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Potential threat factors of abnormal body posture in children—a review of studies on backpack load

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Abstract: Children are a rapid stage of growth and development in human life, and many objective factors affect the formation of children's correct posture. Children are a rapid stage of growth and development in human life, and many objective factors affect the formation of children's correct posture. Based on the information provided by these literatures, several topics worth exploring in the study of children's backpack load are summarized. This study analyzed the independent influence of children's age, gender, backpack weight and backpack mode on their body posture and the interactive influence of multiple factors, explored a reasonable backpack mode, and provided a theoretical basis for the design of more scientific children's backpack, with a view to guiding children's scientific backpack and reducing the occurrence of muscle discomfort and spinal deformity caused by poor body posture.

1. Introduction

The development of children's body posture is affected by the characteristics of growth spurts on the one hand, and inappropriate postures on the other hand, and long-term poor postures will result in positional or structural deviations [1].For example, during the learning period, the learning and working mode of sitting for a long time, the lifestyle changes from decreasing physical activity to more sedentary [4], and in the process of children's external load (backpack), the weight of the load, the distance of transportation, and the change of mode are all negative factors leading to postural development disorders. Most school-age children carry their textbooks and equipment in backpacks every day, a global activity that is estimated to occur in 668 million primary school students [2, 3]. According to the data of the Spinal Disease Prevention and Control Committee of the Chinese Preventive Medical Association, it is estimated that the number of primary and secondary school students in China suffering from scoliosis has exceeded 5 million. And it's increasing by about 300,000 a year.In biomechanics, the center of gravity, as a definite point, is the center of the force system in parallel dimensions of the object, and it is also the stability of the human body to ensure the standing position [17].When the original system of forces is broken by external forces, young children will soon adopt adaptive strategies to compensate so that certain body parts are aligned with each other, and static and dynamic postural sway is a particularly important element that leads to the instability of the center of gravity [18].Multiple aspects of adjustment can threaten the correct development of posture, resulting in the emergence of poor posture or physical abnormalities [16].

The spine has been identified as a common pain site for primary school students, and load handling is associated with spinal pain [17,18].Experts believe that changes in spinal posture during load handling may be a reasonable intermediate variable causing spinal pain [4].Spinal pain experienced during childhood and adolescence is a significant potential risk for experiencing spinal pain later in life [5].Some researchers speculate. If an inactive student's backpack is overloaded, the risk of severe postural deformities is greatly increased [1, 4, 27].For young children, especially those with poor posture or spinal deformities, this should be a biomechanical and ergonomic concern [21,22].The study of variables related to the occurrence of static postural changes and backpack load can help to understand the risk factors for spinal problems.

Backpack load transport is one of the current research hotspots in the field of biomechanics. Scholars' research mainly focuses on the standing and dynamic movement of children's backpack,ground reaction forces and changes in body posture, balance, gait adjustment, changes in muscle activity, changes in lung capacity, as well as spinal and lower limb injuries and back pain caused by these changes. At present, although the literature on student backpack load is increasing, there is little systematic and comprehensive review of the status quo of student backpack load and its impact on body shape. On the one hand, this study collects and collates the research evidence on postural changes of school-age children related to backpack load; on the other hand, it summarizes the current research status at home and abroad on this topic, seeks out the shortcomings of the research, provides information for future research on this topic, and helps to formulate risk management strategies for school backpack load.

2. Literature retrieval and literature combing

2.1. Literature retrieval strategy

Foreign data library master should choose Web ce, Scopus, PubMed, Google Scholar, EBSCO, etc. Boolean logic words "AND" and "OR" are used to connect each search term. The search time range is from January 1, 2000 to June 31, 2024.Foreign language search terms mainly include (" Child* "OR" adolescent "OR" students "OR" youth "OR teen* AND" backpack "OR" bag "OR" Load "AND" ground reaction" force "OR" Body posture "OR" Body shape ", etc., the Chinese database mainly selected China National Knowledge Network, VIP journals, etc., and the search time range was from January 1, 2000 to June 1, 2024.The Chinese search terms mainly include "children" or "teenagers" or "students" and "backpacks" or "backpacks" or "loads" and "planar pressure" or "ground reaction force" or "body posture" or "body type", and the search is set in the title, abstract and keyword.

2.2. Literature screening criteria

According to the above search terms, 2632 articles were retrieved from the English database, 37 were retrieved from the Chinese database, and a total of 2669 articles in both Chinese and English were obtained. The two authors independently cross-checked the title, abstract and full text of the retrieved literature to ensure that at least one of the full text contained the above keywords. After repeated screening, 613 duplicate literatures were excluded, and 645 were excluded by keyword review. The two authors further screened and eliminated the foreign literature obtained by keyword and repetitive review with reference to the following screening criteria:(1) Conference papers; (2) Review papers; (3) Studies on backpack carrying by sick children; (4) Select a backpack instead of a backpack; (5) Research papers that have not been peer-reviewed. Finally, a total of 28 relevant research papers were selected.

3. Analysis of literature search results

Combined with 27 selected research papers. These 27 Chinese and English research papers were read and classified independently by two authors to extract key research information: Such as participant characteristics, load conditions, experimental design, etc., the third author makes a judgment on the inconsistent information and reaches a consensus. This review reviews the assessment of (1) empirical evidence on student load and load conditions;(2) The biomechanical, physiological and physical effects of load on children's body posture and the spinal injury, lower limb injury and back pain caused by these changes;(3) Intervention methods and effects adopted by society, schools and parents.

4. Biomechanical measurements of body posture related to backpack load

4.1. Biomechanical measurement index

The postural deviations evaluated in epidemiological studies usually refer to the anteriorposterior changes (scoliosis posture), dorsal kyphosis, and lumbar hyperlordosis [1]. In studies of human trunk, researchers usually measure the changes in body posture Angle (see Table 1) to prove the relationship between backpack load and trunk forward tilt and spine curvature to achieve the purpose of measurement research.

Table 1: Measuring body posture each posture Angle.

Name	Definition	Meaning
CVA (vranio-vertebralangle)	Angle between tragus and C7 (7th cervical vertebra) and horizontal plane [6]	The degree of curvature of the cervical spine;
CHA (cranio-horizontalangle)	The Angle between the eye and the tragus and the horizontal plane. [6]	Tilt the head in the horizontal plane
SSP (sagittal shoulder Posture angle)	Angle between the line of the tuberositas of C7 and humerus and the horizontal plane [6]	Cervical curvature is related to the shoulder hunch position formed by the shoulder joint leaning forward
TA (truck angle)	Angle between the line of C7 and the trochanter of femur and the horizontal plane [7]	
CSP(coronal shoulder posture angle)	Angle between lateral humerus trochanteric line and horizontal plane [8]	Shows the relative height of the shoulders on both sides, related to the high and low shoulder posture
Thoracic kyphotic Angle KKP	The Angle consisting of the tangent lines extending Th1 and Th2, Th11 and Th12 spinous processes	
Lumbar lordosis Angle KKL	The Angle of the tangent line extending from the spines of L1 and L2 to L5 and S1	
Sacral Angle	The Angle between the line connecting the spinous process S1 and S3 and the frontal plane	

In the study of lower limbs, researchers pay more attention to the stability of the subjects when standing and the change of gait when walking, which will be affected by many internal factors: Limb length, joint range, muscle tone, neuromuscular diseases; There are also external factors: shoes, clothing, or loads, which can change the way they walk [9].The spatiotemporal gait parameters of complete gait cycle include step length, stride length, single leg support time, double leg support time, swing time and standing phase time. Its measurement can effectively identify the diagnosis of walking difficulties, when the child's weight deviates from the recommended value, the peak pressure of the foot is too high, and the load distribution between different parts of the foot develops changes, which can be a source of potential foot problems, including the development of blisters on the sole and skin thickening, which can lead to serious injury of the metatarsal bone or stress fracture.

4.2. Biomechanical measurement of backpack load relative to torso posture

When the load is behind the body in the form of a backpack, the body posture changes due to the change in center of gravity. The body attempts to keep its center of gravity between the feet, which can be achieved by leaning forward at the ankles or hips or by tilting the head, in response to a change in the position of the center of mass of the body-backpack system[10].Compared with walking without load, CVA, CHA, SSP and TA of primary school students with 15% BW load will decrease significantly while CSP will increase significantly. The smaller CVA Angle indicates that the tilt degree of head will increase. Similar studies have also found that CVA gradually decreases with the increase of backpack load, and the decrease becomes significant from 10%WB [11].The change of CHA can be attributed to the hyperextension of the upper cervical vertebra, which increases the tensile force on the neck muscles and compensates for the increase in the degree of curvature of the cervical vertebra to keep the center of gravity of the body-backpack system between the feet. Studies have also found that compared with standing with a backpack equivalent to 18% of body weight, the CVA of standing after dynamic activity is significantly reduced and CHA significantly increased. SSP increases significantly [12].In addition, there are age differences in TA under different load conditions: in no load condition, the TA of primary school students aged 10-12 years is significantly larger than that of students aged 7-9 years. When the weight of the backpack increases to 10%BW, the difference between the two decreases, indicating that the weight of the backpack of 10%BW has caused a large burden for children aged 10 to 12 [13].According to the survey data, lumbar lordotic curvature significantly decreased when the backpack weight increased from 10% BW to 15% BW, while there was no significant difference between the backpack weight of 5% BW and 10% BW [14].Children are able to maintain a normal lumbar spine posture while carrying a lighter backpack, but maintaining a normal lumbar lordosis becomes difficult when carrying a heavy backpack, and the lumbar lordosis is reduced [14].The decrease in loin lordosis also corresponded to more activation of the erector spinal muscles [14]. Spinal stability is provided by increased activation of postural muscles such as the vertical spine [15], which significantly increases when the load reaches 15%BW, possibly due to the children's increased effort to balance the external load such a change leads to an increased back load and thus an increased risk of back injury, a backpack weight of 15%BW should be avoided [16].

The position of the backpack is also an important inducement to the change of body posture. A lower position of the backpack leads to the increase of the moment arm generated by the motion axis of the upper torso. When the subject is wearing a lower position of the backpack and the shoulder strap is longer, the degree of forward leaning of the upper torso will be greater [17], but the higher the position of the backpack is not the better. In the survey of T7,T12,L3, three common backpack positions, the waist discomfort score is the highest when wearing a backpack at L3.In the T7 position, the neck and shoulder discomfort scores were highest; Students are advised to carry their backpack in the T12 position [14].At the same time, the addition of removable fixed belts (belts and chest belts) in the backpack design can alleviate the change of body posture when the backpack is too heavy, which is conducive to improving children's MSD and reducing the occurrence of spinal deformity. When the weight of the backpack is higher than 10% of the body weight, controlling the center height of the backpack at a lower position (waist) and installing a belt and chest belt in the backpack can effectively alleviate the changes in body posture caused by the weight of the backpack [18].There are also different research results: In the experiment of college students (n=12), it is found that when carrying a backpack at a lower position (i.e. waist position), compared with that at a higher position (i.e. chest position), spinal flexion increases and pelvic forward inclination decreases [19].Although this different result may be a difference in the subjects recruited for the experiment, it is still worth further investigation.

4.3. Biomechanical measurement of gait associated with backpack load

In the study on walking with backpack load, we can see that the research results tend to be common: backpack load increases the two peak forces of gait, significantly reduces the single support time, and significantly increases the support time of both legs. The increase of backpack weight reduces the balance ability of children, spatiotemporal parameters change most obviously, and children make adjustments accordingly to help them fight the disturbance of the body and maintain balance [20].When the load is 8%-10%BW, the increased load ratio in the first peak backpack is about twice the load added by body weight, meaning that a 50kg student carrying a 5kg backpack, the size of the first peak force is higher than that of the 55kg backpack, and the increment of the second peak is also 1.3 times of the increased load. The increase of the peak value of spatiotemporal gait slows down, which may be due to the weakening of the loading rate with the extension of the standing time [21].The aim is to minimize the possible harmful effects of high vertical GRF on the musculoskeletal system [22].The combination of load increase and posture change can affect the gait pattern, backpack weight and single support force, and increase the double support force. In this case, children will unconsciously adjust the gait characteristics, namely speed and knee flexion [23].In order to reduce the instability or mechanical stress of the musculoskeletal system, children use a compensatory mechanism to cause changes in space-time walking parameters [22].

In the study of backpack load standing still, most tests have reflected the change of ground reaction force [23].In a study assessing plantar pressure distribution with backpack load, it was found that the contact area between the midsole and heel of the foot increased as the load increased, indicating that the participants slightly changed their posture while carrying the load, the support pattern of the foot changed, and increased as the weight approached. The increase in pressure was concentrated in the toes, metatarsal bones, and midfoot, indicating a shift in the pattern to the forward ball of the foot, with the greatest change in midfoot pressure, which may lead to plantar fasciitis [24].The area of contact increases less significantly when walking, and the plantar pressure changes less when walking than when standing [25].Some studies have shown that when subjects walk with a backpack, the weight load is concentrated in the prefoot area [26],resulting in inconsistent distribution of standing pressure, which is worthy of further discussion, and also indicates that the human body can better adjust its motion control system.

5. Effects of backpack load on pain and physiology

As the weight of the backpack increases, a reduction and shortening of the lumbar spine is observed, which may be a major cause of future spinal overload and degenerative changes. It also helps to explain the occurrence of low back pain in school-age children, which is a vicious cycle in which excessive load leads to abnormal body posture resulting in pain, and the pain distress leads to further compensatory adjustment of body posture, which may lead to irreversible injuries such as spinal deformity, bending and body deformity. Studies have also found significant differences in the growth, birth and development characteristics of primary school students of different ages and genders [27]. In most surveys, the proportion of girls with WB load exceeding 10% is much higher than that of boys, and the prevalence of pain in girls is also higher than that of boys [28, 29].Compared with primary school students, middle school students have a higher rate of back pain, which may be due to differences in bone structure at different ages. The height development of middle school children is mainly based on spinal growth.

6. Improvement measures

In addition, with rising levels of obesity in school-aged children [30] and an increasing overall need for school-aged children to bear these burdens [31], the potential impact of backpacking on children before the musculoskeletal system is fully mature is bound to increase. It is imperative to implement practical and effective intervention means, determining the optimal backpack load is a simple method, implementing the maximum relative load limit of the backpack is a feasible method, and the number of items brought to school is regulated, this helps to mitigate the impact of load transport [32].

Creating a good environment, childhood misbehavior is often manifested in their observation of the world around them, by imitating the senior classmates to gain recognition, by establishing a good atmosphere, so that children understand the subject, and follow the principles of ergonomics.

Students are encouraged to engage in balanced and spontaneous physical activities (such as recreational activities) during the day to ensure optimal physical development, and incorporate compensation exercises into the physical education curriculum.

7. Conclusions

Over the years, researchers have carried out extensive research on the effects of backpack load on children's body, and found that the biomechanical effects of backpack load are statistically significant. And the pain and discomfort of these loads are widespread. Advances in technology and the status quo of student backpacks are an ever-changing fact. The systematic review is very important, from which the direction of further research is found, and five topics worth exploring in the study of children's backpack load are summarized,(1) The age, gender and background of the subjects were limited; (2) The student's backpack load is more than 10%BW ratio is high, the nature of its carrying items is unknown; (3) Under heavy loads, the biomechanical effects of backpack load on body posture were statistically significant; (4) The negative physiological effects of load are also significant; (5) Backpack load brings widespread pain and discomfort.

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