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RESEARCH ARTICLE

Effect of single and double strap backpack load carriage on vital capacity in school going children

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ABSTRACT

Background: There has been growing concern among healthcare professionals, parents, and educators that backpack is damaging the back. Load carriage systems supported by the trunk have been shown to decrease certain indices of pulmonary function by restriction of expansion of the lungs or chest wall. **Aims and Objectives:** Our study investigated the hypothesis that wearing a backpack with a load ranging from 5% to 30% of body weight (BW) produces pulmonary function reductions in school going children. **Materials and Methods:** To investigate this hypothesis, 100 normal healthy school girls from two different schools were selected, out of these 57 girls are from schools carrying backpack load and 43 girls from school with no backpack. Depending on the type of school and % of schoolbag weight of their total BW, they were divided into two groups (Group I-carrying backpack load ranging from 5% to 30% of BW and Group II-no backpack). Forced vital capacity (FVC), forced expiratory volume in 1 s (FEV1), FEV1% and 15 s maximum voluntary ventilation (MVV15) was measured. **Results:** FVC, FEV1, and MVV15 were decreased significantly in girls from the schools carrying backpack when compared with girls from the schools without backpack and the reduction were approximately proportional to the magnitude of the load carried. No change in FEV1% (FEV1/FVC) as FVC and FEV1 were reduced. Depending on the style with which the backpacks are carried to the school (either on one shoulder, i.e., single strap backpack carriage or both the shoulder's, i.e., double strap backpack (DSB) carriage) we examined pulmonary functions and found that FVC, FEV1, and MVV15 values were reduced in group carrying backpack on one shoulder when compared with no backpack and DSB. **Conclusion:** These results indicate a limitation on the ventilatory pump caused by load carriage which is directly related to the load carried and characteristic of restrictive disease of the respiratory system in school going children. Hence, there may be new designs of shoulder pads that could be developed which would provide similar levels of protection without pulmonary restriction. Another alternative may be to provide lockers in the school itself so that schoolbag weight may be reduced. New concept of no bag school is emerging which is also going to be useful.

KEY WORDS: Backpack Load; Forced Vital Capacity; Forced Expiratory Volume in 1 s; Forced Expiratory Volume in 1 s%; Maximum Voluntary Ventilation

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INTRODUCTION

Growing numbers of children are developing irreversible back deformities because of the weight of the bags they carry to school. School-age children are in a critical developmental stage regarding musculoskeletal development. Spinal ligaments and muscles are not fully

developed until after the 16th year of life.[1,2] Overloaded school bags that are up to double the size of those carried 10 years ago are contributing to the surge, it is feared. Pupils routinely carry bags filled with heavy books, laptops, sports kit, and packed lunches, which may weigh as much as 10–30% of their body weight (BW). Health experts say children risk long-term and ultimately permanent damage if they regularly carry more than 15% of their BW over their shoulders.[3] To properly ventilate, both the lungs and the chest wall need to expand with relatively little effort. If this cannot occur, i.e., if lung or chest wall expansion is hindered, either ventilation will be relatively insufficient, or the respiratory muscles will undergo undue fatigue. Restrictive conditions of the chest wall occur in diseases such as obesity[4] or scoliosis,[5] but also with occupational situations such as the wearing of bulletproof vests.[6] Studies of load carriage have mostly concentrated on the metabolic and biomechanical changes associated with load weight, walking speed, gradient, terrain, and other factors as well as medical hazards and performance limitations.[7,8] Students in primary, secondary, and tertiary education commonly use backpacks to carry their books and sporting equipment on a daily basis.[9]

There is, however, very little information on how the carriage of a backpack will affect the pulmonary ventilation of the most vulnerable group, i.e., school going children. Since the backpack frame and mass carried all oppose the expansion of the chest wall during inspiration, several studies have examined these effects and demonstrated that carrying heavy loads close to the trunk can affect lung function.[10-12] A common and very recent design of school bag is one that has a single strap across shoulder and chest. This has a greater restrictive effect on lung volumes which the wearer is not aware of, especially when the bag is heavy. Restrictive changes in lung function have been demonstrated with chest strapping.[13,14] Bygrave *et al*.[15] showed that the effect of the tightness of fit of backpack on lung function is additional to that of the weight of the load alone. Experts recommend that school children should not carry loads exceeding 10% of their BW.[16,17]

The present was designed to determine if there is any difference in lung function associated with backpack load carried and the way they are carried, i.e., either on single or both the shoulders. Almost all studies prove that either backpack that is heavy can alter arthrokinematics of spine which leads to restrictive lung function. However, only a few studies have given proper guidance on the carriage of backpack load by the most vulnerable group of our society (school going children) and their effect on lung function as well as the way they carry the load, i.e., either on one shoulder or both the shoulders. Hence, a need has arisen to rule the hypothesis that we have put forth which will be useful for the schools to use a special designed backpack or merge a new concept of no bag school.

MATERIALS AND METHODS

Study Subjects

The present study was based on the selection of 100 normal healthy primary school girls, aged between 9 and 14 years, who were in grades five to eight (based on Indian primary education system of central board) participated in the study. Children were randomly selected from elementary schools located in the city of Pune (Maharashtra State) in western part India. All children were given a written consent form to be approved by their parents. Both parental and child written consent was obtained before participation in the study. Permission for carrying out the research was granted from the school authorities involved. The Ethics Committee of our Institute approved the study. This cross-sectional, descriptive-analytical study was conducted during a month period between October and November 2013.

Selection Criteria for Students

A total of 100 girls are selected from two different type of schools, and they are divided into two groups.

- Group I: 57 children from schools carrying backpacks.
- Group II: 43 children from (day boarding schools/school with no bags).

Group I is divided into two subgroups depending on % of load carried in respect to BW

a. Group I_a → 10–15% BW.
b. Group I_b → 16–30% BW.

The girls which are selected from school in which backpacks are carried are using the same backpack provided by the schools, but the way they carry backpack is different, i.e., either on one shoulder or both the shoulder's. Based on this data, we further divided children into two categories carrying either on one (using single strap) or both shoulders (using both the straps).

Then, investigators arranged with individual schools and visited each participating school for data collection. Data collection was carried out on an unscheduled day so that children could not alter their school bag weight.

All children were free from neuromuscular disorders at the time of testing, and none had history of chronic low back pain, current or past cardiopulmonary disorders, children with any orthopedic problem, recent upper respiratory tract infection, history of recent or past ear, nose, or throat surgery.

A portable stadiometer was used to measure the standing height of each student (in centimeters to one decimal place). A digital electronic scale was also used to measure the BW and the weight of the school bag (including any additional items carried separately from the school bag). The scale was accurate to 0.01 kg and was calibrated over a range of known weights before data collection. Table 1 summarizes

demographic characteristic of the sample of school children participated in the study.

Schoolbags Weight

Schoolbag weight ranged from 6 kg to 13 kg. As Group I children are using schoolbags, irrespective of the type of backpacks they are using, schoolbag weight % in respect to BW was calculated. The schoolbag weight as a percentage of mean BW carried by the students was ranging from 10% to 30%.

Lung Function Tests

Lung function tests were done according to standard methods using digital spirometer to determine forced vital capacity (FVC), forced expiratory volume in 1 s (FEV1), FEV1%, and 15 s maximum voluntary ventilation (MVV15) (MVV in 15 s) with participants in an erect relaxed standing position during school time. In Group I tests are carried out with schoolbags and in Group II without backpacks.

Statistical Analysis

Data were analyzed through one-way repeated measures analysis of variance across the three conditions (control, cases-Group I_a and I_b). Significant results were further analyzed through Tukey's *post hoc* test. Significance was established at the 0.05 level.

RESULTS

Table 1 summaries the physical characteristics of girls. None of the control group reported any discomfort while performing tests. However, Group I subjects indicated the sensation of chest wall restriction.

Figure 1 FVC values obtained in three different conditions. FVC was decreased significantly in Group I_a and I_b when compared with control group. The reduction was approximately proportional to the magnitude of the load. FEV1 was significantly decreased by both Group I_a and Group I_b when compared to Group II (control) FEV1 were also found to be reduced in proportion to backpack load [Figure 2] given that both the FVC and FEV1 values were decreased proportionally to the load carried, it followed that the ratio of FEV1/FVC was not altered as shown in Figure 3. The result of MVV15 is presented in Figure 4. The MVV15 was significantly reduced in Group I_a and I_b subjects when compared with Group II. The reduction was approximately proportional to the magnitude of the load carried by children.

Table 2 summarizes mean standard deviation results of subjects depending on style with which backpacks are carried to school. In comparison with a control condition of no backpack (N), the single strap backpack (SSB) significantly reduced FVC, FEV1, and MVV15 but there

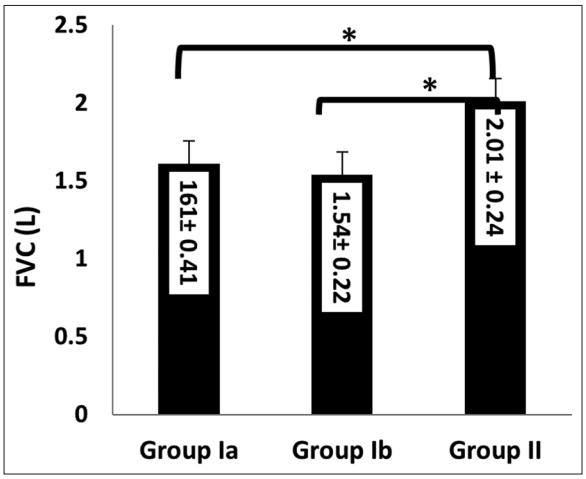

Figure 1: Comparison of forced vital capacity in control and cases. Group mean (± standard error) is plotted. *Indicates significant ($P < 0.05$) difference

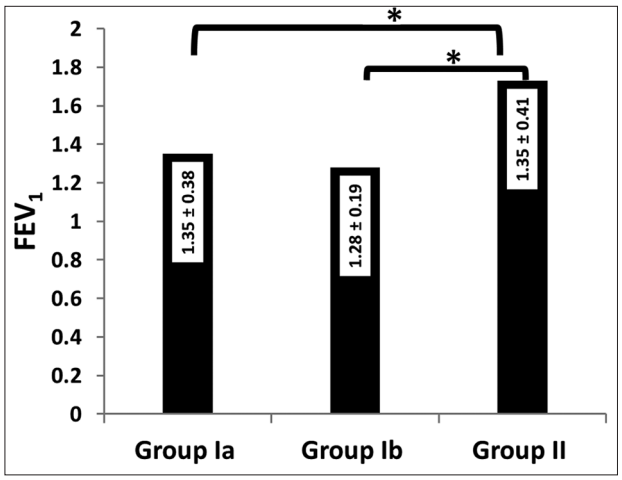

Figure 2: Comparison of forced expiratory volume in 1 s in control and cases. Group mean (± standard error) is plotted. *Indicates significant ($P < 0.05$) difference

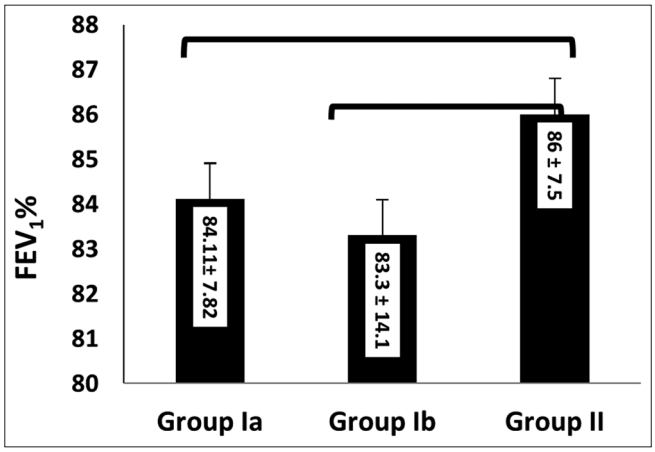

Figure 3: Comparison of forced expiratory volume in 1 s % in control and cases. Group mean (± standard error) is plotted. *Indicates significant ($P < 0.05$) difference

were no significant differences in FEV1%. The double strap backpack (DSB) also significantly reduced FVC, FEV1,

Table 1: Demographic characteristics of school children

Characteristics	Group I (57)		Group II (*n*=43) 0% BW
	Group I_a (*n*=30) 10–15% BW	Group I_b (*n*=27) 16–30% BW	
Age (years)	11.25±1.08	10.24±1.11	10.33±1.00
Height (cm)	133.12±10.86	135±10.32	131.08±7.36
Weight (kg) without backpack	37.46±7.23	43.58±10,72	32.63±5.89
Schoolbag weight (kg)	5.67±1.18	6.85±1.15	Nil

BW - School bag weight as % of mean BW. BW: Body weight

Table 2: Effect of SSB and DSB on lung function (mean±SD) in school going children carrying backpack load

Lung function test	mean±SD			#Percentage difference		
	No backpack (*n*=43)	SSB (*n*=35)	DSB (*n*=22)	SSB/*n* (%)	DSB/*n* (%)	SB/DSB (%)
FVC (L)	2.01±0.24	1.95±0.22	1.97±0.26	4.47**	1.99*	2.53*
FEV1 (L)	1.73±0.26	1.66±0.19	1.70±0.29	4.04*	1.73*	2.35*
FEV1%	86.06±7.82	85.12±7.97	86.29±7.31	0.11	0.26	1.35
MVV15 (L/min)	85.17±14.08	81.17±12.89	83.39±14.89	4.13*	2.08*	2.66*

#Percentage differences calculated as: SSB/*n*=(1-SSB/N)×100, DSB/*n*=(1-DSB/*n*)×100, SSB/DSB=(1-SSB/DSB) ×100. *Significance at *P*=0.05. SSB: Single strap backpack, DSB: Double strap backpack, SD: Standard deviation, FVC: Forced vital capacity, FEV1: Forced expiratory volume in 1 s, MVV15: 15 s maximum voluntary ventilation

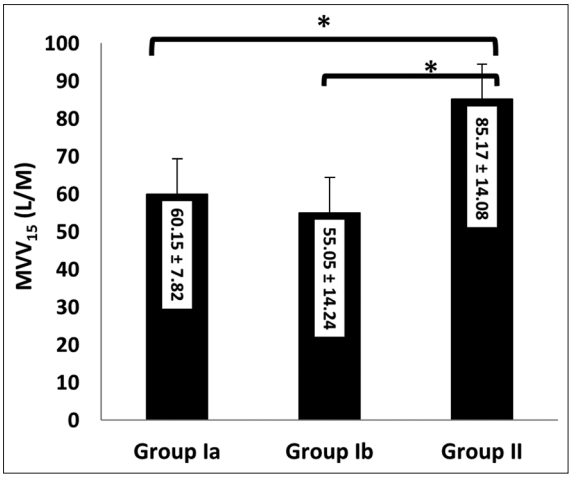

Figure 4: Comparison of 15 s maximum voluntary ventilation in control and cases. Group mean (± standard error) is plotted. *Indicates significant ($P < 0.05$) difference

and MVV. There was no significant change in FEV1%. In comparison with the condition of wearing the DSB, the SSB was associated with a significantly lower FVC, FEV1, and MVV but no change in FEV1%.

DISCUSSION

The aim of this study was to determine whether backpack load had an effect on pulmonary function of school going children and result of the study confirmed our hypothesis, in that there was decrease in vital capacity in school going girls carrying backpack when compared with the girls from the school with on bag concept. These results show that backpack load with increasing load around the back results in a restrictive like conditions in terms of pulmonary function.

Our results showed a decrease in FVC, FEV1, and MVV15 in girls carrying backpack load when compared with the control group but no change in FEV1% which is similar to the studies performed by Coast *et al*., Muza *et al*. 1989, Bygrave *et al*., Legg and Mahanty, and Epstein *et al*.[6,10-12] The changes in lung function are characterized by a restrictive type of ventilatory defect as explained in study done by Cotes[18] in which FVC and FEV1 are reduced without a corresponding decrement in the FEV1/FVC ratio. It is possible that the respiratory restriction of the chest wall associated with load carriage could affect pulmonary ventilation during rest and exercise, resulting in the sensation of dyspnea and in arterial hypoxemia, both of which could limit exercise capacity. The findings of our study correlate with the study done by Coast *et al*.[19] who examined the effect of football shoulder pads on pulmonary function and found similar decrement in FVC and FEV1 values. Legg[20] used bulletproof vests such as those worn by police and military and found decreases in FVC of 2–3%. Muza *et al*.[10] evaluated pulmonary functions in soldiers carrying loaded and unloaded backpacks and they to found decrease in lung functions, suggesting restrictive conditions. Epstein *et al*.[12] reported the same reduction in lung function indices with a 30 kg backpack load. Legg and Mahanty[11] found that the magnitude of the reduction was related to the load carriage system used. These results indicate that this chest wall restrictive device provides a quantifiable added inspiratory load in the breathing cycle that results in reproducible decrements in pulmonary function representative of those seen in some restrictive pulmonary disease and occupational situations.[21]

Our findings of a significant reduction in FVC, FEV1, and MVV in children carrying backpack load on one shoulder (SSB) when compared with DSB and no backpack correlates

with the study done by Legg and Cruz.[22] The present study is, however, one of the few studies to demonstrate that the style of backpack strapping can also significantly affect lung function in a similar way since there was clear and statistically significant evidence of greater chest restriction for SSB than for DSB. The single strap backpack had a wide strap that was worn across the chest and shoulders in a diagonal manner and appears to have produced a greater restrictive effect on the thorax, whereas the double strap backpack had thinner straps attached over each shoulder, resulting in a lesser degree of restriction. An additional possible reason for this finding was that some of the participants found that the strap of the SSB was too short for them so that they had difficulty in securing it firmly. Under these circumstances, it is possible that the effects observed may be due, at least in part, to tightness of fit similar to that reported by Bygrave *et al.*[15] In the Bygrave *et al.* study, patterns of changes in the indices of lung function that reflect flow in small airways were also reduced and associated with tightness of fit of the backpack harness.

This suggested that a tightly fitting backpack could be associated with changes in lung function at the alveolar level. Since the present study has shown that the style of backpack strapping is associated with a mild restrictive pattern of change in lung function, this may also be due to the tightness of fit that the style of backpack strapping presents. The use of single strap (cross chest) backpack harnesses in walking, running and other more dynamic activities may have further effects on lung function.

CONCLUSION

We have demonstrated that carrying backpack load by school going children reduces the reserved breathing volume due to restrictive effect of backpack load and the style with which backpacks are carried produces even greater restrictive effect. Hence, there may be new designs of shoulder pads that could be developed which would provide similar levels of protection without pulmonary restriction. Another alternative may be to provide lockers in the school itself so that schoolbag weight may be reduced. New concept of no bag school is emerging which is also going to be useful.

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REFERENCES

1. Lai JP, Jones AY. The effect of shoulder-girdle loading by a school bag on lung volumes in Chinese primary school children. Early Hum Dev 2001;62:79-86.
2. Kids and Backpacks. Available from: http://www.aaos.org. [Last accessed on 2002 Aug 12].
3. Rodríguez-Oviedo P, Ruano-Ravina A, Pérez-Ríos M, García FB, Gómez-Fernández D, Fernández-Alonso A, *et al.* School children's backpacks, back pain and back pathologies. Arch Dis Child 2012;97:730-2.
4. Parameswaran K, Todd DC, Soth M. Altered respiratory physiology in obesity. Can Respir J 2006;13:203-10.
5. Tsiligiannis T, Grivas T. Pulmonary function in children with idiopathic scoliosis. Scoliosis 2012;7:7.
6. Coast JR, Cline CC. The effect of chest wall restriction on exercise capacity. Respirology 2004;9:197-203.
7. Haisman MF. Determinants of load carrying ability. Appl Ergon 1988;19:111-21.
8. Knapik J, Harman E, Reynolds K. Load carriage using packs: A review of physiological, biomechanical and medical aspects. Appl Ergon 1996;27:207-16.
9. Negrini S, Carabalona R, Sibilla P. Backpack as a daily load for school children. Lancet 1999;354:1974.
10. Muza SR, Latzeka WA, Pandolf KB. Load carriage induced alterations of pulmonary function. Int J Indust Ergon 1989;3:221-7.
11. Legg SJ, Mahanty A. Comparison of five modes of carrying a load close to the trunk. Ergonomics 1985;28:1653-60.
12. Epstein Y, Muza SR, Latzka WA, Pandolf KB. Alterations in pulmonary function caused by a backpack load. Med Sci Sports Exerc 1987;19:531.
13. Ghesquiere J, Billiet L, Reybrouck T, Delamotte G, Vermiere J. Limitation of work capacity by chest strapping in normal subjects. Bull Eur Physiopathol Respir 1979;15:117.
14. Caro CG, Butler J, Dubois AB. Some effects of restriction of chest cage expansion on pulmonary function in man: An experimental study. J Clin Invest 1960;39:573-83.
15. Bygrave S, Legg SJ, Myers S, Llewellyn M. Effect of backpack fit on lung function. Ergonomics 2004;47:324-9.
16. Chow DH, Kwok ML, Au-Yang AC, Holmes AD, Cheng JC, Yao FY, *et al.* The effect of backpack load on the gait of normal adolescent girls. Ergonomics 2005;48:642-56.
17. Forjuoh SN, Lane BL, Schuchmann JA. Percentage of body weight carried by students in their school backpacks. Am J Phys Med Rehabil 2003;82:261-6.
18. Cotes JE. Lung Function: Assessment and Application in Medicine. Oxford: Blackwell Scientific Publications; 1979.
19. Coast JR, Jessica LB, Colleen M, Willeford KS. The effect of football shoulder pads on pulmonary function. J Sports Sci Med 2005;4:367-71.
20. Legg SJ. Influence of body armour on pulmonary function. Ergonomics 1988;31:349-53.
21. Cline CC, Coast JR, Arnall DA. A chest wall restrictor to study effects on pulmonary function and exercise. Respiration 1999;66:182-7.
22. Legg SJ, Cruz CO. Effect of single and double strap backpacks on lung functions. Ergonomics 2004;47:318-23.

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