Health Promotion and Physical Activity
ISSN 2544-9117 ▪ 2023; 25 (4): 16-21
doi: 10.55225/hppa.573

HPPA • 2023; 25 (4): 16-21

Changes in gait parameters and pelvic movement during gait under the influence of light loads carried symmetrically or asymmetrically – preliminary research

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Original article

Abstract

Introduction: Walking is one of the basic human activities. Taking care of the correct gait pattern is important for maintaining proper body posture and preventing dysfunctions of the musculoskeletal system. Since walking often involves carrying a load, the study aimed to evaluate changes in gait parameters and pelvic movement during gait under the influence of light loads carried symmetrically or asymmetrically in a bag or backpack.

Material and methods: The group of 11 women and 15 men aged between 19 and 25 were examined. The BTS G-Sensor device was used. The basic gait parameters were examined, as well as the symmetry coefficient of pelvic motion and the range of pelvic motion in each of the three planes. The test involving walking 30 meters was repeated four times: while walking without a load, with an additional load worn in a backpack on both shoulders, in a bag on the right shoulder, or in a bag worn diagonally on the left shoulder. Each time the load was equal to 10% of the participant's body weight.

Results: Walking speed, stride length to body height ratio, gait symmetry coefficient, and left and right foot propulsive speed did not change significantly during walking while carrying a load of 10% of body weight, regardless of the method of carrying a bag or backpack.

Conclusions: Although carrying a light bag or backpack does not change the basic gait parameters, even such a small load reduces the symmetry of pelvic movement and the range of pelvic motion in the frontal and transverse planes during walking.

Keywords

- walking
- pelvic movements
- gait symmetry
- carrying a bag
- backpack

Contribution

A – Preparation of the research project
B – Assembly of data
C – Conducting of statistical analysis
D – Interpretation of results
E – Manuscript preparation
F – Literature review
G – Revising the manuscript

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Article info

Article history

- Received: 2024-02-09
- Accepted: 2024-03-05
- Published: 2024-03-11

Publisher

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ul. Mickiewicza 8, 33-100 Tarnow, Poland

Conflict of interest

None declared.

Financing

This research did not received any grants from public, commercial or non-profit organizations.

Introduction

Walking is one of the basic human activities. It may change depending on age, gender, previous injuries, diseases, and whether we carry something in our hands or on our shoulders when walking. Research conducted with students shows that a backpack that is too heavy causes discomfort, fatigue, and back pain.[1] This is not only a short-term problem, but may affect the quality of health in the future.[2] Available literature indicates that a safe load (not harmful to the musculoskeletal system) is 10%–15% of body weight.[3] However, these standards were mainly set for children.[4] There is still a lack of knowledge about how much weight can be carried by an adult without Therefore, the main aim of the study is to assess the impact of carrying an additional load equal to exactly 10% of the participant's body weight, carried in a backpack and in a bag worn in two different ways, on the symmetry of pelvic movement during walking. We examined pelvic motion in the sagittal, frontal, and transverse planes. The practical goal was to find an answer to the question: Which of the proposed ways of carrying weight disturbs the pattern of pelvic mobility the least?

Materials and methods

Young adults aged between 19 and 25 were invited to participate in the study and 31 people applied. All of them were informed about the research plan and agreed to participate in the project. The inclusion criteria were good health and mental well-being on the day of the examination, the absence of serious postural deformities or postural-related diseases (congenital skeletal deformities, ankylosing spondylitis, etc.), and the absence of musculoskeletal injuries in the last month (information obtained from the interview). Disqualification criteria were: lower limb length asymmetry of more than 1.5 cm or scoliosis (assessment by the therapist before starting the study). Due to not meeting the exclusion conditions, 5 people were excluded from the study. Ultimately, the study group consisted of 26 people (11 women, 15 men).

The research was conducted by the principles of the Declaration of Helsinki. Each participant's body weight and height were measured, based on which the BMI was determined. Then the main examination began. The BTS G-Sensor device with G-Studio software was used to assess the symmetry and mobility of the pelvic movement during walking. This device has three-axis accelerometers, three-axis magnetic field sensors, and three-axis gyroscopes that allow obtaining information about the movement. The Walk protocol was used to evaluate gait analysis. The basic spatiotemporal parameters were analyzed, such as speed, left-right step length/ height (an indicator assessing stride length consisting of two steps, one taken with the right and the other with the left leg relative to body height), gait symmetry coefficient, propulsion velocity of the left and right foot. The range of motion and the symmetry coefficient of pelvic motion were assessed in the sagittal (pelvic tilt), frontal (pelvic obliquity), and transverse (pelvic rotation) planes.

Study procedure

Before starting the gait analysis, an appropriate load was prepared for each participant, which was exactly 10% of the body weight. According to data described in the literature, this is a weight that does not cause excessive load on the musculoskeletal system.[1] A load in the form of sandbags was placed, depending on the stage of examination, in a backpack or bag.

Gait analysis began by placing a belt around the participant's hips and placing the sensor in the belt pocket. The sensor was placed on the spine, between the L5 and S1 vertebrae. The gait analysis test was performed four times:

1. Test 1 – walking with a free, natural rhythm without additional load (walking distance of approx. 30 m).
2. Test 2 – walking with a free, natural rhythm with an additional load carried in a backpack placed symmetrically on both shoulders (walk approx. 30 m long).
3. Test 3 – walking with a free, natural rhythm with an additional load carried in a bag on the right shoulder (walk approx. 30 m long).
4. Test 4 – walking with a free, natural rhythm with an additional load carried in a bag on the shoulder in a diagonal position, over the left shoulder (walk approx. 30 m long).

During gait analysis, participants were dressed in comfortable sports pants, a T-shirt, and sports shoes.

The analysis was performed in Statistica v13. Basic statistics were calculated. Due to the failure to meet the conditions for parametric tests, the Friedman ANOVA test and post hoc test were used to assess differences between repeated measurements. An alpha level of 0.05 was assumed.

Results

Table 1 provides basic data on the participants' age, body shape, and additional load.

Table 1. Age, somatic data, and the value of additional load

Value	$\bar{x}$	Me	Min	Max	SD
Age	21.81	22.00	19.00	25.00	1.65
Body height [cm]	175.23	174.50	162.00	193.00	8.10
Body mass [kg]	77.46	75.35	52.80	120.00	15.26
BMI index	25.16	24.70	18.06	38.74	4.33
Additional load	7.75	7.54	5.28	12.00	1.53

$\bar{x}$ – mean; Me – median; Min – minimum; Max – maximum; SD – standard deviation.

No significant changes in basic gait parameters were observed in subsequent tests. The additional weight, regardless of how it was carried, did not significantly affect walking speed, stride length, gait symmetry coefficient, or propulsion velocity in the left and right lower limbs (Table 2).

Carrying an additional load in a backpack or bag did not significantly affect the symmetry and range of motion of the pelvis in the sagittal plane (Table 3).

Carrying the bag diagonally over the shoulder resulted in a significant reduction in the symmetry coefficient of pelvic movement in the frontal plane. Carrying a load, regardless of how the bag or backpack was worn, reduced the range of the pelvic obliquity motion in this plane. Although the mean and median values showed the greatest changes when wearing the backpack on both shoulders, a statistically significant difference was found when carrying the backpack on one shoulder (left side of the pelvis) or diagonally (right side of the pelvis) (Table 4).

Carrying an additional, asymmetric load while walking (a bag on the shoulder or a bag worn diagonally) significantly decreased the symmetry coefficient of pelvic movement in the transverse plane. However, a significant decrease in the range of motion of both sides of the pelvis was observed when walking with a backpack and with a bag worn diagonally (Table 5).

Table 2. Basic gait parameters while walking without a load (1), with an additional load worn in a backpack on both shoulders (2), in a bag on the right shoulder (3), or in a bag worn diagonally on the left shoulder (4)

Variable	Test number	$\bar{x}$	Me	Min	Max	SD	p
Speed of gait [m/s]	1	1.21	1.19	0.94	1.53	0.17	1 vs 2 $p > 0.05$ 1 vs 3 $p > 0.05$ 1 vs 4 $p > 0.05$
	2	1.23	1.23	0.86	1.55	0.17	
	3	1.23	1.20	0.91	1.64	0.19	
	4	1.22	1.20	0.82	1.59	0.20	
Stride length/body height [%]	1	75.29	74.00	60.00	93.20	9.29	1 vs 2 $p > 0.05$ 1 vs 3 $p > 0.05$ 1 vs 4 $p > 0.05$
	2	77.57	78.00	63.50	91.40	7.80	
	3	74.47	74.65	60.80	94.80	8.70	
	4	75.57	77.50	59.60	92.80	9.45	
Gait symmetry coefficient [%]	1	94.23	96.70	74.40	99.80	6.65	1 vs 2 $p > 0.05$ 1 vs 3 $p > 0.05$ 1 vs 4 $p > 0.05$
	2	97.30	98.35	90.00	100.00	2.59	
	3	92.20	94.55	59.40	99.80	8.96	
	4	90.94	93.20	70.90	99.90	7.84	
Left foot propulsive speed [m/s]	1	8.24	7.65	4.90	15.70	2.45	1 vs 2 $p > 0.05$ 1 vs 3 $p > 0.05$ 1 vs 4 $p > 0.05$
	2	10.11	8.95	5.40	22.90	4.55	
	3	9.22	8.80	5.10	19.50	3.26	
	4	9.00	8.35	4.60	23.60	3.74	

Variable	Test number	$\bar{x}$	Me	Min	Max	SD	p
Right foot propulsive speed [m/s]	1	8.03	7.35	5.70	14.20	2.33	1 vs 2 p>0.05 1 vs 3 p>0.05 1 vs 4 p>0.05
	2	9.56	8.25	4.40	23.20	4.48	
	3	8.53	7.15	4.00	21.70	3.95	
	4	7.83	7.20	4.10	14.40	2.85	

$\bar{x}$ – mean; Me – median; Min – minimum; Max – maximum; SD – standard deviation.

Table 3. Pelvic tilt in the sagittal plane while walking without a load (1), with an additional load worn in a backpack on both shoulders (2), in a bag on the right shoulder (3), or in a bag worn diagonally on the left shoulder (4)

Variable	Test number	$\bar{x}$	Me	Min	Max	SD	p
Pelvic tilt symmetry coefficient [%]	1	70.13	79.30	18.00	97.60	25.14	1 vs 2 $p > 0.05$ 1 vs 3 $p > 0.05$ 1 vs 4 $p > 0.05$
	2	71.35	84.45	9.80	100.00	27.68	
	3	70.62	78.20	4.00	98.00	24.59	
	4	70.03	79.25	6.50	99.70	26.31	
Pelvic tilt range of motion – left side [°]	1	2.33	2.05	0.50	4.70	1.14	1 vs 2 $p > 0.05$ 1 vs 3 $p > 0.05$ 1 vs 4 $p > 0.05$
	2	2.47	2.05	0.90	5.00	1.35	
	3	2.14	1.55	0.50	4.60	1.15	
	4	3.07	2.25	0.30	11.00	2.45	
Pelvic tilt range of motion – right side [°]	1	2.35	2.00	0.50	5.60	1.21	1 vs 2 $p > 0.05$ 1 vs 3 $p > 0.05$ 1 vs 4 $p > 0.05$
	2	2.47	2.10	0.90	5.10	1.35	
	3	2.19	1.70	0.50	5.50	1.25	
	4	2.86	2.35	0.20	7.30	2.00	

$\bar{x}$ – mean; Me – median; Min – minimum; Max – maximum; SD – standard deviation.

Table 4. Pelvic obliquity in the frontal plane while walking without a load (1), with an additional load worn in a backpack on both shoulders (2), in a bag on the right shoulder (3), or in a bag worn diagonally on the left shoulder (4)

Variable	Test number	$\bar{x}$	Me	Min	Max	SD	p
Pelvic tilt symmetry coefficient [%]	1	92.80	97.10	52.00	99.30	10.81	1 vs 2 $p > 0.05$ 1 vs 3 $p > 0.05$ 1 vs 4 $p > 0.05^*$
	2	82.76	95.05	1.20	99.80	26.78	
	3	85.85	91.95	33.80	99.50	16.31	
	4	74.50	85.10	4.60	99.60	26.37	
Pelvic tilt range of motion – left side [°]	1	3.97	3.75	2.20	7.50	1.39	1 vs 2 $p > 0.05$ 1 vs 3 $p > 0.05^*$ 1 vs 4 $p > 0.05$
	2	2.68	2.70	0.50	5.30	1.48	
	3	3.42	3.15	1.60	8.40	1.50	
	4	3.60	3.35	1.40	7.80	1.55	
Pelvic tilt range of motion – right side [°]	1	3.95	3.75	2.10	7.60	1.45	1 vs 2 $p > 0.05$ 1 vs 3 $p > 0.05^*$ 1 vs 4 $p > 0.05$
	2	2.77	2.65	0.50	5.20	1.45	
	3	3.45	3.10	1.40	8.30	1.55	
	4	3.53	3.25	1.30	8.40	1.66	

$\bar{x}$ – mean; Me – median; Min – minimum; Max – maximum; SD – standard deviation; * – statistically significant difference.

Table 5. Pelvic rotation in the transversal plane while walking without a load (1), with an additional load worn in a backpack on both shoulders (2), in a bag on the right shoulder (3), or in a bag worn diagonally on the left shoulder (4)

Variable	Test number	$\bar{x}$	Me	Min	Max	SD	*p*
Pelvic tilt symmetry coefficient [%]	1	93.45	98.70	16.90	99.90	16.86	1 vs 2 $p > 0.05$ 1 vs 3 $p > 0.05^*$ 1 vs 4 $p > 0.05^*$
	2	78.22	92.60	2.40	99.90	30.29	
	3	88.03	93.10	54.00	99.50	13.19	
	4	78.51	88.90	12.00	98.80	23.88	
Pelvic obliquity range of motion – left side [°]	1	10.19	10.65	4.10	19.20	4.06	1 vs 2 $p > 0.05^*$ 1 vs 3 $p > 0.05$ 1 vs 4 $p > 0.05^*$
	2	6.13	5.90	0.90	19.70	4.17	
	3	7.38	7.25	2.30	12.20	2.88	
	4	6.64	5.50	1.90	22.50	3.93	
Pelvic obliquity range of motion – right side [°]	1	9.81	9.75	3.40	19.50	4.31	1 vs 2 $p > 0.05^*$ 1 vs 3 $p > 0.05$ 1 vs 4 $p > 0.05^*$
	2	6.01	4.45	1.00	20.20	4.24	
	3	7.50	7.25	2.10	13.40	2.89	
	4	6.57	5.60	2.00	22.60	4.16	

$\bar{x}$ – mean; Me – median; Min – minimum; Max – maximum; SD – standard deviation; * – statistically significant difference.

Discussion

It was noted that a small load (not exceeding 10% of body weight) did not change the basic gait parameters or the gait asymmetry coefficient, regardless of how the backpack or bag was worn (symmetrically or asymmetrically). Neither the symmetry of pelvic tilt in the sagittal plane nor the range of pelvic movement in this plane was determined by the way the load was carried. However, it was observed that even such a small load decreased the coefficient of pelvic movement in the frontal plane (pelvic obliquity) and transverse plane (pelvic rotation). Also, the range of motion of the right and left sides of the pelvis in these planes was reduced compared to walking without a load.

The results obtained were compared with those of other authors. Smith et al.[5] analyzed gait with an additional load of 15% of body weight during backpack walking. The study group consisted of 30 women aged 22.4 ± 2.2. Gait was analyzed using the Oxford Metrics Vicon Clinical Manager system during three trials: gait without a backpack, gait with a backpack worn symmetrically over two shoulders, and gait with a backpack worn over one shoulder. The researchers' results indicate that during gait with an additional load of 15% of body weight carried in a backpack worn on both one and two shoulders, there is a significant decrease in pelvic range of motion in the frontal and transverse planes, which appears to be consistent with the results of our study.

The results of research by Hyung et al.[6] were similar. They analyzed gait in a group of 16 people aged 20.68 ± 1.9 years. They used the G-Walk device to assess gait, just like we do. The above-mentioned authors assessed walking over a 10-meter distance with an additional load of 5%, 10%, and 15% of body weight. Participants carried a bag or backpack in different ways: bag held in hand, bag worn on one shoulder, bag worn diagonally, backpack worn on both shoulders. It was shown that when walking with a bag on the shoulder, a bag worn diagonally, and while walking with a backpack worn on two shoulders, with the increase in the load carried (10%–15%), a significant decrease in the range of pelvic mobility in the transverse plane was observed. Additionally, the authors noted a tendency to increase pelvic mobility in the sagittal plane.

In turn, Kim et al.[7] observed basic gait parameters and changes in the center of pressure during walking without and with an additional 10% load placed in a bag placed diagonally. As in our research, the bag with the additional load was always placed on the left shoulder. 29 men aged 24.76 ± 9.21 participated in the study. The research was conducted using a Walk-way gait analyzer. The results indicate that wearing the bag diagonally reduces speed and significantly reduces stride length, but only on the left side of the body. These observations are in opposition to the results of our research.

It seems that additional weight carried in a backpack or bag may not only change the gait pattern but may also affect body posture and may be associated with pain. One third of students report that carrying a backpack causes back pain.[8] A 25% increase in the risk of lower back pain was observed for every 4 kg increase in estimated backpack weight.[9] Research by Chow et al.[10] conducted among 13 healthy adults aged 29 ± 3 indicates that after wearing a backpack weighing 10% of body weight, all spine curvatures deepen (cervical lordosis, thoracic kyphosis, lumbar lordosis), pelvic tilt, and the entire torso leans forward.

In turn, Hardie et al.[11] assessed changes in muscle activity after wearing a backpack and a bag with an additional load of 10% of body weight. The study group consisted of 12 women aged 20.6 ± 1.16 years. Gait analysis was performed during 5 trials: walking without load, walking with a backpack on both shoulders, walking with a backpack on one shoulder, walking with a bag on one shoulder, and walking with a bag worn diagonally. The authors noted significantly greater activity of the trapezius muscle on the side of the loaded shoulder and the erector spinae muscle on the opposite side. Walking with a backpack worn on both shoulders did not significantly affect the activity of the trapezius muscles.

Shamsoddinie et al.[12] conducted research among 213 students aged 12–14. They assessed the relationship between back pain and carrying load using the Nordic Musculoskeletal Questionnaire. The most common area of pain reported by adolescents was the shoulder girdle and neck. Even students who wore a school backpack weighing less than 10% of their body weight felt pain. This observation is also confirmed by studies by other authors.[13,14]

Taking into account the observations of other authors, in subsequent studies we will try to increase the number of participants, expand the age group to include older people, and supplement the observations with an interview regarding back pain and feelings related to comfort or discomfort experienced when carrying a bag or backpack.

Conclusions

Carrying a bag or backpack with a low weight (10% of body weight) does not change the basic gait parameters, but even such a small load reduces the symmetry of pelvic movement and the range of pelvic motion in the frontal and transverse planes while walking.

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