EFFECT OF LOAD CARRIAGE ON PULMONARY MECHANICS IN SCHOOL CHILDREN

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ABSTRACT
Carrying moderate to heavy loads in schoolbags by school children on shoulders compresses the chest, causing a change in lung function that is typical of a restrictive ventilatory impairment. We investigated the hypothesis that these pulmonary function reductions are directly related to increment of backpack load. To investigate this hypothesis, 135 normal healthy school children out of these 63 girls and 72 boys were tested in upright erect posture. Depending on % of schoolbag weight of their total body weight, they were divided into four groups (Group I - less than 10%, Group II-10-20%, Group III-20-30% and Group IV- more than 30-%). Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV1), FEV1% and 15s maximum voluntary ventilation (MVV15) was measured in boys and girls. With increasing schoolbag load from less than 10% to more than 30%, FVC and FEV1 progressively decreased significantly in boys and girls respectively. MVV was also decreased significantly as magnitude of backpack load increases. No change in FEV1% (FEV1/FVC) as FVC and FEV1 were reduced. 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.

Key Words: Backpack Load, School children, FVC, FEV1, FEV1%, MVV

INTRODUCTION
Load carriage systems are used as tools for a variety of industrial, military, recreational and educational situations. One of most common types of load carriage systems used is backpacks. Although backpacks are used to carry a wide variety of loads. (Muza et al., 1989) 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. (Knapik et al., 1969) Education now a day poses a lot of challenge & opportunities to the children. Music, sports, arts etc. are now part of curriculum. Students in primary, secondary and tertiary education commonly use backpacks to carry their books and sporting equipment on a daily basis (Negrini et al., 1999; Smolander et al., 1985; Grimmer et al., 2000; Grimmer et al., 1999; Whittfield et al., 2001). It is generally accepted that the respiratory system does not limit exercise in normal subjects but may limit exercise in patients with lung disease. (Bye et al., 1983) The changes in lung function are characterized by a restrictive type of ventilatory defect (Cotes et al., 1979) in which Forced Vital Capacity (FVC) and Forced Expiratory Volume in one second (FEV1) is reduced without a corresponding decrement in the FEV1/FVC71 ratio. The result put forth by (Legg et al., 1985) indicates a limitation on the ventilatory pump caused by load carriage which is characteristics of restrictive diseases of the lung. Others have used artificial devices to cause chest wall restrictions and have arrived at similar pulmonary function results. (Bradley et al., 1980)

Since previous studies showed effect of backpack load and % of backpack load carried on lung function test in adults. But, there is paucity of information on % of backpack load carriage on Forced vital capacity in school children. So, we were interested in determining whether these load carriage induced decrements of pulmonary functions are dependent upon the size of the load carried. Thus, the present study assessed the pulmonary function responses to carrying different % of backpack load in school children.
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MATERIALS AND METHODS

The present study was based on selection of 135 normal healthy primary school including 63 girls and 72 boys, aged between 9 and 14 years, who were in grades four 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.

Selection criteria for students

135 Students (72 boys and 63 girls) are selected. 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 subjects were free from neuromuscular disorders at the time of testing and none had history of chronic low back pain, current or past cardio-pulmonary disorders and children with any orthopaedic problem, recent upper respiratory tract infection, history of recent or past ear, nose or throat surgery. Children are divided into four groups depending on % of schoolbag weight as a backpack load they carried of their total body weight. Their Demographic characteristics are shown in Table 1:

Table 1: Demographic characteristics of school children

<table>
<thead>
<tr>
<th>Groups (Backpack load)</th>
<th>I (&lt;10% of body weight)</th>
<th>II (10-20% of body weight)</th>
<th>III (20-30% of body weight)</th>
<th>IV (&gt;30% of body weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Numbers (N)</td>
<td>Boys</td>
<td>Girls</td>
<td>Boys</td>
<td>Girls</td>
</tr>
<tr>
<td>Age(Yrs)</td>
<td>11.16±1.0</td>
<td>.0</td>
<td>10.66±1</td>
<td>.1</td>
</tr>
<tr>
<td>Height(cm)</td>
<td>145.5±6.0</td>
<td>.0</td>
<td>137.3±1</td>
<td>.5</td>
</tr>
<tr>
<td>Weight (Kg)</td>
<td>37.52±6.7</td>
<td>.5</td>
<td>35.50±7</td>
<td>.4</td>
</tr>
</tbody>
</table>

Schoolbag weight ranged from 4kg – 11kg. It was found that boys carried heavier schoolbags (6.1 – 10.8kg) than girls (5.8 – 9.8kg). The schoolbag weight as a percentage of mean body weight carried by the students was ranging from 7% - 33%. Boys carried slightly larger proportion of their body weight (8%-33%) than girls (5% - 28%)

Lung function tests were done during school time according to standard methods using digital spirometer (Helios 401) to determine FVC, FEV1, FEV1% and MVV with participants in an erect relaxed standing position carrying schoolbags.

Statistical Analysis

ANOVA test was used to statistical compare the ventilatory responses obtained during the four load carriage conditions in boys and girls. Tukey’s Post hoc test was used to locate significant difference among the fours groups.
RESULTS
Values of FVC obtained in boys and girls with four loaded conditions are shown in Figure 1 and it was found that FVC was decreased as load increased in both boys and girls. In boys, the post hoc test showed that there was a significant difference between Group I and Group II, Group I and Group III, Group I and Group IV and between Group II and IV. There was non significant decrement in FVC between Group II and Group III, Group III and Group IV. In girls, the post hoc test showed significant difference between Group I and Group III and Group I and Group IV, while non significant change between Group I and Group II, Group II and III, Group II and Group IV and Group III and Group IV. The reductions were approximately proportional to the magnitude of load carried in boys and girls. The FVC values obtained in girls are less than boys.

In Figure 2 the FEV1 was also found to be reduced in proportion with the backpack load in both boys and girls. In boys, the FEV1 was decreased significantly when Group I was compared with Group II, III and IV while there was non significant decrement between Group II and Group III as well as Group III and Group IV. In girls, significant decrease in FEV1 was found when Group I was compared with Group III and IV while there was non significant decrement between Group I and Group II as well as between Group II and Group III, Group II and IV and Group II and IV. The result of FEV1 between genders showed significant differences in all four groups.
Given that both FVC and FEV1 demonstrated decrements roughly proportional to the load carried in the backpack, it followed that the ratio of FEV1/FVC (FEV1%) was not altered by increasing backpack load. This is shown in Figure 3 where FEV1% was not changed significantly in boys and girls respectively as magnitude of load increases.

![Figure 3: Comparison of FEV1/FVC (mean± SD) in boys and girls depending on % of load they carried](image)

The results of the Maximum voluntary ventilation (MVV) tests are present in the Figure 4. The MVV15 was significantly reduced in both genders as % of backpack load goes on increasing. In boys, the MVV was decreased significantly when Group I was compared with Group II, III and IV while there was non significant decrement between Group II and Group III as well as Group III and Group IV. In girls, significant decrease in MVV was found when Group I was compared with Group II, III and IV while there was non significant decrement between Group II and Group III, Group II and IV and Group II and IV.

![Figure 4: Comparison of MVV (mean± SD) in boys and girls depending on % of load they carried](image)

**DISCUSSION**

We examined that wearing a heavy bag with a load ranging from 4kg to 11kg on shoulder by school children has effect on static and dynamic lung function. In all four groups, the children selected are of
same age with same height and weight, so possibility of affecting the ventilatory function due to difference in physical characteristics has been ruled out. Thus, our results revealed that several indices of pulmonary function are reduced in proportion to the schoolbag load carried by the children. With increasing backpack load, the FVC, FEV1 and MVV15 were reduced. Over the range of loads examined, there appears to be a linear decrease of FVC, FEV1 and MVV with increasing backpack load. The findings of our study correlates with the study done by Datta et al., (1971) from their study, it seems reasonable to expect that since many carriage systems are most metabolically efficient when carried on the trunk, these systems may alter pulmonary ventilation by interfering with movement of chest wall. While numerous studies have investigated an effect carrying loads on energy expenditure (Goldman et al., 1962; Pimental et al., 1979) walking patterns (Martin et al., 1986) and perception of exertion (Goslin et al., 1986). Legg et al., (1985) found that the magnitudes of the reductions were related to the style of load carriage system used. Thus, the result of our study and the previous report by Legg et al., (1985) and Muza et al., (1989) indicates that the degree of pulmonary function decrement incurred by backpack load is dependent on both the load and the style of carriage system used. Caro et al., (1960), Ghesquiere et al., (1979) and Bauer et al., (1988) have shown that chest strapping and spinal splinting produce a restrictive change in lung function in patients. An additional possibility is that some children used the schoolbags with more wide straps which was worn across the chest and shoulders in a diagonal manner and appears to have produced a greater restrictive effect on thorax as load increases which leads to too tightness of fit similar to that reported by Bygrave et al., (2003). Lai et al., (2001) reported that a schoolbag heavier than 10% of child’s body weight was associated with a restrictive effect on lung volumes. In the present study the mean backpack load % is ranging from 5% to 35% of body weight. The findings therefore indicates that a similar but significant restrictive effect may be produced with a backpack load as load increases from 5% to 30% of body weight.

Conclusion

In conclusion, we have shown that wearing schoolbag on shoulder by school children decreases the ventilatory function. Backpack-Style bags with two straps were found to be the most popular style of schoolbag for both boys and girls. The most common method of carriage was on the back, over two shoulders. It is of concerned that throughout the school week, a total of approximately 70% of schoolbags weighed greater than the approximately guideline of 10% bodyweight. To our knowledge, this is the first study to examine the effect of magnitude of schoolbag load on static and dynamic pulmonary function in school boys and girls. The level of decrease in pulmonary function is related to the % of schoolbag load carried by boys and girls. So, there may be new designs of shoulder pads that could be developed which would provide similar levels of protection without pulmonary restriction. Other 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


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