Plantar Pressure Distribution in Relation to The Way of Carrying Backpack in Adolescentes

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PLANTAR PRESSURE DISTRIBUTION IN RELATION TO THE WAY OF CARRYING BACKPACK IN ADOLESCENTES

By

Amira Ibrahem Mohamed Ahmed

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Cairo University
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CHAPTER I
INTRODUCTION

Adolescents perform a daily routine of carrying school material over their middle and high school years. Considering that backpacks are practical and are the most commonly used means of carrying school material **(Sheir-Neiss et al.**, **2003).** Taking care with the load and the way in which it is supported is fundamental for this age group. When the backpack load is greater than the support capacity of the muscle groups, there is an overload on the vertebral column, which may cause postural alterations, pain or dysfunctions **(Rebelatto et al., 2001)**. Since carrying school material is a daily routine that is repeated over consecutive years, special care is needed to avoid the presence of postural alterations that might become established over the medium to long term, thereby bringing risks to this population's health (**Brackley et al., 2004).**

Several recommendations have been made in the literature regarding the correct way of wearing schoolbags. Most students use backpacks on either shoulders or on one shoulder (**Sheir-Neiss et al., 2003)**. Some reports recommend that the backpack be worn high on the back with the shoulder straps tightened. However, school backpacks should be positioned with the center at waist or hip level and not high on the trunk (**Grimmer et al., 2000**).

There are many types of backpack designs including shoulder bags, traditional double strap backpacks and unilateral backpacks. Despite warnings issued by various professional organizations regarding the harmful effects of carrying unevenly distributed heavy loads, students continue to carry shoulder bags over one shoulder of self-selected body side (**Perrone et al ., 2018).** Decreased availability of school lockers as a result of security concerns, increased homework, larger textbooks, and other objects being carried to school has prompted the increase use of backpacks by school students which in turn, has lead to both an increase in weight and duration of backpack carriage (**Castellucci et al., 2016**).

Load carriage is defined as locomotion while transporting an external mass supported on the upper torso by shoulder straps and\or transporting hip belts .Several studies concerning the carriage of heavy backpacks, are postural modifications are certainly among the most carefully investigated (**Singh and Koh, 2009**). The average weight of the backpack is about 10% to 15% of children's body weight (**Whittfield et al., 2001and Sheir-Neiss et al., 2003)**.

The anatomical differences in foot structures must be a reason to walk in a different way. At birth, the skeletal tissue of the foot consists mainly of cartilage. During the first 6 years of life, ossification and development towards a mature foot structures occurs. At approximately one year of age, when children usually start walking, the talus, calcaneus, and some of the phalanges contain their primary ossification centers still surrounded by cartillagenous tissue **(Kimmeskamp and Henning, 2001)**. The foot is the terminal segment in the lower kinematic chain; proper kinematics within the foot influences the ability of the lower limb to attenuate the forces of the weight bearing. The lower extremity should distribute and dissipate compressive tensile, shearing, and rotatory force during the stance phase of walking **(Neuman, 2002)**.

In the foot there are two longitudinal arches: the medial arch consists of the calcaneus, the talus, the navicular, the three cuneiform bones and the first three metatarsal bones. It is more elastic than the lateral arch that consists of the calcaneus, the cubiod and the fourth and fifth metatarsal bones. This is flattened and in contact with the ground **(Ridola et al,**

2007). There are two transverse arches between longitudinal arches, extending from the medial to the lateral borders of the foot. The first is a lancet dome, between midfoot and forefoot, at the tarsometatarsal joints level; it consists of the bases of the metatarsal bones, the cubiod and the three cuneiform bones. The second is a flat dome, in correspondence of the forefoot at, the metatarsophalangeal joint level; it consists of the bases of the proximal phalanges of the toes and the head of the five metatarsal bones **(Ridola and Palma, 2001)**.

There are three main arches of the foot which are concave in plantar directions. The main function of these arches is to alternate the foot during weight bearing from a rigid lever to a complaint series of joints and reverses it. Two of the foot arches are oriented longitudinally and one is oriented transversely, so, the foot is a biconcave structure **(Richard, 2003)**.

A foot scan is the method by which we examine the biomechanics of the feet. It provides a dynamic weight bearing computerized assessment of the biomechanics of a person’s foot. The system measures the weight distribution at all the contact points along the bottom surface of the feet **(Tan, 2005)**. Changes of plantar pressure, force and contact area during lifting loads have been reported previously **(Pau et al. 2011)**. An increase in plantar pressure and contact area was also demonstrated when backpack loads increased up to 30% **(Pau et al., 2011).** Moreover, an increase in peak force was reported when loads carried was 15% of body weight **(Hong and Li, 2005).** Changes on the plantar pressure, force and contact area with loads in backpacks, using both hands have been extensively reported. However, information on biomechanics of body structures when lifting loads using one hand is limited **(Lloyd et al., 2010)**.

The presence of abnormalities in the plantar force distribution and in the body's pressure center pathway may suggest that inadequate postures are being adopted when carrying school material. Over the long term, this would favor several vertebral column abnormalities. Such abnormalities may cause functional, psychosocial, work and quality-of-life constraints, thus justifying the need for preventive intervention **(Penha et al., 2005**).

Statement of the problem:

Is there any effect of the way of carrying backpack on foot pressure distribution in adolescents?

Purpose of the study:

To investigate the relationship between backpack carriage unilaterally as well as bilaterally and plantar pressure distribution in adolescents.

Significance of the study:

Backpack use can begin at a very young age and continue until adulthood. Often high loads are carried over a number of years which may have an effect on the growing body. Students currently continue to require a mode of carriage for their school supplies. Although the future may change this with the use of lightweight laptops and other smart devices. Heavy items such as textbooks that may overload a bag are still in use and require transport at minimum between school and home **(Qureshi and Shamus, 2012).**

The backpack is still the most common way of carrying school items. Backpack users traditionally carry heavy loads, while simultaneously dealing with the perturbations experienced in daily living **(Costello et al., 2012).** Backpack carriage places increasing demand on the musculature of all of the joints of the lower limb. Increasing backpack load affects the kinematics, moments and powers at the pelvis and hip, but few changes in these parameters are seen at the knee and ankle (**Chow et al., 2006).**

Throughout the ages, mankind has devised a variety of techniques for load carriage (**Wang et al., 2001).** Common carrying methods used by adolescent teenagers are; two strapped backpack (bilateral) and one strapped backpack (unilateral) (**Feingold and Jacobs, 2002**). Researchers suggest that backpack introduces significant increases in overall contact area and in the plantar pressure peaks in midfoot and forefoot regions A significant shift in the average position of the center of pressure towards the forefoot was also observed **(Massimiliano et al., 2011)**.

The feet are considered to be the base of support of the skeletal system, and so the feet loading mechanisms can affect the rest of body. The inadequate distribution of the forces of weight bearing can affect the normal bone growth. Presence of a load alters the physiological weight bearing functions and, when mechanical overloading is repeated in time, it can act as a co-factor in promoting foot discomfort or pain. Therefore, this study aimed to investigate relation between foot pressure distribution and way of backpack carriage in adolescents.

Null hypothesis:

There is no effect of different ways of carrying backpack on plantar pressure distribution in adolescents.

Delimitations:

The study will be delimited to:

1- One hundred and ten healthy adolescents from both sexes will participate in this study. The sample size is based on sample size calculation within factors, α=0.05, β=0.2, effect size = 0.1 using G power statistical analysis.

2- Their age will be ranged from 12 to 18 years

3- All students use backpacks that represent 15% of body weight according to **Chow et al. (2010)**.

4- Foot scan plate system will be used to assess foot pressure distribution.

Basic assumptions:

It will be assumed that:

1- All children will be evaluated in the same way.

2- The methods of evaluation constitute the best objective methods to evaluate foot pressure distribution (Foot scan plate system).

3- The results obtained from this study will be of value in the field of physical therapy.

CHAPTER II

LITERTURE REVIEW

Backpack carriage is common in schoolchildren. More than 90% of schoolchildren in the developed countries are reported to carry backpack **(Sheir-Neiss et al., 2003).** Weight of the backpack appears to be strongly related to the occurrence of shoulder, neck, back, and extremities complaints in students. Although musculoskeletal discomforts are believed to be multifactorial in origin, the carriage and manipulating of heavy backpack is signally a suspected factor and may represent an overlooked daily physical stress for secondary students (**Shamsoddin et al., 2010**).

A person's carrying capacity is affected not only by the magnitude of the load they carry, but also by the way the load is carried, the duration of carriage, the frequency of carriage and the physical capabilities of the person. These other factors must also be considered when attempting to determine the overall physical demands placed on the user. Many backpacks have been designed specifically to improve load distribution, balance, stability, and organization **(Stuempfle et al., 2004)**.

Load weight was clearly the most influential of the load carriage variables that were studied. This seems reasonable as the gravitational pull on the contents of the backpack because the added load would have the greatest effect on the forces at the shoulder straps. A more direct method of determining the physical demands of load carriage in students would be to measure the external forces that directly relate to carrying a backpack, such as the pressure on the shoulders that occur as a result of the tension in the shoulder straps of a backpack. Based on the present findings, school students should wear their backpacks with the least weight possible, use the hip-belt if present, allow a reasonable amount of looseness in the shoulder straps and should position the heaviest items closest to their back **(Hamish et al., 2005)**.

Most of the children adapted the proper carriage mode of strapping the backpack to both shoulders posteriorly. While adolescents, prefer using one shoulder for backpack carriage **(Waston et al., 2003).** The optimal mode of carrying a load should increase the body's stability, have the load close to the COM and use muscles of large mass **(Fowler et al., 2006)**. The increased use of school bags has deepened our need for knowledge about the consequences of different modes of carriage school bag **(Pau et al., 2016)**.

Current recommendations for school bag carriage are mainly concerned with reducing bag weight and optimizing bag design in order to minimize postural changes when carrying school bag (**Yoon, 2014).** The type of schoolbag and the way of carrying it may depend on student's preferences. On the other hand, students often tend to choose their schoolbag using fashion criteria rather than ergonomic characteristics. Fashion trends might be country and age specific **(Skaggs et al., 2006)**.

Wearing the back pack should be over the strongest mid- back muscles. It is also important to pay close attention to the way the back pack is positioned on the back. The backpack should rest evenly in the middle of the back and shoulder straps should be adjusted to allow the child to put on and take off the backpack without difficulty and permit free movement of the arm. The straps should not be too loose and that the backpack does not extend below the low back. Carrying the backpack with two shoulder straps affects posture and gait less than carrying it on one shoulder **(Cottlorda et al., 2004)**. Back pack is one of the most common designs used by most children. Backpack-style bags with two straps were found to be the most popular style of schoolbag for both boys and girls **(Docker et al., 2006)**.

Carrying a backpack over two shoulders is the most efficient means of carriage, but often backpacks are carried over one shoulder. Although backpacks have been shown to be most effectively used when two shoulder straps and hip straps are properly fitted to better distribute the weight of heavy backpack across the shoulders and down the back, backpacks often are not adjusted or worn correctly. However carrying backpacks on one shoulder significantly altered posture and gait parameters in adolescent children **(Barbara et al., 2008)**.

The feet are important structures for the human body mechanics they are considered the base of support of the skeletal system. The feet are considered in normal state when they are pain free, having normal muscle balance, absence of contracture, a central heel, straight mobile toes and three sites (big toe, lateral border of foot and heel) of weight bearing while standing, and during stance phase of walking **(Cailli, 1999)**.

The foot is a multibone structure with numerous articulations. Included the subtalar and midtarsal joints and several tarsometatarsal, intermetatarsal, metatarsophalangeal, and interphalangeal joints, together the bones and joints of the foot provide a foundation of support for the upright body position **(Hall, 2003)**. The normal foot is made up of 26 bones, 33 joints, 128 ligament, 22 muscles and 49 tendons. This structures are all arranged in such a way as to be rigid enough to support the weight of the body **(Kinon and Schoppe, 2001)**.

Normal foot is flexible enough to conform to the contours of the ground and absorb shock at others during every step taken while walking or running, the foot switches from rigid to flexible and back to rigid **(Kinon and Schoppe, 2001).** The foot has two important functions: to support the body weight and to serve as a lever to propel the body forward in walking and running. If the foot possessed a single strong bone, instead of a series of small bones, it could sustain the body weight and serve well as a rigid lever for forward propulsion. However, with such an arrangement, the foot could not adapt itself to uneven surfaces and the forward propulsive action would depend entirely on the activities of the gastrocnemius and soleus muscles **(Lawren et al., 2001)**.

The foot-ankle complex is generally divided into three units: the hind foot, the mid foot, and the forefoot. The hind foot is composed of talus and calcaneus and is generally the first point of contact of the foot with the ground in many loco motor activities, the mid foot is composed of the navicular, cuboid, and cuneiform bones. This system of bones forms the bridge between the hind foot and forefoot. The forefoot is composed of the metatarsals, which are referred to as rays. These rays fan out from a constricted beginning in the mid foot, with the relative movement between them increasing as they fan out. The joints of the foot has individual actions, these individual actions are in fact highly coordinated, allowing the foot to function dynamically as a unit. The actions of the joints are highly integrated, and action at one joint usually results in a functional compensatory movement in another joint. The pronation/ supination actions of the foot illustrate these compensatory movements **(Sammar, 2001)**.

The muscles of the sole of the foot are conventionally described in four layers, interspersed with the long tendons of muscles originating in "the posterior and lateral compartments of the leg .Functionally, however, it is easier and quite useful to think of the foot muscles as lateral, central, and medial. The lateral group includes the abductor digiti minimi and flexor digiti minimi brevis. These insert on the base of the proximal phalanx of toe number five, and they abduct and flex the fifth toe. The central group includes the flexor digitorum brevis, flexor digitorum longus, flexor hallucis longus, flexor accessorius (quadratus plantae), lumbricals **(Basmaji and Stecko, 2003)**. Only one muscle is found on the dorsum of the foot, the extensor digitorum brevis extending, from the calcaneus to the proximal phalanx of the great toe and the tendons of the extensor digitorum longus for toes two to five. Some recognize the slip to the great toe as a separate muscle, the extensor hallucis brevis **(Richard, 2003)**.

The tendons of the anterolateral leg muscles may be seen through the thin skin of the dorsum of the foot, the otherwise thin deep fascia of the dorsum of the foot thickens to form two specialized structures-the extensor and peroneal retinacula. The extensor retinaculum has superior and inferior subdivisions. The superior extensor retinaculum connects the distal ends of the fibula and the tibia. The inferior extensor retinaculum begins on the calcaneus laterally and arches over the dorsum of the foot to attach to the tibial malleolus and the medial side of the calcaneus. It surrounds or covers all of the deep tendons, vessels and major nerves on the anterior surface of the foot. The superior peroneal retinaculum connects the lateral malleolus and calcaneus; the inferior peroneal retinaculum connects the calcaneus and plantar aponeurosis. The peroneus longus and brevis are enclosed in these retinacula **(Thibod & Patton, 2000)**.

The medial longitudinal arch (MLA) is thought to develop most rapidly until the age of 6 years, after which changes are less apparent. There is, however, much debate on MLA development during the critical age range of 7 to 9 years. Within this age range, some studies demonstrated that the MLA remained fairly stable, whereas other studies showed that the foot arch was becoming higher. The foot arch also was reported to become flatter from 7 to 8 years of age and to show a reversal to a higher arch from 8 to 9 years of age. Therefore, it is still uncertain at which point the MLA stops developing in children. In addition, it is currently unknown whether MLA development differs between boys and girls, although cross-sectional studies suggested that boys tend to have a flatter foot type than girls. There is a need to clarify the conflicting reports on MLA development in boys and girls during the critical age range from 7 to 9 years using a longitudinal approach. Subsequently, health care practitioners can make informed decisions when managing flexible flatfoot in children **(Waseda et al., 2014)**.

The structures of the foot are anatomically such that the load is evenly distributed over the foot during weight bearing. Approximately 50%of body weight is distributed through the subtalar joint to the calcaneus, with the remaining 50% transmitted across the metatarsal heads. The head of the first metatarsal sustains twice the load borne to by each of the other metatarsal heads. A factor that influences this loading pattern, however, is the architecture of the foot. Several factors may affect the foot pressure distribution. Those factors may be structural (e.g. bony prominence), functional (e.g. restricted range of motion) and type of footwear (e.g. pointed shoes), body weight, and walking speed (**Nurse and Nigg, 2001)**.

CHAPTER III

SUBJECTS, MATERIALS AND METHODS

I- Subjects:

This study will be conducted on ninty two healthy adolescents from both sexes to determine the effect of different backpack carriage styles on plantar pressure distribution in adolescents. They will be recruited from public and private schools at Mansoura city.

Inclusion criteria:

- Their age will be ranged from 12 to 18 year.
- Their body mass index (BMI) is within normal range according to BMI for age percentile score **(WHO, 2007).**
- All adolescents will be free from postural deviation, the trunk rotation in all students is within normal degree determined by scoliometer **(Bunnel, 1993)**.

Exclusion Criteria:

- Visual, auditory or perceptual deficits.
- Deformities at any joint of the lower limbs and spine.
- Surgical intervention in foot.
- Deep sensory loss.
- Musculoskeletal disorders.

II- Instrumentations:

- For selection:

1- Weight and height scale:

A valid and reliable weight and height scale will be used for all students to measure weight in kgs and height in cm.

2- Body Mass Index for age percentile charts:

Body mass index will be calculated using BMI for age percentile score charts to determine BMI category according to **(Who, 2007)** through the formula of (BMI=Body weight (Kg)\$Height^2$ per meter (m^2)

3-Scoliometer:

The scoliometer is an inclinometer designed to measure trunk asymmetry, or axial trunk rotation **(Gideon et al., 2017**). Strong levels of evidence exist for scoliometer measurements, with a high reliability (r = .86–.97) and high validity (**Ashleigh Prowse et al., 2016)**. It is hand-held circular fluid filled disc with a weighted gravity pendulum indicator that remains oriented in the vertical direction **(Katarzyna et al., 2018).**

- For evaluation:

1-Foot scan plate system:

A foot scan is the method used to examine the biomechanics of the foot. It provides a dynamic weight bearing computerized assessment of the biomechanics of a person's feet. The system measures the weight distribution at all contact points along the bottom surface of the foot **(Tan, 2005)**. It is valid and reliable tool for quantifying static and dynamic plantar pressure **(Huang et al., 2017)**.

Foot scan plate system includes the following components:

- The pressure sensors platform.
- Computer for data acquisition, storage and retrieval for analysis.
- Software to allow the physical therapist to divide the planter surface of the foot into numerous regions to permit the analysis of data.
- The pressure plate containing sensors (pressure gauges), which convert the mechanical pressure of the foot into electrical signals routed to the computer system **(Morag and Cavanagh, 1999)**.

2-Backpack:

Two backpacks will be used for all students, one with unilateral padded shoulder strap and the other with bilateral padded shoulder straps. The features that were typical in the majority of school backpacks, comprising a soft fabric backpack with no internal framing or back support and no internal compartments. Different weights will be used inside each backpack to represent the percentage of 15% of body weight.

III- Procedures:

- For selection:

Scoliometer will be used to measure any asymmetry of the sides of the trunk in axial region in degrees. The students will be examined from standing position, with bare trunk, with trunk anteriorly flexed and almost parallel to the ground, with relaxed arms, hanging perpendicular to the trunk. The trunk rotation is within normal limits from 0^{o} to 3^{o} (**Bunnell, 1993)**.

- For evaluation:

The purposes and procedures will be explained in details for all students and their parents to obtain their interest, confidence and cooperation. All parents of students will sign a consent form approving their children participation in this study.

Subject preparation:

- The adolescent personal data (name, age, weight and height and shoe size) will be collected and then stored on the computer in their specific folder.
- Each student stands with eyes open and looking forward.
- Each student takes off shoes and stand with two leg stance on the platform of the device.
- Each student will carry the backpack with its bottom at the level above the posterior iliac spine (backpack at the level of the hip) either during unilateral or bilateral backpack carrying **(Kellis and Arabatzi, 2009)**.

Adjustment of apparatus:

- Callibiration of the instrument needs the subject to stand over the platform by his feet then by single foot.
- The system is activated and ready to record the pressure.
- The software provides the calculations for the pressure values according to the pressure imposed on the plate.
- It uses specified color to display the pressures acting on the planter surface of the foot in various preset colors the red and purple colors denoted graphically the highest pressure, while the green, blue and black colors represented the lowest pressure values.
- The area calculated refers to the amount of surface contact between the planter surface of the foot and sensor.
- The measurement will be done in the preset scanning direction denoted by the manufacturer.

Measurement procedures:

- All students will be assessed during four conditions as follows; without carrying backpack, carrying backpack bilaterally, carrying backpack unilaterally on right and left sides.
- Measurements will be taken during standing (static plantar pressure) and walking (dynamic plantar pressure).
- Analysis will be initiated by locating the second metatarsal head then the foot area is divided into eight zones.
- The measured variables will represent peak pressure, average pressure and surface contact under the three anatomical regions of the foot, the fore foot including the medial fore foot (big toe and first metatarsal), lateral fore foot including (small toe and fifth metatarsal), the mid foot including (medial and lateral mid foot) and the heal regions (medial and lateral hind foot).

Data analysis

The data will be analyzed as follow:

- Descriptive statistics for age, height, weight and BMI.
- The mean value and standard deviation will be calculated for all measured variables.
- Analysis of variance (ANOVA) with repeated measures will be used to compare measured variables at different conditions.
- Level of significance will be determined at $P<0.05$.

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توزيع ضغط القدم وعلاقته بطريقه حمل حقيبه المدرسه عند المراهقين