2017 CMBEC40 Conference
Winnipeg, Manitoba
May 23–26, 2017

PHYSIOLOGICAL AND BIOMECHANICAL RESPONSES IN MALE SCHOOL GOING CHILDREN USING FRAMELESS AND INTERNAL FRAME BACKPACKS

[1]Ishant Gupta, [2]Snigdha Sharma, [3]Harpreet Singh, [4]Harpreet Singh Banwait
[1]Center of Excellence in Industrial & Product Design, PEC University of Technology, Chandigarh, India
[2]Department of Mechanical Engineering, Concordia University, Montreal, Canada
[3,4]Production & Industrial Engineering, PEC University of Technology, Chandigarh, India

INTRODUCTION

There is a common equipment used by almost every school student throughout the entire world, the backpack. Backpacks come in various types, shapes, sizes and brands. Recently back pain in school going children has been associated with the carriage of heavy backpacks [1, 2, 3]. In India 195 million of students below the age of 18 need a backpack to carry books, notebooks and other belongings to and fro from school every day [4]. Studies conducted by many researchers in different parts of world investigated that significant number of school going children carried backpack more than the recommended weight limit (10% to 15 % of body weight) [5, 6]. Carriage of a backpack exerts substantial amount of load to the spine [7]. Prolonged carriage of backpacks has been suggested as one of the main cause of back pain [8].

As per the research conducted by the chow et al. on female adolescents for different loading conditions, there were significant effect of backpack on the variations in spatial-temporal parameters when compared with baseline readings (readings recorded when subjects walk without any backpack load) [9]. Further, other researches show that carrying a heavy backpack caused decrease in walking speed [10] due to the reduced stride length and an increase in double support time. The backpack had significant effect on postural angles especially in trunk forward lean [11, 12, 13]. Several other studies also discussed the effect of backpack on physiological parameters such as an increase in heart rate and oxygen consumption [14]. In few studies, researchers also claimed that by educating school children about proper packing, wearing and carrying of backpack may decrease the musculoskeletal disorders [15, 16]. In addition to these studies, some researches also suggested that oxygen consumption was significantly less when the backpack was placed in the high position of the back [17]. Few other studies also focused on the design of the backpack which distributed the load between front and back of trunk [18, 19].

Most of the previous researches on school going children only considered the effects of frameless backpacks. Recently, internal frame rucksacks have become an increasingly popular method of carrying heavy loads for climbing and hiking purposes. An internal frame rucksack is comprised of two aluminum staves (supports) that are sewn into the back panel to provide some rigidity, yet allow the load to ride directly on the user's back whereas frameless backpacks caused uncompensated torque due to its flexible nature.

Apart from several studies on the ergonomic features and design of the backpack, few works also focused on the posture evaluation of male and female subjects while standing with internal and external frame backpacks at same loading condition [20]. The objective of this paper is to evaluate the physiological and biomechanical responses in male school going children while using frameless and internal frame backpacks.

METHODOLOGY

a) Selection of Sample

A total of 20 male school going participants with similar weight, height and age were selected for this study. They walked on a walkway for 7 mins. Permission was sought from the Principal of the school and voluntary consent form was signed by each of the students and their parent/local guardian prior to the study. Detailed procedure about the study was explained to them. The study had approval from the Institutional Human Ethical Committee, Department of Industrial & Product Engineering, PEC University of Technology, Chandigarh, India. Summary of physical parameters of the subjects like age, height, weight and Body Mass index (BMI).

Table 1: Summary of physical parameters of the subject

Parameter	Mean	Standard Deviation	Minimum	Maximum
Age (year)	11.17	0.9	10.8	11.7
Body Mass (kg)	38.41	3.32	36.64	42.48
Height (m)	1.48	0.08	1.45	1.53
BMI (kg/m^2)	18.12	1.1	17.41	18.87

b) School Backpacks Used for the Study

There were two types of backpacks selected for this study see figure 1 (a & b). First, the backpack without frame (BWoF) used by all subjects for the study. Second, the modified version of backpack with an internal frame (BWF). The internal frame of the backpack consisted of two aluminum staves bent in the shape of the spine with the flat surface that supported the bottom of the backpack. The internal staves were correctly contoured for backpack fit and functionality. Internal staves to the back enabled the frame to simulate the flex action of the spine. The base of the backpack didn't protrude outside or away from the body and sat squarely on the lower back. Volume of the selected backpack was 25 liters. Both backpacks had two compartments.

Figure 1 (a & b): Backpack without frame (BWoF) (a) and a frame comprises of an internal staves incorporated in the former (b).

c) Measurements of Response Parameters

Forward lean of trunk also known as height of earlobe (HoE) was measured by using marker less Kinect V2. Kinect V2 has capability to detect 25 bony joints location which all combine to form an automated virtual skeleton model by using the artificial intelligence algorithms supported in SDK 2.0. The skeleton information is converted into a large set of features which were fed in to a customized program written in LabVIEW by using the Haro3D library for the evaluation of selected parameters. HoE was measured by using the outcomes which were calculated from the recorded coordinates for head joint and left ankle joint by using Euclidean distance formula.

$$d\ (i, \mathrm{j}) = \sqrt{(xi - xj)^2 + (yi - yj)^2 + (zi - zj)^2}$$

Walking speed (WS), double support time (DST) and energy expenditure (EE) of the participants were calculated while carriage of backpack at different loading conditions by using Minisun IDEEA accelerometery system. A body mounted system composed of 5 biaxial sensors based on accelerometer system [21].

Mechanical load on the lumbar spine is considered as a contributing factor to many lower back anomalies [22]. But the calculation of forces in real time at the spinal joints of human is the costly process. Computer-aided Design (CAD) and Digital Human Modeling (DHM) technologies can be used to solve this issue by simulating the human model in the virtual environment. The development and assessment in a virtual environment have numerous benefits like shorter design time, reduced redundant changes, lower manufacturing costs, better quality, increased output, enhanced safety leading to heightened morale.

Mechanical design feature of Solid Works software was used to create the CAD model of the two backpacks (with and without the framework). Manikins were created according to the anthropometric anatomical and biomechanical dimensions for all 20 participants. Each manikin was separately evaluated for both types of backpacks under the three loading conditions by using the biomechanical module in Jack Software. The module has the capability to calculate the load on different joints of spine which give us the knowledge about the amount of load transfer to the particular joint. This part of study aimed to calculate the compressive forces on L4–L5 lumbar spines due to carriage of backpack.

During the experiment normalization method was employed by using the baseline measurements (when participants walked without backpack). The method is described as follows:

$$Aijk = \left(\frac{Bijk}{Ciz}\right) * 100$$

Where (i) is the participant number (i = 1, 2, 3……..20); (j) is the backpack number (j=1, 2); (k) is the load carried condition (k= 5%, 15%, 25%) and (z) is condition of walking without a backpack. (Aijk) is the normalized value of ith participant for j type of backpack carried at kth loading condition. (Bijk) is the response parameter value of ith participant for j type of backpack carried at kth loading condition whereas (Ciz) is the response parameter value of ith participant when walk without backpack.

Experimental Protocol

Each participant went through seven different sessions of walking over a period of one week. The seven sessions being walking with no load and walking with 5%, 15% and 25% of body weight (BW) for each internal frame and frameless backpack. The participants walked in the laboratory setup for 7 mins. Each sequence of session consisted of at least three trials of data collection. From these trials, the most consistent set of data for each loading condition was selected for the study.

To measure the height of earlobe (HoE), Kinect V2 was placed at the center of the walkway facing the line of motion at 90 degrees, 1m above the floor to capture the virtual skeleton of a walking subject along the path at a frequency of 30 Hz. The Kinect has low capture volume capability and only records motion within 3m - 4m of distance in its x-axis. Participants with the IDEEA system mounted on the body walked on walkway setup in the laboratory for the measurement of WS, DST, EE. The IDEEA system consists of 5 biaxial accelerometers that are connected to a microprocessor. Sensors were placed according to the recommendations of the manufacturer [20].

Biomechanical lower back analysis of JACK software for school going children while carriage of backpack was used to calculate the forces and moments on L4/L5 joint. For every participant, digital human model was created as per the anthropometric, anatomical and biomechanical dimensions. The weight of backpack was also adjusted according to loading condition of each session.

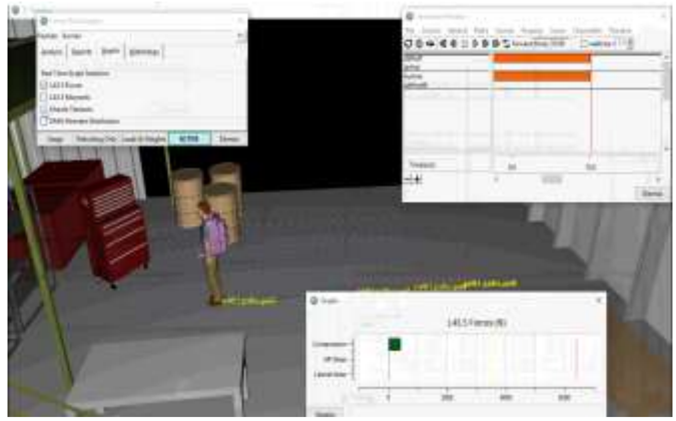

Figure 2: Calculation of L4/L5 force while carriage of backpack simulated in JACK

RESULTS AND DISCUSSIONS

Figure 3 presents the mean values of normalized response parameters measured every 15 seconds during the 7 mins walk while carrying each type of backpack at each loading conditions during the experimental protocol as well as simulation done on manikin in Jack software for the same timeframe. The results obtained from both the backpacks was statistically evaluated by using paired sample t test. The value of height of earlobe (HoE) during the first 3 minutes of walking while carrying the internal frame backpack tended to be slightly more than the HoE obtained while carriage of frameless backpack. However no significant difference in HoE was found between two packs at $p<0.05$. Mean walking speed (WS) for all the subjects while carriage of internal frame backpack was significantly more than the walking speed obtained while carriage of frameless backpacks. Type of backpack had a significant effect on the walking speed. Whereas the normalized mean of double support time (DST) in case of frameless backpack was more than internal frame backs. Energy expenditure (EE) responses for internal frame backpacks were slightly less than EE obtained but there was no significant difference. The compressive forces on L4/L5 lumbar spines, due to the mass of a body and the backpack load acting on the trunk. In case of internal frame backpacks mean L4/L5 compression strength was 873 N which is less than the value in the case of frameless backpacks.

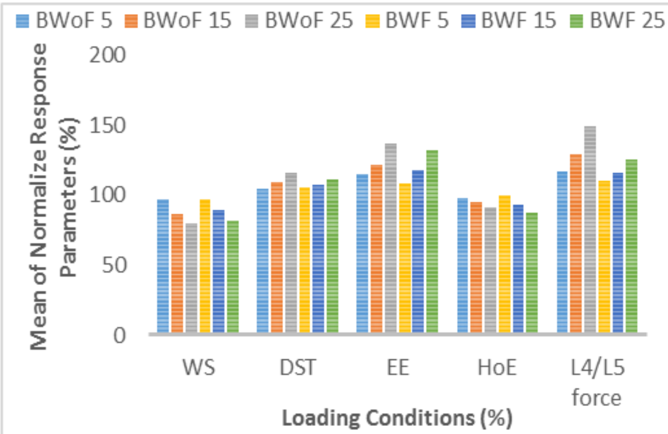

Figure 3: Mean value of normalize response parameters (%) at different loadding conditions

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