OPEN ACCESS

Journal of Advances in Sports and Physical Education
Abbreviated Key Title: J Adv Sport Phys Edu
ISSN 2616-8642 (Print) |ISSN 2617-3905 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com

Original Research Article

A Review of Research on the Effects of Backpacks on Body Posture and Spinal Morphology in Children and Adolescents

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DOI: 10.36348/jaspe.2022.v05i08.003 | **Received:** 22.07.2022 | **Accepted:** 17.08.2022 | **Published:** 24.08.2022

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Abstract

Introduction: The purpose of the study was to investigate the effects of backpacks on body posture and spinal morphology in children and adolescents, and the relationship between them and back pain in adolescents, in order to provide a theoretical basis for further research in this area. ***Methods:*** The literature on backpacks, body posture, spinal morphology and back pain was searched and the results were analyzed. ***Results:*** The studies mainly focused on the effects of backpack type, weight and position on their muscle activity; and the main muscles studied were upper trapezius, erector spinae, and rectus abdominis, while the studies on other muscles were still insufficient. ***Conclusion:*** Backpack type and method, backpack weight, backpack strap design, backpack position, and backpack time all have different effects on muscle activity in various parts of the adolescent body, and these effects may lead to back pain, which is one of the factors affecting spinal health that cannot be ignored.

Keywords: backpack, muscle activity, electromyography, back pain, spinal health.

1. INTRODUCTION

In the 21st century, adolescent back pain has become a great problem, and there are various problems that cause adolescent back pain, but backpack has become one of the important aspects. For adolescents, backpacks are one of the indispensable tools in their lives, and carrying them to and from school every day is one of the things they must do (Zhu Houwei, 2020). The unreasonable weight and manner of backpack can cause changes in body posture, which in turn can cause neck, shoulder, and back discomfort (musculoskel *et al.*, discomforts, MSD), and can even cause spinal deformities in students, and such long-term spinal deformities caused by abnormal posture are considered irreversible (Qureshi, 2012; Mohan, 2007; Hundekari, 2013; Dianat, 2011). However, the effects of backpacks on the human body have not been given enough attention (Wang, Min, 2016). According to surveys, the backpack burden among adolescents has gradually increased over the past decades, and the corresponding incidence of various cervical and lumbar spine related spinal disorders have increased extremely compared to the past, with 40% of young people aged 9 to 21 years worldwide reporting that they suffer from low back pain (Calvo *et al.*, 2013), which is closely related to people's use of backpacks. 82% of children aged 11 to 14 years believe that their back pain is caused by the use of backpacks (Shymon, 2014), which has led doctors and parents to believe that backpacks may have harmful effects on their health and are very concerned about it (Al Khabbaz, 2008). Therefore, many scholars have started to work on the effects of backpacks on the human body, constantly regulating posture, relieving fatigue, developing new types of backpacks, and reducing the risk of physical injury. The purpose of this paper is to summarize the research findings on backpack and spinal morphological abnormalities and back pain in adolescents from around the world, to provide a reference for other scholars to further explore this area of research, and to provide theoretical support for the development of new types and methods of backpacks, as well as to promote the rationalization of backpacks and the prevention of backpack injuries.

2. RESEARCH METHODOLOGY

2.1 Search Strategy

In this paper, we mainly used the literature method to obtain relevant literature. We searched for relevant literature through computer searches of CNKI, web of science, Pubmed and other full-text electronic journals, and Google academic search engine, using "adolescent, backpack, schoolbag, spine, back pain, low back pain" as the main Chinese search keywords and " backpack, schoolbag, spine, posture, back pain, low back pain" as the main English search terms, and the period was set from 1985 to 2022. The literature with more complete structure, clearer research methods, and closer relationship with "backpack, spine morphology, body posture, and back pain" were selected for preliminary review, and organized according to different research directions: the data on spine morphology and back pain were categorized separately, and further categorized according to different backpack The data on spinal morphology and back pain were categorized separately, and further categorized according to different backpacking methods and weight.

2.2 Inclusion and Exclusion Criteria

The literature included in this study was all experiments that addressed the effects of backpacks on adolescents' bodies and included the effects of backpacks on adolescents' body posture or spinal morphology in the experiments. No restrictions were placed on the activity pattern or the subject's gender, height, weight, or physical health status during backpacking in the experiment. Exclusion criteria: 1) effects on the spine were not morphological or postural; 2) changes in body posture or spine morphology were not specifically described; 3) experimental subjects were not adolescents; 4) lack of relevant data; 5) duplicate publications.

2.3 Literature Screening and Data Extraction

Articles were searched and evaluated to screen the literature according to inclusion exclusion criteria. The literature was first searched using keywords, and duplicate articles were eliminated from the retrieved literature; the initial screening was performed by reading the titles to remove literature that was not relevant to the topic; the abstracts of the remaining literature were read to exclude reviews, articles that were not relevant to the content, non-experimental articles, and those whose effects on the spine were not morphological or postural; the literature that was obtained as potentially eligible after re-screening was read in full to exclude duplicate publications, lack of The full text of the potentially eligible literature was read to exclude duplicate publications, lack of relevant data, and literature without specific descriptions of changes; 11 articles were finally included (Figure 1). The data extracted included: author, year, number of subjects, gender, age, and main findings.

3. RESULTS

Currently, foreign scholars on the issue of the effect of backpacks on body posture and spinal morphology mainly focus on the type of backpack, backpack position, and backpack weight, and a few studies also start from time. Through the summary of research data, scholars in this field generally believe that unreasonable backpacks will bring additional pressure on the spinal structure of growing adolescents and may lead to changes in their spinal morphology resulting in this may lead to poor postural changes (grimmer). This permanent change in posture from long-term backpacking can create a resistant pressure on the spine leading to a series of pathological diseases such as degenerative disc disease or disc herniation in the back (Harbum). This paper summarizes, summarizes and analyzes the research of foreign scholars in several aspects of backpack type, backpack weight and backpack position.

3.1 Influence of Backpack Type and Backpack Mode on Body Posture and Spine Morphology of Adolescents

The normal human spine is located in the middle of the human back. Longitudinal spine, basically in a straight line. The cervical spine is short and horizontally oriented with bifurcation, and the 7th cervical vertebra (longitudinal vertebra) is a counting bone with a prominent backward appearance. The thoracic spines are elongated, mostly oblique posteriorly and inferiorly, and arranged in an imbricate shape. The lumbar spines are plate-like and extend horizontally to the posterior. (3) Lateral view of the spine: The adult spine has four physiological curves from the lateral view, namely, cervical curve forward, thoracic curve backward, lumbar curve forward, and sacral curve backward (Li S. C., 2010). When the head is positioned more forward in relation to the trunk, this condition indicates poor posture, and features known as poor posture include "forward head tilt," "jaw poking," and "rounded shoulders" (Raine and Twomey, 1997).

3.1.1 Effects of Backpack Type on Adolescents' Body Posture and Spine Morphology

There are many different types of backpacks used by adolescents in their daily life, and the effects of different types of backpacks on body posture are not the same, and by reviewing the literature, many scholars have done a lot of research on this, and many scholars have provided novel ideas for the design of new backpacks. Backpack (with two identical backpacks at the front and back); 4. Modified double backpack (weighing 10% and 5% of body weight, respectively), as shown in Figure 2. It was found that the forward angle and forward distance of the head were significantly higher when the children were carrying a normal double backpack than in the other cases. The head backward tilt angle increased and the head forward distance decreased when carrying the double backpack. The forward head tilt angle and forward head distance

decreased when carrying a modified double backpack compared to the other two conditions and were not significantly different from when carrying no backpack. These findings suggest that postural changes can be minimized when carrying the modified double backpack. It was also found that sternocleidomastoid muscle activity was enhanced when the head backward angle was increased, suggesting that body posture and muscle activity are also inextricably linked. In another study, a similar experiment was conducted on 20 young subjects, in which the stability of body posture was significantly reduced when carrying a normal duffel bag, while no significant changes in body posture occurred when carrying a double backpack (with two identical backpacks in front and back) (chow). According to the above two scholars' research results, it is easy to find the difference between chow and Kim's findings. The former study showed that although the postural changes were smaller when carrying a double backpack, they still produced significant changes compared to no backpack, and only when carrying a modified double backpack could achieve no significant difference from no backpack. The results of the latter study showed no significant change in posture when carrying a double backpack with equal front and back weight. The reasons for this may be due to differences in muscle strength and body stability depending on the age of the subjects, but they all indicate that the effect of using a double backpack type on body posture is significantly less than that of a regular shoulder bag.

In a study of a backpack with abdominal support (Marsh), 20 adolescents were asked to carry a backpack with abdominal support and a backpack without abdominal support, and the changes in their posture and perceived exertion were measured. It was noted that when carrying a backpack with abdominal support, there was less postural forwardness, less change in body posture, and less perceived strain. It can also be seen that changes in body posture can lead to physical strain, which can cause physical injury and illnesses such as back pain. It also provides some reference for the design of future backpacks, which should consider the factor of abdominal support when designing backpacks.

3.1.2 Effects of Backpack Style on Body Posture and Spine Morphology in Adolescents

Some scholars have also compared the changes in body posture that occur when using symmetrical backpacks versus asymmetrical backpacks. Previous studies have suggested that a safe load for children's backpacks is 10% of body weight (Hong). However, other scholars have argued that carrying an asymmetrical backpack can still cause significant negative spinal effects even when using the safe load for children's backpacks suggested by previous studies. Grabiec *et al.*, investigated the effect of backpack asymmetry on scoliosis parameters in adolescents, using backpacks weighing 10% of body weight in 162 elementary school students aged 11-13 years. However, the results of the study still showed that even within the safe load, there was still a significant negative impact on spinal morphology, with body posture showing more movement of the trunk towards the other shoulder, increased shoulder asymmetry and more pronounced lateral spinal curvature. It is clear that asymmetrical backpacks are more likely to put children and adolescents at "risk" and that the 10% body weight safety load does not apply to symmetrical backpacks.

Chansirinukor *et al.*, found an increase in head pronation and cervical flexion in adolescents aged 13-16 years after weight-bearing, and the changes were more pronounced with single-shoulder backpacks. The effects of asymmetric backpacks on spinal morphology have been confirmed by several other scholarly studies, such as Norkin *et al.*, who concluded that one-shoulder backpacks increase lateral flexion movements of the spine; thus, individuals who frequently carry one shoulder are prone to fatigue because one-shoulder backpacks increase muscle movement in the opposite direction of weight bearing. In addition, the increased muscle activity means that greater resistance stress will act on the spine, altering the spinal morphology and increasing the risk of spinal injury.

Negrini *et al.*, noted that students carrying a symmetrical backpack had a forward tilt of the trunk and a decrease in lumbar angle, while carrying an asymmetrical backpack had postural changes in all anatomical planes, with significant changes in the sagittal plane after fatigue. The negative effects of asymmetric backpacks on body posture and spine morphology were further demonstrated. However, this study also examined the recovery of the body after weight-bearing and found that all changes recovered after the pack was removed, especially the anterior lumbar convexity. Hung-kay *et al.*, showed that trunk posture and repositioning ability were not fully recovered after removing the backpack after backpack walking in young people; there were significant changes in spinal curvature during the backpack, which also increased the risk of spinal repositioning errors and increased the risk of spinal injury. The reason for the inconsistent conclusions of the scholars may be the different ages of the two study subjects. Adolescent children are in their adolescent development, and external stimuli to their bodies are fast-acting and fast-recovering, while youths' body shape is basically set, and external influences on their bodies make them recover relatively slowly, so there is a significant lag effect (Wang Min, 2016). This also suggests that when conducting research, special attention needs to be paid to the effect that the age factor of youth can have on the experimental results.

3.2 Effects of Backpack Weight on Body Posture and Spine Morphology in Adolescents

Walicka-Cupry *et al.,* found that backpack weight exceeding 10% of body weight affected lumbar spine morphology, resulting in reduced lumbar lordosis, flattened lumbar curvature, and a tendency for the sacral angle to be vertical. Chow *et al.,* obtained similar results, finding that as backpack load increased, the degree of lumbar lordosis and upper thoracic lordosis decreased significantly and the lumbar and upper thoracic curvatures flattened. The study by Hong *et al.,* had children exercising with asymmetrical backpacks while measuring their spinal tilt angles and spinal range of motion and found that asymmetrical body posture was observed when male children carried backpacks of different weights up and down stairs (equal to 0%, 10%, 15%, and 20% of their body weight, respectively), suggesting that school-age children using symmetrical backpacks It is recommended that school-age children should not exceed 20% of their body weight when using a symmetrical backpack and 10% of their body weight when using an asymmetrical backpack.

Martin *et al.,* found that females carried 48% (29 kg) and 60% (36 kg) of their body weight in a backpack with a more pronounced forward tilt than males, so females need to carry less weight in a backpack, which is related to their physiology and the stresses they need to overcome during walking. Kinoshita also concluded that subjects carrying 20% BW or 40% BW backpacks had a significant forward tilt and altered spinal morphology. A study by Grimmer *et al.,* on the relationship between changes in atlanto-occipital joint angle and backpacks in boys and girls of similar age groups, using atlanto-occipital joint changes of ≥5° as a criterion for determining spinal compression, showed that 35%, 20%, 17%, 24%, and 22% of students in each age group from 8 to 12 years were considered at risk, with maximum atlanto-occipital joint changes of 12°, 13.2°, 31°, 30.2°, and 11.3° respectively. All indications are that these at-risk students had significantly heavier backpack weights than the rest of the students.

Brackley *et al.,* showed significant changes in trunk forward tilt (TFL) and cranial vertebral angle (CVA) when the backpack weight reached 15%. Cheung *et al.,* divided the subjects into two groups in their experiment, a group with neck pain and a group without neck pain. It was found that starting from 10% of body weight, the CV angle of the study subjects in both groups in the experiment decreased gradually with increasing backpack load, but the CV angle of the neck pain group decreased significantly at a load of 10% of body weight, while this value was 15% of body weight in the non-neck pain group. This suggests that for patients with neck pain, body posture is more sensitive to increased load and changes in spinal morphology and posture are more significant, and more care should be taken not to overload the backpack when it is used. Neuschwande consequence of increasing backpack load significantly compressed lumbar disc height measured in the midline sagittal plane. Four of the eight subjects had angles greater than 10° with an 8 kg backpack load. A study by Kistner *et al.,* investigated the effects of backpacks carrying no more than 20% of body weight on posture and pain in elementary school children. Sixty-two children aged 8-11 years were asked to walk with 10%, 15%, or 20% of their body weight in a backpack, and sagittal photographs of the children were taken before and after walking to measure their cranial vertebral angle, anterior trunk tilt, and pelvic tilt angle. The results of Chansirinuko *et al.,* showed that the effect of backpack weight on adolescents' posture was in the neck and shoulders. When carrying a backpack, the forward head tilt increased, especially with heavier backpacks. For adolescents, a backpack weight of 15% body weight is unacceptable and seems too heavy for the still growing body to maintain a normal standing posture. Ramprasad *et al.,* also found significant changes in CV angle when carrying a backpack weight of 15% body weight, decreasing from a mean of 55.11° to 51.49°. The head-neck angle and the head-neck-torso angle changed significantly when the backpack weight was 10% of body weight. The trunk and lower limb angles also changed significantly after a backpack weight of 5% body weight.

In summary, for adolescents, backpack weight has a significant effect on body posture and spine morphology. The optimal backpack load is between 10% and 20% of body weight, and if the backpack weight exceeds this appropriate range, it will cause changes in various body posture angles, and as the backpack weight increases, the changes in body posture and spine morphology become more significant. These changes mainly include flattening of the cervical and lumbar spine curvatures and an increase in the forward tilt of the head and torso, leading to damage to the spine or surrounding tissues, causing a series of problems such as back pain in adolescents. On the other hand, a large number of studies have shown that research on the effects of backpack loading on human spine morphology has been discussed mainly in adolescents, while studies on the effects of backpacks on spine morphology in middle-aged and elderly people are few, especially in this population, and it is necessary to study the effects of backpacks on spine morphology in elderly people (Wang Min, 2016).

3.3 Effects of Backpack Position on Adolescents' Body Posture and Spine Morphology

The position of the backpack on the body has been one of the hot topics of research on backpacks around the world, and it has been suggested that the backpack should be placed higher on the body. Some scholars have investigated this issue (Grimmer *et al.*,), but have come to different conclusions. A controlled experimental study was conducted on 250 adolescent subjects (12-18 years old) with marker points placed on

the head, neck, shoulders, hips, thighs, knees and ankles. The position of the backpack was set at different parts of the body (backpack concentrated at T7, T12 or L3). The results showed that when the backpack was positioned at T7, the distance of forward horizontal displacement of all marker points was the greatest. This indicates that the T7 position of the backpack causes the greatest body postural changes and should be avoided. This also refutes the previous rumor that backpacks should be placed higher on the body and that when adolescents are backpacking, they should be placed at the center of the waist or hips. However, studies by other scholars have shown different results (DEVROEY *et al.*,), with increased spinal flexion and pelvic torsion observed when backpacks were placed at the lumbar region.

It has been suggested that placing the backpack position at T12 and in front of the body has relatively little effect on the change in spinal morphology in children. Chow *et al.,* analyzed the change in spinal curvature in children carrying a 15% body weight backpack in different positions (anterior or posterior to T7, T12, or L3). Both the anterior- posterior position of the backpack and the height of the backpack affected spinal curvature. There was relatively little change in spine when the pack was positioned anterior to the body and when the pack height was at T12. The findings also suggest that occasional changes in backpack position and height at the anterior-posterior side of the body may help mitigate the effects of backpacks on the spine.

4. CONCLUSION

Backpack type and style, backpack weight, and backpack position all have different degrees of influence on adolescent body posture and spine morphology. Both symmetrical and asymmetrical backpacks caused significant changes in body posture and spine morphology, but the effects of asymmetrical backpacks were more pronounced; the heavier the backpack, the more pronounced the changes in posture and spine morphology, and the more likely to cause spinal health problems. The longer the backpack, the more significant the changes in body posture and spine morphology of adolescents. The current ideas for improving the backpack are mainly to disperse the weight concentrated on the back or adjust the flexibility of the backpack.

5. Problems and Prospects

The research on backpack and spinal morphological abnormalities and back pain in adolescents has been studied by scholars at home and abroad. Studies on the effects of backpacks on adolescent spine morphology have focused on the effects of different backpack styles, and studies on backpack-induced back pain in adolescents have focused on the different weights of backpacks, while few studies have reported on the effects of different backpack positions on both. In addition, to date, a large number of studies have focused on adolescents, and only a small number of scholars have studied the effects of backpacks on adults.

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