Original

Effect of Trunk Rotation Exercises on Walking Ability in Post-stroke Hemiplegic Patients

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Abstract

Background: A previous study investigated trunk rotation exercises as physical therapy for improving walking ability of post-stroke hemiplegic patients.

Objective: To examine the association between improvement in swing motions on the paralyzed side and walking ability in post-stroke hemiplegic patients.

Methods: Post-stroke hemiplegic patients who could walk by themselves over 15 m without a lower extremity orthosis were included. Stride indices (step length and stride length), pitch index (cadence), balance index (step width), walking speed after trunk rotation exercises (passive exercises of rotation towards the paralyzed side of the lower trunk/rotation towards the unparalyzed side of the upper trunk/rotation towards the paralyzed side of the neck), and angles between trunk, pelvis, and hip joint when the heel on the paralyzed side touched the ground were analyzed.

Results: Step length, stride length, cadence, step width, walking speed, and anterior pelvic tilt angle increased when the heel on the paralyzed side touched the ground. The ability to propel the pelvis also improved.

Conclusion: Physical therapy, such as trunk rotation exercises, are effective in improving walking ability and anterior pelvic tilt motions during walking in post-stroke hemiplegic patients.

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—Key words—

post-stroke hemiplegic patients, walking motions, trunk rotation exercises

Introduction

Physical therapy in Japan seems to have been largely conducted by applying the therapeutic concept and pathophysiological findings that have been developed in Western countries, which are subjective and based on the clinical experiences of each physical therapist. In the actual practice, no optimal physical therapy has been established yet owing to the large difference in the practice among physical therapists to make clinical judgements based on scientific grounds, the concept of evidence-based medicine (EBM) was proposed by Guyatt (1991).Taking EBM into consideration, Japanese physical therapists have attempted to switch from conventional physical therapy based on clinical experience to evidence-based practice. However, interventions in the field of physical therapy are complicated and diverse, and clinical judgement based on the subjective concept leads to a difference in technique among physical therapists. The current situation makes the "standardization of assessment format by disease"/"construction of the evidence of the effectiveness of physical therapy" difficult in the field of physical therapy (Kimura, 2007).

Needless to say, walking ability in post-stroke hemiplegic patients is a factor that determines activities of daily living, and stable walking ability needs to be achieved for the improvement of activities of daily living. In several studies (Ezure et al, 2010; Nagasawa, 2013; Hachiya et al, 2009; Verheyden et al, 2007), the impairment of trunk function seems to be one of the factors that impede improvement in walking ability in post-stroke hemiplegic patients, and targeting trunk function has been widely recognized to be a useful therapeutic strategy (Davies, 1999; Fujiwara, Okajima, and Kimura, 2001; Sato, 1994; Tomita and Uno, 1993). However, the fact that features of physical therapy, such as subjective concept/complicated and diverse, make standardization of the approach difficult cannot be denied.

In a previous study (Taniuchi and Kawasaki, 2014), the authors focused on rotation exercises of the trunk and analyzed walking motions before and after trunk rotation exercises (passive exercises involving rotation towards the paralyzed side of the lower trunk/rotation towards the unparalyzed side of the upper trunk/rotation towards the paralyzed side of the neck) to examine whether rotation exercises can become an effective physical therapy for the improvement in the walking ability of post-stroke hemiplegic patients. The results of that study (Taniuchi and Kawasaki, 2014) showed that trunk rotation exercises in post-stroke hemiplegic patients facilitate the improvement in swing motions on the paralyzed side, thereby leading to the improvement in the ability to move forward.

Kitatani et al (2013) showed that among post-stroke hemiplegic patients, those who were unable to move forward by large distances using the leg on the paralyzed side had a poor walking ability; hence, they reported the importance of the distance of forward movements by the leg on the paralyzed side. A study by Otao et al (2012) then investigated the association between the anterior pelvic tilt angle and walking ability in post-stroke hemiplegic patients demonstrated that the anterior pelvic tilt is important for the forward movement of the body centroid during motions. In addition, Kamijo and Yamamoto (2010) reported that, based on the relationship between trunk alignment and the degree of gait independence in post-stroke hemiplegic patients, the higher the ability to tilt the pelvis, the higher the walking ability. According to the abovementioned studies showing the association between walking ability and anterior pelvic tilt angle during walking in post-stroke hemiplegic patients, we considered that the ability to move forward and pelvic movements (motions) during walking are important.

In the present study, we aimed to examine the association between improvement in swing motions on the paralyzed side and ability to move forward by analyzing the angles between the trunk, pelvis, and hip joint at the time when the heel on the paralyzed side touched the ground. We also sought to investigate the effectiveness of trunk rotation exercises as a physical therapy for improving walking ability of post-stroke hemiplegic patients and the associated factors.

Subjects and Methods

The subjects were 14 patients with post-stroke hemiplegia who could walk by themselves for 15 m without using a lower extremity orthosis and for whom images of the pelvis were obtained throughout the entire therapy period. Neurological examination excluded people with Parkinsonism, dystonia, and other complications, such as bone and joint disease, that may have an effect on their walking ability.

This study was approved by the ethics committee of our institution. Based on the principles of the Declaration of Helsinki, we prepared a study description, a consent form, and consent withdrawal form, confirmed subjects' free will and right to participate in the study, fully explained the consideration of protecting personal information to subjects, and obtained consent. In addition, during the measurement of the patients' walking ability, a physical therapist was present to ensure the safety of the tests performed.

Patients were asked to walk at the maximum speed on the zebris high-performance pressure distribution measurement system, Win FDM (Inter Reha Corporation, Tokyo, Japan), before and after trunk rotation exercises (passive exercises involving rotation towards the paralyzed side of the lower trunk/rotation towards the unparalyzed side of the upper trunk/rotation towards the paralyzed side of the neck) (Fig. 1). The measurement items included stride indexes, step length, and stride length on the paralyzed and unparalyzed sides, pitch index, cadence, balance index, step width, and walking speed (km/h). The step length (cm) on the paralyzed side, step length/stride length (cm) on the unparalyzed side, and step width (cm) were shown as percentages of the normalized values by height [%body height (%BH)].

For the measurement of the motion of the joint and pelvis during walking, we used the DIFF marker set recommended by the Clinical Gait Analysis Forum and placed it on the acromion, anterior superior iliac spine,

Fig. 1 Trunk rotation exercises

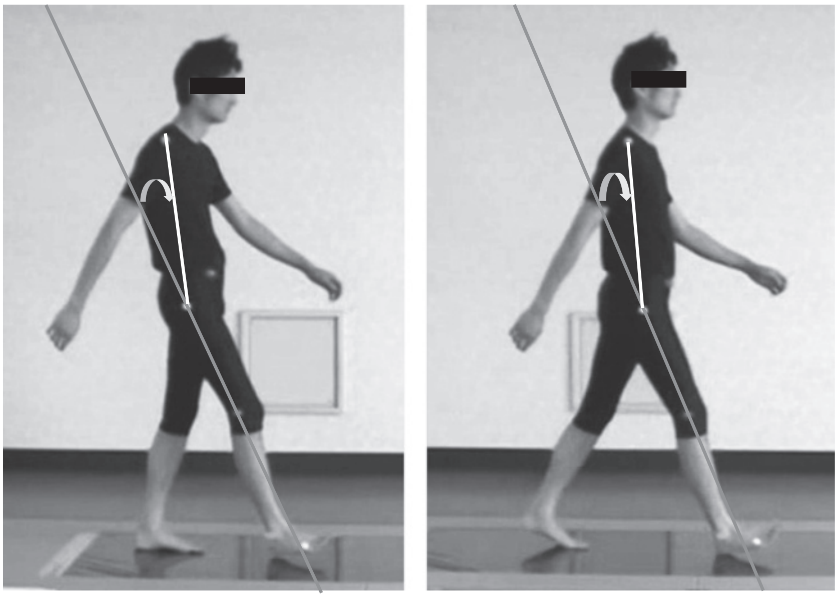


Fig. 2 The flexion angle of the hip joint and trunk

greater trochanter, and cleft between the knee joint and lateral articulation. The movements of the markers during walking before and after trunk rotation exercises were consecutively recorded on the paralyzed side using a video camera, High Speed EXILIMHS EX-FH100 (Casio Computer Co., Ltd., Tokyo, Japan); the recorded data were imported to the computer at a sampling frequency of 100 Hz. Then, based on the trunk-hip joint flexion angles, anterior pelvic tilt angles, and the positional relationship between the acromion and anterior superior iliac spine from the sequential data, the ability to propel the pelvis from the trunk was defined and used for the analysis.

The trunk-hip joint flexion angle was defined as an acute angle between the line segment connecting the acromion and the greater trochanter and that connecting the greater trochanter and the cleft between the knee joint and lateral articulation (Fig. 2). The anterior pelvic tilt angle was defined as an acute angle between the line segment connecting the anterior superior iliac spine and the greater trochanter and that connecting the greater trochanter and the cleft between the knee joint and lateral articulation (Fig. 3). The ability to propel the pelvis, which is indicated by the positional relationship between the pelvis and the trunk, was defined as an acute angle between the perpendicular line from the anterior superior iliac spine and the line segment

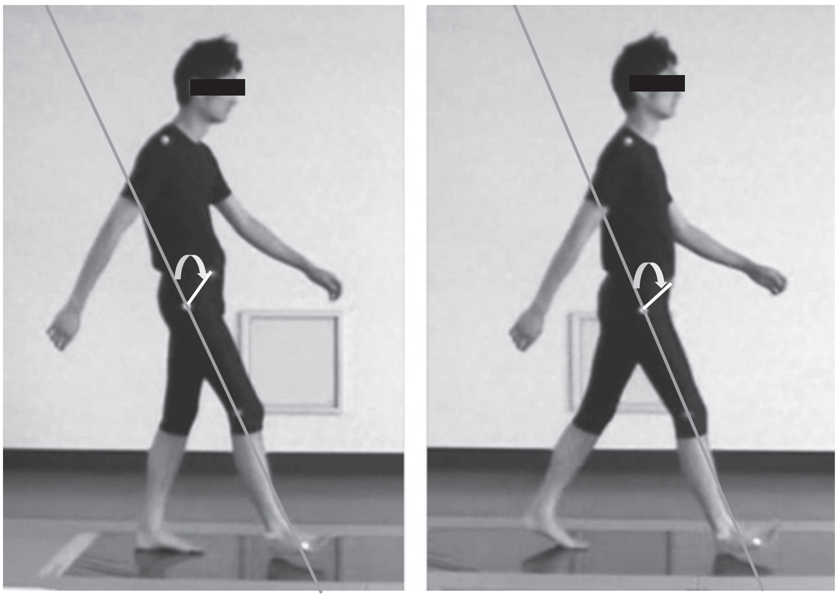


Fig. 3 Anterior pelvic tilt

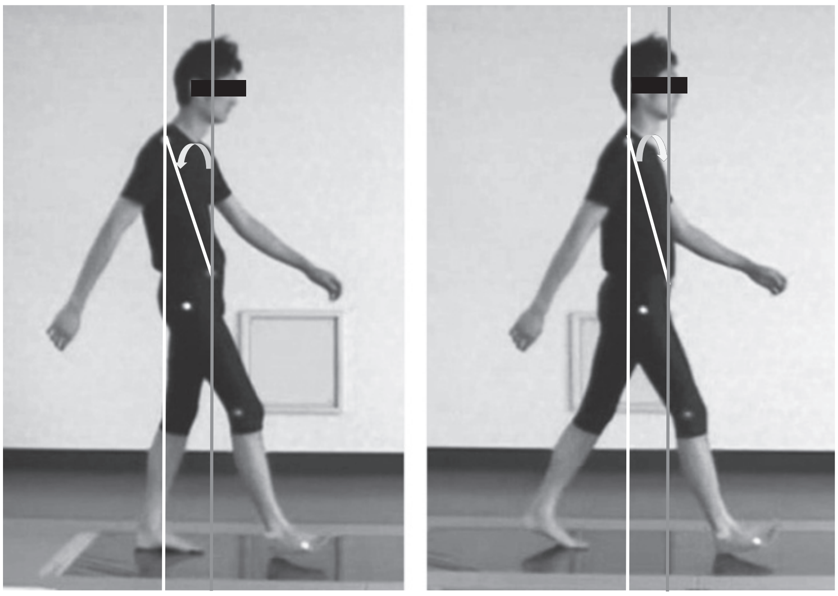


Fig. 4 Measurement of the propulsive force of the pelvis-The positional relationship between the pelvis and trunk

connecting the anterior superior iliac spine and the acromion, which was measured at the time when the heel on the paralyzed side touched the ground during walking (Fig. 4).

Changes in walking parameters before and after trunk rotation exercises were analyzed by using a corresponding t-test after the normality of data was confirmed. We set the significance level at 5% in the analysis. For the statistical analysis, we used the analytical tool of the Microsoft spreadsheet software, Microsoft Excel 2010 (Microsoft Corporation, Washington, United States).

Results

Altogether, six men and eight women (right hemiplegia: n=5, left hemiplegia: n=9) were included. The mean (standard deviation) age was 61.4 (11.4) years (range: 37 to 80 years), mean height was 158.2 (9.0) cm (range: 147.0 to 172.0 cm), mean weight was 58.9 (13.2) kg (range: 42.0 to 86.3 kg), and mean time from the onset was 91.0 (44.7) days (range: 20 to 187 days). The Brunnstrom recovery stages for the lower extremities were III

Table 1 Measured value in walking motion before and after the intervention to examine rotational movement of the neck and trunk

	The step length (%BH)		Stride length (%BH)	Cadence (Steps/minute)	Step width (%BH)	Walking speed (km/h)
	The paralyzed side	Non-paralyzed side				
Before	29.30 (7.18)	27.76 (8.54)	56.77 (14.08)	105.79 (24.02)	7.75 (3.06)	2.91 (1.13)
After	31.20 (7.97) *	31.87 (8.10) *	61.89 (14.88) *	110.00 (20.61) *	7.65 (2.68) *	3.31 (1.22) *

Average value (standard deviation) * $p<0.05$

Table 2 Measured value in walking motion before and after the intervention to examine rotational movement of the neck and trunk. The point at which the heel contacts the paralyzed side.

	The flexion angle of the hip joint and trunk (°)	Anterior pelvic tilt (°)	To measure the propulsive force of the pelvis (°) "the positional relationship between the pelvis and trunk"
Before	22.65 (8.10)	52.89 (10.29)	8.66 (5.26)
After	24.84 (7.24)	58.30 (8.71) *	6.76 (4.91) *

Average value (standard deviation) * $p<0.05$

(n=3), IV (n=3), V (n=4), and VI (n=4). Regarding the state of daily living, nine patients used a cane and seven patients used an ankle-foot orthosis.

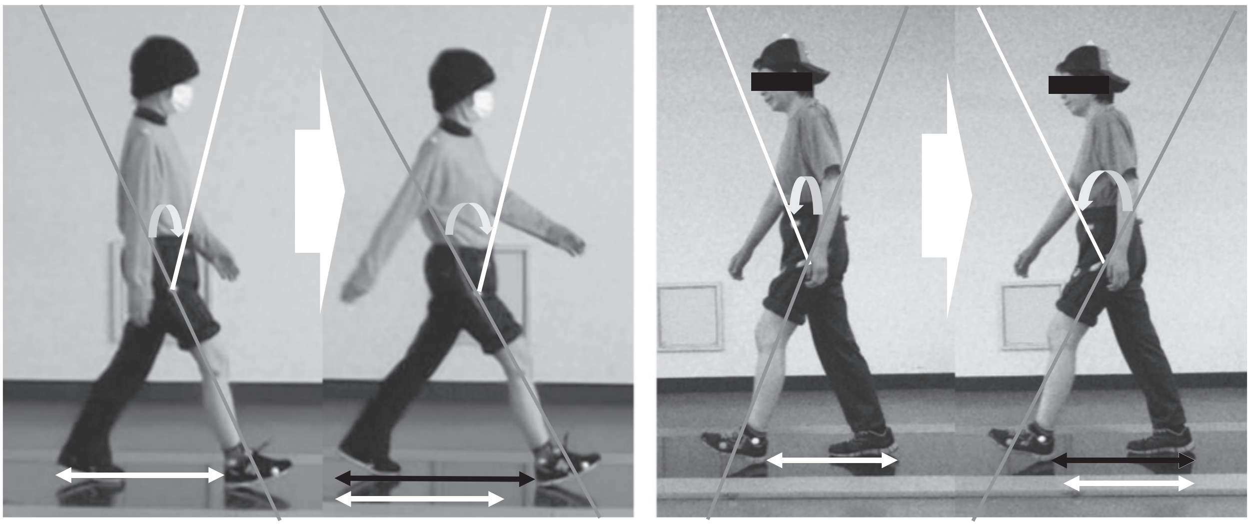
There were significant increases in step length on the paralyzed side, step length and stride length on the unparalyzed side, cadence, and walking speed ($P<0.05$) and a significant decrease in step width ($P<0.05$) (Table 1). In addition, significant increases in anterior pelvic tilt angle ($p<0.05$) and ability to propel the pelvis ($p<0.05$) at the time when the heel on the paralyzed side touched the ground were observed, but there was no significant difference in trunk-hip joint flexion angle (Table 2).

Discussion

Similar to the results of a previous study (Taniuchi and Kawasaki, 2014), the present study also showed a significant increase in stride length and step length on the paralyzed side and a significant decrease in step width in walking motions after trunk rotation exercises. The trunk rotation movements included passive rotation to the lower trunk of the paralyzed side, passive rotation from the as-is state to the upper trunk of the paralyzed side, and further passive rotation from the as-is state to the cervical part of paralyzed side; each movement was hold for 10 seconds. In addition, there were also significant increases in step length on the unparalyzed side, cadence, and walking speed. This could be explained by the study findings of Kaneko (2014) showing "the relation of walking (running) speed and stride/pitch", which indicate that stride length and pitch change as the running speed increases, wherein the initial increase in speed results from an increase in stride length. We considered that, since in the present study we instructed the patients to walk fast in contrast to walking at any speed, as in the previous study (Taniuchi and Kawasaki, 2014), fast walking increased the walking speed, which affected not only the stride indices, step length, and stride length, but also the pitch index (cadence). The results of the present study suggested that trunk rotation exercises in post-stroke hemiplegic patients are effective physical therapy for improving their ability to move forward during walking.

We also examined the factors that lead to the improvement in the ability of post-stroke hemiplegic patients to move forward during walking, including the angles between the trunk, pelvis, and hip joint at the end of swing motions on the paralyzed side at the time when the heel on the paralyzed side touched the ground. The results showed significant increases in the anterior pelvic tilt angle and ability to propel the pelvis, but there was no significant difference in trunk-hip joint flexion angle. Thus, an increase in the values of stride indices (step length and stride length) and a resulting improvement in walking speed are presumably caused by motions of the anterior pelvic tilt and forward movements of the pelvis rather than by trunk-hip joint flexion.

The ability of post-stroke hemiplegic patients to perform anterior pelvic tilt by active movement is associ-



Before exercise therapy ⇒ After exercise therapy **Before exercise therapy ⇒ After exercise therapy**

Fig. 5 Anterior pelvic tilt-usefulness of two-dimensional analysis evaluation

ated with not only walking ability, but also the ability to perform basic motions, such as standing up, sitting, and keeping an upright posture (Otao et al, 2012). Anterior pelvic tilt in a sitting position is positively associated with patient's walking ability (Kamijo and Yamamoto, 2010). In addition, muscles participating in the anterior pelvic tilt are those involved in posture control and rising/walking; thus, the association between ability to perform anterior pelvic tilt and rising/walking has been shown in a number of studies (Jackson and Newmann, 2009; Oddsson and Thorstensson, 1990; Miura and Sakuraba, 2010; Teragaki, Shintani, and Usuda, 2008; Keagy, Brumlik, and Bergan, 1966; Hughes, Myers, and Schenkman, 1996; Rantanen and Avela, 1997; Okada, 1972). Considering the association between ability to move forward and walking ability (Kitatani, 2013; Ochiai, Nishida, and Fuchioka, 2015), the results of the present study also demonstrated the importance of practicing anterior pelvic tilt exercises for the improvement in walking ability in post-stroke hemiplegic patients. We intend to further review our outcomes and conduct studies in the future to establish an evidence-based approach to improve walking ability.

The ability to move forward during walking with improvements in the stride indices (step length and stride length) in post-stroke hemiplegic patients was not associated with the trunk-hip joint flexion angle at the time when the heel on the paralyzed side touched the ground as most post-stroke hemiplegic patients perform trunk forward flexion by bending the upper trunk (Messier et al, 2004), which is the characteristic bend in the upper trunk when the motion of the anterior pelvic tilt is insufficient to move the head forward (Campbell et al, 2001). In the present study, an acute angle between the line connecting the acromion and the greater trochanter and that connecting the greater trochanter and the cleft between the knee joint and lateral articulation was regarded as the trunk-hip joint flexion angle resulting in a complicated index, in which elements of the trunk, pelvis, and hip joint were incorporated. Therefore, it is possible that we did not obtain an index that purely represents the trunk-hip joint angle in post-stroke hemiplegic patients. Considering that none of the 14 patients in the present study presented an extreme forward trunk posture, it is still suspected that the patients in whom the assessment of the "ability to propel the pelvis" (an acute angle between the perpendicular line from the anterior superior iliac spine and the line segment connecting the anterior superior iliac spine and the acromion), indicated by the positional relationship between the pelvis and the trunk, can be conducted are limited. Therefore, future studies investigating trunk movement in post-stroke hemiplegic patients and ways to assess the movement towards a moving direction in the pelvis are warranted.

The improvement in the ability to move forward accompanied by anterior pelvic tilt in the present experiment is a result of a two-dimensional analysis, and rotational movements are considered to be a part of the limitation at the current stage. However, the results of the present study demonstrating that an increase in anterior pelvic tilt angle and an increase in ability to propel the pelvis during walking in post-stroke hemiplegic patients leading to the force to propel the legs are consistent with those of several reports (Jackson and Newmann, 2009; Oddsson and Thorstensson, 1990; Miura and Sakuraba, 2010; Teragaki, Shintani, and Usuda, 2008; Keagy, Brumlik, and Bergan, 1966; Hughes, Myers, and Schenkman, 1996; Rantanen and Avela, 1997; Okada, 1972) on the association of anterior pelvic tilt angle with walking ability. Taken together, it is important to examine anterior pelvic tilt angles during walking in post-stroke hemiplegic patients, and "an assessment of anterior pelvic tilt angles" by two-dimensional analysis is useful as a simple and quick method for the assessment of walking ability in such patients (Fig. 5).

Conclusions

The present study showed that trunk rotation exercises in post-stroke hemiplegic patients are an effective physical therapy strategy to improve the indices [stride indexes (step length and stride length), pitch index (cadence), balance index (step width), and walking speed] that measure the ability to move forward during walking. Moreover, our data suggest that the improvement in the ability to move forward during walking is attributable to motions of the anterior pelvic tilt and forward movements of the pelvis rather than the motions of trunk-hip joint flexion. Our study also introduced an effective practical method of improving walking ability of these patients and demonstrated the importance of motions of the anterior pelvic tilt. Our data may contribute to the standardization of physical therapy for the improvement in walking ability of post-stroke hemiplegic patients.

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脳卒中片麻痺者における体幹部回旋運動が歩行動作に及ぼす影響

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―キーワード―
脳卒中片麻痺者，歩行動作，体幹部回旋運動

目的：脳卒中片麻痺者に対する歩行能力向上のための理学療法として，体幹部の回旋運動に着目した先行研究を受けて，体幹部回旋運動後における歩行時の前方移動能力向上が運動学的にどのような動き（運動）に繋がっているのかを検証した．

対象と方法：下肢装具なしにて15m以上の独歩可能な脳卒中片麻痺を呈する患者を対象とした．体幹部回旋運動（体幹下部麻痺側へ回旋・体幹上部非麻痺側へ回旋・頸部麻痺側へ回旋する他動運動）後におけるストライド指標（ステップ長・ストライド長），ピッチ指標（ケイデンス），バランス指標（歩隔），歩行速度および歩行時の前方移動能力向上に及ぼす影響として，麻痺側踵接地時における体幹～骨盤～股関節の角度を分析した．

結果：ストライド指標（ステップ長・ストライド長），ピッチ指標（ケーデンス），バランス指標（歩隔），歩行速度の向上に加え，麻痺側踵接地時での骨盤前傾角度の有意な増加および骨盤の推進性の有意な増加がみられた．

考察：脳卒中片麻痺者に対して体幹部回旋運動を行うことで，swing動作といった前方移動能力向上とともに，骨盤前傾運動増加を引き起こしていることを確認した．本研究から，脳卒中片麻痺者に対する歩行能力向上のための理学療法として，体幹部回旋運動は有効であり，脳卒中片麻痺者における歩行時の骨盤前傾運動は，前方移動能力向上に繋がっている可能性が示唆された．このことから，2次元分析による骨盤前傾角度の評価は，脳卒中片麻痺者に対して，簡便・敏速にできる歩行能力評価法として有用であると考える．

利益相反：利益相反基準に該当無し

（日職災医誌，68：129―136，2020）