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The Effect of Carrying School Bag on Electromyographic Activity of Muscles and Biomechanical Parameters of Walking in Iranian Students: a Systematic Review Study

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Abstract

Context: Carrying a backpack with an inappropriate weight and non-optimal postures play a pivotal role in developing musculoskeletal pain. Studies have shown that school bags affect muscle activity and biomechanical variables in children and adolescents. Accordingly, the present study aimed to systematically review the effect of school bags on electromyographic activity of muscles and kinematic and kinetic parameters during walking in Iranian students.
Methods: Relevant articles were searched through Scopus, PubMed, Web of Science, MagIran, and SID databases. Original articles in Persian and English published in peer-review journals were selected without time limitation. Eligible studies were divided based on various biomechanical factors that were examined.
Results: A total of 1975 articles were found in the mentioned databases. Twelve studies were eligible based on the inclusion criteria in this study. In general, it seems as though weight, type, the height of placement of schoolbag, slope of the surface, and the manner of carrying the schoolbag had significant effects on the trunk, neck, ankle, and knee angles, length and frequency of steps, symmetry index, and vertical forces. Additionally, the weight and type of the bag had significant effects on the electromyographic activity of rectus abdominus, paraspinal, and lower limb muscles.
Conclusions: Factors such as weight, the slope of the surface, method of carrying, and schoolbag height of placement could affect the kinetic and kinematic variables whereas the weight of the bag and the type of school bag could affect the electromyographic activity of the muscles in Iranian students.

Keywords: Lifting, Posture, Electromyography, Students

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1. Introduction

Humans use various tools to meet different needs during the day, exposing them to various diseases and postural changes (1). One of the sciences that contributes to the proper use of these devices is ergonomics, which helps use these devices effectively, thereby preventing chronic diseases and improving lifestyles (2). In this regard, paying attention to children and adolescents is highly important since they are in the critical period of growth (3). In addition, musculoskeletal problems at younger ages are important risk factors for musculoskeletal disorders in adulthood (4). Students carry various items, such as books and other educational supplies daily; in other words, they spend a considerable amount of time carrying bags (5).

Studies have shown that carrying a backpack weighing 10% of body weight for 30 minutes leads to irreversible tissue changes at least for a while (6). It has also been shown that load-carrying may alter the gait kinematic and ground reaction force (7-9). Biomechanical changes in static and dynamic postures by carrying a load could lead to musculoskeletal pain and a heavy backpack can exacerbate such changes (10). Carrying a heavy bag by students causes lumbar hyperlordosis or head and trunk flexion to support the bag›s weight. Excessive load on the neck and back muscles may trigger extreme fatigue and injury (11). These changes may also have certain consequences; for example, asymmetry in muscle activity due to the backpack›s weight results in instability in the trunk and consequently back pain (12, 13). Therefore, because students use these backpacks for a long time, the asymmetry of muscle activity when carrying heavy backpacks leads to postural changes with numerous consequences, like low back pain (14). Asymmetry in load-bearing may lead to the trunk›s lateral deviation towards the inactive muscles and pressure on the lumbar region (15). Other researchers have reported permanent postural deviations due to asymmetrical activity of the trunk muscles when carrying heavy backpacks. Studies have also shown that musculoskeletal complaints depend on a variety of factors. The combined effects of a heavy bag, its carrying time, movement, method of carrying, and load position on students› body are important risk factors associated with musculoskeletal problems in students using school bags (16, 17). Therefore, it is essential to take these factors into account while examining the risks associated with the school bag. Since the use of bags and backpacks is common among students to carry educational equipment, their improper use may lead to changes in body structure and some biomechanical, physiological problems, in addition to various diseases (18). Conducting a review study on the effects of school bags could play an effective role in taking appropriate preventive measures and compiling comprehensive guidelines for safe carrying in students. Accordingly, the current work aimed to systematically investigate the effect of carrying a school bag on electromyographic activity of muscles and kinematic and kinetic parameters during walking in Iranian students.

2. Methods

For this study, the titles and abstracts of scientific sources in the databases of PubMed, Scupus, Web Of Science, SID, and MagIran were searched in Persian and English without time limitation. Search keywords included the following:

(Student OR Children OR Child OR Adolescent OR Juvenile OR Teenager OR Pediatrics) AND (Iran OR Persian OR Farsi) AND (Backpack OR Bag OR Load OR Carriage OR Carrying OR Carried OR Knapsack OR Rucksack OR Pack).

Only the sources that were published in either English or Persian were extracted among the articles found in the search. Only the studies that had examined the effect of school bag on the electromyographic activity of muscles and kinematic and kinetic parameters of walking in Iranian students were selected. Only the papers that published in journals with peer-review process were considered. There was no time limitation for publications. Initially, a total of 1975 articles were found in the databases, as mentioned earlier. All the searched reports were exported to Endnote.7 software. Subsequently, using the software, 58 duplicate articles were excluded from the general list and the first two authors of the article evaluated the rest of the sources independently. At first, the titles and abstracts of the sources searched by the two researchers were reviewed. In case of disagreement, the researchers decided whether or not to include the sources in the systematic review process in consultation with each other. Out of this number, 47 articles were selected based on the review of abstracts and their titles. Afterwards, by studying the full text of these articles, 12 eligible articles were selected.

3. Results

Out of 1975 records found in various sources, 12 articles were eventually identified as eligible for the review (Figure 1). The research results were classified based on electromyography of different muscles or postural variables. Since there was heterogeneity among the study methods and the research designs, and the reporting methods and data presented in the research, meta-analysis was not applicable. The results of this study are presented below based on different biomechanical and physiological variables during walking (Table 1).

Neck angle

Two studies examined the effect of carrying a backpack on neck angle while walking. Jadidian and colleagues examined the kinematic variables of four modes of walking (including without a backpack, backpack-low, backpack-middle, modified backpack-low, and modified backpack-middle). They demonstrated that the craniovertebral angle in both lumbar and thoracic positions was significantly greater than that without a backpack and the angle increased more at the thoracic position (19). Moreover, Namazizadeh and colleagues examined the kinematic effects of carrying a backpack on

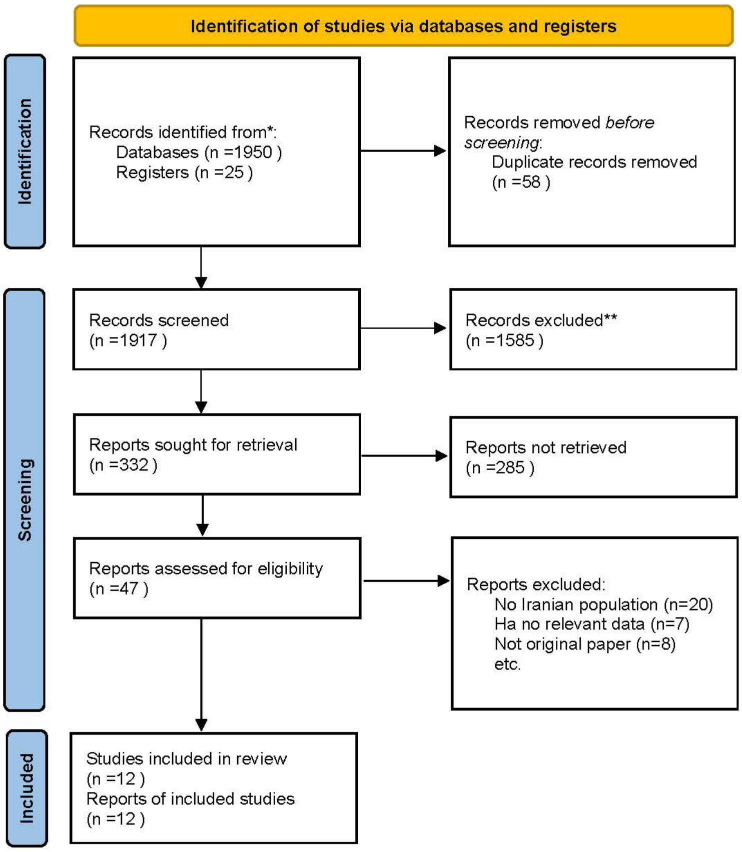

Figure 1: The figure shows the flow diagram for eligible studies.

walking and standing posture of adolescents in four different conditions, including without load and carrying a backpack with 7.25, 10, and 15% of body weight. The neck angle (the angle between a line passing through the front of the head and the shoulder joint and horizontal line) decreased significantly in the dynamic state under 10 and 15% of body weighing backpack conditions compared to the no-load condition (20). In general, these studies showed that carrying a backpack in the lumbar region increases craniovertebral angle and carrying a backpack above 10% leads to a decrease in neck angle.

Trunk angle

Four studies examined the effect of backpacks on trunk angle while walking. Rezaei and co-workers reported that carrying a unilateral backpack compared to bilateral backpacks in students with an average age of 12 years led to an increase in upper body flexion (the angle between a line connecting the acromion process to the trochanter of the thigh and a horizontal line passing through the trochanter) (21). It has also been observed that carrying a normal and modified backpack with 10% of the body weight in the lumbar and thoracic areas compared to the no backpack condition led to a significant increase in the bending of the trunk. The amount of bending of the trunk while carrying the modified backpack was significantly less than that while carrying a standard backpack. Still, the change in the height of the backpacks did not cause a significant change in the trunk angle (22). In addition, it has been shown that trunk flexion angle (the angle between a line connecting the shoulder and thigh joints and the horizontal line) increases significantly when carrying a backpack weighing 10 and 15% of body weight compared to non-load condition during standing and walking (20). Another study showed that the upper body bending angle increased significantly when carrying bags weighing 0 to 10 and 15 to 20% of body weight unilaterally (23). In general, it could be concluded that carrying a standard backpack unilaterally and more than 10% of body weight leads to increased trunk flexion angle.

Knee flection

Three studies investigated the effect of backpack carrying on a knee angle while walking. Rezaei and co-workers

Table 1: Description of eligible studies

Study	Sample Size (Mean age)	Weight of Schoolbag	Examining task	Measured Variables	Main Outcomes
Ahmadi-Gomdidni et al., 2021	18 elementary school boy (10.95±0.76)	No weight, 10 and 15% of body weight	Walking on a treadmill (three times on a flat surface) and two times on a +15% gradient, and two times on a -15% gradient	Vertical ground reaction force, first force peak, second force peak, mid support force, loading rate, push-off rate, and time-to-peak	Gradient had a significant effect on walking kinetics, but the weight of schoolbag had no effects.
Jadidian et al., 2020	27 elementary school boys	10% of body weight	Walking without a backpack , carrying backpack on lumbar spine and thoracic spine, modified backpacks on lumbar spine, and thoracic spine	Craniovertebral angle, trunk forward lean anngle	In contrast to carrying backpack on the lumbar spine, carrying backpacks on thoracic spine decreases craniovertebral angle. Carrying modified backpack did not result in craniovertebral angle change.
Ebrahimpour and Naderi, 2020	17 healthy females (21.17±1.28)	0, 5, 10, and 15% of body weight	Unilateral and bilateral carring od 0, 5, 10, and 15 % of bodyweight	Stance duration, swing duration, double support duration, step length, cadencestep frequency, step length symmetry index, step frequency symmetry index	Increasing backpack weight resulted in increased stance, swing, and double support duration while decreased step and cadence length. Gait symmetry decreased by carrying backpack unilaterally or with higher weight.
Hoseini et al., 2019	12 male elementary school students (9.5±0.45)	10% of body weigh	carrying backpacks, shoulder bags and hand bags during 1 minute of direct standing, after 15 minutes of carrying each bag on a treadmill at 1.1 (m/s) speed	EMG of rectus abdominis and erector spine	EMG of the selected muscles increased in contralateral side while it decreased in ipsilateral side of the body while using shoulder or handbags. However, using backpacks had no significant effects on the muscles activity.
Jadidian and Shirzad,2018	28 elementary school boys (9.70±1.07)	10% of body weight	Backpack-low, backpack-middle, modified backpack-low, and modified backpack-middle	1st and 2nd peak vertical GRF, minimum force, loading rate, cadence, step length, step width, swing and double support phases	Carrying backpack in the middle spine position altered gait mechanics significantly in comparison to carrying in lower spinal segments. Carrying backpacks at lower spinal segments had significant effect on vertical forces.
Rezaei et al., 2017	20 secondary school boys (12.3±1.5)	0, 10, 15, and 20% of body weight	Bilatral and unilatal carrige while walking on teadmill with speed of 1/1(m/s) for 30 minutes.	Step frequency, step length, trunk forward lean angle, lean knee angle, dorsi flexion angle, plantar flexion angle	Carrying backpack unilaterally led to increased trunk forward lean, decreased height and step length, and increased knee lean angle and step frequency.
Ghamari Hoveyda et al., 2017	15 elementary school students (9.6±0.61)	0, 10, 15, and 20% of their body weight	20 minutes of walking on the treadmill at a speed of 1.1 (m/s)	Step length, step fequennty, ankle dorsiflexion, ankle plantarflexion, knee flexion	Increasing backpack weight resulted in significantly increased in knee flexion and ankle dorsiflexion angles, and step length while it decreased in ankle plantar flexion angle and step frequency.

Table 1 (continued).

Ghamari Hoveyda et al.,2016	15 elementary boy students (9±0.61)	No weight, 10, 15, and 20% of body weight	Walking on the treadmill at a speed of 1.1 (m/s) for 20 minutes	EMG of rectus femoris, vastus medialis, vastus lateralis, biceps femoris vastus medialis and tibialis anterior	By increasing backpack load, the EMG activity of all muscles significantly increased, exept for tibialis anterior. Moreover, carrying heavier loads caused decrease in the median frequency of vastus lateralis, medial gastrocnemius, rectus femoris, and biceps femoris.
Rezaei and Babakhani, 2016	20 secondary school boys (12.3±1.5)	0, 10, 15, and 20% of body weight	Walking with speed of 1.1(m/s) on treadmill for 30 minutes	Trunk forward lean anu gle, knee lean angle, step length, Step frequency	Trunk forward lean decreased by carrying schoolbag unilaterally with every weights carried. In addition, heavier loads led to significant changes in step length and step frequency.
Ebrahimi Atri et al., 2014	20 elementary grade girl students (9.75±0.71)	10% of body weight	Walking on treadmill with a speed of 1/1 (m/s) for 15 minutes and one minute standing	EMG of erector spine and rectus abdominis	Carrying shoulder bags ad handbags unilaterally caused increased EMG activity of contralateral rectus abdominis and erector spine muscles while it decreased EMG activity of ipsilateral ones. Carrying backpack resulted in decreased EMG of rectus abdominis and erector spine muscles bilaterally.
Hoseini et al., 2013	12 male elementary schools student (9.1±1.5)	9.5, 11, 12.5, and 14% of body weight	15 minutes of carrying backpacks on a treadmill at 1.1 m/s	EMG of rectus abdominis and lumbar erector spine muscles	Carrying backpacks weighing more than 11% of bodyweight significantly decreased EMG activity of erector spine muscles and increased EMG activity of rectus abdominis muscle.
Namazizaade et al., 2003	12 scondeery school boy(3.26±0.32)	0, 7.25, 10, and 15% of body weight	Walking for 200 meters with preferred speed	Stride length, stride fequenty, forwad lean angle of tunk,forward lean angle of head and neck	Carrying backpacks weighing more than 10% of bodyweight resulted in decreased stride length and increased stride frequency and forward lean of trunk and head.

reported that the flexion angle of the knee increases when carrying a unilateral backpack compared to a bilateral backpack (21).

Ghamari Hoveyda and co-workers investigated the effect of carrying a backpack with loads of 0, 10, 15, and 20% of body weight for 20 minutes of walking on the kinematic parameters while walking among elementary school students in Hamadan. A significant increase in knee flexion angle in 20 and 15% was observed compared to non–load condition, but no significant differences were observed between 10% and non-load conditions (24).

Nonetheless, in another study, no significant differences in knee flexion angle was observed between the non-load position and backpack carrying with 10, 15, and 20% of body weight (23). It seems as though carrying a backpack unilaterally weighing more than 15% of body weight increases the flexion angle of the knee.

Ankle angle

Two studies examined the effect of the backpack on the angle of the ankle while walking. One showed that carrying a bag has no significant impact on the dorsi and plantar flexion angles (21). On the other hand, another study concluded that there was a significant increase in relative plantarflexion angle in a backpack weighing 15 and 20% of body weight compared to that without load. Still, there were no significant differences between different weights (24). It seems as if the increased backpack weight leads to a significant decrease in dorsiflexion angle and a significant increase in ankle plantarflexion angle.

Step length and frequency

Five studies investigated the effect of backpack carrying on step length and frequency. Rezaei and colleagues stated that compared to bilateral carrying, unilateral carrying leads to a significant reduction in step length and a significant increase in step frequency per minute (21). Furthermore, Ebrahimpour and Naderi reported that with the increase in the weight of the backpack, the duration of the stance, swing, and double support phase increases and the length and frequency of the walking step decreases (25).

Ghamari Hoveyda and colleagues also reported that carrying a backpack equal to 20% of body weight compared to a non-load position increases step length and decreases step frequency (24). In addition, the study results by Namazizadeh and co-workers revealed that the frequency of steps in carrying a bag was higher while carrying a backpack weighing 10 and 15% of body weight compared to the load-free position and the length of the step was significantly reduced (20).

Rezaei and Babakhani observed a significant increase in step length and step frequency while carrying schoolbags with a weight greater than 10% of body weight (23). According to the results of studies, it could be concluded that unilateral carriage of a backpack and the increased backpack weight results in a reduction in step length and escalation in step frequency.

Symmetry index

One study investigated the effect of a backpack on symmetry index. By evaluating the symmetry of temporal-spatial gait parameters when carrying a backpack with different weights in unilateral and bilateral methods, Ebrahimpour and Naderi reported a significant difference in the symmetry of step time between walking without a backpack compared to carrying a backpack weighing 10 and 15% of body weight (in both unilateral and bilateral positions).

In addition, a significant difference was reported in the symmetry of stride length between walking without a backpack compared to with a backpack weighing 10% of the bodyweight (unilateral position) and 15% of the body weight (both). In addition, carrying a backpack unilaterally reduces the symmetry index compared to carrying a bilateral backpack. When carrying a backpack with 15% body weight, this difference is significant in both symmetry indices, namely step frequency and step length (25).

According to this study, step time and stride length symmetry decrease significantly with carrying a backpack over 10% of the weight and carrying a unilateral backpack with 15% of body weight.

Ground vertical force

Two studies were found investigating the effect of a backpack on the vertical ground force. Ahmadi-Goodini and co-workers examined the effect of carrying a backpack on the variables of ground reaction force in different weights and gradients in students and reported that gradient (smooth, 15% high, and 15% low with 10% and 15% of body weight) had a significant effect on the variables of the first and second peaks, loading rate, push-up rate and time to peak while walking. The vertical force was higher in the downhill, but the effect of backpack weight on these variables was not significant (22). Moreover, by examining the effect of schoolbag placement height (fifth lumbar vertebra and twelfth thoracic vertebra) of two types of backpacks (conventional standard backpack and modified three-compartment backpack) on the kinetic and kinematic variables of students during walking, Jadidian and Shirzad reported a significant difference between the backpack-low and backpack-middle in the first maximum ground reaction force variable (first peak). A significant difference was also seen in the variable of the second maximum ground reaction force (second peak) in backpack-middle and modified backpack-low. In addition, there was a significant difference between the minimum vertical force variable between backpack-low and both modified backpack-middle and backpack-low (19). A downward slope and backpack position on the lumbar spine seems to significantly increase the vertical force.

Rectus abdominus muscle

Three studies examined the effect of school bags on rectus abdominus muscle activity. Hoseini and colleagues examined the effect of carrying backpacks with different weights on the electromyographic activity of this muscle. They observed that carrying backpacks weighing 12.5 and 14% of the body weight significantly reduced rectus abdominus activity whereas carrying backpacks with 9.5 and 11% had no significant effects on the activity of this muscle. The activity of the left and right sides was the same in all the positions (26). Additionally, they reported that carrying a shoulder bag on the right side and carrying a handbag with the right-hand leads to a significant increase in the activity of this muscle on the left side and a significant decrease on the right side. In addition, carrying a backpack significantly increased the activity of this muscle and similar activity of both sides was observed (27).

In their study, Ebrahimi and colleagues. observed that carrying a backpack led to a significant difference in the activity between the two sides and a significant increase in the left side; however, carrying a handbag and a shoulder bag led to a significant increase in the contralateral side and a significant decrease in ipsilateral muscle (28). In general, it could be concluded that carrying a backpack weighing more than 12.5% of the body weight triggers a significant increase in rectus abdominus muscle activity. Carrying unilateral bags also leads to increased activity of this muscle on the opposite side and asymmetrical activity.

Paraspinal muscles

Three studies were found in this regard. Hoseini and co-workers reported that carrying backpacks of 12.5% and 14% of the body weight led to a significant increase in paraspinal muscle activity. A significant difference was observed between the activity of the right and left side activity. Meanwhile, carrying backpacks weighing 9.5% and 11% of the body weight had no significant effects on the activity of this muscle (26).

Furthermore, they studied electromyographic changes in student›s trunk muscles in three conditions, using handbags, backpacks, and shoulder bags with a relative weight of 10% of the body weight and reported that backpacks caused a slightly significant decrease in paraspinal activity. Based on the results of this study, there were no significant differences between the right and left muscular activity, but carrying a shoulder bag and handbag on the right side led to a significant increase in muscle activity on the left side and a significant decrease on the right side (27).

Ebrahimi and colleagues observed no significant differences between the two sides when carrying a backpack. Still, the handbag and shoulder bag led to a significant increase in the muscles of the opposite side and a significant decrease in that of the carrying side (28). Therefore, carrying a backpack with a weight of more than 12.5% of the body weight significantly increases the paraspinal muscle activity. Furthermore, carrying unilateral bags reduces the activity of this muscle on the carrying side and increases its activity on the opposite side.

Leg muscles

Two studies investigated the effect of a backpack on lower limb muscle activity. Ghamari Hoveyda and colleagues reported that the activity of the rectus femoris, vastus medialis, vastus lateralis, biceps femoris, and medial gastrocnemius muscles while carrying a backpack increased significantly with the rise in the weight of the backpack. Meanwhile, no changes were observed in tibialis anterior muscle activity. The median frequency of the rectus femoris, vastus lateral, biceps femoris, and medial gastrocnemius muscles also decreased significantly in line with the weight of the backpack, indicating that these muscles suffered from muscle fatigue as the weight of the backpack increased. However, no changes were observed in the middle frequency in vastus lateralis and tibialis anterior muscles (24). According to these studies, the activity of leg muscles, except for that of tibialis anterior, and fatigue of these muscles, except for that of vastus medialis and anterior tibialis, increase along with the rise in the weight of the backpack.

4. Discussion

The present review study focused on investigating the effect of school bags on electromyographic activity of muscles and kinematic and kinetic parameters during walking in Iranian students. In this regard, studies in this field were categorized based on different biomechanical factors and different muscles.

The results revealed that different factors related to school bags significantly affect various biomechanical factors and muscular activity. In addition, discrepancies were observed in the results of the studies, which could be due to the difference in the sample size and the length of carrying time.

Given the information gathered in this study, the following results could be expressed in relation to school bags on various biomechanical factors and muscular activity:

Neck angle: A backpack weighing more than 10% of the body weight and placement of the backpack in the lumbar region cause an increase in neck angle.

Trunk angle: A backpack with a weight of more than 10% of the body weight and unilateral carrying of the backpack can increase trunk angle.

Knee angle: Carrying a backpack weighing more than 15% of the body weight and carrying it unilaterally increases the flexion angle of the knee while walking.

Ankle angle: Increased weight of the backpack increases the dorsiflexion angle of the ankle.

Step length and frequency: Increase in backpack weight and unilateral carrying of the bag is associated with a reduction in step length and rise in step frequency.

Symmetry index: A backpack weighing more than 15% of the body weight and unilateral carrying of the backpack changes the symmetry index while walking.

Vertical force: The downward slope of the walking surface and the backpack placement on the lumbar region can increase the vertical ground reaction force while walking.

Rectus abdominus muscle activity: Once the backpack weight is more than 12.5% of the bidy weight, carrying unilateral school bags, significantly affects the activity of the rectus abdominus muscle.

Paraspinal muscle activity: A weight of more than 12.5% of the body weight attributes to the increased activity of these muscles and unilateral carrying of a school bag is associated with increased activity of the opposite muscles.

Leg muscle activity: The weight of the backpack has a significant effect on the lower limb muscle activity.

Given the results of previous studies, the effect of different factors related to backpack on different biomechanical variables and muscular activity is quite evident; Using a backpack, in addition to weight, other factors, such as placement, should also be considered. A heavy backpack could lead to serious consequences for a person by altering biomechanical variables and muscular activity. Research has shown that changes in the curvature of the spine lead to tensile and shear forces and ultimately damage the spine (29). Increased knee flexion angle also increases the risk of meniscus injury. In addition, reduction in the number of steps decreases the time a person spends on the ground, causes improper transfer of force due to gravity, and increases the risk of sprain injury (2). Altered mechanical force on the lower limbs may also be associated with weight-related abnormalities in the lower extremities (30). In addition, using unilateral bags increases the activity of the muscles of the opposite side to prevent lateral flexion on the side of the bag holder, which leads to gait imbalance and lateral deviation (31, 32). Nevertheless, the critical point is that the effects of these changes in children and adolescents in adulthood may predispose the students to certain musculoskeletal disorders in the future (33).

Since most studies have focused on the weight of the backpack, it is essential to further investigate the relationship between other factors, such as the slope of the surface, type of backpack, mode of carrying, time of carrying on biomechanical factors, and muscle activity. Moreover, the majority of studies have examined the muscle activity of the trunk; hence, further studies are needed to explore the muscles of the lower and upper limbs. In addition, it could be suggested that further investigation be conducted on middle and high school age groups.

5. Conclusion

Examination of the results of various studies shed light on the fact that various factors, such as bag weight, the slope of the surface, placement height, and type of bag or backpack, could affect biomechanical variables and muscle activity. For this reason, it is recommended that further attention be paid to these factors when designing and using schoolbags for Iranian students.

Conflict of interests: None declared.

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