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The effect of using walking poles on the spatiotemporal gait parameters in patients who underwent surgery for hip fractures

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Purpose: This study aimed to investigate the differences in spatiotemporal gait parameters in patients who underwent surgery for hip fractures when using walking poles and T-canes. *Methods*: This cross-sectional study enrolled eight patients who underwent surgery for a unilateral hip fracture (mean age of 79.0 ± 7.9 years) and 34 healthy individuals who had no symptoms (mean age of 32.1 ± 6.2 years). The outcome measures were the walking speed, trunk acceleration, and lateral lean angles of the trunk, shoulder and pelvis during walking. The results were compared among the three types of walking aids, namely, a T-cane, double T-canes and walking poles. *Results*: Acceleration indices step symmetry in the vertical and anteroposterior directions in walking with walking poles were significantly larger than that in walking with a T-cane. These results were common in patients with fractures and healthy individuals. *Conclusions*: Walking with walking poles might be a more symmetrical gait style than walking with a T-cane in patients who underwent surgery for hip fractures.

Key words: *kinematic, gait symmetry, hip fracture, gait, walking poles*

1. Introduction

Restoring the walking ability is one of the most important goals in the physical therapy of patients who underwent hip fracture surgery. Globally, approximately 1.6 million patients sustain hip fractures annually [12]. The incidence is expected to increase with the aging of the world's population [5]. In the early postoperative phase of hip fracture surgery, disuse syndrome due to loss of walking ability significantly impairs patients' physical functions, including muscle mass and strength [30]. Impaired physical function is associated with increased mortality and worse functional outcomes [13], [33]. The mortality rate within 1 year after fracture was 21.9% for women and 32.5% for men [4], and 11% of older adults living in the community were bedridden in the first year after fracture [23]. Therefore, early restoration of the walking ability is important for patients who underwent hip fracture surgery to prevent mortality and worse functional outcomes.

Improving gait symmetry is an important factor in restoring walking ability. Gait symmetry is generally defined as the identical behavior of the left and right limbs during gait [28]. Reduced gait symmetry is associated with reduced walking speed [39], chronic joint

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pain, and osteoarthritis [34]. Furthermore, reduced gait symmetry is an independent factor associated with falls in older adults [2], [39]. Because hip fractures are unilateral lower extremity injuries, reduced gait symmetry is a typical gait characteristic of patients who underwent hip fracture surgery [6], [32]. Therefore, gait symmetry must be assessed to restore walking ability in patients who underwent hip fracture surgery.

Despite the importance of improving gait symmetry in patients who underwent hip fracture surgery, the optimal method of improving gait symmetry has not been established. In recent years, an increasing number of studies have assessed gait symmetry. Specifically, some studies have evaluated gait symmetry for stroke [8], osteoarthritis [17], total hip replacement [15], anterior cruciate ligament injury [38], Parkinson's disease [3] and lower limb amputation [27]. Despite studies on the effectiveness of body weight-supported treadmill [8] and walking program incorporating real-time biofeedback [36] to improve gait symmetry, the widespread use of these training programs in clinical practice is hindered by the need for specialized equipment. Therefore, a method that can easily improve gait symmetry in patients who underwent hip fracture surgery is desired.

Walking with walking poles (WP) may improve gait symmetry in patients who underwent hip fracture surgery. In this form of locomotion, a person holds a pole in each hand, and one of the poles touches the ground simultaneously with contralateral lower limb heel contact [24]. For healthy individuals, the use of WP decreases the vertical direction of the ground reaction force [37], decreases the muscular activity of the gluteus medius and increases the lateral margins of stability [25]. For patients with Parkinson's disease, the use of WP increased the stride length and reduced the range of motion and velocity of the trunk in the frontal plane [7]. These studies have revealed that WP help reduce the burden on the lower limbs, expand the base of support and improve pelvic and trunk stability. Additionally, WP were effective in improving gait symmetry in patients with osteoarthritis [22]. These actions of WP may improve gait symmetry in patients who underwent hip fracture surgery.

To investigate whether WP improve gait symmetry in patients who underwent hip fracture surgery, the effect of using WP on gait parameters must be examined from a kinematic perspective. Thus, this study aimed to investigate the differences in spatiotemporal gait parameters in patients who underwent hip fracture surgery when walking using WP and T-canes, which are frequently used in clinical practice.

2. Materials and methods

2.1. Participants

The study included also healthy individuals to check whether the effect of the WP was unique on the patients. The patients were screened according to the following inclusion criteria: (1) diagnosed with hip fractures, (2) undergone hip fracture surgery and (3) independently walk 10 m with a T-cane. The exclusion criteria for all participants were as follows: (1) mini-mental state examination (MMSE) score <20 points, (2) difficulty grasping the WP with both hands and (3) presence of skin lesions that would interfere with surface electromyography tests.

This study was approved by the institutional ethics committee of Shigei Hospital (Approval no. 2021-018). All participants provided written informed consent after they received an explanation of the nature and purpose of the study.

2.2. Experimental setup and procedures

The participants performed walking tasks using three walking aids, namely, a T-cane, double T-canes (DT), and WP. Gait analysis was performed on a 14-m long smooth flat walkway, with a space of 2 m at each end for acceleration and deceleration. To measure the lateral lean angles of the trunk, shoulder and pelvis, the position of the camera was set at both ends of the 14-m walkway. Two iPhoneSE (256 GB, Apple, Inc., Cupertino, CA, USA) at 30 frames per second were used from the frontal plane of the participants. In addition, the height to the center of the camera lens was unified to 1.0 m, and the camera was installed parallel to the floor using a level. The participants were instructed to walk at a comfortable walking speed, and measurements were performed over the middle 10 m. In each walking task, measurements were performed after three trials. A physical therapist closely watched the participants to prevent falls.

2.3. Outcome measure and data analysis

The main outcome measure was the walking speed. The secondary outcomes were trunk acceleration and lateral lean angles of the trunk, shoulder and pelvis.

Signal processing of the trunk acceleration and lateral lean angles was performed using MATLAB R2020b (The MathWorks, Inc., Natick, MA, USA).

Walking speed

The time taken to complete the middle 10-m distance was recorded to the nearest hundredth of a second using stopwatch, and walking speed was expressed in meters per minute. The average of three trials was used as the representative value.

Trunk acceleration

Trunk acceleration during gait was measured using a 40 × 50 × 14 mm wireless accelerometer that weighed 27 g (TSND151; ATR-Promotions, Inc., Kyoto, Japan). A sensor unit was fixed to a belt at the level of the L3 spinous process. Trunk linear accelerations were measured in the mediolateral (ML), vertical (VT) and anteroposterior (AP) directions, while the participants walked along a walkway. The curvature of the body can affect the angle of the baseline axis in the accelerometer. Therefore, to correct for any potential effects of this angle, the accelerometer was calibrated in a standing position before the walking trial to take into account the effect of static gravity. All signals were sampled at 200 Hz and synchronously wirelessly transferred to a personal computer via a Bluetooth personal area network. Before the analyses, all acceleration data were Butterworth-filtered with a cutoff frequency of 20 Hz. The initial-contact events were identified from the AP direction of the three-axis accelerometer. To analyze the trunk acceleration indices, three consecutive gait cycles in steady walking condition were picked from the 10-m walking path section. The three gait cycles including the gait cycle 5 m from the camera were selected to analyze same sections in the lateral lean angles of the trunk, shoulders and pelvis. The average in the three gait cycles was calculated in each trial, and the average in three trials was used as the representative value.

To evaluate gait symmetry and gait regularity, the step symmetry (SS) and step regularity (SR) were calculated using the autocorrelation sequence of trunk acceleration, respectively. In this study, an unbiased estimate of the autocorrelation coefficient (unbiased) was calculated according to the method by Moe-Nilssen and Helbostad [20]. The SS and SR indicate the similarity of acceleration signals between contralateral and ipsilateral steps, respectively. The SS and SR range from 0 to 1, with 1 indicating the highest symmetry or regularity. The SS values in the ML, VT and AP directions were represented as the SS-ML, SS-VT and SS-AP, respectively. The SR values in the ML, VT and AP directions were denoted as the SR-ML, SR-VT and SR-AP, respectively.

The step time variability (STV) was calculated as the coefficient of variation for three-step time values for each leg. The STV value indicates gait variability. The STV was calculated using this equation: [(standard deviation of step time/mean step time) × 100] [9]. A smaller STV value shows better stability during gait. The step time asymmetry (STA) was calculated using this equation: [(longer step time – shorter step time)/longer step time × 100]. The time for one step was defined as the time between one heel contact and the next heel contact of the contralateral leg.

The root mean square (RMS) value indicates the amplitude of acceleration; thus, the larger the value, the larger the sway. The RMS of trunk acceleration during walking is affected by walking speed [16]. Therefore, in this study, the normalized RMS calculated by dividing by the square of the walking speed was used. The RMS was calculated separately for each step of the right and left stance phases. The RMS values in the ML, VT and AP directions were represented as RMS-ML, RMS-VT and RMS-AP, respectively. The difference in the RMS (D-RMS) was calculated to evaluate the difference in the amplitude of acceleration during the left and right stance phases. The D-RMS was calculated using the following equation: [(larger RMS – smaller RMS)]. The D-RMS values in the ML, VT and AP directions were denoted as the D-RMS-ML, D-RMS-VT and D-RMS-AP, respectively.

Lateral lean angles of the trunk, shoulder and pelvis

The lateral lean angles of the trunk, shoulders and pelvis were calculated from the positions of the reflective markers on the video using motion analysis software. Reflective markers were applied on the bilateral anterior superior iliac spines (ASISs) and the bilateral anterior tips of the acromion as reference point. Using the methods of previous studies, the lateral lean angle of the trunk was calculated as the angle of a line drawn from the midpoint of the ASISs to the midpoint of the anterior tips of the acromion processes with respect to the vertical direction [10]. The lateral lean angle of the shoulder or pelvis was calculated as the angle between the horizontal line and the line connecting the bilateral anterior tips of the acromion or ASISs. Data were analyzed using freeware motion analysis software (Kinovea, version 0.9.5, available for download at http://www.kinovea.org). Kinovea, used in clinical motion analysis, is a valid and reliable tool that can measure trunk angles accurately [11]. The analysis target of the lateral lean angle was a section of three gait cycles, including the gait cycle at 5 m from the camera. In each trial, the maximum value during three gait cycles was calculated, and the maximum value of the three trials was used as the representative value.

2.4. Statistical analysis

Using repeated-measures analysis of variance, the results of analyses were compared among the three types of walking aids. When a significant difference was found in the comparisons among all three sequences, a paired post-hoc comparison was performed using Bonferroni's correction. Data are presented as mean and standard deviation (mean ± SD). The effect sizes were expressed as partial eta-squared values (η_p^2; small ≥ 0.01, medium ≥ 0.06, large ≥ 0.14). All statistical analyses were performed with EZR [14], which is for *R*.

2.5. Sample size

The required sample size was calculated using G*Power 3.1.9.7. Assuming an alpha-error of 0.05, a statistical power of 0.80, and an effect size η_p^2 of 0.06 (moderate), at least 27 persons were required. In addition, assuming a maximum failed measurement of 20%, the target sample size was set at a maximum of 34 participants.

3. Results

Participants' characteristics are shown in Table 1. Eight patients who underwent surgery for a unilateral hip fracture (mean age, 79.0 ± 7.9 years) and 34 healthy individuals who had no symptoms (mean age, 32.1 ± 6.2 years) participated in this study. Patients who underwent hip fracture surgery were all women, and the healthy individuals were all men. All patients in the study had 24 or more MMSE points.

The spatiotemporal gait parameters of the healthy individuals are shown in Table 2. The walking speed in the WP condition was significantly higher than that in the T-cane condition (T condition) and DT condition. The SS-ML and SS-VT in the WP condition were significantly larger than those in the T condition. The SS-AP in the DT and WP conditions was significantly larger than that in the T condition. The SR-ML on the right side in the WP condition was significantly larger than that in the T condition. The SR-VT and SR-AP on the right side in the DT condition were significantly larger than those in the T condition. The RMS in the WP condition was significantly larger than that in the T condition. The RMS in the DT condition was significantly larger than that in the WP condition. The STAs in the DT and WP conditions were significantly smaller than those in the T condition. The STV on the left side in the DT condition was significantly smaller than that in the T condition. No significant differences in d-RMS and lateral lean angles of the trunk, pelvis and shoulder were found among the three conditions.

The spatiotemporal gait parameters of the patients with hip fractures are shown in Table 3. The SS-VT and SS-AP in the WP condition were significantly larger than those in the T condition. The RMS-VT on the operative side in the WP condition was larger than that in the T condition. The RMS-AP on the nonoperative side in the DT and WP conditions was larger than that in the T condition. Walking speed, SS-ML, SR, d-RMS, STA, STV and lateral lean angles were not significantly different among the three conditions.

Table 1. The participants' characteristics

Characteristics	Hip fracture patients	The healthy individuals
Gender (men/women)	0/8	34/0
Age [years]	79.0 ± 7.9	32.1 ± 6.2
Height [cm]	150.7 ± 7.7	173.3 ± 4.0
Weight [kg]	45.6 ± 8.3	66.0 ± 7.8
Fracture type (FNF/TF)	6/2	–
Surgical type (BHA/CCHS/γ-nail/CHS)	3/3/1/1	–
The days from the surgery to the measurement	56.1 ± 34.3	–
MMSE score	27.8 ± 2.2	–

FNF – Femoral Neck Fracture, TF – Trochanteric Fracture, BHA – Bipolar Hip Arthroplasty, CCHS – Cannulated Cancellous Hip Screw, CHS – Compression Hip Screw, MMSE – Mini-Mental State Examination.

Table 2. The spatiotemporal gait parameters of the healthy individuals

The healthy individuals (N = 34)		Type of walking aid			P-value	Post-hoc test	Effect size (η_p^2)
		T-cane	Double T-canes	Walking poles			
Speed (m/sec)		1.19 ± 0.16	1.18 ± 0.18	1.24 ± 0.19	0.000	T, DT < WP	0.31
SS-ML		0.50 ± 0.23	0.55 ± 0.19	0.59 ± 0.20	0.015	T < WP	0.14
SS-VT		0.85 ± 0.11	0.89 ± 0.06	0.89 ± 0.08	0.016	T < WP	0.13
SS-AP		0.89 ± 0.06	0.93 ± 0.03	0.92 ± 0.04	0.000	T < DT, WP	0.29
SR-ML	Right side	0.75 ± 0.16	0.80 ± 0.10	0.82 ± 0.13	0.009	T < WP	0.13
	Left side	0.77 ± 0.16	0.81 ± 0.11	0.81 ± 0.12	0.122		0.06
SR-VT	Right side	0.91 ± 0.09	0.95 ± 0.02	0.94 ± 0.08	0.023	T < DT	0.11
	Left side	0.92 ± 0.09	0.95 ± 0.03	0.94 ± 0.06	0.086	NS	0.08
SR-AP	Right side	0.93 ± 0.07	0.96 ± 0.02	0.95 ± 0.06	0.007	T < DT	0.14
	Left side	0.94 ± 0.07	0.97 ± 0.02	0.96 ± 0.05	0.037	NS	0.11
RMS-ML	Right side	0.88 ± 0.28	1.50 ± 0.24	1.25 ± 0.18	0.000	T < WP < DT	0.77
	Left side	0.86 ± 0.24	1.50 ± 0.18	1.34 ± 0.23	0.000	T < WP < DT	0.82
RMS-VT	Right side	0.85 ± 0.27	1.50 ± 0.23	1.29 ± 0.22	0.000	T < WP < DT	0.82
	Left side	0.89 ± 0.26	1.51 ± 0.23	1.31 ± 0.24	0.000	T < WP < DT	0.79
RMS-AP	Right side	0.92 ± 0.30	1.54 ± 0.25	1.32 ± 0.22	0.000	T < WP < DT	0.74
	Left side	0.88 ± 0.31	1.49 ± 0.22	1.32 ± 0.26	0.000	T < WP < DT	0.78
D-RMS-ML		0.13 ± 0.09	0.12 ± 0.10	0.12 ± 0.12	0.899		0.00
D-RMS-VT		0.12 ± 0.08	0.11 ± 0.10	0.09 ± 0.07	0.137		0.06
D-RMS-AP		0.17 ± 0.17	0.16 ± 0.15	0.11 ± 0.09	0.040	NS	0.09
STA		4.06 ± 2.67	2.74 ± 1.69	3.09 ± 2.07	0.001	DT, WP < T	0.22
STV	Right side	2.45 ± 1.85	1.86 ± 0.86	1.91 ± 1.44	0.043	NS	0.09
STV	Left side	2.36 ± 1.85	1.42 ± 0.59	1.77 ± 1.40	0.007	DT < T	0.14
Trunk lean angle [°]		4.52 ± 1.84	4.53 ± 1.29	4.43 ± 1.24	0.838		0.00
Shoulder lean angle [°]		5.28 ± 1.87	5.18 ± 1.56	5.31 ± 1.38	0.843		0.01
Pelvis lean angle [°]		6.76 ± 2.26	6.92 ± 2.21	7.11 ± 2.61	0.476		0.02

Values are given as mean ± standard deviation. Post hoc analysis with Bonferroni correction.

η_p^2 – Partial eta-squared values, small ≥ 0.01, medium ≥ 0.06, large ≥ 0.14; T – T-cane, DT – Double T-canes, WP – Walking poles, NS – Not significant, SS – Step Symmetry, SR – Step Regularity, RMS – Root Mean Square, D-RMS – Difference of Root Mean Square, STA – Step Time Asymmetry, STV – Step Time Variability, VT – Vertical, AP – Anteroposterior, ML – Mediolateral.

Table 3. The spatiotemporal gait parameters of the patients with hip fractures

The patients with hip fractures (N = 8)		Type of walking aid			P-value	Post-hoc test	Effect size (η_p^2)
		T-cane	Double T-canes	Walking poles			
Speed [m/sec]		0.76 ± 0.22	0.74 ± 0.24	0.77 ± 0.25	0.327		0.15
SS-ML		0.30 ± 0.22	0.25 ± 0.21	0.31 ± 0.28	0.441		0.11
SS-VT		0.54 ± 0.20	0.61 ± 0.21	0.65 ± 0.17	0.002	T < WP	0.59
SS-AP		0.63 ± 0.26	0.68 ± 0.27	0.74 ± 0.20	0.018	T < WP	0.44
SR-ML	Operative	0.54 ± 0.26	0.60 ± 0.19	0.68 ± 0.18	0.088		0.34
	Non-operative	0.62 ± 0.19	0.68 ± 0.10	0.69 ± 0.24	0.624		0.07
SR-VT	Operative	0.77 ± 0.19	0.82 ± 0.17	0.85 ± 0.13	0.141		0.24
	Non-operative	0.79 ± 0.11	0.83 ± 0.10	0.86 ± 0.11	0.412		0.12
SR-AP	Operative	0.84 ± 0.16	0.88 ± 0.16	0.89 ± 0.15	0.203		0.22
	Non-operative	0.91 ± 0.05	0.92 ± 0.06	0.94 ± 0.05	0.316		0.15
RMS-ML	Operative	2.04 ± 1.74	3.03 ± 2.26	2.38 ± 1.02	0.129		0.29
	Non-operative	1.74 ± 0.77	2.40 ± 1.40	2.60 ± 1.50	0.028	NS	0.40
RMS-VT	Operative	1.88 ± 1.19	2.46 ± 1.40	2.67 ± 1.34	0.005	T < WP	0.54
	Non-operative	1.99 ± 1.70	2.68 ± 1.82	2.19 ± 0.79	0.166		0.25
RMS-AP	Operative	1.92 ± 1.48	2.69 ± 1.64	2.31 ± 1.03	0.078		0.36
	Non-operative	1.84 ± 1.10	2.40 ± 1.24	2.64 ± 1.38	0.001	T < DT, WP	0.64
D-RMS-ML		0.54 ± 0.93	0.73 ± 1.00	0.38 ± 0.49	0.151		0.24
D-RMS-VT		0.43 ± 0.41	0.41 ± 0.48	0.47 ± 0.61	0.779		0.02

Table 3 continued

D-RMS-AP		0.37 ± 0.27	0.31 ± 0.39	0.36 ± 0.57	0.891		0.02
STA		9.72 ± 8.01	9.65 ± 10.09	7.03 ± 6.85	0.164		0.23
STV	Operative	6.06 ± 3.97	3.72 ± 2.90	3.48 ± 1.70	0.133		0.25
STV	Non-operative	5.37 ± 2.29	4.22 ± 2.81	3.29 ± 1.63	0.124		0.26
Trunk lean angle [°]		4.63 ± 1.27	4.37 ± 1.71	4.83 ± 1.66	0.485		0.10
Shoulder lean angle [°]		4.58 ± 0.77	4.98 ± 1.28	4.92 ± 0.47	0.595		0.07
Pelvis lean angle [°]		6.72 ± 2.99	6.49 ± 2.58	6.19 ± 3.24	0.523		0.09

Values are given as mean ± standard deviation. Post-hoc analysis with bonferroni correction

η_p^2 – Partial eta-squared values, small ≥ 0.01, medium ≥ 0.06, large ≥ 0.14, T – T-cane, DT – Double T-canes, WP – Walking poles, NS – Not significant, SS – Step Symmetry, SR – Step Regularity, RMS – Root Mean Square, D-RMS – Difference of Root Mean Square, STA – Step Time Asymmetry, STV – Step Time Variability, VT – Vertical, AP – Anteroposterior, ML – Mediolateral

4. Discussion

This study investigated the differences in spatio-temporal gait parameters in patients who underwent hip fracture surgery when using WP and T-canes. The walking speed, trunk acceleration, and lateral lean angles of the trunk, shoulder and pelvis during walking were measured in healthy individuals and patients who underwent hip fracture surgery. In healthy individuals, the walking speed and all SS parameters in the WP condition were significantly larger than those in the T condition, and the STA in the WP condition was significantly smaller than that in the T condition. The RMS in the WP condition was significantly larger than that in the T condition and smaller than that in the DT condition. In patients, the SS-VT, SS-AP and RMS-VT on the operative side and the RMS-AP on the nonoperative side were significantly larger in the WP condition than those in the T condition. These results were common in the healthy individuals. No differences in walking speed and lateral lean angles of the trunk, pelvis, and shoulder were found among walking aids in patients who underwent hip fracture surgery.

The novelty of this study is the examination of the effect of using WP on gait symmetry in patients who underwent hip fracture surgery. Previous studies have evaluated the effects of the use of WP on gait symmetry in healthy individuals [31], patients with osteoarthritis [22], stroke [1] and Parkinson's disease [35]. However, no study has examined the effect of WP on the gait symmetry of patients who underwent surgery for hip fractures. Because the characteristics of gait kinematics differ by disease, the effect of using WP on gait symmetry may also differ by disease. To our knowledge, this is the first study to investigate the effect of using WP on gait symmetry in patients who underwent surgery for hip fractures.

In this study, the SS-VT and SS-AP in the WP condition were significantly larger than those in the T condition, suggesting that WP may assist with walking in patients who underwent surgery for hip fractures. The SS indicates the similarity in the acceleration signal between the left and right stance phases during walking. Muscle weakness and loading pain result in prolonged underloading of the operated lower extremity in patients who underwent surgery for fractures [21], [26]. Consequently, the center of gravity fails to accelerate upward in the initial to mid-stance of the operative lower limb, and the forward propulsive force is reduced in the terminal stance phase. Because the WP can increase the dynamic stability in the lateral direction by expanding the base of support and assisting the hip abductor muscles [25], it facilitates loading to the operative lower extremity and smoothens the load transfer. Because of the high similarity of acceleration waveforms in the VT and AP directions during the left and right stance phases by facilitating load transfer to the operative lower extremity, the SS-VT and SS-AP in the WP condition were significantly larger than those in the T condition. Thus, compared to T-canes, WP may be a walking aid that improves gait symmetry in patients who underwent surgery for hip fractures.

The use of WP may exert immediate effects on gait symmetry but may have a less immediate effect on gait regularity. In this study, gait regularity indicates the similarity of acceleration signals between ipsilateral steps. The SS and SR were calculated simultaneously, and only the SS showed significant changes among walking aids in patients who underwent surgery for hip fractures. The effect of long-term use of walking aids on SS and SR changes is unknown, however, the simultaneous calculation of SS and SR provides some indications of an immediate effect of using WP in patients who underwent surgery for hip fractures.

Walking with DT and WP may be a more dynamic gait motion than walking with a T-cane. The RMS in the DT and WP conditions were larger than those in the T condition for healthy individuals and patients with hip fractures. The acceleration RMS indicates the magnitude of trunk acceleration during gait [16]. The higher the acceleration RMS, the greater the trunk instability or sway [18], [19]. To improve gait stability through only movements, the strategy is to reduce the flexibility of movements [29]. The use of walking aids, such as DT or WP, enlarged the basal plane of support and increased stability during walking. This diminished the need for reduced flexibility of movements. Consequently, walking with DT and WP produced dynamic gait movements, and the RMS was considered to increase.

This study is meaningful as a theoretical basis indicating that walking with WP may be an effective intervention to improve gait symmetry in patients who underwent surgery for hip fractures. In clinical practice, gait training with a T-cane, which is shorter than WP and held on one side, is frequently employed in patients who underwent surgery for hip fractures. However, reduced gait symmetry tends to remain in patients who underwent hip fracture surgery, and establishing optimal methods to improve it is challenging. In contrast, this study suggested that walking with WP, which are longer than conventional T-canes and held bilaterally, might be a more symmetrical walking style than walking with a T-cane in patients who underwent hip fracture surgery. Therefore, the results of this study may provide a basis for recommending walking with WP as a part of exercise therapy to improve gait symmetry during walking without WP for patients who underwent hip fracture surgery in clinical practice. The long-term effects of the use of WP on walking without WP in patients with fractures have not been demonstrated, which is the aim in one of our upcoming studies.

This study has several limitations. First, the sample size of patients with hip fractures was insufficient to generalize the results. Second, the healthy individuals were all men, and patients who underwent hip fracture surgery were all women. Although the sex-based difference between the healthy individuals and the patients was purely coincidental, the sex-based differences may influence the results and their generalizability. However, because the results for SS and RMS were common for healthy men individuals and women patients, these parameters are unlikely to be affected by sex-based differences. Thus, the study participants are insufficiently representative of the entire population of patients who underwent hip fracture surgery. Therefore, a larger study is needed to increase the generalizability of the results. Third, the measurement is made at only one point. Long-term use of WP may cause changes in parameters other than gait symmetry. Thus, changes in spatiotemporal gait parameters over time must be assessed by analyzing gait at multiple time points. Fourth, the short walking distances and short analysis section used in our study may affect the generalizability of the results. In the real-world situation, fatigue may alter gait symmetry and other gait parameters as people usually walk distances of 10 m or more. Due to the measurement environment in which the subjects walked towards the camera, many steps could not be included in the analysis. This raises concerns about the representative nature of the data used in the analysis. Therefore, in the future, it may be better to include a larger walking distances and greater number steps to verify the results.

5. Conclusions

This study investigated the difference in spatiotemporal gait parameters in patients who underwent hip fracture surgery when walking using WP and T-canes. The results showed that acceleration indices SS-VT and SS-AP in the WP condition were significantly larger than those in the T condition for the studied patient group. Therefore, walking with WP might be a more symmetrical gait style than walking with a T-cane.

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Declaration of interest

The authors declare no conflict of interest.

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