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Ergonomic design of school backpack by using anthropometric measurements for primary school students (6–12 years)

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ABSTRACT

The use of school backpack with ergonomic dimensions and suitable weight (10%–15% of body weight) can reduce musculoskeletal injuries/disorders among school students. This study aimed to conduct an ergonomic design of school backpack for primary school students (6–12 years) based on anthropometric measurements. Three anthropometric characteristics, including sitting shoulder height, thigh thickness, and shoulder breadth-bideltoid were measured for each of the 2236 students. The data were collected using the anthropometric chair, camera and camera stand, and anthropometric photo graphical software. The anthropometric dimensions were obtained in the form of mean, minimum, maximum, standard deviation, and percentiles of 2.5–97.5. Sitting shoulder height was higher in boys than that in girls up to the age of 10 years; however, this dimension gradually increased in girls compared to boys at the ages of 11 and 12 years. Shoulder breadth-bideltoid and thigh thickness were higher in boys than those in girls in all age groups. Finally, the ergonomics dimensions of the school backpack, including the backpack height and breadth were obtained for the students aged 6 to 12 years by using anthropometric characteristics.

1. Introduction

There is a high rate of the incidence of musculoskeletal injuries and disorders especially back pain in school students, which can limit their daily life activities (Trevelyan and Legg, 2010; Murphy et al., 2007). In addition, large populations of the adults who have experienced low back pains have reported that they have experienced their first back pain during adolescence or early adulthood (Papageorgiou et al., 1996; Trevelyan and Legg, 2011). Also, some studies have reported that the highest levels of back and neck pains in children have been of non-specific origins and it has been estimated that there is a high prevalence rate of these pains (Whittfield et al., 2001, 2005; Balague et al., 2003). Among the other factors that cause muscular disorders and deficits in school students, school backpacks and carriage of them are among the major risk factors (Grimmer and Williams, 2000; Whittfield et al., 2005). Furthermore to pains and musculoskeletal disorders, the use of non-ergonomic backpacks causes covert and overt consequences, including hyperlordosis, lateral deviation of the spine, gait pattern changes, the occurrence of cardiovascular changes (such as heart rate, systolic and diastolic blood pressure), respiratory problems (such as the number of breaths per minute and ventilation of pulmonary volumes), and metabolic problems (Motmans et al., 2006; Daneshmandi et al., 2008; Hong et al., 2000). In addition to the observance of a healthy weight for the school backpack (10%–15% of body weight (Moore et al., 2007)) and prevention of excessive load to it, the ergonomic design of backpack by using anthropometric characteristics can largely decrease musculoskeletal disorders (MSDs) in students. Moreover, the use of anthropometric measurements in the design of backpacks helps students reach an adjustment and performance level in learning (Taifa and Desai, 2017). Anthropometrics is defined as “the measurement science of human body and the art of its application that describes the physical geometry, mass properties, and the capabilities of the human body” (Del Prado-Lu, 2007).

The majority of the studies that have been carried out on school backpack among students have evaluated the effect of backpack weight on the spine pains (such as pain in the lower back, shoulders, and neck) (Haselgrove et al., 2008; Korovessis et al., 2005; Skaggs et al., 2006; Murphy et al., 2007; Puckree et al., 2004; Skoffer, 2007), spinal curves and trunk alignment, and students' postures while carrying the school backpack (Ramprasad et al., 2010; Chansirinukor et al., 2001; Hong and Cheung, 2003; Mackie and Legg, 2008; Korovessis et al., 2005). The weight limit of school backpack has been suggested to be about 10% of

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Fig. 1. A view of the student sitting on the anthropometric chair in front of camera.

the body weight. However, this suggestion has been made based on subjective observations rather than objective findings, and other aspects of carrying school backpack, such as the adjustment and design of school backpack or carrying patterns of school backpack have not been considered. Mackie (2006) showed that the design of school backpack has had a significant effect on musculoskeletal disorders (Mackie, 2006). In another study, Mackie et al. (2003) indicated that the design of school backpack may reduce perceived physical demands among students (Mackie et al., 2003). From among the studies conducted on school backpacks, little attention has been paid to the design dimensions of school backpack. Except for Mackie et al. who have examined the effects of school backpack design, no academic research was found on school backpack design via anthropometric characteristics. In another study, Mackie et al. (2003) examined four different school backpacks for the students' use (Mackie et al., 2003). This study had been designed based on the subjective observations and responses of students as a result of using backpacks and no school backpack had been designed based on anthropometric characteristics (objective findings) in that study. The final result of that study showed that backpack manufacturers need to spend more time on the research and development of ergonomic dimensions of backpacks so that customers can use it in the long run without any discomfort. Adams (2017) provided an appropriate guide for child backpack (Adams, 2017). Adams showed that a good ergonomic backpack should not be larger than the child's back. In order to achieve this goal, he presented the measurement of height (shoulder line to the waistline plus two inches) and the width of back for the 4-to-18-year age group. Moreover to these studies, Fonfeder (2005) provided a patent for the design of school backpack (Fonfeder, 2005). Wyant (2000) presented a school backpack with a zip that made the backpack more spacious (Wyant, 2000). Similarly, a number of other patents have been provided in this field (Archbold, 1980; Horne, 1998). These registered patents show the design dimensions of school backpack in the form of shapes, but the backpack design data and anthropometric characteristics are not available.

Most of the students use different backpacks to carry their books and school supplies. If the school backpack is not designed and selected based on the ergonomic principles, in addition to the imposition of excessive loading on students' backs, it may cause musculoskeletal disorders in the lower back, shoulders and/or neck due to the inappropriate dimensions of the back and disharmony with students' body weight. These disorders/injuries are more serious especially in primary school students due to the faster physical growth and may affect everyday life and learn at school. Despite the numerous studies carried out on the weight of school backpack and its effects on musculoskeletal disorders, little attention has been paid to the ergonomic design of school backpack and the determination of its dimensions based on anthropometric characteristics. In this study, the height and breadth of school backpacks for primary school students (6–12 years) have been designed based on three anthropometric measurements, including sitting shoulder height, thigh thickness, and shoulder breadth-bideltoid.

2. Materials and methods

This study was conducted on primary school students (6–12 years) in Mazandaran, Iran. The sampling was conducted using stratified random sampling method. Given the wide distribution of the statistical population of the study and economic justification, the cities with more than 5000 students were selected. In each geographic region, a number of schools were selected in accordance with the student population. The number of 6 classrooms was randomly selected out of each school and 5 sample units were randomly selected from each classroom. Through equation (1), the number of 2336 students, including 1164 girls and 1172 boys was randomly selected from the population in a stratified method. The two factors of age and gender were taken into account to estimate the anthropometric data of primary school students.

$$n = \left(\frac{Z_{1-\frac{\alpha}{2}} \times S}{d} \right)^2 \quad (1)$$

In this equation, α represents the statistical significance level (0.05), S indicates the standard deviation of the traits under study (10.4 mm), and d denotes the minimum expected the difference between the estimation of the sample mean and the actual mean value (1.5 mm). S and d values were determined from previous studies.

To determine the anthropometric measurements, the researchers designed an adjustable anthropometric chair and the anthropometric photographical software item that was designed by researchers. These instruments were used along with Fujifilm FinePix S4500 Digital Camera and the camera base in the practical phase of the research. Fig. 1 shows the students' position on the chair in front of the anthropometric camera. The image was entered into the software after its full