Physiological Effects of Backpack Packing, Wearing and Carrying on School Going Children

Ishant Gupta, Parveen Kalra and Rauf Iqbal

Abstract Thirty male school children from primary school, aged 12 years, were selected to carry backpacks of 10% body weight where 0% body weight was used as a baseline. Heart rate and blood pressure tests were conducted on the subjects. Subjects had walked on a treadmill for 20 min at each load condition at 1.1 m/s. This was done in both cases when subjects followed the normal pattern of packing and wearing and when they followed the American Occupational Therapy Association (AOTA) recommendations. Heart rate was recorded before, during and 5 min after walking on treadmill whereas blood pressures were measured before and immediately after trial, and at 3 and 5 min after every trial. The results showed a significant difference in heart rate, blood pressure and its recovery for 10% body weight load conditions before and after recommendations. The packing, carrying, wearing of backpack should be done as per the AOTA guidelines.

Keywords School children · Heavy backpack · Physiological parameters · Packing strategies · AOTA

I. Gupta (✉) · P. Kalra
Center of Excellence in Industrial & Product Design,
PEC University of Technology, Chandigarh, India
e-mail: igupta3423@gmail.com

P. Kalra
e-mail: parveenkalra@pec.ac.in

R. Iqbal
National Institute of Industrial Engineering, Powai, Mumbai, India
e-mail: rauf.nitie@gmail.com

A. Chakrabarti and D. Chakrabarti (eds.), *Research into Design for Communities, Volume 1*, Smart Innovation, Systems and Technologies 65, DOI 10.1007/978-981-10-3518-0_70

1 Introduction

The most common form of load carriage used in the world since ages is backpacks, especially used by school going students. The education system prevailing in the country lays lot of emphasis on textbook based learning. In view of inability of teachers to specify the subject textbook to be used in a particular period and, the practice of giving homework to students and at times the children are usually forced to carry a number of books and notebooks between school and home resulting in heavy backpacks. According to the data released by Ministry of Human Resource Development in 2014 approximately 223 million students in India need a backpack to take away items to and from school every day [1]. The ideal load carrying system would be one that does not disturb the body's natural posture, balance and movements. The load must be dispersed onto the skeletal structure in a balanced way and should not put strain on the body in any direction.

School going children are the building blocks for their nation. Hence there has been a growing concern among health parents, practitioners, and educators to reduce the increasing load of school backpack that may cause serious effect on the growth of the students [2]. In US alone there were 12,688 acute injuries associated with backpacks [3]. As per the findings of the researchers around the world weight carried by the school going children should limits to 10% of the body weight [2, 4, 5]. According to the study conducted in Bengaluru, school going children carried backpacks of more than 25% of their body weights load conditions, which were two and a half times more than the recommended weight limit (10% of body weight) for backpacks carried by school children [6]. Another study conducted in India, by Malhotra and Sen Gupta which investigated the physiological variations due to backpack carriage of 2.6 kg on six school boys aged 7–11 years in different positions. The findings of this research showed that, double strap style rucksacks, resulted in the least energy expenditure as compared to backpack carried on the lower portion of back single shoulder and hand [7]. According to the study conducted by Voll and Klimt in Germany regarding the distance between home and school for the school children and weight of backpacks of class I to class IV. The weight of backpacks varied from 11.5 to 14.5% of body weight load conditions, and the averaged time taken by school children between school and home was 29 min. the findings of this study was suggested school bags weight should not exceed the optimum weigh limit of about 10% of the body weight, and the upper limit of the weight for the school backpacks should be 13% of the body weight [8]. Several health practitioners and ergonomist recommended that 10% of body weight should be the carrying weight of backpacks for school going children [2, 4, 5]. The research conducted by Pascoe determined the impact of backpack weight on human gait parameters and posture of school going children aged between 11 and 13 years, in four different cases i.e. without bag, single strap backpack, single strap athletic bag and double strap backpack [9]. The backpack weight carried by the subject were loaded with 18% of their body weight. With the help of video filming analysis, it revealed that single strap backpack caused shoulder elevation and lateral spinal

bending, whereas the angular motion of trunk and head was also greater in case of single strap athletics bag as compared to the double strap backpack. Forward lean of the head and trunk was more in case of carrying the backpack as compared to carrying the athletics bag or for children without a bag. As per the results of the study, heavy backpack carriage caused increase in stride frequency but stride length was decreased. Wong and Hong conducted the study on the walking pattern of school going children while carrying different backpack loads. This study comprised of 10 school going boys aged 12 years having similar BMI walked on a treadmill for 15 min under four different conditions at a speed of 1.1 m/s. The load conditions carried by subjects in the form of backpacks were 0% (without backpack), 10, 15 and 20% of body weight [10]. The load carriage induced a steady state heart rate, which was approximately 50 ± 60% of the individual maximal heart rate. The study of above researchers proved that carrying heavier weight would increase the physiological strain especially in basic vitals like heart rate and blood pressure. The continuously increase of these physiological factors may causes the occupational burnout of school children due to school backpacks and they may also not recover from this strain due to daily carrying of backpack load. The above findings justify the need for creation of prevention programs and various interventions to reduce the risk of back pain and postural changes in schoolchildren because of improper utilization of school backpacks. In view of this American Occupational Therapy Association (AOTA) recommended the 1, 2, 3's of basic backpack wearing, carrying and packing guidelines which can helps to prevent back pain and postural changes in children and adolescents which helps to reduce the postural deformities of school children. AOTA guidelines includes three basic points of packing, carrying and wearing whereas Figs. 1, 2 and 3 shows these key points of school backpack [9, 11].

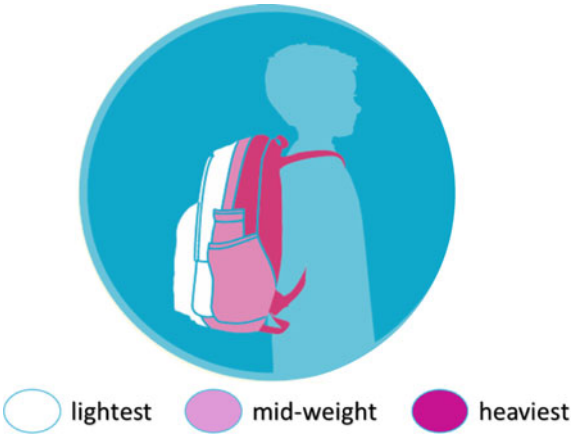

Fig. 1 Distribution of books and other items in the backpack

Fig. 2 Wearing of backpack in an appropriate manner

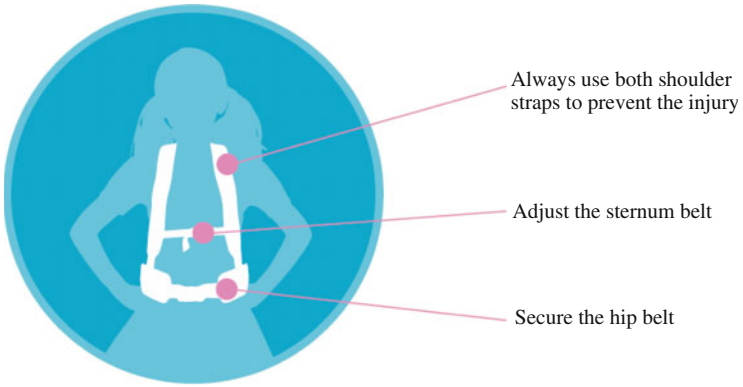

Fig. 3 Proper adjustment and carriage of backpack

1.1 Pack It Well

- Backpack weight for school going children should not be more than 10% of your child's weight whereas heavy backpacks can cause spinal damage and falls.
- School going children should utilize different pockets and compartments for place their study material to distribute weight.
- Students should place heavier items closest to the back and lighter items should be place in the front of the backpack.

1.2 Put It on in an Appropriate Manner

- Teach your child to pick up the backpack by using the squat posture (bending and lifting at the knees) instead of using the stoop posture (waist) to prevent back injury.

- Backpack should be carried on both shoulders for distribution of weight evenly. Wearing a pack slung over one shoulder can cause a child to lean to one side, curve the spine and cause pain or discomfort.
- Backpacks should be design in such a manner, it comprises of shoulder straps adjustment feature so that the pack fits snugly on the child's back. A pack that hangs loosely from the back can pull the child backwards and strain muscles.

1.3 Adjust and Carry

- The way backpacks are worn affects your health. The height of the backpack should extend from approximately 2 in. below the shoulder blades to waist level or slightly above the waist.
- Backpack always wear on both shoulders so the weight is evenly distributed.

The purpose of this paper was to differentiate the physiological effects of proper packing and wearing of backpack carrying backpack load of 10% of subject's body weight before and after intervention followed by the school children. It was hoped that the findings of this paper would help to guide the parents, schools and educators to promote the AOTA guidelines on proper packing and wearing of school backpacks.

2 Methodology

A case study was conducted in the schools located in Chandigarh with one month follow up. Thirty male subjects without any orthopedic, neuromuscular or cognitive disorder and with most representative Body Mass Index (BMI) of 22–24 were selected in this study from three different schools. Permission was sought from Principal of each 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 and Product Engineering, PEC University of Technology, Chandigarh, India. None of them had practiced any physical activity for more than 12 h per week. The average age, height and the weight of students was 11.77 (±0.52) years; 1.44(±0.12) m; 37.97 (±8.51) kg respectively.

Presentation was prepared on three basic steps of wearing, packing and carrying of backpack as discussed in introduction and it was explained to all the subjects so that they got to know about the basics of packing & wearing it helps them to pack and carry their backpacks accordingly as per the guidelines. After inclusion in the study, the school children were submitted to pre- and post-intervention evaluations which consisted of taking heart rate and blood pressures when they carried 10% of

their body weight on treadmill. The treadmill was used as an experimental apparatus in this study. Trials for post-interventions readings were recorded after a week of pre-interventions. Presentation on interventions was given in between the recordings. To ensure that, variability/test order effects due to interventions regarding packing and wearing are taken care of. The subjects wore their school uniform dress with socks and sporting shoes and using the same backpack in order to minimize the variability effects. The Loads were put inside the backpack. Each subject participated in three trials: walking on a treadmill without load (0% body weight); walking on a treadmill before packing and wearing intervention with 10% body weight; and walking on a treadmill after packing and wearing intervention with 10% body weight after a week. Subjects were warmed up for 3 min at 1 m/s and then subjects were asked to walk on a treadmill for 20 min at a speed of 1.1 m/s, a comfortable speed of walking for children, with school backpack carried. Heart rate was continuously monitored by using polar heart rate sensor and recorded automatically throughout and until 5 min after the walking tests with the load carriage. The heart rate recorded when subjects did not carried any load were taken as a baseline. Subjects then began the walking trial and all measurements were continuously monitored and averaged every 20 s at every 3-min interval of the 20 min walking period and 3 and 5 min after walking were used for analysis. Blood pressure was measured by using UA-767 V monitor (A and D Instruments) before walking, immediately after the trails and at 3 and 5 min after walking trails and they still carried the load at that time. Three sessions (without load; with load before intervention; and with load after intervention) were recorded by using heart rate sensor and blood pressure device for each subject. To reduce possible order effects due to a repeated-measure aspect of the experimental design, the presentation order of the experimental conditions to the subjects was randomized to minimize learning effects. Each session were carried out on subject after seventh day from the previous session on the same subject.

Statistical Package for the Social Sciences (**SPSS)** was used for statistical analysis of all the measurements and this was followed by paired sample t test to test for significance effect of packing and wearing intervention as recommended by AOTA. The 95% level of confidence was used for all tests as the criterion value when determining the presence or absence of statistically significant results.

3 Results

The minimum and maximum heart rate for the subjects in this study were 70 and 125 bpm respectively. The mean and standard deviation of the heart rate and blood pressure before and after the packing and wearing intervention as recommended by AOTA are listed in Tables 1 and 2.

The effect of packing, carrying and wearing intervention on heart rate for 20 min walking and heart rate for 5 min after walking is also calculated as shown in Table 1. Paired sample t-test showed the significant effect of AOTA intervention on

Table 1 Comparison of mean and standard deviation of heart rate before and after packing and wearing interventions

Variables	Time (mins)	Relative backpack weight load (%)		
		0 (baseline reading)	10 (B.I.)	10 (A.I.)
Heart rate (bpm)	0	79.44 (7.72)	84.62 (7.92)	83.94 (6.94)
	5	91.38 (7.23)	96.46 (5.49)	95.63 (6.67)
	10	96.59 (6.34)	101.47 (8.82)	99.78 (7.91)
	15	101 (6.37)	109.08 (6.33)	106.64 (7.43)
	20	106.63 (7.72)	113.32 (6.66)	110.49 (8.82)
	23*	95.47 (6.59)	99.42 (6.09)	98.62 (7.13)
	25#	84.62 (6.14)	92.46 (7.34)	91.12 (7.11)

B.I. Before Proper Packing and Wearing Intervention; *3 min recovery time
A.I. After Proper Packing and Wearing Intervention; #5 min recovery time

Table 2 Comparison of mean and standard deviation of blood pressure before and after interventions

Variables	Time (mins)	Relative backpack weight load (%)		
		0 (baseline reading)	10 (B.I.)	10 (A.I.)
Systolic pressure (mmHg)	0	100.04 (6.27)	101.32 (8.55)	100.97 (7.13)
	20	112.38 (7.34)	114.51 (7.21)	113.48 (8.72)
	23*	104.62 (8.31)	106.91 (9.38)	104.76 (9.17)
	25#	100.15 (7.62)	102.05 (6.71)	100.46 (8.58)
Diastolic pressure (mmHg)	0	69.30 (6.15)	69.90 (5.41)	69.75 (6.29)
	20	74.17 (7.70)	76.24 (6.69)	74.76 (5.36)
	23*	71.09 (6.81)	72.11 (4.47)	71.89 (5.06)
	25#	69.45 (6.13)	70.02 (6.81)	69.87 (5.41)

B.I. Before Proper Packing and Wearing Intervention; *3 min recovery time
A.I. After Proper Packing and Wearing Intervention; #5 min recovery time

heart rate. The average heart rate calculated after every 5 min of subjects before and after an intervention were significantly different and results obtained from the statistical test are given in Table 3. The heart rate increased significantly in the first 5 min of walking ($p < 0.05$), and then gradually increased over time during walking. After 3 min of recovery, heart rate steadily fell to achieve the normal state.

The minimum and maximum blood pressures for the subjects were 95/62 and 116/94 respectively. The effect of interventions on systolic and diastolic blood pressures is shown in Table 2. Paired sample t-test showed the significant effect of intervention on blood pressures. The results obtained from the statistical data are given in Table 3.

Paired-sample T test shows that there is a significant effect of packing and wearing interventions on heart rate, systolic and diastolic blood pressures. The measured physiological parameters of school children before and after ergonomic

Table 3 Paired sample T test to check the signify cant effect of interventions on the heart rate and blood pressures

Physiological parameters_(A. I-B.I) at any point of time	Paired differences					t	dof	Sig. (2-tailed)
	Average of mean diff.	Std. deviation	Std. error mean	95% confidence interval of the difference				
				Lower (%)	Upper (%)			
Heart rate	−0.66	0.913	0.118	−0.430	−0.902	−5.64	29	0.004
Systolic Pressure	−2.40	4.52	0.583	−3.57	−1.23	−4.11	29	0.002
Diastolic Pressure	−4.89	3.96	0.511	−5.914	−3.86	−9.56	29	0.001

intervention were significantly different and the results obtained from the statistical test are given in Table 3. The values given in the column of mean difference for heart rate and blood pressures demonstrates that average of mean difference of physiological parameters before and after intervention at any point of time were decreased after the intervention.

4 Discussions

The present study evaluated the guidelines suggested by AOTA on packing, wearing and carrying of school backpacks. The study set to measures the strain, children receive from carry heavy loads for after an extended period of time. In this investigation physiological variables have been used such as heart rate and blood pressures. Although the previous reported studies focuses were on the effects of backpack either on physiological or biomechanical parameters when students carried it on their backs. But this study is unique because of considering the effects of packing, wearing and carrying of backpacks on the school children. The main findings of this study were that, walking for 20 min with backpack load of 10% body weight before intervention induced longer recovery periods for heart rate and blood pressures than the same load carried by the subjects after intervention. However the mean heart rate at any point of time decreased by 0.66 bpm for 10% carrying load after the intervention. Although measurements of blood pressure also shows significant effect for intervention, mean systolic blood pressure decreased by 2.40 mm-Hg at any point of time after intervention whereas mean diastolic blood pressure decreased by 4.89 mm-Hg. When subjects walked for 5 min there was significant increase in heart rate and blood pressure and afterwards both were gradually increased. These findings shows very similar results with the findings of Malhotra and Sen Gupta, Wong and Hong studies on load carriage by school children. The paired sample T test also showed the significant effect of AOTA interventions on the physiological parameters for load 10% of bodyweight. This paper enlighten the benefits of AOTA guidelines on

packing, wearing and carrying techniques, but still there are certain ill effects of backpacks which pushes the physiological, biomechanical and psychological strains [12]. There is an urgent need of modified design of backpack in order to equally distribute the load carry by school children.

This study has some limitations such as it was done in laboratory; subjects performed dynamic activities on a treadmill instead of normal walking on the ground; only male subjects were selected because of non-availability of female physician for the placement of sensors; the study was conducted on a single backpack thus the results cannot be carried over to all backpacks and it must be tested on each kind of backpacks to make valid conclusions; the study also not conducted on higher backloads loads so interventions are not valid for these loads.

Awareness regarding packing, wearing and carrying of backpacks as per the guidelines should be created among healthcare professionals, teachers and parents. The backpack load should be restricted to 10–12% of bodyweight as per the investigation reported by the previous researchers. [2, 9, 11]. From the above evidence it seems clear that, the present study has demonstrated that when subjects do not carry school backpack with proper interventions as per AOTA guidelines there is more chances of physiological strain in terms of heart rate, blood pressure.

5 Conclusions

It is hypothesized that carrying load with AOTA guidelines (interventions regarding packing, wearing and carrying of backpacks would help to reduce the physiological strain in school going children. For the participants in this study, carrying a load of up to 10% of bodyweight while walking on the treadmill before and after the interventions resulted in the increase of heart rate and blood pressures. It was hoped that the findings of this paper would enlighten the scope of the issue on backpack packing, carrying and wearing. It also help health practitioners, parents and teachers to give guidelines on the proper packing, wearing and carrying of school bags.

Acknowledgements We would like to express our gratitude to the management of the various schools and the students who whole heartedly cooperated with our survey despite their busy curriculum. This study was undertaken by Center of Excellence in Industrial and Product Design under TEQIP-II. We would also like to acknowledge NITIE, Mumbai for their valuable inputs.

References

1. MHRD. http://mhrd.gov.in/. Department of School Education and Literacy/AR2013-14.pdf (2013)
2. Grimmer, K., Dansie, B., Milanese, S., Pirunsan, U., Trott, P.: Adolescent standing postural response to backpack loads: a randomised controlled experimental study. BMC Musculoskelet. Disord. **3**(1), 10 (2002)

3. Tinsworth, Deborah, K.: Special Study: Injuries and Deaths Associated with Children's Playground Equipment. US Consumer Product Safety Commission, Washington, DC (2001)
4. Song, Q., Yu, B., Zhang, C., Sun, W., Mao, D.: Effects of backpack weight on posture, gait patterns and ground reaction forces of male children with obesity during stair descent. Res. Sports Med. **22**(2), 172–184 (2014)
5. Hong, Y., Brueggemann, G.P.: Changes in gait patterns in 10-year-old boys with increasing loads when walking on a treadmill. Gait Posture **11**(3), 254–259 (2000)
6. Mayank, M., Singh, U., Quddus, N.: Effect of backpack loading on cervical and shoulder posture in Indian school children. Indian J. Physiotherapy Occup. Therapy **1**(2), 3–12 (2007)
7. Malhotra, M.S., Gupta, J.S.: Carrying of school bags by children. Ergonomics **8**(1), 55–60 (1965)
8. Voll, H.J., Klimt, F.: On strain in children caused by carrying school bags. Das Offent. Gesundheitswes **39**(7), 369 (1977)
9. Pascoe, D., Pascoe, D.E., Wang, Y.T., Shim, D.M., Kim, C.K.: Influence of carrying book bags on gait cycle and posture of youths. Ergonomics **40**(6), 631–641 (1997)
10. Hong, Y., Wong, A.S., Robinson, P.D.: Effects of load carriage on heart rate, blood pressure and energy expenditure in children. Ergonomics **43**(6), 717–727 (2000)
11. AOTA. http://www.aota.org/-/media/corporate/files/backpack/meet-your-backpack-8-2014.pdf (2014)
12. Ramaprasad, M., Allias, J., Raghuveer, A.K.: Effect of backpack weight on postural angles in preadolescent children. Indian Paediatr. **47**(7), 575–580 (2009)