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Effect of Magnitude of Backpack Load and Duration of Carriage on Pulmonary Function Parameters among Urban Young Adults of West Bengal, India: An Ergonomic Study

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Abstract

Background: The college students (18-25 years) compelled to carry backpack load are susceptible to physiological stress. Acceptable load limit is 10-15% of Body Weight (BW) among children and adolescents. Pulmonary function is an important physiological parameter which governs the cumulative stress on the body. The relationship between backpack carriage and pulmonary function parameters has not been explicitly studied among young adults.

Objectives: The study aimed to investigate the changes in Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV1) and Tiffeneau index (FEV1%) with different duration of carriage at the level of 15% and 10% load of BW compared to no load condition.

Methods: Pulmonary function tests were performed using Mini Spir (software Winspiro PRO) at 0-1 min, 10-11 min, 15-16 min of carriage among males (n=13) and females (n=19) with 15% load of BW; females (n=10) with 10% load of BW. Repeated measures ANOVA and paired two tailed student's t test were performed.

Results: Repeated measures ANOVA revealed, there was significant difference in FVC and FEV1 at different durations, when females carried both 15% and 10% load of BW.

While carrying 15% load of BW at 0-1 min,10-11 min,15-16 min, females showed significant difference in FEV1 (p=0.004; p=0.0001; p=0.0001, respectively), FVC (p=0.031; p=0.003; p=0.0002, respectively) and FEV1% (p=0.026; p=0.010; p=0.047, respectively); males showed significant difference in FEV1 at 15-16 min (p=0.044) compared to no load. Females carrying 10% load of BW showed significant difference in FEV1 at 0-1 min (p=0.027) and 15-16 min (p=0.020), FVC in 15-16 min (p=0.024) compared to no load. Obstructive pattern was observed among females (n=10) with increased load.

Conclusion: Males must not carry 15% static load of BW for more than 15 min and females should carry load lower than 10% of BW.

Keywords: Backpack load carriage; Duration of carriage; Pulmonary function parameters

Introduction

Young adults are commonly exposed to heavy bag carriage and annual prevalence of self-reported low back pain in the lumber region has been observed to be related with the magnitude of the backpack load. [1,2]. The Appendicular skeletal growth is complete by the age of 16 years in female and 18 years in male [3], but secondary ossification continues till mid-20s [4]. Load limit of 10% -15% of Body Weight (BW) among children and adolescents for backpack carriage is acceptable according to physiological data [5,6]. Load carriage has been observed to affect physiological parameters like heart rate, blood pressure and energy expenditure among children [7]. Literature survey revealed that significant amount of work has already been done to show relationship between backpack carriage and lung function parameters among children and adolescents but has not been explicitly studied among young adults [8].

Lung function is related with oxygen uptake and hence with the energy expenditure [7] thus lung function is a vital physiological parameter which governs the cumulative stress on the body. Heavy load placed near trunk affects lung function and reduction in lung function is dependent on the percentage of load. Load imposes mechanical constraints on thoracic cage which directly affects the lung function [8]. Hence, the effect of carrying load at the upper and lower level of recommended limit (15% and 10% load of BW) at different duration and its resultant effect on the pulmonary function are important to study in order to make further amendments in the existing recommendation. Forced Vital Capacity is the largest amount of air that can be forcefully expelled from lung after a maximal inspiration. It is frequently measured clinically as an index to determine both the presence and severity of ventilation impairment. It gives useful information about the strength of the respiratory muscles. 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 impediment to expire, if any. FEV1/FVC ratio also known as FEV1% is a standard index for assessing and quantifying limitation of airflow. This study aimed to comprehend the relationship between the pattern of changes in Forced Vital Capacity (FVC), Forced Expiratory

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Volume in one second (FEV1) and Tiffeneau index (FEV1%) with different duration of carriage at the level of 15% and 10% load of BW compared to no load condition.

Materials and Methods

Ethical approval

Consent letters were filled up by the participants before the data was collected and all data collection was done following 'Institutional Ethical Committee (human)' guidelines and with the Helsinki Declaration of 1975, as revised in 2008.

Subject selection

Students in the age group of 18-25 years were chosen, since during this period secondary ossification continues [4]. Urban college-university students of Kolkata, West Bengal, India, free from neuromuscular disorders at the time of testing were taken into consideration for the study. The mean (SD) of age (in years), height (in metre), weight (in kilogram), body mass index (in kg/m^2) for both male and female in different load carriage condition was given in table 1.

All the anthropometric measurements were done following the standard techniques [9]. None had history of chronic low back pain, current or past cardiopulmonary disorders, any orthopaedic problem, recent upper respiratory tract infection or history of recent or past ear, nose or throat surgery that can interfere with their performance.

Study design

According to the recommended load limit, that is 10-15% of BW [3] the upper and lower limit of the range was considered for the experimental protocol. At first 15% load of BW was applied on both males (n=13) and females (n=19) for different durations as mentioned later. The test was also repeated with 10% load of body weight in case of females only (n=10). The test was done on the same subjects in two phases in the decreasing load condition (15%-10% of BW, respectively). Out of nineteen participants with 15% load of BW, only ten could participate and complete the protocol with 10% load of BW. Since in case of male's significant difference in pulmonary function parameters' results were observed only at 15-16 min duration at the level of 15% load of BW so, they were not considered with 10% load of their BW. In case of females, there were significant differences in pulmonary function parameters in all durations so, they were considered with 10% load of their BW. Only those who participated in both the tests were considered for the statistical analysis. Same subjects at different durations were taken into consideration. Hence paired t-test was performed. Repeated measures ANOVA have been done to identify the significant differences between the groups.

The centre of gravity was seen to have altered with difference in the loading pattern and position of load [5], so a particular traditional double strap backpack was used for the entire experiment and the position of the bag was kept fixed in order to standardize the posture.

The bag was placed on the two shoulders in a balanced distribution and lowest end of bag was placed below the lumbar vertebra (L-5) region of the spine and above the buttock. The subjects maintained standing static posture for 16 min.

Measurement of Pulmonary Function

The participants were given initial instruction and familiarization as a group on the techniques required and were also reminded before and during each testing procedure. Pulmonary Function Test was performed following the standard protocol of MiniSpir and software Winspiro PRO at the instant of 0-1 min of loading, 10-11 min of loading and 15-16 min of loading. At each instant three readings were taken at an interval of 30 seconds [8] and the best effort with that of the highest value among the three attempts in each condition was used to compute the mean data for all subjects. The interval between sixteen min of carriage and next loading, a period of rest was offered to the subjects according to their perception of rest requirement. The rest period never exceeded 5 min. Pulmonary function parameters like FVC, FEV1 and FEV1 % (also known as Tiffeneau index i.e., FEV1/FVC X 100) were taken into consideration. The non-invasive method of pulmonary function test is demonstrated below:

- The mouthpiece was supplied into the hollow part of the turbine by at least 0.5 cm.
- The nose clip was fitted onto the nose of the subject to ensure that air cannot escape through the nostrils.
- MiniSpir was held in one hand.
- The mouthpiece was inserted well into the mouth beyond the teeth to ensure that air cannot escape from the sides of the mouth.
- It was suggested to perform the test in a standing position and during an expiration lean forward in order to help the expiratory action with a compression of the abdomen.

All the above mentioned experiments were conducted in laboratory condition.

Online survey

A survey was developed in Google form format and the link of the form was circulated among the university students. There were 141 respondents of the survey. The data collected was automatically documented in a spreadsheet format in the response section.

Statistics

Repeated measures ANOVA was done to identify the significant differences between the groups and paired two tailed student's t test was performed to analyse the difference between the parameters of lung capacities taken at the level of 15% and 10% of BW, at different duration of carriage. The observations were taken on same subjects repeatedly under different conditions. The statistical analysis was done by using Minitab 17 and R.

Results

Online survey revealed that among 141 respondents (51 female, 90 male), 70.9 % preferred carrying backpack on double shoulder on the posterior side. The survey also revealed that 52.2% of the 136 respondents walked daily with load for duration of at least 15 min. Of 138 respondents 71.7 % carried load while travelling in the vehicle they use to reach college (bus, train, metro). Among them, 64.64% carried the load for 15 min or more.

Table 1 shows the values of mean and standard deviation (SD) of age, height, weight, body mass index of participants.

Table 2 shows ANOVA for FVC in females at 15% load of body weight at different durations (0-1 min, 10-11 min, 15-16 min). There was significant difference between the groups at 0.05 level ($p<0.05$).

Table 3 shows ANOVA for FEV1 in females at 15% load of body weight at different durations (0-1 min, 10-11 min, 15-16 min). There

Sl. No	Variable	Females carrying 15% load of BW (n=19)	Females carrying 10% load of BW (n=10)	Males carrying 15% load of BW (n=13)
1	Age (in years)	21.6 (1.74)	22.2 (1.40)	21.6 (1.33)
2	Height (in m)	1.56 (.058)	1.56 (.067)	1.70 (.076)
3	Weight (in Kg)	56.7 (10.25)	58.2 (9.84)	66.4 (11.32
4	Body mass index (Kg/m^2)	23.2 (3.65)	23.8 (2.87)	22.9 (3.12)

Table 1: Values of mean (SD) of age, height, weight and body mass index of participants.

Source	DF	Adj. SS	Adj. MS	F	P-Value
D	3	1.352	.45053	12.60	0.000
ID	18	7.446	.41366	11.57	0.000
Error	54	1.931	.03576		
Total	75	10.729			

Table 2: ANOVA for FVC in females at 15% load of BW at different durations.

Source	DF	Adj. SS	Adj. MS	F	P-Value
D	3	1.206	.40212	8.38	0.000
ID	18	9.198	.51102	10.65	0.000
Error	54	2.592	.0480		
Total	75	12.997			

Table 3: ANOVA for FEV1 in females at 15% load of BW at different durations.

was significant difference between the groups at 0.05 level ($p<0.05$).

Table 4 shows ANOVA for FEV1% in females at 15% load of body weight at different durations (0-1 min, 10-11 min, 15-16 min). There was no significant difference among groups at 0.05 level ($p>0.05$).

Table 5 shows ANOVA for FVC in males at 15% load of body weight at different durations (0-1 min, 10-11 min, 15-16 min). There was no significant difference between the groups at 0.05 level ($p>0.05$).

Table 6 shows ANOVA for FEV1 in males at 15% load of body weight at different durations (0-1 min, 10-11 min, 15-16 min). There was no significant difference between the groups at 0.05 level ($p>0.05$).

Table 7 shows ANOVA for FEV1% in males at 15% load of body weight at different durations (0-1 min, 10-11 min, 15-16 min). There was no significant difference between the groups at 0.05 level ($p>0.05$).

Table 8 shows ANOVA for FVC in females at 10% load of BW at different durations ((0-1 min, 10-11 min, 15-16 min). There was significant difference between the groups at 0.05 level ($p<0.05$).

Table 9 shows ANOVA for FEV1in females at 10% load of BW at different durations ((0-1 min, 10-11 min, 15-16 min). There was significant difference between the groups at 0.05 level ($p<0.05$).

Table 10 shows ANOVA for FEV1% in females at 10% load of BW at different durations ((0-1 min, 10-11 min, 15-16 min). There was no significant difference between the groups at 0.05 level ($p>0.05$).

Figure 1 shows mean (SD) of FVC of females at no load condition and while carrying 15% load of body weight at 0-1 min, 10-11 min, 15-16 min duration. There was significant difference with no load condition and at 0-1 min ($p=0.031$), 10-11 min ($p=0.003$), 15-16 min duration ($p=0.0002$). In all cases FVC were decreased with increase in duration.

Figure 2 shows mean (SD) of FEV1 of females at no load condition and while carrying 15% load body weight at 0-1 min, 10-11 min, 15-16 min duration. There was significant difference in FEV1 in all cases when compared with no load condition ($p=0.004$, $p=0.0001$, $p=0.0001$, respectively) and decrease in all the conditions.

Figure 3 shows mean (SD) of FEV1% of females at no load condition and while carrying 15% load of body weight at 0-1 min, 10-11 min, 15-16 min duration. There was significant difference (decrease) in FEV1% in 0-1 min, 10-11 min, 15-16 min ($p=0.026$; $p=0.010$; $p=0.047$, respectively) when compared with no load condition. However, at 10-11 min and at 15-16 min there was progressive increase in FEV1% from 0-1 min duration.

Figure 4 shows mean (SD) of FEV1 of males at no load condition and while carrying 15% of load of body weight at 0-1 min, 10-11 min, 15-16 min duration. There was significant difference (decrease) in FEV1 only at 15-16 min duration when compared with no load condition ($p=0.044$).

Figure 5 shows mean (SD) of FEV1 of females at no load condition and while carrying 10% load of body weight at 0-1 min, 10-11 min, 15-16 min duration. There was significant difference (decrease) with no load

Source	DF	Adj. SS	Adj. MS	F	P-Value
D	3	457.4	152.47	2.47	0.072
ID	18	3886.7	215.93	3.40	0.000
Error	54	3332.5	61.71		
Total	75	7679.7			

Table 4: ANOVA for FEV1% in females at 15% load of BW at different durations.

Source	DF	Adj. SS	Adj. MS	F	P-Value
D	3	.1025	.03418	.93	0.436
ID	12	7.2777	.60648	16.51	0.000
Error	36	1.3227	.03674		
Total	51	8.7030			

Table 5: ANOVA for FVC in males at 15% load of BW at different durations.

Source	DF	Adj. SS	Adj. MS	F	P-Value
D	3	0.8132	.2711	2.36	0.088
ID	18	11.5137	.9595	8.34	0.000
Error	54	4.1430	.1151		
Total	75	16.4699			

Table 6: ANOVA for FEV1 in males at 15% load of BW at different durations.

Source	DF	Adj. SS	Adj. MS	F	P-Value
D	3	497.4	165.80	2.48	0.077
ID	18	5785.3	482.10	7.21	0.000
Error	54	2408.5	66.90		
Total	75	8691.2			

Table 7: ANOVA for FEV1% in males at 15% load of BW at different durations.

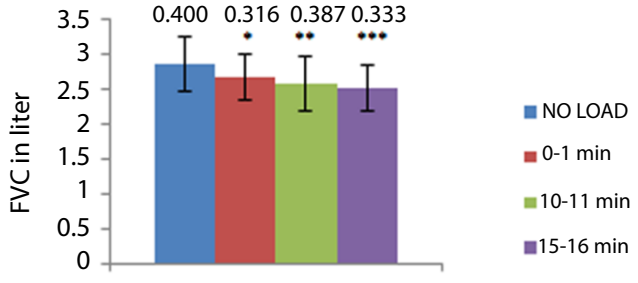

Figure1: Mean (SD) of FVC of females at no load condition and while carrying 15% load of body weight at 0-1 minute, 10-11 min, 15-16 min duration. There was significant difference with no load condition and at 0-1 minute ($p=0.031$), 10-11 min ($p=0.003$), 15-16 min duration ($p=0.0002$). In all cases FVC were decreased with increase in duration.

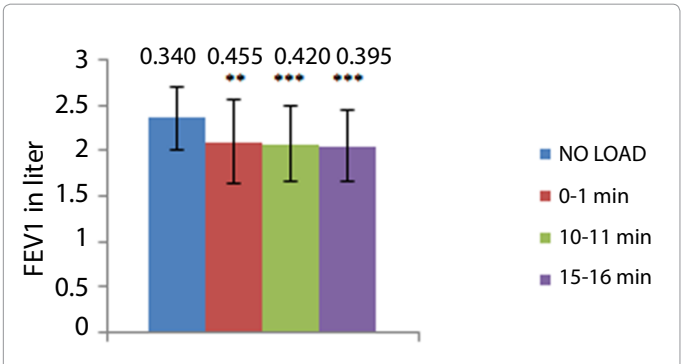

Figure 2: Mean (SD) of FEV1 of females at no load condition and while carrying 15% load body weight at 0-1 minute, 10-11 min, 15-16 min duration. There was significant difference in FEV1 in all cases when compared with no load condition (p=0.004, p=0.0001, p=0.0001 respectively) and decrease in all the conditions.

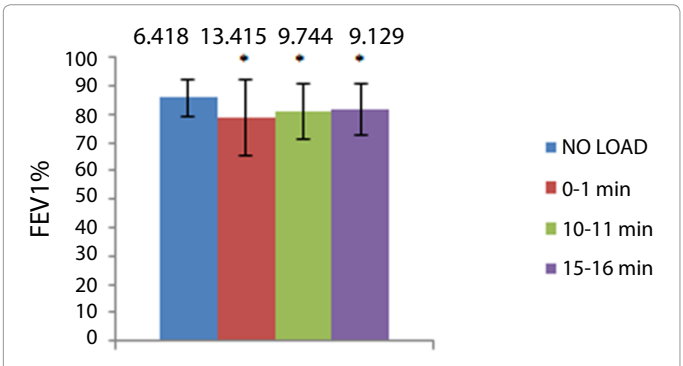

Figure 3: Mean (SD) of FEV1% of females at no load condition and while carrying 15% load of body weight at 0-1 minute, 10-11 min, 15-16 min duration. There was significant difference (decrease) in FEV1% in 0-1 minute, 10-11 min, 15-16 min (p=0.026; p=0.010; p=0.047 respectively) when compared with no load condition. However, at 10-11 min and at 15-16 min there was progressive increase in FEV1% from 0-1 minute duration.

Error: ID	DF	SS	MS	F	P-Value
Residuals	9	2.821	0.3135		
Error: Within					
D	3	0.7668	0.25561	4.904	0.00755
Residual	27	1.4072	0.05212		

Table 8: ANOVA for FVC in females at 10% load of BW at different durations.

Error: ID	DF	SS	MS	F	P-Value
Residuals	9	3.751	0.416778		
Error:Within					
D	3	0.2709	0.0903	3.966325	.0183
Residual	27	0.6147	0.022767		

Table 9: ANOVA for FEV1 in females at 10% load of BW at different durations.

condition and at 0-1 min (p=0.027) and15-16 min duration (p=0.020). However there was no significant difference at 10-11 min duration.

Figure 6 shows mean (SD) of FVC of females at no load condition and while carrying 10% load of body weight at 0-1 min, 10-11 min, 15-16 min duration. There was significant difference (decrease) with no load condition and at 15-16 min duration (p=0.024). However there was no significant difference at 0-1 min and 10-11 min duration.

Figure 7 shows mean (SD) of FEV1 of females at 15% and 10 % load of body weight at different durations (0-1 min, 10-11 min and 15-16 min).

Figure 8 shows mean (SD) of FVC of females at 15% and 10 % load of body weight at different durations (0-1 min, 10-11 min and 15-16 min).

Figure 9 shows mean (SD) of FEV1% of females at 15% and 10 % load of body weight at different durations (0-1 min, 10-11 min and 15-16 min). Increase of load from 10% to 15% results in decrease of FEV1% indicating obstructive pattern of pulmonary function.

The asterisks marked on the graph in figure 1 to 6 represent the significant difference when compared with no load condition.

'*' represents significant difference at 0.05 level. (p<0.05)

'**' represents significant difference at 0.01 level. (p<0.01)

'***' represents significant difference at 0.001 level. (p<0.001)

Repeated measures ANOVA revealed, there was significant difference only in FVC and FEV1 at different durations, when females carried both 15% and 10% load of BW. In case of males no significant

Error: ID	DF	SS	MS	F	P-Value
Residuals	9	1965	218.3333		
Error:Within					
D	3	39.6	13.2	0.89	0.459
Residual	27	400.3	14.82593		

Table 10: ANOVA for FEV1% in females at 10% load of BW at different durations.

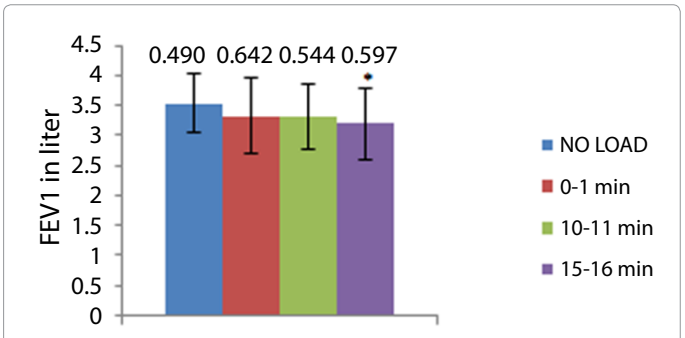

Figure 4: Mean (SD) of FEV1 of males at no load condition and while carrying 15% of load of body weight at 0-1 minute, 10-11 min, 15-16 min duration. There was significant difference (decrease) in FEV1 only at 15-16 min duration when compared with no load condition (p=0.044).

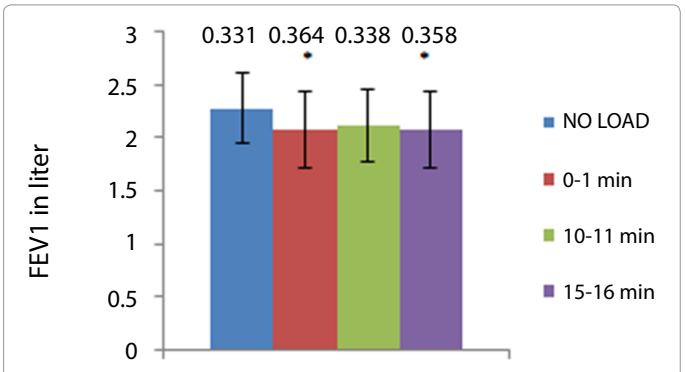

Figure 5: Mean (SD) of FEV1 of females at no load condition and while carrying 10% load of body weight at 0-1 minute, 10-11 min, 15-16 min duration. There was significant difference (decrease) with no load condition and at 0-1 minute (p=0.027) and15-16 min duration (p=0.020). However there was no significant difference at 10-11 min duration.

difference between groups in any parameter was observed. Further paired two tailed t test showed that in case of males, while carrying 15% static load of their body weight for different durations, parameters like FVC and FEV1% showed no significant differences with that of no load condition. So, investigation of the condition with decreased load was not taken into account. However, since females showed significant differences in all parameters while carrying 15% static load of their body weight for different duration, so conditions while carrying 10% static load of their body weight was further investigated. Only FEV1% showed no significant differences with that of no load condition.

It was found that with an increase in load FVC increased and FEV1 decreased. Thus it results in decrease of FEV1%.

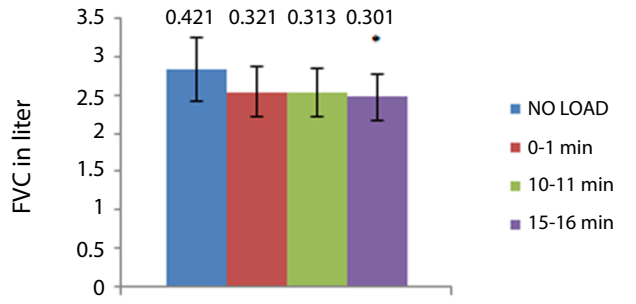

Figure 6: Mean (SD) of FVC of females at no load condition and while carrying 10% load of body weight at 0-1 minute, 10-11 min, 15-16 min duration. There was significant difference (decrease) with no load condition and at 15-16 min duration (p=0.024). However there was no significant difference at 0-1 minute and 10-11 min duration.

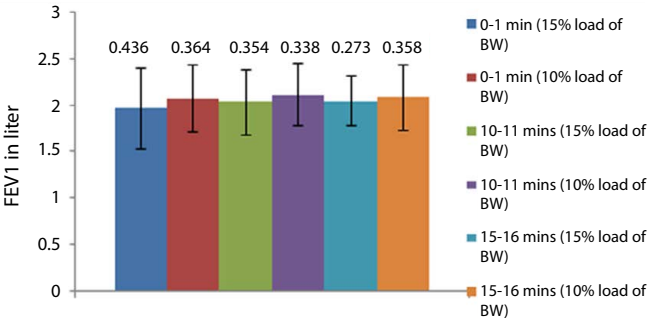

Figure 7: Mean (SD) of FEV1 of females at 15% and 10 % load of body weight at different durations (0-1 minute, 10-11 min and 15-16 min).

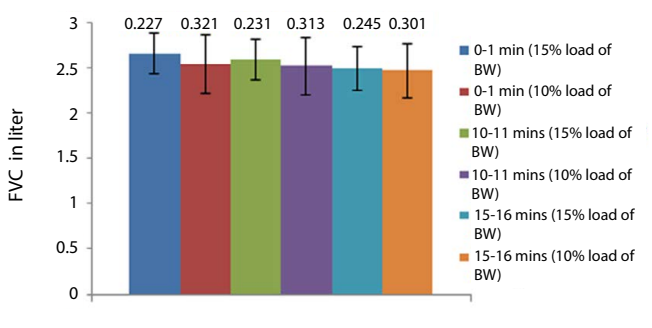

Figure 8: Mean (SD) of FVC of females at 15% and 10 % load of body weight at different durations (0-1 minute, 10-11 min and 15-16 min).

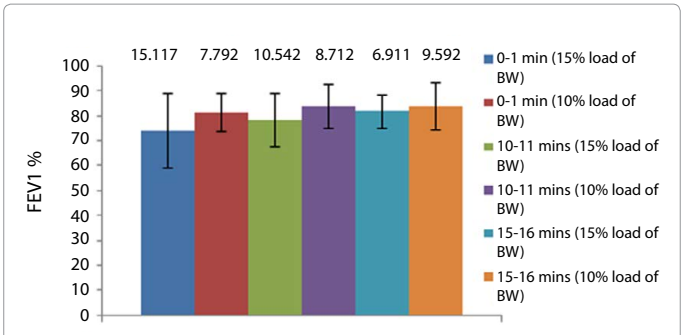

Figure 9: Mean (SD) of FEV1% of females at 15% and 10 % load of body weight at different durations (0-1 minute, 10-11 min and 15-16 min). Increase of load from 10% to 15% results in decrease of FEV1% indicating obstructive pattern of pulmonary function.

Discussion

The study indicates that the degree of pulmonary function decrement incurred by backpack load is dependent on both the magnitude of load and duration of the carriage. It was demonstrated that there was gender variation in pulmonary function, with females being more susceptible to detrimental effects of backpack load. It was found from the online survey that 40.4% of college students carry books, laptops along with other necessary paraphernalia in urban areas which contribute to the weight of the bag. Due to daily journey from home to college they have to walk and also stand for prolonged duration of time which increases the effect. During the process of inhalation and exhalation, expansion and reduction of thoracic volume occurs with assistance from diaphragm and intercostal muscles. Backpack load acts a 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.

Increase of load results in decrease of FEV1% indicating obstructive pattern of pulmonary function. In case of males duration of carriage for with 15 % load of their BW should be less than 15 min. In case of females the magnitude of load to be carried must be less than 10% of their BW. If lung function parameters are taken into consideration in determination of acceptable load limit for carriage among young adults, it should be noted that the load in both case of males and female must not exceed 15% and 10% of BW, respectively so as to ameliorate the cumulative effect of duration of load carriage. It is also revealed through the study that pulmonary function needs deeper elucidation as it can be a potent marker for indicating the optimization of load carriage. Also this study indicates the importance of further investigation of pulmonary function with dynamic load carriage.

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