and Rosenbaum [15], the regions were Hallux (HA), Second Toe (T2), Lateral Toes (T3-5), Lateral Forefoot (LF), Central forefoot (CF) and Medial Midfoot (MH). Similarly, according to the areas of concern of the Chun et al. [17], the foot was divided into 6 significant areas to allow an experimental recording of pressure which were Hallux (HA), Medial Forefoot (MF), Central Forefoot (CF), Lateral Forefoot (LF), Lateral Midfoot (LM), and Hindfoot (HF).

The information gained from the results of this study might be used to oblige clinicians and health practitioners in procurement of suitable type of materials in shoes and insoles provided for individuals with discomfort on feet and to decide the most cost-effective approach to treating musculoskeletal foot and ankle disorders in patients. Nevertheless, evidence derived from a plantar pressure appraisal can be used by the physical therapist in the evaluation and management of adult and paediatric patients with a wide spectrum of foot and lower extremity conditions involved with the neurological, integumentary and musculoskeletal structures. Plantar pressure distribution systems provide the clinicians or researchers with information and guidance on the results of various interventions, including the development of
footwear, use of foot orthotics, physical gait training and surgical assistance, the pressure and strength applied to particular regions of the foot [10].

**Conclusion**

There were 5 significant areas were detected with significantly high-pressure distribution of feet; the plantar side of Central Forefoot (CF), Medial Forefoot (MF), Lateral Midfoot (LM), Lateral Forefoot (LF) and Lateral Heel (LH). Indeed, lateral heel exerted the most pressure in the right and left foot (94 kPa vs 85 kPa). As overall, finding showed a significant difference as the right foot exerted more pressure in every part of the foot than the left foot. By revealing this findings, plantar pressure distribution data among school teachers aided the researcher in understanding how the various plantar regions of the foot produced different pressure value that might be linked to lower extremity discomfort and MSDs. Hence, plantar pressure distribution data had been utilized for the assessment and development of footwear intervention, especially insole, should be designed to promote posture dynamics that did not place excessive stress on the foot and lower limbs muscles. Footwear intervention might be capable of providing an ideal support and comfort to the school teachers, especially for teachers to adapt to various posture while teaching. The intervention can therefore be referred to selected regions of feet with high pressure distribution of foot. The aftereffect can be evaluated by analysing the distribution of plantar pressure after major adjustments have been made to the footwear intervention especially insole intervention that has direct contact to the feet of individual. Hence, it might reduce muscle fatigue and pain and indirectly reduce the significant prevalence of foot discomfort among female primary school teachers in Malaysia, to be exact.

**Declarations**

**ACKNOWLEDGEMENT**

Fellow researchers are thankful to all respondents who involved and sparing their time to provide with all the information details within this time frame of the project.

**AUTHOR CONTRIBUTIONS**

A.N.A- study concept and design, literature search, data collection, data interpretation, writing and editing the manuscript. K.K.- supervision and editing the manuscript. V.H- Software, statistical analysis and validation. V.P.- data interpretation and editing the manuscript

**COMPETING INTERESTS**

The authors declare no competing interests.

**References**


**Figures**
Figure 1

Regions of foot
Figure 2

Mean Pressure Distribution of Feet