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# The influence of different ways of backpack carrying on pelvic kinematics during gait among male students

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## Abstract

**Background:** Carrying a backpack incorrectly can have an impact on the musculoskeletal system. The aim of this study was the influence of different ways of backpack carrying on pelvic kinematic during gait among male students.

**Methods:** Twelve boys aged 7–12 years from Yazd participated in this study. Using a three-dimensional motion analysis system, unilateral and bilateral evaluations of walking while carrying backpacks were conducted. The data were processed using MATLAB software. The Shapiro-Wilk test was performed to determine data distribution, and the paired t-test was employed for statistical analysis ($p<0.05$).

**Result:** According to the research's findings, the two carrying techniques had similar amounts of anterior pelvic tilt. However, the unilateral backpack approach had slightly greater values for this angle. Due to the positioning of the body on the ground and the slower rate of thigh extension, the graph is downward throughout the stance phase of stepping, which comprises approximately the first 60% of the gate cycle. Additionally, the two carrying techniques in this range differ the most from one another. The levels of coordination variability differed by 30 to 40 degrees in various deciles between the two carrying tech. Furthermore, compared to the bilateral carrying approach, the unilateral carrying strategy had substantially higher hip rotation variability.

**Conclusion:** Generally, the results indicated that except for hip-thigh coordination during walking, there are no appreciable differences in the effects of various backpack carrying techniques on the risk factors for hip-thigh injuries. Except for pelvic-thigh coordination during walking while using various backpack carrying techniques, a significant difference was noticed.

**Keywords:** backpack, walking, coordination, variability, pelvic, pelvic-thigh injury

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## 1. Introduction

The most popular equipment for carrying daily work materials is a backpack, and mountaineers, soldiers, schoolchildren, and college students frequently utilize a range of backpacks for their diverse needs. Additionally, these people frequently carry an imbalanced weight when walking as part of their everyday lives and diverse occupations (1-3). Any consequence of continuous movement patterns during this period might result in musculoskeletal illnesses in the future (3-5). Carrying a backpack incorrectly may have an impact on the musculoskeletal system, notably walking characteristics. According to various elements of the load and its impact on the spine, there is a connection between the load and forward bending of the trunk, which is thought to be a risk factor for postural disorders (6,7). When carrying a hefty backpack, the musculoskeletal system tilts the pelvic anteriorly when walking to compensate for the weight of the load. Furthermore, incorrectly holding this load causes the pelvic to compensate by rotating inward, which affects the spine's anterior-posterior supporting structure and produces discomfort and musculoskeletal pain (8). The pelvic, which is a component of the spine and links the spine to the lower limb, supports the body, helps a person maintain their weight while sitting, and transfers weight from the spine to the lower limb (9,10). Compensatory pelvic motions due to increased load result in gait alterations, additional movements at superior levels of the spine, as well as increased torque and linear forces on bodily structures (8). These changes may contribute to orthopedic, musculoskeletal, or soft tissue injuries. The system of the spine, pelvic, and thighs works together as a coordinated functional unit to adjust the body's posture (11). When performing weight-bearing activities, the distal and proximal joints' pelvic and kinetics might be affected by defects in any element in the human body's movement chain (12). Some transitional stages in both legs are used to explain the cycle of actions that make up walking (13). Both walking on the ground and walking on a treadmill can be used in walking analyses (14-16). Due to the significance of this assessment, several techniques may be divided into two broad pelvic and kinetics categories. Additionally, the kinematic analysis represents movement patterns under spatiotemporal variables without taking into account the forces responsible for movement generation (17-19). Given that human mobility is dynamic and that carrying a backpack while attending school is necessary, as well as the fact that children's musculoskeletal systems are less developed than those of adults, carrying a bag unilaterally will have an unnatural and damaging effect on these systems. This study focus on the influence of different ways of backpack carrying on pelvic kinematic during gait among male students.

## 2. Material and methods

### 2.1. Subjects

Twelve male teenagers (7–12 years old) from Yazd who had no anomalies in their lower limbs and were willing to take apart in the study and were fully aware of its goals were the participants.

### 2.2. Tools

Reflective markers, American-made Optitrack camera (DUO120), MATLAB software, German-made Treadmill (h/p/cosmos), one-millimeter-accurate seca brand stadiometer for measuring heights, and German-made Force plate with ten-gram accuracy.

### 2.3. Procedures

The article describes the method used to collect data on the movement of subjects walking on a treadmill with a backpack. The method involved the following steps:

1. Participants were given 10 minutes to get used to the treadmill and practice moving and walking at their speed.
2. The treadmill's speed was increased and decreased until it reached the required speed for each individual.
3. The individual had their lower limbs marked with reflective markers attached to a hard body for the cluster markers.
4. Static data of the subject was obtained before the treadmill was turned on, and then the treadmill was switched on and its pace was adjusted to the person's preferred speed.
5. A minute's worth of walking data was gathered in a method that captures 20 full cycles of walking.
6. The data gathering was finished after determining the movement's variability, and the procedure was repeated at least three times.
7. MATLAB software was used to process the data, and the markers' three-dimensional coordinates were accessible at this point.

8. The data were smoothed and the noise was reduced using the Gaussian filter, and the empty spaces between the data were filled using the cubic spline approach and fitted to the markers' information.
9. The procedure of identifying gate cycles was carried out in the subsequent stage, which involved performing gate event detection on the data.
10. Finally, the inverse pelvic procedure was applied to the data, and the marker data was transformed into the angle of the joints in three dimensions by choosing an appropriate number of cycles.

The method was designed to ensure that the data collected was accurate and consistent across all subjects.

### 2.4. Statistic

The data collected was categorized using descriptive statistics such as mean and standard deviation. Inferential statistics were also used to analyze the data. The three different ways of carrying a backpack were compared using the paired t-test after performing the Shapiro-Wilk test to determine whether the data distribution was normal. A confidence level of 0.05 was taken into account for all tests. The SPSS26 software was used to analyze and examine the statistical differences between the methodologies.

## 3. Results

Table 1 shows the general characteristics of the participants.

**Table 1: General characteristics of the subjects**

| Feature | Mean ± standard deviation |
|---|---|
| Age (year) | 9.07 ± 0.82 |
| Height (cm) | 133.5±9.36 |
| Mass (kg) | 30.44±10.0 |
| BMI | 3.80±16.73 |

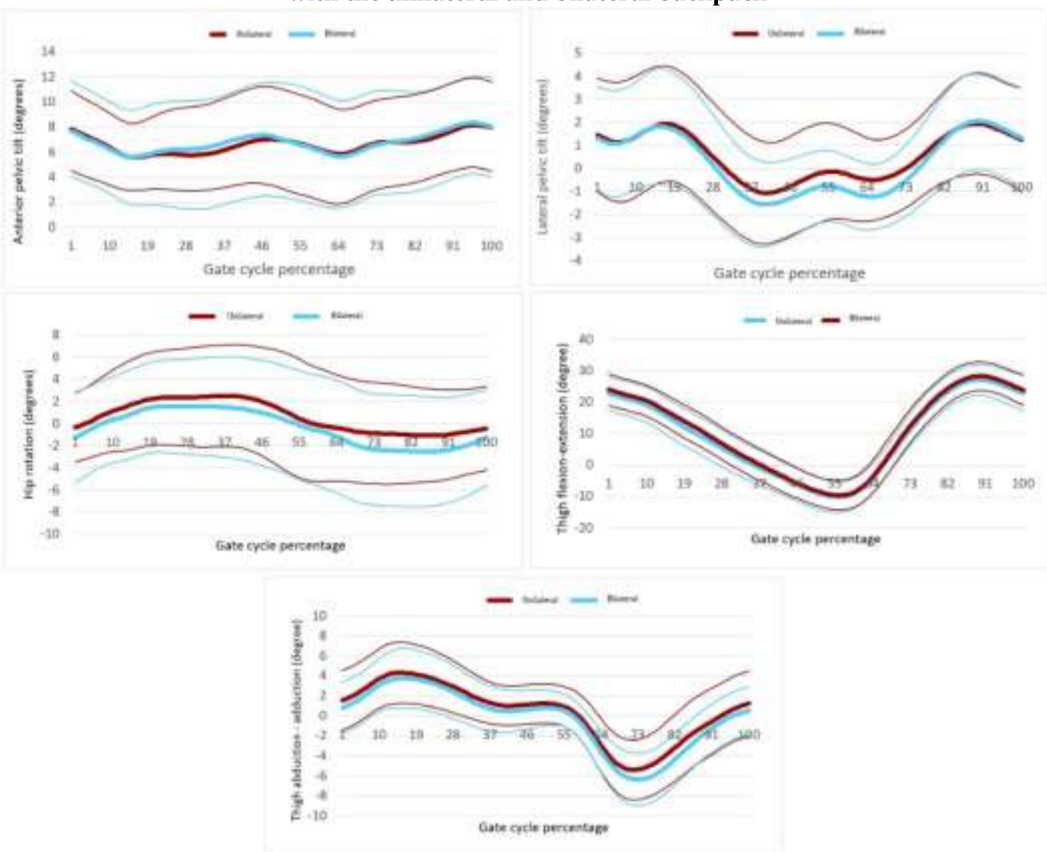
The normality of the distribution of the hip and thigh kinematic variability data is discussed in table 2 as shown, everything in the data was normal.

**Table 2: Normality of data distribution**

| Variables | Unilateral backpack | Bilateral backpack |
|---|---|---|
| Variability of anterior hip tilt during walking | 0.992 | 0.512 |
| Variability of lateral hip tilt during walking | 0.556 | 0.209 |
| Variability of hip rotation during walking | 0.502 | 0.458 |
| Thigh flexion-extension variability during walking | 0.448 | 0.185 |
| Variability of hip abduction-adduction during walking | 0.991 | 0.169 |

The study calculated the kinematic data of two joints in five degrees of freedom and normalized it following the gait cycle to determine the variability of hip and thigh pelvic when walking and carrying backpacks, both unilateral and bilateral. Figure 1 shows the movement patterns of the pelvic and thigh in the sagittal and frontal planes and the pelvic in the horizontal plane during a complete cycle of the right foot gait. The graphs also show deviations of one standard deviation from the mean that are both positive and negative.

**Figure 1: The mean and standard deviation of hip motions during 10 consecutive cycles of walking with the unilateral and bilateral backpack**

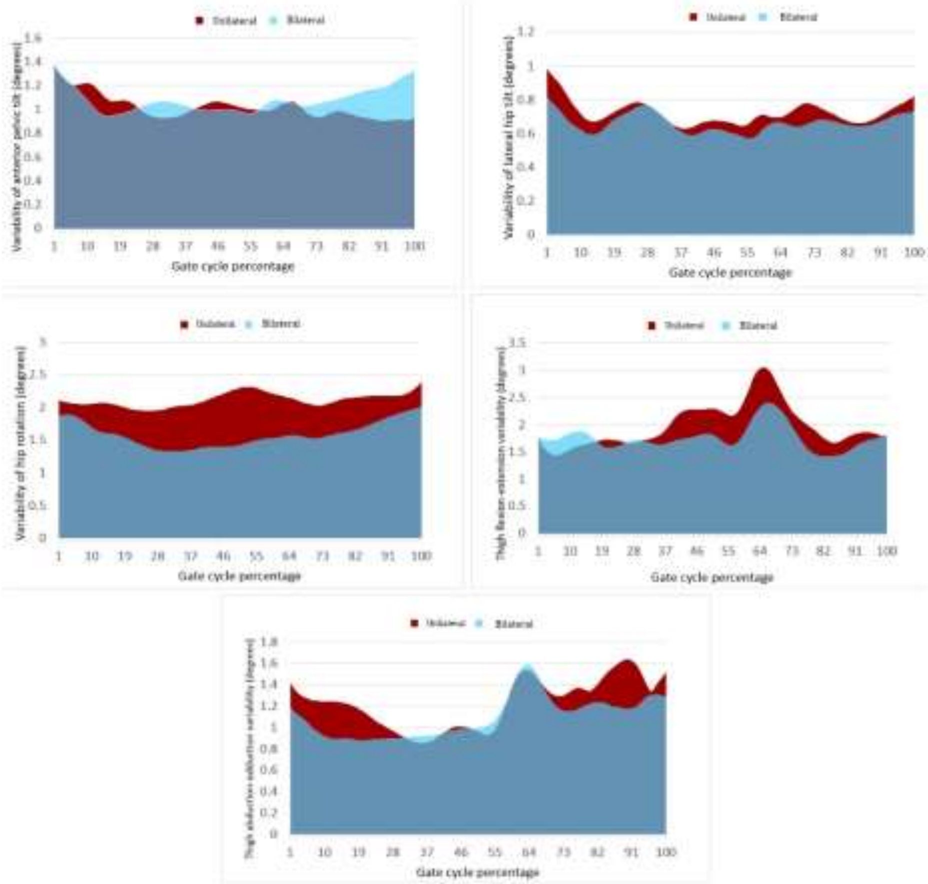



The statistical comparison between the two techniques of carrying a backpack did not focus on kinematic aspects because examining hip and thigh pelvic was not a goal of the study. However, it was necessary to determine the movement pattern of the hip and thigh in various degrees of freedom before calculating the kinematic variability. As a result, this section of the study calculated and displayed the pelvic of the joints involved.

Figure 2 illustrates how the hip and thigh's range of motion might vary when a person is walking and carrying a unilateral or bilateral backpack. The variable values of the anterior-posterior pelvic tilt in the two specified carrying ways are similar to one another, as shown in figure it can be seen from table 3 that there is no statistically significant difference between the two carrying methods in the integral variability of anterior-posterior hip tilt, although there was more variability in the stance phase of unilateral backpack carrying and the swing phase of bilateral backpack carrying than the other. Table 3 shows that there was no statistically significant difference between the two methods of carrying a backpack in the integral of pelvic lateral tilt variability.

The variation in lateral pelvic tilt during carrying using the two approaches is depicted in figure 2. As can be observed, the unilateral transport approach has higher variability values over all gate cycles than the alternative method.

Figure 2: The variability of anterior pelvic tilt during gait with unilateral and bilateral backpacks



The variation in hip flexion-extension during unilateral and bilateral backpack carrying is depicted in figure 2. As can be observed, from around 15% of the gate cycle to the end, the unilateral transport approach is more variable than the bilateral transport method. Table 3 shows, however, that there is no statistically significant difference between the two techniques. The variation in thigh abduction-adduction during walking and while carrying a backpack is depicted in figure 2. As shown, the unilateral transport approach exhibits greater variability at the start and stop of the gate cycle than the bilateral transport method. This increase results in a statistically significant difference between the two techniques, as shown in Table 3.

**Table 3: The mean, standard deviation and P-values were obtained from comparing the integral variability of hip and thigh pelvic in the unilateral and bilateral backpack carrying**

| **Variables** | **Unilateral backpack** | **Bilateral backpack** | P-Value |
|---|---|---|---|
| | Mean ± standard deviation | Mean ± standard deviation | |
| Variability integral of anterior pelvic tilt during gait | 0.36 ±1.02 | 0.16±1.07 | 0.54 |
| Variability integral of lateral hip tilt during gait | 0.12±0.72 | 0.17±0.66 | 0.33 |
| Variability integral of hip rotation during gait | 0.63±2.12 | 0.38±1.59 | *0.015 |
| Variability integral of hip flexion-extension during gait | 0.86±1.98 | 0.37±1.76 | 0.867 |
| Variability integral of abduction - hip adduction during gait | 0.25±1.23 | 0.27±1.10 | *0.047 |

## 4. Discussion

Research comparing one-way and two-way backpack carrying methods among students has shown that the most significant difference in hip rotation occurs when wearing a one-way backpack. The range of motion of hip rotation is significantly increased when wearing a backpack on one side compared to using a backpack on both sides. Previous studies have primarily focused on the weight of the backpack and have indicated that even with a heavier load, there is a significant biomechanical compensation. Carrying a backpack bilaterally shifts the subject's center of gravity backward, leading to increased hip tilt or forward bending in order to maintain an upright posture. Carrying a backpack on one side moderately increases the flexion and extensor angle of the thigh, but there is no significant difference compared to carrying it on both sides. Previous research has also noted the pelvic tilt when using either one-way or two-way backpack carrying methods, and our study confirms that the anterior tilt of the pelvis increases when using a one-way backpack, although this increase is not statistically significant. Perrone et al. (2018) reported that compared to walking without a backpack, wearing a bilateral or unilateral backpack increases hip inclination (20). However, Obeidat et al. (2023) stated that the amount of hip angular deviation and rotation during the walking cycle was not significantly different across the three states (21). When carrying a backpack in one direction, oblique standing is increased compared to normal walking. Perrone et al. found that changes in range of motion only occurred when youth carried a shoulder bag placed at waist level instead of a regular backpack (20). The subjects leaned laterally towards the side where the backpack was carried, which was predicted to reduce hip rotation when lying down. When walking with a backpack, there is increased contraction of the trunk muscles to provide static and dynamic stability, thereby reducing hip rotation. Hip rotation when carrying a backpack on one side may be attributed to standing in a tilted manner. In general, carrying a two-way backpack minimizes the muscular demands on the spine (22), while carrying a backpack on one shoulder increases lateral bending of the spine (23). Therefore, individuals who consistently use one-sided carrying techniques may be prone to increased muscle activity on the opposite side, which places greater strain on the vertebral structures (24,25). Among the limitations of this study, we can mention the lack of accurate information about the mental and psychological conditions of the subjects on the day of the test, the lack of access to groups with a large number of samples, and the lack of information about the motivation of the subjects on the day of the test. It is also suggested that in future research, the effect of the duration of backpack carrying on the postural posture is investigated and the degree of involvement of different muscles is determined by accurate tools such as an electromyogram while carrying the backpack.

## 5. Conclusion

In conclusion there is a significant difference in hip rotation during gait among male students. And unilateral carrying cause more rotation in hip. It has been observed that the use of one-way backpacks leads to increased thigh rotation in children. This rotational movement is a natural response to maintain balance and cannot be avoided. However, it also results in increased muscle activity on one side of the body. If this situation persists over a long period or happens repeatedly, it can exert physiological pressure and increased stress on the muscles, ligaments, and bones of the pelvis, thighs, and spine in teenagers.

Consequently, there is a possibility of skeletal-muscular injuries such as back pain, muscle tension, numbness, and chronic fatigue.

Therefore, it is strongly recommended that students, parents, physical education teachers, and school officials pay special attention to how students carry their school bags in order to mitigate these potential issues.

## Declarations

### Ethical Considerations

### Compliance with ethical guidelines

There were no ethical considerations to be considered in this research.

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### Authors' contributions

All authors equally contributed to preparing article.

### Conflicts of interest

The authors declared no conflict of interest.

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