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Biomechanical analysis of gait with double backpack

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Review Article

Abstract

When observing the gait associated with the transportation of backpacks by children and adults, there were differences in posture and gait when compared to gait without back overload. Over time, the problem seems to get worse. Access to information technology, contrary to expectations, has aggravated the problem because people carry in their daily lives more electronic equipment of a non-negligible weight. If we take as example of the military soldiers, they carry some of the material in a bag next to their chest. Using a backpack type double backpack, studies suggest its performance is better than traditional transport. This solution has not been systematically studied for the civilian population .The goal of this work is to study the problem of the transport of a non-negligible load, on the back, during a distance corresponding to a journey. Check for the advantages of using a double backpack. The method used is biomechanics. Will be analyzed the several parameters of gait in particular will be used electromyography, thermography and kinetics. For this study, we will take healthy young adults with ages between 18 to 30 and it is expected to confirm the advantages of using double backpack by the civilian population for the transport of high loads minimizing possible future injuries. ***DOI****: https://doi.org/10.24243/JMEB/2.5.175*

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Keywords: biomechanical; double backpack; gait transport; gait overload; gait

1 Introduction

The backpack type double backpacks (front and back: double pouch or double backpack) and bilateral backpacks (supported on both shoulders) are ergonomically superior compared to simple backpacks (unilaterals) charged only with one shoulder. Adults in professions such as the military, firefighting, and mountain rescue routinely carry packs loaded with 60% body weight **[1]**.When the subject walks he needs to compensate sideways posture; when using the double-bag (front and back), causes less contraction of the spinal musculature and less cardiovascular effort **[2]**-**[4]**.

When investigating the effects of using an exoskeleton (EXO), in order to facilitate the transport of high loads on the back, in metabolic cost during gait with loads, that in the case of military can reach 57% of body mass.Gregorczyk **[5]** concluded that the use of this type of device, increases the metabolic cost, not being metabolically sustainable for more than brief periods even in physically fit young people, thus opening an important window relevant for study with "double backpack". In addition, the growing practice of adventure sports for recreational purposes like

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universal students or hikers, create the need and opens an opportunity to study this type of backpacks. According to Liew [6], differences on the effect of total mass normalization between studies could be attribute to the differences in the population sampled. Same studies recruited adult students, other recruited Xhosa women with at least 10 years of load carriage experience and other study native African women and so on.

The present paper intends to define the parameters for accomplish the best strategy to prove the hypothesis that the use of "double backpack" by the civilian population is more efficient and can be used in alternative of the simple backpacks, contributing to a better posture that allows to prevent future injuries

2 Literature review

When investigating the definition of Biomechanics, the attempt to profiling its definition is constant. In recent years we have seen several definitions of the word, each author having suggested his contribution to the interpretation of the definition of this science. Thus, from the point of view of Barbosa [7] Biomechanics will be the application of the principles of mechanics to living beings, since in a basic analysis of the word "Biomechanics" can be separated into two distinct parts as prefix "Bio" of biological, relating to living beings and mechanics. According to McGinnis [8] we have a clear definition between internal and external biomechanics, the internal one being dedicated to the study of the mechanics of the biomaterials, skeletal system, muscular system and nervous system. The external one referring to the characteristics observable externally in relation to the quantitative and qualitative parameters related to the position of the body and changes of place. Thus, part of this external biomechanics is the study of kinetic and linear and angular kinematics, balance of forces or change of motion, fluid mechanics and causes of movement in terms of work, power and energy [7]. Amadio [9], [10] states that internal biomechanics focuses on the determination of the internal forces and consequences resulting from these forces while the external biomechanics represents the parameters of quantitative or qualitative determination regarding the changes of place and position of the body, this is, refers to the characteristics observable externally in the structure of movement.More recently, Amadio [11] has added four major areas of research derived from this scientific area: cinematography, dynamometry, electromyography and anthropometry [12]. These areas allow us to study and characterize the mechanical parameters involved in a particular movement so that it can be performed more safely and efficiently. The study of historical and biomedical aspects of soldier load carriage aims that the load should be carried as close as possible horizontally to the center of mass of the body [13], carrying half load on the back and the other half at the front using double backpack. Those methods have been shown to be associated with a lower energy cost than most other forms of load carriage [14]. Double backpack produce fewer deviations from normal walking and less forward lean of the trunk than a backpack, besides it, the increasing load produces reduction in stride length and increase stride frequency, which seems to be better to reduce stress on bones of the foot.

3 Methods

3.1 Participants and procedures

We will study the transport with "double backpack" on the civilian population in young healthy adults in ages comprehended between 18 to 30 years old. The main reason is due to the fact that in this age occur the activities of greater transport of loads on the back, excluding carriage in academic environment. To minimize errors caused by health problems, an initial screening will be performed so that we can select only individuals with low or normal body fat (important to the measurement of the thermography technique) and no relevant health history that may adulterate the intended measurement values, like asthma, other king of allergies or any other kind of limiting movement. Thus, it will be accepted only healthy young adults to perform the tests on this study.

Based on the laws, principles and methods of mechanics and anatomo-physiological knowledge, when searching for the studies that have been perform in gait transport, the differences between protocols may explain the variations in the results of the tests that have been achieved. This differences are gait velocity, ability to transport heavy weights, displacement of the posterior load away from the body or hip belt use an so on [6]. Differences in the effect of total mass normalized between different studies may be due to the sample involved as Lloyd [15] recruited Xhosa women with at least 10 years of load carriage experience, and Cavagna [16] recruited native African women that were better able to harness pendulum exchange of potential and kinetic energy during walking. With the suggestion of

Liew [6] that mentioned previous studies concluded that the response of backpack carriage may only be apparent when carrying significant heavier weight (e.g.,>40% BW Body Weight) coupled with a faster walking speed (e.g. >1.6m.s^{-1}). In the transport of bags and backpacks with load, Hong [17], [18] have showed that greater metabolic cost in the load conditions with 15% and 20% of body weight, by measuring the volume of oxygen consumption. Lai [19] showed alterations to the respiratory volume during transport loads of 20% and 30% of body weight in primary school children. The experimental protocol employed at young adults will consists to walk on the treadmill without inclination with speed of 1.67 ms^{-1} [6], [20] for 5 minutes with relative body weight loads that corresponded at 0% and 40% of BW always with the same backpack, since the response to backpack carriage may only be apparent when carrying significantly heavier weight [6]. The tests will be performed without load and with 40% BW overload using backpack only at the back and 40% BW overload distributed from front and back with a double backpack. It will be evaluated the general parameters of the gait cycle (pitch frequency and cycle distance), angular kinematics parameters (absolute angle between the trunk and the horizontal plane, the relative angle between the foot and the leg), as well as parameters of linear kinematics (vertical amplitude of the mass center). Also it will be evaluated the EMG signal of the interest muscles, oxygen consumption (VO_2) and the body temperature using thermography.

3.2 Data Collection and Handling

To perform and obtain the collection of the required data it will be used various techniques. For the kinematic, some systems on the market use "inertial measurement units" (IMUs), resorting to the use of accelerometers and gyroscopes and recent techniques based on flexible optical motion capture systems, enable high speed and are reliable, based on the capture of marker positions. Another technique is the electromyography that is used in many areas from medical clinic, rehabilitation and anatomy to biomechanics [21], [22]. The Electromyography refers to the study of neuromuscular activity through the graphical representation of the electrical activity of the muscle [23] that indicates the neurological stimulation sent to a muscular system [12].Oxygen consumption of an individual with a gait speed of 1.11 to 1.38$ms^{-1}$is around 100 milliliters per kilogram of body weight per minute. Gait efficiency can be defined as the energy cost per distance traveled [24], the lowest value is considered maximum efficiency, i.e., the highest efficiency is achieved when it is required minimal energy per distance unit [25], [26].The measurement of VO_2, during gait, reflects the efficiency of the movement pattern [27]-[31].The thermography can be used in clinical trials measuring the skin temperature changes in response to physiological state of an individual. The temperature difference (ΔT) is a measure of the temperature difference between similar body locations and a difference of more than 1 ° C is accepted as an abnormal [32]. With this technique, it is possible to study muscle activity during physical activity, checking possible imbalances. With thermography, it is possible to study the functional and metabolic activity of tissues including muscle tissue, joint, the neuro vegetative nervous system, the peripheral nervous system fibers, etc. This technique enables real-time analysis, dynamic observation of the reactions of the locomotor system to provocative tests of painful syndromes and evidence of stress and efforts [3].When performing a physical activity with gait for about 5 minutes, the temperature measured at the beginning of an exercise, at the end and after 5 minutes of rest decreases to increase at the end [3], [33].Also, when analyzed Ground Reaction Forces (GRF) and plantar pressure peaks were scaled to body weight (or body weight plus backpack weight), it's possible to observe peaks in the rear foot, forefoot and hallux when the participants walked carrying a backpack at high gait cadences compared to walking at low gait cadences. Differences between loaded and unloaded conditions in both gait cadences were also observed [34]-[35].

3.3 Statistical Analysis

To make the data analysis it will be used specific software for statistical analysis which includes: SPSS; EXCEL; MATLAB, etc. It will be used commercial equipment and software and when necessary adapted to obtain the relevant data. For this work, we intend to adapt two commercial backpacks in one double backpack so that will take in account the comfort and usage of the user like the adjustable front backpack inserts, breathable back pad, chest strap adjustment, waist support and belt adjust buckles. An analysis of variance will be made to verify the dependence of the variables and also apply the "Tukey" method to verify significant differences between groups.

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