Effects of different baggage carrying methods on walking while wearing an arm sling in simulated hemiplegic stroke patients

Misato Makino, RPT, PhD¹, Akiyoshi Takami, RPT, PhD¹*, Fumitake Yamada, RPT, MS², Shiori Kakae, RPT, PhD³

¹) Hirosaki University Graduate School of Health Sciences: 66-1 Honcho, Hirosaki-shi, Aomori 036-8564, Japan
²) Feel Your Breath Co., Japan
³) Asakuraen Day Service Center, Japan

Abstract. [Purpose] We aimed to clarify the effects of different baggage carrying methods on the movement of the trunk and pelvis while walking with an arm sling in simulated hemiplegic stroke patients. [Participants and Methods] The participants were 14 healthy young adults. Measurements were obtained using a three-dimensional motion analysis device in the following order: normal walking, walking with an arm sling on the upper left limb, walking with baggage on the right side, vertical walking, and diagonal walking. The range of motion of the trunk and pelvis during one walking cycle was analyzed. [Results] The range of motion of the lateral tilt of the pelvis significantly differed between normal and vertical walking, as well as between normal walking and diagonal walking. A significant difference was observed in the range of movement in pelvic rotation during the three walking cycles—walking with baggage, vertical walking, and diagonal walking. The range of movement in pelvic rotation was seemingly smaller under other conditions compared to that in normal walking. [Conclusion] It was shown that walking with restrictions on the upper limbs, such as wearing an arm sling or carrying baggage, may impose slight restrictions on the lateral tilt as well as on the rotation of the pelvis.

Key words: Walking, Arm sling, Baggage carrying

INTRODUCTION

Many activities in daily life involve carrying baggage, and once a person with hemiplegic stroke acquires the ability to walk and resumes participating in society applied gait, or carrying baggage while walking (e.g., shopping and commuting to the hospital) is required. There are several reports on carrying baggage and walking¹⁻⁵, but most of them are based on the movements of healthy people, with very few on considering people with hemiplegic stroke. It has been reported that hemiplegic stroke patients often rotate their pelvis and upper trunk to the paralyzed side and tilt laterally throughout one walking cycle, and the relative angle change between the pelvis and upper trunk is larger than that of healthy participants⁶. This indicates that gait differs between hemiplegic and healthy people. In this context, we conducted a study on healthy adults with simulated hemiplegic stroke patients and reported that trunk sway varied depending on the method of carrying baggage⁷.

In addition to the difference in gait between hemiplegic and healthy people, subluxation of the shoulder joint is often observed in hemiplegic stroke patients. One of the ways to deal with this dislocation is by wearing an arm sling. Gait analyses with arm slings and shoulder orthoses for hemiplegic stroke patients reported that the load on the non-hemiplegic side eased,

*Corresponding author. Akiyoshi Takami (E-mail: a-takami@hirosaki-u.ac.jp)
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The participants included 14 healthy young adults (4 males and 10 females, age 20.5 ± 1.2 years, with height of 163.1 ± 9.0 cm, and weight of 55.7 ± 7.7 kg). Those participants with a medical history that interfered with the measurement (e.g., fractures of lower limbs, orthopedic conditions, etc.) were excluded. Participation in this study was voluntary and all participants provided written informed consent. This study was carried out after obtaining approval from the Ethics Review Board of the Hirosaki University Graduate School of Health Sciences (reference number: 2018-010).

The research design used in this study was analytical observational study. For the measuring the range of motion of the pelvis and trunk, a three-dimensional motion analysis device (Vicon Motion Systems, Vicon Nexus, Oxford, UK), which consisted of eight infrared cameras and three floor reaction force meters (AMTI, 400 mm × 600 mm) was used. The sampling frequency of the device was set to 100 Hz. Infrared reflective markers with a diameter of 14 mm were attached to 35 places on the participant’s body, according to the Plug-in Gait Full Body model set in the 3D motion analysis device. The analysis software Polygon 4 was used for the analysis.

While there are various types of arm slings, this study emphasized “ease of wearing”, such as the patients could wear the sling themselves. Okamura et al.14), for instance used a loop arm sling that was introduced as “an easy to make, wear and use, and excellent as a protective arm sling for the upper limbs in daily life”. For our study, we used two commercially available bandage supporters (T-15 bandage supporter 70 cm, Tagami Co., Ltd., material: polyester/rubber, Osaka, Japan) and attached them together as a loop arm sling. The latter was attached to the upper left limb, and the length was adjusted according to each participant so that the elbow joint flexion on the arm sling side was approximately 90°. As baggage, we used a commercially available mini bag (approximately 160 g) and placed a 1 kg strap-on weight in the bag. The bag was placed on the right side of the body.

A walking path of approximately 10 m was set to pass through the floor reaction force meter. The walking speed and stride were arbitrary, and walking was performed under the five conditions in the following order: 1) normal walking; 2) walking with arm sling (arm sling on upper left limb), 3) walking with baggage (arm sling on the upper left limb while carrying a bag with the right hand); 4) vertical walking (arm sling on the upper left limb, the shoulder strap of the bag in the right shoulder, and the bag hanging over the right iliac ridge); 5) diagonal walking (arm sling on the upper left limb, shoulder strap on the left shoulder, and the bag located over the right iliac ridge). After several practices under each condition, successful walking was measured five times for each condition, and the analysis was performed on each of them.

The period from the left heel contact to the next left heel contact was defined as one left walking cycle, and the analysis was performed on the left side of the walking cycle. The range of motion of the trunk and pelvis during one walking cycle (anterior-posterior tilt, lateral tilt, and rotation) on the left side was inspected. Regarding the trunk and pelvis, in this study, the left thorax calculated by Vicon Nexus was considered the trunk, and the left pelvis was considered the pelvis. The position of thorax was calculated based on the four markers placed between the clavicle, xiphoid process of the sternum, spinous process of the seventh cervical vertebra, and spinous process of the tenth thoracic vertebra, and the calculation was done at an angle to the floor of the measurement room. The position of pelvis was calculated based on the four markers placed on both sides of the anterior superior iliac spine and the posterior superior iliac spine, and the calculation was done at an angle to the floor of the measurement room similar to the thorax. For both the trunk and pelvis, the maximum and minimum values during one walking cycle on the left side were calculated for anterior and posterior tilt, lateral tilt, and rotation. The difference between these values was regarded as the range of motion during one walking cycle on the left side.

For statistical analysis, Statcel 3 (OMS Inc., Saitama, Japan) was used, multiple comparison tests (paired t-test and Shaffer’s correction) were used between each condition, and the significance level was set at 5%.

RESULTS

Table 1 shows the results of the range of motion of the trunk. No significant differences were observed among the five conditions in terms of the range of motion of the anterior and posterior tilts, lateral tilt, and rotation of the trunk, as well as
the anterior and posterior tilts of the pelvis.

Table 2 shows the results of the range of motion of the pelvis. Pelvic tilting motions were $10.7 \pm 3.0^\circ$ for normal walking, $9.8 \pm 2.5^\circ$ for walking with an arm sling, $9.7 \pm 2.4^\circ$ for walking with baggage, $9.0 \pm 1.9^\circ$ for vertical walking, and $9.6 \pm 2.5^\circ$ for diagonal walking. Significant differences were observed between normal walking, vertical walking, and diagonal walking (both $p<0.05$).

Similarly, the pelvic rotation was $14.9 \pm 6.9^\circ$ for normal walking, $11.6 \pm 4.3^\circ$ for walking with an arm sling, $11.9 \pm 6.4^\circ$ for walking with baggage, $10.7 \pm 4.8^\circ$ for vertical walking, and $10.1 \pm 5.5^\circ$ for diagonal walking. There was a significant difference between normal walking, walking with baggage, vertical walking, and diagonal walking, and walking with baggage, and diagonal walking (normal walking and diagonal walking were $p<0.01$, and others were $p<0.05$). Compared with normal walking, the range of motion of pelvic rotation tended to be smaller under other conditions.

**DISCUSSION**

Summarizing the contents of six books\(^{12, 15-19}\) that describe the movement of the trunk and pelvis during walking, the trunk has a rotation of approximately $5-9^\circ$ and does not require the anterior and posterior tilts and the lateral tilt. The pelvis tilts forward by $4^\circ$, tilts backward by $4-5^\circ$, rotates by about $4-5^\circ$ on the same side as well as the contralateral side, and by approximately $8-10^\circ$ overall.

In the results of the range of motion in the anterior and posterior tilts, lateral tilt, and rotation of the trunk shown in Table 1, no significant differences were observed among the five conditions. In addition, the numerical values were approximate values, which were not significantly different from those in the referenced books. The results of the range of motion in the anterior and posterior tilts, lateral tilt, and rotation of the pelvis shown in Table 2 were not significantly different from the values in the referenced books; however, significant differences were noted in the range of motion in the lateral tilt and rotation. In lateral inclination, a significant reduction in the range of motion in vertical walking and diagonal walking was noted compared with normal walking; however, the difference was only as small as less than $2^\circ$. As for rotation, its range of motion tended to be smaller under other conditions compared to normal walking. This tendency became stronger in vertical walking and diagonal walking.

In the lateral tilt of the trunk and pelvis, vertical walking had small values, but with little difference. Based on the subjective opinions of the participants, vertical walking was the most difficult because the baggage was about to slip off their shoulders. To prevent the baggage from slipping off, the participants raised their right shoulder or applied force in the adduction direction of the right shoulder joint to interpose the baggage between the right arm and the trunk. As such, we assumed that this would reduce the range of motion in the lateral tilt of the trunk; however, the results showed only slight differences. We believe that because the participants were healthy young adults, they were able to respond and walk without significantly changing the movement of their trunk.

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**Table 1.** The range of motion of the trunk (unit: °)

|                  | 1) Normal walking | 2) Walking with arm sling | 3) Walking with baggage | 4) Vertical walking | 5) Diagonal walking |
|------------------|-------------------|--------------------------|------------------------|---------------------|---------------------|
| Anterior and posterior tilts | $3.9 \pm 0.8$ | $4.4 \pm 1.2$ | $4.2 \pm 1.5$ | $4.6 \pm 1.8$ | $4.1 \pm 1.1$ |
| Lateral tilt     | $3.1 \pm 1.2$ | $2.9 \pm 0.8$ | $3.1 \pm 0.8$ | $2.7 \pm 1.4$ | $2.8 \pm 1.3$ |
| Rotation         | $7.8 \pm 1.4$ | $7.7 \pm 1.9$ | $8.3 \pm 2.5$ | $9.6 \pm 3.8$ | $8.3 \pm 2.9$ |

Values are shown as mean ± SD.

**Table 2.** The range of motion of the pelvis (unit: °)

|                  | 1) Normal walking | 2) Walking with arm sling | 3) Walking with baggage | 4) Vertical walking | 5) Diagonal walking |
|------------------|-------------------|--------------------------|------------------------|---------------------|---------------------|
| Anterior and posterior tilts | $3.0 \pm 0.6$ | $3.0 \pm 0.9$ | $3.2 \pm 1.5$ | $2.7 \pm 0.9$ | $2.9 \pm 0.7$ |
| Lateral tilt     | $10.7 \pm 3.0$ | $9.8 \pm 2.5$ | $9.7 \pm 2.4$ | $9.0 \pm 1.9$ | $9.6 \pm 2.5$ |
| Rotation         | $14.9 \pm 6.9$ | $11.6 \pm 4.3$ | $11.9 \pm 6.4$ | $10.7 \pm 4.8$ | $10.1 \pm 5.5$ |

Values are shown as mean ± SD.

*p<0.05, **p<0.01.
The participants also commented that it was difficult to rotate the trunk because the arm sling prevented them from swinging their arms. Elfman stated that the upper limb movement pattern was the exact opposite of the other physical movement patterns, which allowed the lower limbs to perform the necessary movements without significant trunk rotation. It has also been reported that the pelvis and trunk performed opposite rotation movements during walking, and this contrasting rotation movement contributed to efficient walking. No significant differences were observed, but compared to normal walking, the range of motion during trunk rotation slightly increased, and the range of motion during pelvic rotation decreased in vertical walking and diagonal walking. We posit that the range of motion during trunk rotation decreased and the range of motion during pelvic rotation increased because the upper limb on one side was fixed by the arm sling and the baggage was located near the trunk. However, although participants noted the difficulty in rotating, there was a slight difference in the range of motion, which we believe could be handled by healthy young adults.

Walking with restrictions on the upper limbs, such as wearing an arm sling or carrying baggage, may restrict the lateral tilt and rotation movement of the pelvis. In particular, this tendency became stronger when walking with baggage on the trunk, such as in vertical walking and diagonal walking. However, the difference was at most 5° or less, which was so small that it was difficult to confirm through observation.

This study targeted 14 healthy young adults and examined the effects of wearing an arm sling, and carrying baggage while wearing an arm sling, in simulated hemiplegic stroke patients. The motion of the trunk and pelvis was examined during walking, using a three-dimensional motion analyzer. Compared to normal walking, walking with restrictions on the upper limbs (e.g., wearing an arm sling or carrying baggage) may restrict the lateral tilting and rotation of the pelvis. This tendency became stronger when suspending the baggage vertically, diagonally, or placing it near the trunk. However, since this study solely targeted healthy young adults, further studies are necessary for hemispheric stroke patients in the future.

Conflict of interest
The authors have no conflict of interest.

REFERENCES

1) Naoi S, Katsuhira J, Maruyama H: Effects of backpack use on kinematics and kinetics of gait motion: young and elderly subjects. Rigakuryoho Kagaku, 2014, 29: 923–926 (in Japanese). [CrossRef]
2) Shima N, Kanai A, Takeyama T, et al.: Influence of bag carrying methods on hip joint during walking. J Aichi Phys Ther Assoc, 2013, 25: 10–14 (in Japanese).
3) Ozawa H, Matsuzaki T, Nakayama Y, et al.: Physiological responses of different carriage during level walking on a treadmill by healthy Subjects. Rigakuryoho Kagaku, 2010, 25: 909–912 (in Japanese). [CrossRef]
4) Abiko T, Murata S, Yomasaki K, et al.: Influence of different methods of carrying a load on gait parameters of healthy young adults. Rigakuryoho Kagaku, 2014, 29: 147–149 (in Japanese). [CrossRef]
5) Ozawa H, Matsuzaki T, Nakayama Y, et al.: Physiological responses of healthy subjects to holding two kinds of objects in front of the chest and wearing belts on the wrists during level walking on a treadmill. Rigakuryoho Kagaku, 2011, 26: 231–234 (in Japanese). [CrossRef]
6) Sakurai A, Yamamoto S, Tazawa E, et al.: Trunk movements during walking in hemiplegia due to stroke. Bull Jpn Soc Prosthet Orthot, 2007, 23: 54–64 (in Japanese).
7) Yamada F, Takami A, Makino M, et al.: The effect of the difference of baggage carrying methods in the hemiplegic assumed patients on trunk sway during walking. Physical Therapy Research, 2019, 36: 9–13 (in Japanese).
8) Ohashi N, Abe H, Seki T, et al.: Effect of wearing shoulder orthosis for upper limb suspension on gait of hemiplegic stroke patients with severe upper limb paralysis. Annual report of the Miyagi Physical Therapy Association, 2018, 29: 27–34 (in Japanese).
9) Yavuzer G, Ergin S: Effect of an arm sling on gait pattern in patients with hemiplegia. Arch Phys Med Rehabil, 2002, 83: 960–963. [Medline] [CrossRef]
10) Hwang YI, An DH: Immediate effects of an elastic arm sling on walking patterns of chronic stroke patients. J Phys Ther Sci, 2015, 27: 35–37. [Medline] [CrossRef]
11) Makino M, Takami A, Kakae S, et al.: Effects of an arm sling on the trunk and pelvis while walking. Clin Gait Anal Forum Jpn, 2019, 6: 1–7 (in Japanese).
12) Nakamura R: Fundamental kinesiology, 6th ed. Tokyo: Ishiyaku Pub, 2003, pp 384–389 (in Japanese).
13) Murray MP, Drought AB, Kory RC: Walking patterns of normal men. J Bone Joint Surg Am, 1964, 46: 335–360. [Medline] [CrossRef]
14) Okamura T, Takeshita A, Kawata M, et al.: Introduction of arm sling for subluxation of shoulder joint in patients with stroke hemiplegia. MB Med Rehabil, 2005, 49: 7–14 (in Japanese).
15) Perry J, Burnfiled JM: Gait analysis normal and pathological functional, 2nd ed. SLACK, (Takeda I (Supervised Translation) (2012). Perry Hoko bunseki: Seijo hoko to ijo hoko, Original work 2nd ed. Tokyo: Ishiyaku Pub, 2010, pp 83–92 (in Japanese).
16) Neumann DA: Kinesiology of the musculoskeletal system foundations for rehabilitation, 2nd ed, ELSEVIER. (Shimada T (Supervised Translation) (2012). Colored version. Kinkokkakukei no Kinesiology, Original work 2nd ed. Tokyo: Ishiyaku Pub, 2010, pp 706–715 (in Japanese).
17) Kirsten Göte-Neumann. Gehlen verstehen Ganganalyse in der Physiotherapie, Georg Thieme Verlag. (Tsukihiro K, Yamamoto S, et al. (Translated) (2005). Kansatsu ni yoru hoko bunseki, Tokyo: Igaku-Shoin, 2003, pp 68–80 (in Japanese).
18) Hatanaka Y: Checkpoints for normal movements. Hatanaka Y (ed.), PT OT bijunaretukisuto shisei dosa hoko bunseki (PT and OT Visual Text Posture, Movement, Walking Analysis) 1st ed. Tokyo: Yudosha, 2015, pp 32–43 (in Japanese).
19) Tateuchi H: Hoko (Walking). Ichihashi N (ed.), Shintai undo-gaku kansetsu no seigyo kinto kin kinto (Physical kinetics: joint control and muscle function). Medical View, 2017, pp 416–444 (in Japanese).
20) Elfman H: The function of the arms in walking. Hurn Biol, 1939, 11: 529–535.