Effect of front pack and backpack load on pulmonary function among 9-12 years old saudi girls

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Abstract

Background: Load placement is an important factor in the efficiency of load carriage. Two types of packs have aroused special interest, backpack and front pack. The backpack is one of several forms of manual load carriage that provides versatility and is often used by school children. There is a change in kinematics when the placement of the load was altered.

The purpose: of this study was to investigate the efficacy of backpack and front pack on ventilatory functions.

Methods: A pretest-post test (2×3) design was used in this study. Forty Saudi girls with mean age (10.5±0.9 and 10.5±0.7) years old participated in this study. They were assigned into two groups of equal sizes (group I and group II). Subjects in group I, n=20. Subjects in group II, n=20:- Subjects in group I were assessed without a load (NP) and carrying a load (10% of body weight) in a backpack (BP) while Subjects in group II were assessed without a load (NP) and carrying the same load in a front pack (FP). They were required to the cardiopulmonary laboratory for testing on two separate occasions, they provided three maximally forced expirations under each of the following two conditions: no pack (NP), load carriage (10% of BW) either backpack (BP) or front pack (FP). They rested for 1 min between each individual expiration and for 5 min between each condition. Forced vital capacity (FVC), forced expiratory volume in one second (FEV1) and peak expiratory flow (PEF) were measured. Paired t-test was used to distinguish between the two groups before and while carrying the packs in each group separately. Unpaired t-test was used to further distinguish between both types of packs.

Results: The results revealed that both front pack and backpack significantly decreased ventilatory functions. Comparing both groups, this decrease was non-significant.

Conclusion: The finding revealed that both types of packs decreased the ventilatory functions, the decrease in ventilatory functions when carrying a front pack is higher than when carrying a backpack, so the backpack has the advantage over the front pack in terms of ventilatory functions.

Keywords: Backpack, Front pack, load carriage, Forced Vital Capacity, Forced Expiratory Volume in 1 s, Peak expiratory flow

Introduction

Students in primary, secondary and tertiary education commonly use backpacks to carry their books and sporting equipment on a daily basis. The backpack is one of several forms of manual load carriage that provides versatility and is often used by backpack-

ers, as well as school children. The backpack is an appropriate way to load the spine closely and symmetrically, while maintaining stability [1]. Backpacks come in various sizes, shapes and brands. They also come with various types of straps. The backpack represents an external load stressing the spine to bend and press [2].

However daily carriage of a school backpack imposes a substantial load on the spine and is a frequent cause of discomfort in children. Reported mean weights of school backpacks in children over the age of 10 years old range from approximately 10% of body weight (BW) to over 20% BW [3].

Young adult and school's student are commonly exposed to carrying heavy bags and the resultant musculoskeletal symptoms have been observed to be related with the magnitude of the backpack load [4]. The increasing self-reported backpack weight is associated with increased prevalence of annual low back pain. Weighted backpack carrying has been observed to affect lung mechanics and breathing patterns during treadmill walking among healthy men [5].

Carrying a backpack with a load more than 8% body weight can significantly change cardio-respiratory parameters among male adolescent students [1]. In a study showed that spinal compression during anterior carriage was larger than that of posterior carriage [6].

There is a change in kinematics when the placement of the load was altered. The front pack showed a significant change in hip flexion/extension values, along with a significant reduction in forward head position. The upright posture seen with the use of a front pack may reduce the shearing forces acting on the spine, which has been identified as a risk factor for back injuries [7].

Lung function is related with oxygen uptake and hence with the energy expenditure, thus lung function is a vital physiological parameter, which governs the cumulative stress on the body [8]. Furthermore, pulmonary function is an important component of general body health. Holding heavy load near to the trunk affects pulmonary function and reduction in pulmonary function is dependent on the load percent. Load imposes mechanical restriction on thoracic, which affects the pulmonary function. The restriction cause changes in Forced Vital Capacity (FVC) and Forced Expiratory Volume in 1 s (FEV1) are reduced without a corresponding decrement in the FEV1/FVC-1 ratio [9].

Forced Vital Capacity (FVC) is the largest amount of air that can be forcefully expired from lung after a maximal inspiration. It is often measured clinically as an index to determine both the presence and severity of ventilation impairment. It gives information about the respiratory muscles strength. The fraction of the vital capacity expired during the first second of a forced expiration (FEV1, timed vital capacity) gives additional information about the cause of hindrance to expire, if any. FEV1/FVC ratio also known as FEV1% is a standard index for assessing and quantifying limitation of airflow [8].

Some researchers showed that alternating the backpack's load positions could be beneficial on different physiological aspects. Short-term putting a backpack anteriorly might be useful for temporarily relieving postural changes induced by posterior backpack carriage [6]. Alternating the backpack carriage has showed some benefits for osteoporotic patient's rehabilitation [10]. The pulmonary functions changes are influenced by alternating the backpack carriage [11].

Extensive research has been performed on variations of load carriage. Studies have shown that changes in load distribution give rise to alterations in metabolic and biomechanical parameters. Increasing the mass of the load, thus increasing overall workload, consistently results in increased energy expenditure [12], forward lean in posture with increased spinal curvature [13]. There are significant amount of work has already been done to show relationship between backpack carriage and pulmonary function parameters but the relationship between Front pack carriage and pulmonary function has not been specifically studied. Therefore, this study would help to investigate the effects of both the front pack and a traditional backpack on Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV1) and peak expiratory flow (PEF) at the level of 10% load of body weight.

Materials and methods

Subjects

Forty Saudi girls, age ranged from 9-12 years with mean age (10.5 ± 0.9 and 10.5 ± 0.7) years old participated in this study, all subjects met the inclusion criteria; body mass index within the normal range for child's age (from 5th percentile to less than the 85th percentile), using a car to go to and from school and being able to perform the spirometry maneuvers appropriately and free from any musculoskeletal abnormalities of the lower limb or trunk. Subjects with a history of chronic cardiovascular, respiratory or renal diseases and orthopedic disorders were excluded. orthopedic disorders involving the thorax such as scoliosis, kyphosis, history of spinal or shoulder trauma, overweight, obese, or underweight children, recent surgeries (in a period of less than 3 months) involving the thorax, abdomen, or eye, systemic disorders such as diabetes mellitus, participating in any physical activities (1/hour, 3 times/week) or formal training and organized sports [8].

Procedures

Design of the Study

A pre-post (2x3) design was used in this study. The subjects participating in this study were forty Saudi girls, with mean age (10.5 ± 0.9 and 10.5 ± 0.7) years old. They were assigned into two groups of equal numbers, Subjects in group I, $n=20$, they used backpack, Subjects in group II, $n=20$ (they used front pack). All subjects were required for testing on two separate occasions; they provided three maximally forced expirations under each of the following two conditions: no pack (NP), load carriage (10% of BW) either backpack (BP) or front pack (FP). They rested for 1 min between each individual expiration and for 5 min between each condition [14]. Forced vital capacity (FVC), forced expiratory volume in one second (FEV1) and peak expiratory flow (PEF) were measured.

Instrumentation

Backpack

One backpack (a medium) was used in this study **Figure 1**.

Figure 1. Backpack size.

Adjustable dual buckle closure to sides for width extension

- Top grab handle and padded shoulder straps
- Adjustable chest and hips straps
- Height (cm) 42.00
- Width (cm) 32.00
- Length (cm) 14.00

Portable spirometer

This study used Portable spirometer (SpirOx) **Figure 2**.

Figure 2. spirometer (SpirOx) apparatus for measuring lung function.

- Color TFT Display
- Ultrathin design for portable carrying, easy operation for convenient test.
- Large TFT screen to display the test result clearly.
- Measure FVC, PEF, FEV1 etc., and Parameters synchronously.
- Peak expiratory flow (PEF), 25% flow of the FVC (FEF25), 75% flow of the FVC (FEF75) and average flow between 25% and 75% of the FVC (FEF2575).

- Support diagnosis evidence by volume and flow rate chart display. With precise, credible test result and good consistency.
- Built-in predicted value, display the tested current condition by red, yellow and green bar.
- Provide repeated measure and memorize the correlatice data.
- Communication with the computer with the USB (or Bluetooth), which can calculate data, analyze trend and export.
- Built-in lithium battery, battery power display.
- Automatic power-off when there is no operation in one minute.
- Pulmonary function measurements were measured according to standard methods [15,16].

Procedure

The participant parents signed the consent form before starting the study, the procedures to be used, and the health hazards and risks of the study had been fully explained to each of them verbally and in writing. They were medically screened for any history of neck, shoulder, back and respiratory problems. The weight and height of the subjects were taken by digital weight-height scale (SOEHNLE Type 7831 Professional Digital Columns Scale) then calculate the BMI as the ratio of weight (kg) over height (m) squared [17]. Explain to the subjects the instruction about spirometry technique, the measurement of pulmonary function was done with the subjects in an erect relaxed standing position and wearing their usual scrub suits and shoes, three maximally forced expirations was taken first with no pack (NP), second carrying backpack then carrying front back and record the measurement, with 5 min a rest in between [14].

The backpack was filled with weights to achieve the recommended load limit, which was 10% of BW [8], the subject was initially helped to adjust the backpack that best suited their body size and took a sufficient time to become familiar with the packs load before the start of pulmonary function measurements [14].

Lung function measurements were made by portable spirometer (SpirOx) in an erect relaxed standing position and subjects were wearing nose clip, take a deep and slow breath in, place lips around the disposable mouthpiece, exhale fully and with as much force as possible, blasting out all the air in the lungs, the highest value of the 3 trials was recorded. Following initial instruction about spirometric technique, the subjects made three familiarization maximally forced expirations. They provided three maximally forced expirations under each of the following two conditions: no pack (NP), load carriage either front pack (FP) or backpack (BP). They rested for 1 min between each individual expiration and for 5 min between each condition [14]. Variables measured were; forced vital capacity (FVC), forced expiratory volume in one-second (FEV1) and peak expiratory flow (PEF). All lung volumes and flows were corrected to body temperature and

pressure saturated with water vapor. The single highest value observed for each lung function measurement was used to calculate mean and standard deviation for all subjects and conditions in the data analysis.

Statistical Analysis

The statistical analysis was done by using SPSS Statistics V21. General characteristics of all subjects (name, weight, height, BMI and ventilatory function tests) were described as means and standard deviations. The significance of differences was calculated by standard T- test, where P value less than 0.05 was considered significant.

Result

1-Demographic Data of the investigated subjects of both groups

As observed in **Table 1**, the mean values of age for subjects of first and second group were (10.5 ± 0.9 and 10.5 ± 0.7 years) respectively. While the mean values of weight for subjects of first and second group were ($37.3 \pm 6.2 \pm 1.53$ and 36.2 ± 6.5 kg) respectively, the mean values of height for subjects of first and second group were (135 ± 8.7 and 137 ± 7.5 Cm) respectively.

Table 1. The mean and standard deviation of age, height, weight and Body mass index of subjects in both groups.

Parameter	Groups	X $\pm$ SD	Minimum	Maximum
Age $\pm$ SD (years)	Backpack	10.5 ± 0.7	9.0	12.0
	Front pack	10.5 ± 0.9	9.0	12.0
Weight $\pm$ SD (Kg)	Backpack	36.2 ± 6.5	20.5	52
	Front pack	37.3 ± 6.2	21.5	52.5
Height $\pm$ SD (Cm)	Backpack	137 ± 7.5	115	159
	Front pack	135 ± 8.7	110	160
Body mass (%) index	Backpack	17.3 ± 1.2	2.6	8.7
	Front pack	17.3 ± 1.2	2.6	8.7

SD. standard deviation

Furthermore the mean values of Body mass index for subjects of first and second group were (17.3 ± 1.2 and 17.3 ± 1.2) respectively.

II. Comparison between Unloaded and loaded mean values of ventilatory functions in both groups (I and II)

A. Unloaded and loaded mean values of ventilatory functions in group I

Data presented in **Table 2** and illustrated in **Figures 3** and **4**

showed that, in group I, the unloaded and loaded mean values $\pm$ SD of FVC were 1.87 ± 0.52 and 1.8 ± 0.50 (liter) respectively. The mean difference was 0.07.

Furthermore, in group I, the unloaded and loaded mean values $\pm$ SD of FEV1 were 1.83 ± 0.39 and 1.79 ± 0.38 (liter) respectively. The mean difference was 0.04.

In addition, in group I, the unloaded and loaded mean values $\pm$ SD of PEF were 254.5 ± 6.77 and 222.81 ± 7.05 (ml/sec) respectively. The mean difference was 31.69. For all variables, the differences between the unloaded and loaded mean values $\pm$ SD were significant ($P < 0.05$).

Table 2. Loaded and unloaded mean values of ventilatory functions in group I.

Variables	NP $\pm$ SD	BP $\pm$ SD	Mean Difference	Change %	t-test	P value	Significance
FVC (liter)	1.87 ± 0.52	1.8 ± 0.50	0.07	3.74	9.35	$<.001$	S
FEV1(liter)	1.83 ± 0.39	1.79 ± 0.38	0.04	2.18	7.9	$<.001$	S
PEF(ml/sec)	254.5 ± 6.77	222.81 ± 7.05	31.69	12.45	3.321	$<.001$	S

SD. standard deviation P: probability *Non-significant as $P > 0.05$. ** Significant as $p < 0.05$.

B. Unloaded and loaded mean values of ventilatory functions in group II

Data presented in **Table 3** and illustrated in **Figures 5** and **6** showed that, in group II, the unloaded and loaded mean values $\pm$ SD of FVC were 1.88 ± 0.54 and 1.79 ± 0.50 (liter) respectively. The mean difference was 0.09.

Furthermore, in group II, the unloaded and loaded mean values $\pm$ SD of FEV1 were 1.85 ± 0.35 and 1.77 ± 0.36 (liter) re-

spectively. The mean difference was 0.08.

In addition, in group II, the unloaded and loaded mean values $\pm$ SD of PEF were 254.9 ± 6.73 and 222.83 ± 7.08 (ml/sec) respectively. The mean difference was 32.07. For all variables, the differences between the unloaded and loaded mean values $\pm$ SD were significant ($P<0.05$).

III. Comparison between the difference between the unloaded and loaded mean values of energy expenditure variables in both groups (I and II)

It is evident from **Table 4** and demonstrated in **Figures 7** and **8** that, the difference between the loaded and unloaded mean values $\pm$ SD of FVC in both groups (I and II) were 0.07 ± 0.25 and 0.09 ± 0.10 (liter) respectively. The differences between the loaded and unloaded mean values $\pm$ SD of ventilatory functions in both groups were non-significant ($p>0.05$).

Table 4. The difference between the unloaded and loaded mean values of ventilatory functions variables in both groups (I and II).

Variables	Backpack MD $\pm$ SD	Front pack MD $\pm$ SD	t value	P value	Significance
FVC (liter)	0.07 ± 0.25	0.09 ± 0.10	1.116	.271	NS
FEV1(liter)	0.04 ± 0.19	0.08 ± 0.1	1.12	.148	NS
PEF(ml/sec)	31.69 ± 30.99	32.07 ± 30.99	1.66	.542	NS

SD. standard deviation P: probability *Non-significant as $P>0.05$.
** Significant as $p<0.05$.

Figure 5. Unloaded and loaded mean values of FVC & FEV1 in group II.

Figure 6. Unloaded and loaded mean values of PEF in group II.

Figure 7. The difference between the unloaded and loaded mean values of FVC & FEV1 in both groups.

Table 3. Loaded and unloaded mean values of ventilatory functions in group II.

Variables	NP $\pm$ SD	FP $\pm$ SD	Mean Difference	Change %	t-test	P value	Significance
FVC (liter)	1.88 ± 0.54	1.79 ± 0.50	0.09	4.78	10.557	<.001	S
FEV1(liter)	1.85 ± 0.35	1.77 ± 0.36	0.08	4.32	7.109	<.001	S
PEF(ml/sec)	254.9 ± 6.73	222.83 ± 7.08	32.07	12.58	3.42	<.001	S

SD. standard deviation P: probability *Non-significant as $P>0.05$. ** Significant as $p<0.05$.

Also, the difference between the unloaded and loaded mean values $\pm$ SD of FEV1 in both groups (I and II) were 0.04 ± 0.19 and 0.08 ± 0.1 (liter) respectively.

In addition, the difference between the unloaded and loaded mean values $\pm$ SD of PEF in both groups (I and II) were 31.69 ± 30.99 and 32.07 ± 30.99 (ml/sec) respectively.

Discussion

The effect of both the front pack and the traditional backpack on the ventilatory functions is the issue of the present study. Forty Saudi girls, age ranged from 9-12 years with mean age (10.5 ± 0.9 and 10.5 ± 0.7) years old participated in this study. They were assigned into two groups of equal sizes (group I used front pack, while group II used backpack). Load placement is an important factor in the efficiency of load carriage and should be considered in the design and loading of backpacks [18].

They were required for testing on two separate occasions: no pack (NP), load carriage (10% of BW) either backpack (BP) or front pack (FP). All girls were assessed before and while carrying the pack on spirometer. On basis of literature review, little information was available regarding the effect of front pack on ventilatory functions in children. But most of literature presented the role of posterior load carriage on the physiological and perceptual parameters.

The results of this study showed that the mean values $\pm$ SD of ventilatory function parameters including; FVC, FEV1, PEF were significantly decreased ($p < 0.001$) in both groups.

However comparing the difference between the unloaded and loaded mean values of ventilatory function in both groups (I and II), there was no significant differences between both groups.

These findings can be explained by understanding the mechanics of breathing in which the main power of ventilatory function is pressure differences and thoracic cage movement so any change of this mechanism by carrying backpack load will affect breathing and decrease the pulmonary function. In normal breathing the chest is expanded in three diameters;

vertical diameter by downward movement of the diaphragm, transverse diameter by external intercostals muscles' contractions and antero-posterior diameter by the sternomastoid muscle's action [19].

During carrying backpack, the chest wall kinematics and breathing pattern will be changed in different mechanisms. The first mechanism is the forward leaning of trunk results in kyphotic posture while carrying a backpack, this will affect the respiratory muscles lead to restriction of the downward movement of the diaphragm, as the weight of the backpack increases, the inspiratory and expiratory volumes will be decreased [20].

Increase leaning forward of the trunk may affect the movement of the respiratory muscles of the chest and abdomen. [17] The second mechanism that influences chest wall kinematics during the carrying of backpack is that the side-to-side movement of the rib cage may be restricted by compression of both sides of the backpack on sides of the rib cage and opposition of its movement, which decreases the transverse diameter and limits the antero-posterior diameter of the chest [15]. The third mechanism was discussed, as tight-fitting shoulder/chest straps of the backpack were associated with decreased FVC and FEV1 values as they oppose the expansion of the rib cage [21].

Furthermore backpack load acts as restriction on the chest wall, impeding it to expand and reduce during inhalation and exhalation, respectively. This reduces the volume of inhaled air and exhaled air consecutively, reflecting in the reproducible decrement in FVC when compared with no load condition. A quantifiable increase in inspiratory force due to added load on the muscles associated with breathing leads to their probable fatigue causing decrease in both FEV1 and FVC. Accordingly, the FEV1% also decreases at different duration in comparison with no load. Similar studies have reported that, wearing chest wall-restrictive device cause decrease in inhaled air volume causing a decrease in FVC and FEV1. On the other hand, it was found that with increase in load FVC increases. It is evident that increase in load consequently increases energy expenditure, oxygen consumption and thereby increases the perfusion of air at the lungs. With increase in load FEV1 was observed to decrease, possibly the heavier load compress the thoracic cavity and therefore cause increased resistance to airflow [8].

It is also known that the efficiency of the respiratory muscles is not constant and decreases as ventilation increases. [22]. It is possible that the combination of forward or backward lean and increased activity of the postural muscles in supporting the load may have further compromised the efficiency of the respiratory muscles. This may explain at least part of the increase in $\dot{V}O_2$ in both types of packs.

The extra cost associated with carrying a front load may be attributed to the increased work of breathing due to decreased ventilation and decreased the dorso-ventral movement of sternum and rib cage during respiration as a result of anterior load [23].

Conclusion

Based on the findings of this study, the following conclusion appeared to be warranted:

-It was concluded that both front pack and backpack significantly decreased Forced vital capacity (FVC), forced expiratory volume in one second (FEV1) and peak expiratory flow (PEF).

-Comparing both groups, this decrease was non-significant.

-It can be concluded that the decrease in ventilatory functions when carrying a front pack is higher than when carrying a backpack, so the backpack has the advantage over the front pack in terms of ventilatory functions.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

Authors' contributions	AMY	SEA	SAA
Research concept and design	✓	✓	✓
Collection and/or assembly of data	✓	✓	✓
Data analysis and interpretation	✓	✓	✓
Writing the article	✓	✓	✓
Critical revision of the article	✓	✓	✓
Final approval of article	✓	✓	✓

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