RESEARCH ARTICLE

Pulmonary ventilation ratios in normal and overweight/obese children carrying variously loaded backpacks

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ABSTRACT

Objectives: Pulmonary response to physical activity (PA) varies with intensity, as does body mass index (BMI). The study records the inspiratory:expiratory ratio [I:E ratio] reflecting oxygenation status and breath counts during the progression of PA, which is undocumented, specifically during schoolbag carriage- the most common PA in children. *Design*: 60 walk sessions (N = 60), 20 minutes each, were recorded in 12 male schoolchildren (10–15 years) (n = 6 normal BMI, n = 6 overweight/obese BMI). They walked at their preferred pace with schoolbags weighing 0, 4, 8, 12, and 16% of body weight on five different occasions. *Methods:* The body weight and height were recorded for participants on obtaining a guardian's consent. Pulmonary response during the walk was recorded using COSMED k4b2, which records data for each breath taken during the 20-minute walk. *Results*: Breath counts increased with load, duration of schoolbag carriage, and BMI. Inspiratory time (Ti) and expiratory time (Te) differed significantly (p <0.01) with load, duration of schoolbag carriage, and BMI. The percentage of breaths deviating from the normal I:E ratio of 1:2 was higher in the case of higher loads and BMI. *Conclusion*: Equal and inverse ratio ventilation increased during the end of PA and maybe the normal physiological response to improve oxygenation in the body. Based on the breathing pattern, 12 and 8% of the bodyweight load for normal and overweight/obese BMI participants is safe, respectively.

Keywords*:* Physical activity, Inspiratory time, Expiratory time, Breath counts, BMI, Schoolchildren.

Indian Journal of Physiology and Allied Sciences (2025); DOI: 10.55184/ijpas.v77i02.301 **ISSN:** 0367-8350 (Print)

INTRODUCTION

Amongst different forms of load carriage, backpack carriage is one of the most common forms of physical activity globally.[1] Millions of people carry backpacks daily, starting from elementary school children. India's highly demanding education curriculum makes the backpacks very heavy and their carriage mandatory. Although someone leads a sedentary lifestyle, schoolbag carriage is a common physical activity among all schoolchildren.

The physiological response to carrying heavy backpacks manifests derogatory musculoskeletal symptoms indicating harmful consequences.[2] The physical activity of schoolbag carriage has also been evaluated in terms of muscle activation, fatigue, cardio-pulmonary response, and energetics.[3-5] The physical activity of schoolbag carriage increases in intensity as the load of schoolbag carried increases.[6] As the duration of physical activity increases, the demand for oxygen increases, and to compensate for it, the respiratory response is also enhanced.[7] It is very important to note the changes in pulmonary response as the duration of schoolbag carriage increases.

One of the main indices in pulmonary response is the frequency of respiration or breath counts. Breath count is strongly associated with perceived exertion during exercise, making it a strong marker of physical effort.[8] While the literature survey revealed increased breathing frequency during intermittent trekking, compared to continuous trekking in adults carrying a 7 kg rucksack,[9] the breath count report during the physical activity of schoolbag carriage in children was undocumented. Another important aspect of the pulmonary response that is seldom documented while investigating physical activity is the ratio of inspiratory time (Ti) to the expiratory time (Te) [I:E ratio]. The normal I:E ratio is 1:2,[10] and increasing the inspiratory time compared to the expiratory time in a respiratory cycle can improve oxygenation.[11] It is, therefore, important to understand the changes in Ti:Te during the progression of schoolbag carriage as it can give us important insights into the oxygenation status of the body.

Any physical activity is more demanding to an individual with an increased BMI. The physical activity of schoolbag carriage is reportedly different among individuals belonging to different BMI categories.[12] There is a paucity of literature on the comparative evaluation of pulmonary response regarding breath counts and I:E ratio in normal and overweight/obese BMI individuals during schoolbag carriage. This pilot study deals with the observation and documentation of pulmonary response with physical activity progression.

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How to cite this article: Mukherjee R, Sahu S, Sen D, Mukhopadhyay A. Pulmonary ventilation ratios in normal and overweight/obese children carrying variously loaded backpacks. *Indian J Physiol Allied Sci* 2025;77(2):21-26.

Conflict of interest: None

Submitted: 18/07/2024 **Accepted:** 20/12/2024 **Published:** 20/06/2025

MATERIAL AND METHODS

Healthy male schoolchildren in the growing age group of 10 to 15 years, residing in Kolkata, West Bengal, were approached for participation in the study. Partaking in the study was subject to receiving a signed consent form from guardians. The age of 10 to 15 years is marked by expeditious growth and development.[13] Moreover, any musculoskeletal pain perceived in these formative years might also be carried on to adulthood,[14] making this age group critical for investigative studies. Height and weight were measured for each participant using Martin's anthropometric rod (Seiber & Heigner, Switzerland) and weighing machine (Libra, India), respectively. Their BMI was calculated, and the participants were divided into two categories based on BMI. The participants were categorized under normal BMI, overweight, or obese BMI based on cutoffs documented in the manual of the National Institute of Nutrition (Indian Council of Medical Research (ICMR).[15] Six participants with normal BMI and six overweight/obese individuals were engaged in the study. Each participant was asked to walk on a flat surface at their preferred pace while carrying no load (0%) or carrying a load (4, 8, 12, and 16% of body weight). Therefore, a total of 60 walks (N = 60) were considered in the study. The bag weights were measured before each walk on a weighing machine and adjusted to the percentage of body weight before each walk. As each subject had to walk five times, each walk was conducted on a different day so that the results from one walk did not interfere with the recordings from another walk. The same ergonomically designed backpack was given to the participants each day at their mid-back region. The environmental temperature was checked each day, and walks were conducted only if the temperature was less than or equal to 25°C. During each walk, the pulmonary parameters like breath count, time of inspiration, and expiration for each breath were recorded by COSMED k4b2. The study was approved by the Institutional Ethical Committee (Human).

Exclusion Criteria

Since the study investigated physical activity, athletes were not considered in the study. Children with any congenital disease or under any form of medication were excluded. Finally, given that prior findings indicate sex-based differences in pulmonary response among males and females,[16] this pilot study did not consider the female population.

Statistical Analysis

The normal inspiration to expiration ratio is 1:2. Each breath was coded as normal or abnormal based on whether the ratio (rounded up) exceeded 2. Given that the participants had different breath counts through the course of 20 minutes' walk, for each of the 60 walks considered in the study, the entire time period was grouped into 30-sec intervals, and the normal and abnormal breaths for each 30 sec were counted and changed into a percentage for further analysis. Independent samples t-test and ANOVA were done to find significant differences between the means.

RESULTS

The pulmonary response of the participants during each 20-minute walk session was analyzed. Average walk duration in overweight/obese BMI category participants was seen to decrease progressively with an increase in the load of the schoolbag (Figure 1). The lowest walk duration was recorded during the carriage of schoolbags weighing 16% of body weight. The participants belonging to the normal BMI category completed all the walks. In the overweight/obese BMI category, while all participants completed walks with 0% load, only half of the participants completed walks with 4 and 8% load of body weight. In the case of higher loads, only 2 participants completed walks with a 12% load, and none of the participants completed walks with a 16% load of body weight.

Since the k4b2 assessment recorded a breath-by-breath analysis, each breath taken by a participant was analyzed to assess the breathing pattern during physical activity. The average total number of breaths for participants in each BMI category was correlated with time. It was observed that, with an increase in the load of the schoolbag, the breath counts got higher with time.

In the normal BMI category, a significant negative correlation was found when carrying no load (Figure 2). During load carriage, this inverse relationship was observed to change. For 4 and 8% load carriage, no correlation between time and breath counts was observed. Still, for 12 and 16% load carriage, the number of breaths taken by the participants increased as they gradually reached towards completion of a 20-minute walk session. The statistical power of these correlations amounted to 0.89 and 0.98 for 12 and 16% carriage, respectively.

Conversely, for the above-normal BMI category participants, an inverse relationship was not obtained even while walking without a schoolbag (Figure 2). The inverse relationship obtained in this case, during 16% load carriage, was not found to be significant. A stronger positive association was obtained

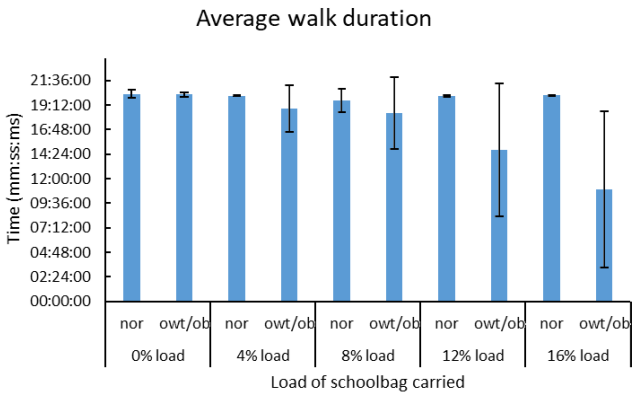

Figure 1: Average walk duration in participants belonging to different BMI categories. Nor = normal BMI, owt/ob = overweight or obese BMI children.

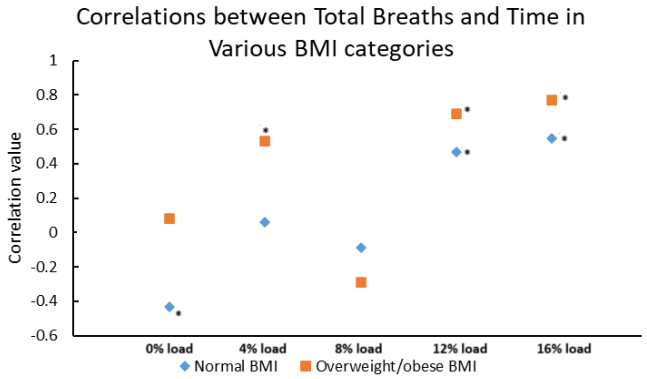

Figure 2: Correlation between total breaths and time in various BMI Categories (NOTE: the significant correlations [p <0.05] have been labeled with * mark)

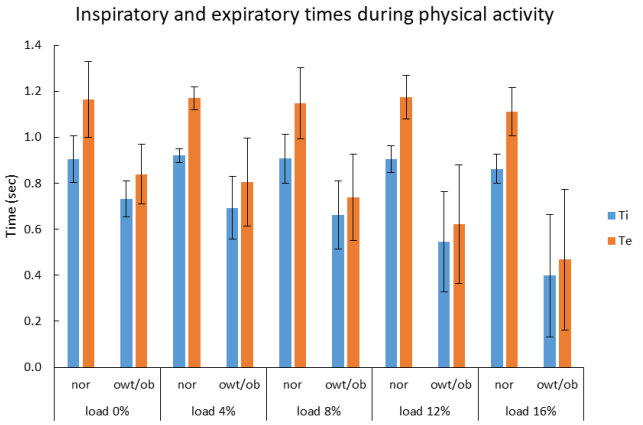

Figure 3: Inspiratory and expiratory times during physical activity (Ti = time of inspiration, Te = time of expiration, Nor = normal BMI, owt/ob = overweight or obese BMI children)

between breath counts and progression time during 12 and 16% load carriage, as indicated by a statistical power of 1.00 for incidences.

After analyzing the breath counts and their change over time, the inspiratory and expiratory time taken for each breath was analyzed. The expiratory time is normally twice or thrice as long as the inspiratory time. The average inspiratory time (Ti) among normal BMI participants was not observed to vary much with an increase in the intensity of physical activity, but the average Ti decreased progressively with an increase in the intensity of physical activity for the overweight/obese BMI category (Figure 3). The same pattern was observed for expiratory time (Te). Thus, these observations bolstered the previous observation of increased breath counts during high-intensity physical activity. Also, it was evident that the difference between Ti and Te is greater in the case of participants with normal BMI compared to participants who were overweight/obese.

When all the walks were considered together, ANOVA results showed that inspiratory time (Ti) varied significantly between the two BMI categories (df = 1, 408; F = 332.3; p <0.01), not considering the load of the schoolbag carried. Ti also varied significantly with the load of the schoolbag (df = 4, 405; F = 11.2; p <0.01). Ti was also found to vary significantly when the difference in the load carried is considered along with the difference in BMI (df = 9, 400; F = 68.1; p <0.01). Similar, ANOVA results were obtained for expiratory time (Te) as well when all the walks were considered together. It varied significantly with BMI (df = 1, 408; F = 21.6; p <0.01), with load (df = 4, 405; F = 6.7; p <0.01) and when load-BMI considered together (df = 9, 400; F = 87.9; p <0.01).

The total number of abnormal breaths recorded based on inspiratory and expiratory times in the overweight/obese BMI category was significantly higher than that recorded among normal BMI participants (p <0.01, independent samples t-test). When the average percentage of abnormal breaths was plotted against time for each incidence of load carriage, more abnormal breaths were found for higher load carriage in both normal BMI participants and above-normal BMI participants (Figure 4). The slopes of the best-fitting lines increased with an increase in the intensity of physical activity, indicating a higher percentage of abnormal breaths during greater loads carriage.

The average percentages of abnormal breath in various BMI categories during different loads of schoolbags carried have been tabulated in Table 1 for further clarity.

It can be inferred from Figure 3 that the duration of each breath decreases with an increase in the load of the schoolbag carried. In the case of normal BMI, the no-load condition shows a low number of breaths with an increase in walk duration (Figure 2) but a long duration of Ti and Te (Figure 3), thus indicating slow, deep breaths towards the end of the 20-minute walk. However, with the increase in load in the normal BMI category and overweight/obese BMI (Figure 2), breath count increased towards the end of physical activity. Additionally, the duration of breaths decreased (Figure 3), thus indicating multiple short breaths towards the end of the walk or breathlessness. Figure 4 sheds light on the physiology of these rapid short breaths, observing them have deviated from the normal I:E ratio of 1:2. Therefore, higher loads of schoolbags carried result in rapid short breaths, which are physiologically equal or inverse ratio ventilation.

Table 1: Average percentage of abnormal breaths in various participants

Description	*0% load*	*4% load*	*8% load*	*12% load*	*16% load*	*Average*
Normal BMI	76.2	83.6	82.3	79.9	82.6	80.9
Overweight/obese BMI	93.0	92.4	89.3	92.8	94.8	92.4
Average	84.6	88.0	85.8	86.4	88.7	86.7

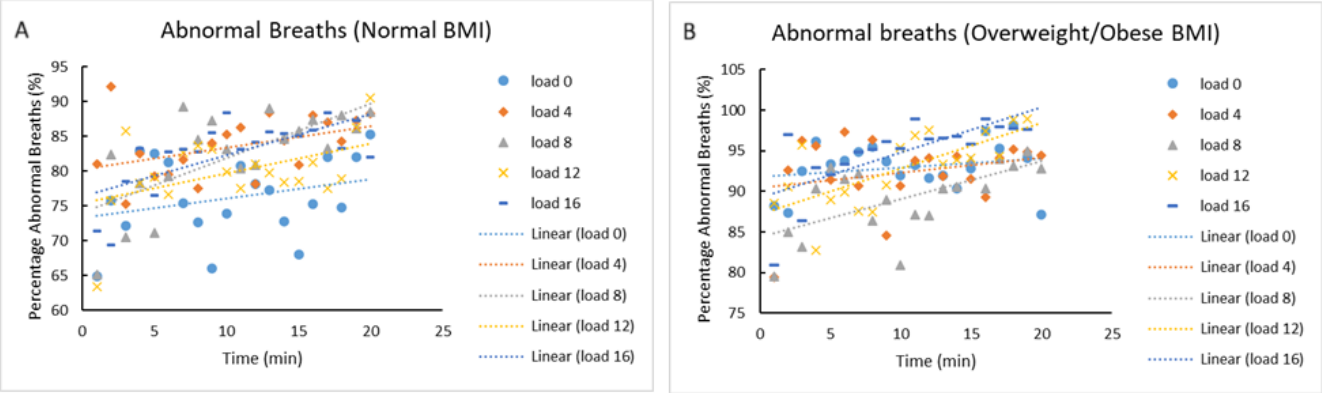

Figure 4: Percentage of abnormal breaths in participants- A. Normal BMI category, B. Overweight/obese BMI category (NOTE: The slopes during different load carriage in- A. normal BMI participants- 0%: 0.2779, 4%: 0.3092, 8%: 0.7823, 12%: 0.4234, 16%: 0.5909; B. overweight/obese BMI participants- 0%: 0.1121, 4%: 0.1851, 8%: 0.4655, 12%: 0.5651, 16%:0.5552)

The load pertaining to 8% of body weight did not adhere to the pattern, which may be due to the limited sample size.

An attempt was made to delineate the safe load limits based on the breathing pattern during the physical activity of the schoolbag carriage. The loads were considered in a descending order, while the slopes were considered in an ascending order. For the normal BMI category, the load of 12% is the highest load with the lowest slope (Figure 4) and is therefore considered safe. For the participants belonging to the overweight/obese BMI category, 8% load is the highest load, with the lowest slope recorded. It is, therefore, considered to be the safe load limit based on the breathing pattern of pulmonary response during schoolbag carriage.

DISCUSSION

The study highlights changes in breath counts, inspiratory time and expiratory time of each breath during the progression of a 20-minute physical activity session of differing intensities. A survey on trekkers carrying rucksacks found increased respiratory frequency during intermittent trekking.[9] It has previously been reported that carrying heavy backpacks adversely affects the pulmonary parameters in schoolchildren.[17,18] This study corroborates these findings.

Extensive studies on obesity and physical activity highlight that breathing frequency increases during exercise in overweight/obese individuals with strong evidence.[19] This study found similar results when the physical activity of schoolbag carriage was examined. The respiratory frequency, that is, the breath counts, was higher in overweight/obese individuals compared to normal BMI individuals at the beginning and at the end of the 20-minute schoolbag carriage.

A study reported normative breathing patterns in sedentary males and females, stating that Ti and Te were reduced during incremental physical activity.[20] This study found that in the case of non-athlete children, the Ti and Te decreased proportionally with the increase in schoolbag load carried only for overweight/obese children. Such changes were relatively not as pronounced in normal BMI participants, and deviation from the I:E ratio was higher in the case of overweight/obese BMI. Childhood obesity is associated with ventilation and airflow imbalance[21] and might be the cause behind the observations. Breaths with longer inspiratory time characterized as abnormal breaths in this study were observed more frequently for overweight/obese participants compared to their normal BMI counterparts.

Similar inspiratory and expiratory times or equal ratio ventilation reportedly increases oxygenation.[22] Inverse ratio ventilation (longer inspiratory time compared to expiratory time) or equal ratio ventilation has been reported to improve oxygenation status and treat respiratory distress.[23] Carrying heavier backpacks requires more oxygen[24] and inverse ratio ventilation may be the natural response to improve the oxygen status of the body. It has been previously reported that during physical activity, the oxygen deficit is significantly higher in overweight individuals compared to normal BMI individuals.[25] This may be the reason behind observing higher abnormal breaths for overweight/obese individuals compared to the normal BMI category. However, it is also notable from Figure 4 that although overweight/obese BMI have higher percentages of abnormal breath, the slopes of the best-fitting lines were greater in the normal BMI category. This indicates a higher rate of increase in abnormal breaths, i.e., children with normal BMI have a greater capacity to meet the oxygen demands of their body through a change in the I:E ratio.

Physical activity stimulates the sympathetic nervous system, and the faster respiratory rate is known to be associated with higher levels of sympathetic traffic in the body, in addition to potentiated responses to hypoxia.[26] Moreover, obesity contributes to increased sympathetic nerve activity.[27] These may be the reason behind the differences in the observed changes among the participants belonging to different BMI categories.

Studies on pulmonary response throughout the duration of physical activity are rare, and no such reports were observed for schoolbag carriage after a thorough literature search. This is the first outline of changes in respiratory parameters as the physical activity of load carriage progresses. This is also the pioneer report on incidences of equal and inverse ratio ventilation as a normal response to physical activity, which might fulfill the body's oxygen demands. This pilot study may be extrapolated to the female population. The results of this study could be useful for researchers investigating various modes of load carriage and manual material handling, such as brick carriers, soldiers, rescue workers, and more. The study also has major implications in devising athlete training sessions.

The study recorded each breath taken during a 20-minute span of physical activity in children, revealing (a) a higher number of equal, inverse ratio breaths observed during higher intensity physical activity corresponding to heavier schoolbag carriage, (b) abnormal breaths increased towards the end of 20-minute physical activity, (c) abnormal breaths were higher in overweight/obese individuals, (d) equal or inverse ratio breath reflects physiological endeavor to improve oxygenation status in the body. Training focuses on increasing oxygenation capacity, which should encompass low occurrence of equal, inverse ratio breaths. This pilot study can, therefore, be used as a base for formulating training.

While the sample size in this pilot study is small, which is a limitation of the study, each of the 12 participants walked on five different occasions, bringing the total instances of physical activity to N = 60 (30 instances of physical activity or walks in the two different BMI categories). This constitutes an elaborate study design with 60 various cases of physical activity. The speed at which the participants walked was not kept constant and might have contributed to the variations in the intensity of physical activity. However, the study design endeavored to mimic the real-life conditions of daily conveyance to and from schools while carrying backpacks where there can be no uniformity in the adopted pace. The study did not include female children and may be extrapolated in the female population in the future.

CONCLUSION

Increased respiratory breaths accompanied by either comparable expiratory and inspiratory time or inspiratory time longer than expiratory time (inverse ratio ventilation or equal ratio ventilation, respectively) may be the normal physiological response to increased oxygen demand in the body. The incidences of inverse or equal ratio ventilation increase as the duration of physical activity of schoolbag carriage increases. This pulmonary response is more enhanced in overweight/obese individuals. Based on the breathing pattern, 12 and 8% of the bodyweight load for normal and overweight/obese BMI participants is safe, respectively. Based on the breathing pattern, schoolbags weighing 12% and 8% of bodyweight for normal and overweight/obese BMI participants respectively, is safe.

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PEER-REVIEWED CERTIFICATION

During the review of this manuscript, a double-blind peer-review policy has been followed. The author(s) of this manuscript received review comments from a minimum of two peer-reviewers. Author(s) submitted revised manuscript as per the comments of the assigned reviewers. On the basis of revision(s) done by the author(s) and compliance to the Reviewers' comments on the manuscript, Editor(s) has approved the revised manuscript for final publication.