

# Effects of Backpack's Weight on School Children – a Review

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**Abstract-** A review of literature was conducted to search what are the past studies approach and observation related to the effects of school backpack carrying on primary school children below 12 years old and solutions in reducing the effects. Engineering Village, Science Direct and Google Scholars were searched with the following keywords: backpack, back pain, load, children, adolescent and physical fitness for related articles. Sixteen articles were reviewed to see the findings of past researchers. From the review we came to the conclusion that there are several factors which contributed to the risk of back pain and the effects can be observed through their gait postures response [3, 8, 9] physiological and psychological, [4, 7,10, 11, 16] and the ground reaction force during walking [12, 14]

In summary, the change in postures include trunk leaning forward developing a experience of back pain, he time carrying pack may strongly contribute to back pain. Load should not exceed 15% of body weight. When carrying load of 15% of body weight, the children adopted a trunk inclination. This case is worsened when the load increase to 20% of body weight. This is because a significant effect was observed at load of 20% of body weight, where the GRF and trunk inclination increased almost three times.

**Keywords-** children, posture, backpack, gait, back pain

## I. INTRODUCTION

In recent years, school health has been the object of attention in the community, especially with regards to the effects of backpack's weight. There are many reasons why children have to load up their backpacks; no storage facilities provided to keep their books at school, several textbooks per subject and increased level of homework and other necessities such as water bottles and physical education gear. A review of literature was conducted to search what the past researchers approaches and observation related to the effects of backpack's weight on primary school children. Schoolchildren within the age group of below 12 years old are observed carrying the highest load to school up to 20% of their body weight.

Even though periodic timetable and serial textbook have been introduced in educational system to reduce the weight of the backpack, it seems insignificant as some subjects required four to five exercise books, not including the textbook. At one time, the bag could weight up to 10 kilograms, which is about 50% of students' body weight. The

bags could weight up to 10 kg each which is about 50% of student body weight.

The rolling backpacks have been recommended by United Kingdom health professionals, but lead to other challenges, such as difficult manipulation on stairs, storage within school and passage through crowded hallways and buses (Furjuoh et al. 2003). Furthermore, an empty roller bag can weight up to 80% more than an empty backpack. Ergonomics awareness in school environment have not being implemented seriously in Malaysia, and as the result most of the children poses greater risk to ergonomics hazard due to the heavy lifting of school bag and incorrect sitting posture in classrooms. This can lead to development of MP at any body part in the future. In promoting safety and health among school children pertaining to ergonomic issues, the teachers play major role enhancing healthy behaviors. Intention to adopt healthy behaviors, like any other type of behaviors, is motivated or 'trigger' by stimuli in an individual's environment (Egger et al. 2004).

In an attempt to determine a safe weight limit for school children backpack, several studies have examined the effects on increasing backpack loads on physiological parameters, which are measured in Ground Reaction Force when walking carrying backpack [12] Some researchers observe the pattern of posture inclination when different load carried.(Grimmer et. Al.)

In the aspect of psychological, questionnaires have be distributed to gain the students' response regarding the backpack. The questionnaire was carried out to sough information on type of backpack used, any presence of low back pain and the time spent carrying the backpack to and from school everyday [13]. Bauer and colleagues and have done experiments to find out the effects on the heart rate and

In other countries, many researches about load carriage among students had been done. The majority of biomechanical studies with children's backpacks have examined the effect of different loads on a few main parameters: trunk inclination, cranio-vertebral angle, respiratory and gait. The studies suggested that the suitable load carry by the students is 10-15% from their body weight. When load is carried more than that, a student probably will have changes in his or her physical such as bad posture and shoulder depression.

Other studies of children posture and contour of the spine have shown a clear association between backpack load

and postural response. Children, assume a compensatory forward head posture under backpack loads greater than 10% - 15% of their body weight. In addition to musculoskeletal and postural problems, heavy loads on the spine also affect lung mechanics and volume [10]. There is a widely held belief that repeated carrying of heavy loads, such as school backpacks, places additional stress on rapidly growing adolescent spinal structures, making them prone to postural change.

A significant change in craniovertebral angle was found at every year level, when comparing standing posture with no backpack with posture when carrying a backpack. The change was greatest for the youngest students. Incremental change in craniovertebral angle was not strongly associated with backpack loads. The association became stronger for the oldest girls when controlled for body mass index and for weight. The results support a differential postural response per gender and per level of spinal development but also suggest that the craniovertebral angle may not be the most sensitive measure of head-on-neck postural change for adolescents. (Grimmer et al.)

## II. REVIEW OF LITERATURE

### Postural effect

Changes of trunk posture in children carrying loads have been reported in several studies. Malhotra and Sen Gupta (1965) have compared the trunk forward bend using visual observation for children carrying about 10% of their body mass and they found out this level of load did not produce appreciable trunk forward bend. Pascoe et. al. examined the impact of different methods of carrying book bags (without bag, one strap backpack, two strap backpacks, and one strap athletic bag) weighing 17% of the subjects' body mass on static posture and the gait kinematics. The athletic bag promoted greater angular motion of the head and trunk when compared with other carrying methods. The carrying of the backpack promoted significant forward lean of head and trunk compared to the athletic backpack or without a bag.

Recently, Grimmer et al. (1999) investigated the effects of backpack weight on adolescent head-on-neck posture through the response of craniovertebral angle to backpack load. They measured the posture of 985 students, aged 12s-18 year, with and without a school backpack, using photographs of the erect standing body.. The results showed that there was a significant change in the craniovertebral angle in response to a backpack for each of the five groups. This response was inversely related to age of students, suggesting that as the spine matures, a less obvious head-on-neck response to load is invoked. Study of normal adult gait showed that trunk inclination angle was 1 (0.5 - 1.5) during walking (Winter 1995). Based on a study in adult females, Watson and Trott (1993) suggested a trunk inclination of 5.0 or more as being a significant indicator of the likelihood of spinal stress in adults in at rest status without load carrying experiences. The present study found that walking with a load of 20% body

mass resulted in a trunk forward lean of 5.63\_ in the 1st min of walking and 6.85\_ in the 20th min, which are larger than the angle that is evident in normal gait (Winter 1995) and has been thought to indicate spinal stress in adults (Watson and Trott 1993). A similar critical degree of trunk forward lean (4.18\_) was also found in the 15% load condition. But whether the significantly increased trunk inclination angles which occurred in the 20% and 15% load conditions might influence the spinal development of school children whose skeleton is not yet mature is still unclear.

There are also a few studies on the response of the range of motion of the trunk to carry loads in children. Pascoe and colleagues again found out that carrying backpack with one strap promoted greater angular motion of the head and trunk as compared to carrying backpack with both straps. The anterior-posterior swing of the trunk at higher carrying loads would cause the abdominal, back and muscle to work harder to maintain the dynamic balance. To avoid harmful muscle strain the children need to make a greater effort to keep the body more stable in the anterior-posterior direction. This is concluded when trunk motion range was found decreased from 7.88° when carrying 15% of body mass to 7.90° when carrying 20% of body mass. The decreased trunk motion range indicates that walking with a heavy load made the abdominal, back and leg muscle become stiffer through greater contraction [10]. Symptoms of back pain will then occur and were most prevalent in the neck, shoulders, upper back and lower back.

### Respiratory parameters

Jing Xian Li and colleagues studied respiratory muscle activity during walking with different loads through examining the volume changes in thoracic and abdominal muscles. The result showed that thoracic respiration increased during walking with load carriage. For healthy children, the findings of their study suggested that the respiratory turnovers in children mainly rely on changes in thoracic respiration when metabolic rate increases due to load carrying.

With the increase of the backpack's weight, breath frequency increased linearly. A significantly increases ventilation observed when carrying 15% to 20% of body weight. However, walking with 10% body mass for 20 minute did not significantly change the respiratory parameters. This suggests that load up to 10% of body mass might be a safe load for schoolchildren. [10]

### Ground Reaction Force During Walking Carrying Load

While research by Le Ren and colleagues found out that backpack weight and strap stiffness has little effect on the reaction force during walking for adult [17], Shasmin and colleagues in their research has observed significant effects of trunk inclination and Ground Reaction Force when backpack load increased for their subjects. When carrying load of 15% of body weight, the children adopted a compensary trunk inclination. This case is worsened when the load increase to

20% of body weight. This is because a significant effect in Ground Reaction Forces (GRF) and trunk inclination at load of 20% of body weight, where the GRF increased almost three times. The heavier the backpack, the greater force exerted when stepping. Figure 1 shows mean changes in trunk forward lean angle when the load of school bag increased.

For the anterior-posterior GRF, some of their subjects showed decrement in force at 15% load conditions but their force increased again at the 20% load condition. Fig. 1 represents an example for some anterior-posterior GRF. Carrying backpack of 20% body weight resulted in significant increase in medial-lateral force for four boys. Significant differences ( $P < 0.05$ ) were found only on one or two boys for other load conditions. This result almost similar to the vertical and anterior-posterior GRF statistical analysis.

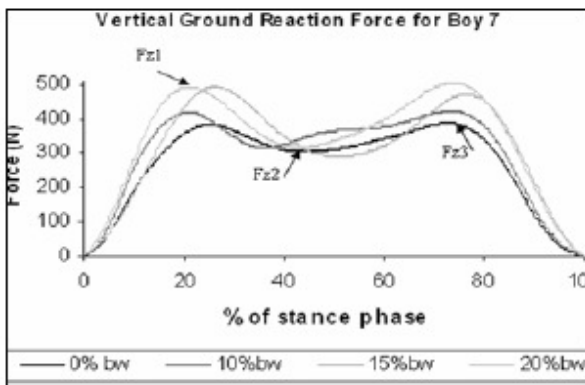


Fig 1: an example of Anterior-Posterior Ground Reaction Force from a subject. The force is increased when load increases. Fx1 is breaking force and Fx2 is propulsion force [13]

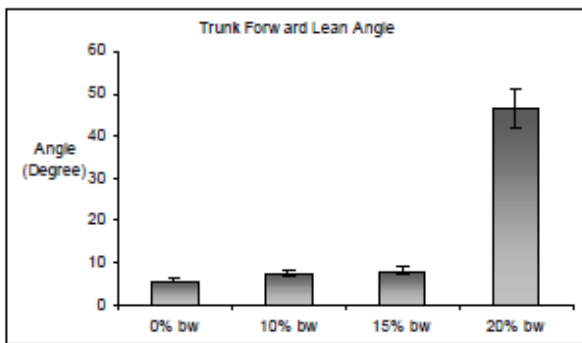


Fig 2: Mean forward lean angle of male students. Significant difference occurred at 20% load condition.

Lindstrom-Hazel D. in her literature review found out that girls are more likely to experience back pain compared to boys, the time carrying a pack may be strong contribution factor to the pain and that psychosomatic behaviors may contribute to back pain. Students who are comfortable carrying backpack experience less back pain. This may

influenced by using backpack that suits them, bearable weight and physical fitness. Several studies have supported the idea of carrying backpack with both straps to evenly distribute the load. Table 1 summarize her findings in the literature review.

Table 1: Are school children actually at risk for back pain because of carrying backpack?

Authors/ Study Location	Conclusion
Moore, White & Moore  USA	No-pain reporters 9.9% relative backpack weight supports 10% cutoff weight for backpacks.
Al-Hazzaa, H.M. Saudia Arabia	Recommend limiting backpack weight to no more 5–10% of child's body mass
Chiang, Jacobs & Orsmond USA	Relationship between low back pain and time spent carrying backpack may suggest that spinal tissue loading (resultant pain) occurs after a certain critical period of backpack carrying time.
Skaggs, Early, D-Ambra, Tolo & Kay USA	Girls more likely to report back pain than boys Younger children report more back pain than older children Greater backpack weight predictor of back pain Unable to make recommendation for weight limitation in backpack
Watson, Papageorgio, Jones, Taylor, Symmons, Silman & Macfarlane UK	Suggest co-morbidity with low back pain and frequently occurring common childhood complaints – Psychosomatic rather than mechanical factors important for low back pain – Low back pain may be a marker of childhood somaticism.  No relationship: 1. load & LBP Relationship found with LBP 1. conduct problems 2. emotional problems 3. headaches

III. PREVENTION

Wear both straps

Wearing a backpack on one shoulder can cause a person to lean on one side in order to handle the uneven weight. Over time, this can cause excessive stress on upper and lower back, neck, shoulders and even functional scoliosis. Hauling a heavy backpack over one shoulder everyday also may cause serious postural misalignments.

Proper weight

Schoolchildren in age group between seven to nine years old are observed to carrying the heaviest load to school. Even when worn properly with both straps, leaning forward to compensate for the weight can affect the natural curve of the spine. A good rule to follow is to keep the weight 10 to 15 percent (or less) of the child’s body weight to maintain normal posture. Reducing the weight also helps to maintain good gait and walking posture.[16]

Backpack style or type

It is suggested to choose a backpack which has broad straps and a waistband to transfer some of the load from the spine to the pelvis. Narrow straps can be painful on the shoulder and put pressure on nerve and blood vessels. Backpacks with only one strap are not recommended for children in this group age. Another factor to be considered when choosing a backpack is the weight of bag without load. Choosing light material for the backpack is essential, as it helps to lessen the burden. Another solution is personalizing the fit to suit the child’s comfort. The backpack also should be sturdy and appropriately sized for their age. An ill fitting pack can cause backpain, muscle strain or nerve impingement. If possible choose bags with defined spine contour design on the back to lessen the muscle stiffness.

Educational approach

It is important to expose the children to the risk of poorly wearing a backpack. The preliminary educational approach should be guiding them to properly wear the backpack. Before wearing the straps, the knees must bend to prevent the tension focusing on the spine. Lifting should be with the legs, not jerking with their back. Grimmer and colleagues suggested that their study findings should provide the impetus for parents and teachers to insist on constraints that limit load carrying for schoolchildren.

The American Chiropractic Association has developed a guideline for recommended limits based on the child’s weight which, at the mean time should be a useful guideline for the authorities to aid in designing new curriculums. Table 2 shows the weight limit according to child’s body weight

Table 2: Recommended Load Limit

Child’s Weight (lb.)	Maximum Backpack’s Weight (lb.)
60	5
60-75	10
100	15
125	18
150	20
200 or more	25*
* no one should carry more than 25 lb.	

Although heavy backpacks are not clearly established as a cause of back pain in children, the evidences on recent researches suggest that reducing the load to 10% of body weight maintain normal posture and lung function in children. Ways to reduce the risks of back pain proper sized backpack that is snug to the middle of the back and has padded, broad straps and a waistband to transfer some of the load from the spine to the pelvis and reduce the carrying duration.

Authoritative action

Other factors, such as ensuing revised timetable that reduce the number of subjects per day may also help to reduce the backpack load.

IV. CONCLUSION

From this literature review, it can be concluded that there are many issues that surround the use of backpacks including the child’s physical and psychological well being as well as knowledge on how to safely carry a backpack. Until now there are no specific global recommendations for using backpack. There are issues that maybe considered for further research. This include overall time that the child carries a backpack, time the child climbing stairs while carrying a backpack, the type of backpack used and the design of shoulder straps and back support of the backpack. The relation between backpack and pain may include the child’s physical status, the perceived needs for what to carry in the backpack, the best pack for the individual person and how to best carry that pack for the person’s unique body composition (size, strength and fitness level) [1]

H.N Shasmin and colleagues have conclude that the safe load carriage for children below 12 years old is between 10% to 15% of their body weight.[12]. From their research, the vertical Ground Reaction Force(GRF) increased almost three times when load increased up to 20% of body weight compared to 10% of body weight. If Ground Reaction Forces and trunk inclination are important as the criteria to determine the acceptable backpack loads for children, those loads should not exceed 15% of body weight.

In the aspect of physiological, survey by Linstrom-Hazel has concluded that the low back pain caused by the heavy load may lead to other symptoms such as headaches and emotional problems. The effects also may cause them to purposefully lighten their backpack by leaving their school necessities at home and not performing well in class.

## V. FURTHER RESEARCH RECOMMENDATION

There is a need to perform a research on wider range of subjects and not only on specified percentage of body mass. To help eliminate the idea that students that have a greater mass can carry more in their backpack, subjects should also be examined in BMI percentile group for each year in primary school. The use of load limit based on percentage of body weight indicates that an obese student is able to carry heavier load when, in fact they may be at higher risk for injury due to lack of physical fitness. The children could be characterized in percentiles as it is difficult to get a study population with the same Body Mass Index. Regardless of their body sizes, a guideline on backpack weight should be developed for references of the authorities to design a suitable range of recommended total weight for textbook or exercise book for every levels of primary school..

Studies also should be carried out with different types of backpacks, choosing from the most popular type and the ones considered ergonomically designed to get more accurate findings on the effects to the children.

Futher research on this field should be carried on to provide a guideline on recommended backpack load limit specially for Malaysian primary school students.

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