



Original Article

# Immediate effect of different ankle-foot orthosis functions with the same dorsiflexed setting of initial ankle joint angle on walking ability in individuals with chronic stroke: a randomized crossover trial

ERI NOJIRI, MD<sup>1, 2)</sup>, YOSHITAKA WADA, MD, PhD<sup>2, 3)\*</sup>, MIDORI MOCHIZUKI, MD<sup>2)</sup>, MIZUKI SUGIYAMA, MD<sup>2)</sup>, NOBUYUKI KAWATE, MD, PhD<sup>1, 2)</sup>

<sup>1)</sup> Department of Rehabilitation Medicine, Graduate School of Medicine, Showa University, Japan

<sup>2)</sup> Department of Rehabilitation Medicine, Showa University Fujigaoka Rehabilitation Hospital, Japan

<sup>3)</sup> Department of Rehabilitation Medicine I, School of Medicine, Fujita Health University: 1-98 Dengakugakubo, Kutsukake, Toyoake, Aichi 470-1192, Japan

**Abstract.** [Purpose] To investigate how different ankle-foot orthosis functions with the same dorsiflexed setting of initial ankle joint angle affect the walking ability in individuals with chronic stroke. [Participants and Methods] In this randomized crossover study, participants underwent a 10-m walking test and walked on a WalkWay MW-1000 three times under these conditions: (1) without ankle-foot orthosis; (2) with ankle-foot orthosis with an adjustable posterior strut at 5° of fixed dorsiflexion; and (3) with ankle-foot orthosis with an adjustable posterior strut at 5–20° of restricted dorsiflexion. The primary outcome was walking speed on the 10-m walking test. The secondary outcomes were walking speed and spatiotemporal factors measured by the WalkWay MW-1000. [Results] Fifteen individuals (mean [standard deviation] age, 60.9 [8.6] years; male, 12) were enrolled. Walking speeds of the ankle-foot orthosis with fixed and restricted dorsiflexion groups were significantly higher than those without the orthosis; however, no outcomes differed significantly between ankle-foot orthosis with fixed versus restricted dorsiflexion groups. [Conclusion] In individuals with chronic stroke, ankle-foot orthosis function may be less important than the dorsiflexed setting of initial ankle joint angle in the ankle-foot orthosis.

**Key words:** Stroke, Hemiparesis, Ankle foot orthosis

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## INTRODUCTION

Over the last 30 years, mortality rates due to stroke have decreased, whilst the morbidity of chronic stroke has increased in tandem<sup>1)</sup>. Gait disturbance is common in stroke patients<sup>2)</sup>. The use of an ankle-foot orthosis (AFO) is an effective approach for gait disturbance after stroke<sup>3)</sup>. Guidelines from the American Heart Association/American Stroke Association assert that using AFO prevents foot drop during the swing phase and improves the gait of stroke patients<sup>3)</sup>. A systematic review and meta-analysis showed that AFOs increase the dorsiflexion angle of the ankle joints during walking and improve walking ability<sup>4)</sup>.

There have been no standardized recommendations for which AFOs should be used in stroke patients. A previous systematic review and meta-analysis showed that there was no difference in the walking speed with different types of AFOs<sup>5)</sup>.

\*Corresponding author. Yoshitaka Wada (E-mail: yoshi1201.wada@gmail.com)

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Although studies included in this report compared the differences in the type of the AFOs, they did not compare AFO functions, i.e., the setting of ankle joint angle of the AFO, which could be replicated. Regarding the comparison of different AFO functions, a previous randomized controlled trial showed no difference in the walking ability between an AFO with plantar flexion stop and an AFO with plantar flexion resistance<sup>6</sup>). However, there have been no reports focusing on the comparison between different AFO functions with the same dorsiflexed setting of the initial angle of the ankle joint. We believed that this setting would allow us to focus on AFO function more precisely. Furthermore, as the number of stroke-surviving patients is increasing<sup>1</sup>), we consider it is highly necessary to provide suitable AFOs for individuals with chronic stroke.

This study aimed to investigate how different AFO functions with the same dorsiflexed setting of the initial angle of the ankle joint affect the walking ability in individuals with chronic stroke.

## PARTICIPANTS AND METHODS

The study followed a randomized crossover design in which the same participants were randomly assigned to three different orders of conditions, and their gaits were measured in sequence. The participants underwent a 10-m walking test and walked on the WalkWay MW-1000 three times under each of the following three conditions: (1) without AFO; (2) an adjustable posterior strut AFO (APS-AFO) with fixed dorsiflexion at 5° (AFO-DF); (3) APS-AFO set at 5–20° dorsiflexion range of motion; restricted (AFO-DR), indicating that both AFO-DF and AFO-DR had a setting of initial angle of the ankle joint of 5°. All three conditions were tested on the same day. The intervention order was determined in advance using a random allocation tool on a computer by a person who was not involved in the measurement. The person in charge was informed of the examination on the same day. We measured the parameters immediately after the participants were fitted with the AFO such that there was no time for habituation because the purpose of this study was to examine the immediate effects. A 10-min break was set between each condition as a wash-out period.

This study was registered in the University Hospital Medical Information Network (UMIN) clinical trial registration system (examination ID: UMIN000041889) and was approved by the ethics committee of Showa University Fujigaoka Hospital (approval number: F2020C65). The study purpose was fully explained to the participants in writing and verbally, and the study was conducted after obtaining their consent. The data were measured at the Showa University Fujigaoka Rehabilitation Hospital between October 2020 and March 2021. We assumed an effect size of 0.8, alpha of 0.05, and power of 0.8. Using the G-Power program (Kiel University, Kiel, Germany), the required sample size was calculated to be 15.

The inclusion criteria were as follows: individuals with hemiplegia due to initial cerebral hemorrhage/cerebral infarction more than 6 months prior; those aged between 20 and 80 years at the time of consent; those with functional ambulation categories<sup>7, 8</sup>) 4 or higher; those with or without assistive devices; those who were able to follow simple instructions and use AFO daily (regardless of the type of orthosis). The exclusion criteria were a history of neuromuscular and spinal diseases or cerebral palsy.

In this study, we used a ready-made APS-AFO (Tomei Brace, Aichi, Japan) (Fig. 1). The APS-AFO consists of a flat plate support, ankle joint, lower leg cuff, and foot. The elastic flat plate support is flexible with respect to its plane, and its rear position defines the direction of the lower limb movement during walking<sup>9</sup>). The ankle joint has a range of motion of 50° plantar dorsiflexion and is adjustable with fixation and freedom settings at any angle<sup>9</sup>). We used three different sizes of APS-AFOs and determined the size most suitable for each participant.

The primary outcome was walking speed (m/s), calculated from the 10-m walking test in the three conditions. Secondary outcomes were walking speed (m/s), cadence (steps/minute), stride length (m), and single stance and double stance time (s) in the walking cycle automatically measured by WalkWay MW-1000 in the three conditions. The stride length, single stance



**Fig. 1.** APS-AFO, adjustable posterior strut-ankle-foot orthosis (picture provided by Tomei Brace Company).

time, and double stance time were analyzed on the affected and unaffected sides. Since WalkWay MW-1000 cannot measure the swing phase, the single stance time on the unaffected side was defined as the swing time on the affected side, and the single stance time on the affected side was defined as the swing time on the unaffected side<sup>10</sup>.

In the 10-m walking test, we asked the participants to walk 2 m for acceleration, 10 m for actual measurement, and 2 m for deceleration, making a total of 14 m<sup>8, 11</sup>. The time required to walk 10 m was measured by the examiner using a stopwatch. The participants were instructed to walk at a comfortable speed in advance.

We used a sheet-type foot pressure sensor (ANIMA, WalkWay MW-1000, Tokyo, Japan) to measure the temporal and distance factors. The WalkWay MW-1000 automatically measured temporal factors (stance and swing time) and distance factors (step length, stride length, step width, and cadence) in real-time, as the participant walked on the sheet. The size of the walking sheet was 2.4 m in length and 1.2 m in width, the sensor thickness was 5 mm, the sensor spatial resolution was 10 × 10 mm, and the number of measurement points was 14,400. When walking on the WalkWay MW-1000, we asked the participants to walk 2.4 m on the sheet for the actual measurement, 0.8 m for acceleration, and 0.8 m for deceleration, making a total of 4 m. Therefore, the cadence, stride length, and single and double stance time in the gait cycle were automatically measured and recorded. The participants were instructed to walk at a comfortable speed in advance.

The data used were the average of three measurements; if accurate data could not be obtained due to falls, wobbling, or mechanical malfunction, the data were discarded, and the measurements were repeated. In cases where three measurements could not be performed due to pain or other reasons, and one or two measurements were completed, the data were used as-is or averaged. During the examination, it was possible to use assistive devices that were normally used.

The motor function of the participants was evaluated using the Stroke Impairment Assessment Set<sup>12</sup>) on the affected side of the lower limbs, spasticity was evaluated using the modified Ashworth Scale<sup>13</sup>) of the ankle joint, and the range of motion of the ankle joint was evaluated using a passive range of motion.

The 10-m walk test, WalkWay MW-1000 measurements, and measurement of motor function, spasticity, and range of motion were performed by different examiners. In the 10-m walk test and WalkWay MW-1000 measurements, the order of the tests could not be blinded. However, since as this is an objective evaluation, we judged that the influence of non-blinding was not significant.

All gait parameters were presented as the average of the gait cycles for each condition. The data were assessed for normality using the Shapiro–Wilk test. As the primary outcome, walking speed was compared among the three conditions: without AFO, AFO-DF, and AFO-DR groups with Friedman’s non-parametric tests. For comparisons of secondary outcomes between three conditions, Friedman’s non-parametric tests was used. Steel–Dwass test was used for post hoc analysis. Any p-values less than 0.05 was considered as statistically significant. JMP<sup>®</sup> 15 (SAS Institute Inc., Cary, NC, USA) was used for the statistical analysis.

## RESULTS

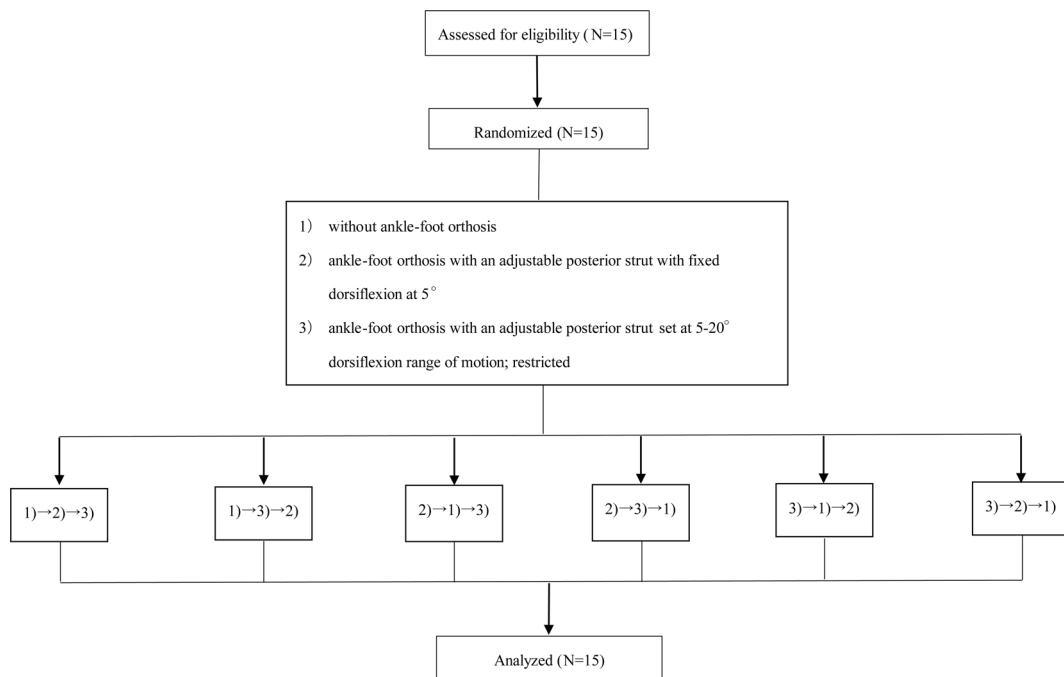
A total of 15 individuals (12 males and 3 females) with chronic stroke, who met the eligibility criteria, were enrolled in this study, and there were no dropouts (Fig. 2). Participant’s characteristics are presented in Table 1. Mean (standard deviation, SD) age was 60.9 (8.6) years. Seven of the participants had right hemiplegia, and eight of them had left hemiplegia. The median (interquartile range, IQR) time from stroke onset to the study was 1,677 (882–4,145.5) days. All participants used their personal AFOs in daily life.

The walking speed calculated from the 10-m walking test of the AFO-DF and AFO-DR groups were significantly increased compared to the without AFO group (without AFO: 0.45 [0.30] [m/s]; AFO-DF: 0.59 [0.22] [m/s]; AFO-DR: 0.62 [0.24] [m/s]; AFO-DF:  $p=0.0030$  and AFO-DR:  $p=0.0014$ ). However, the walking speed was not significantly different between the AFO-DF and AFO-DR groups ( $p=0.39$ ) (Table 2). This result was the same as the walking speed measured by WalkWay MW-1000.

The cadence was significantly improved in AFO-DF and AFO-DR groups compared to the without AFO group (without AFO: 68.12 [33.00] [step/min]; AFO-DF: 73.96 [16.70] [step/min]; AFO-DR: 74.31 [18.67] [step/min]; AFO-DF:  $p=0.034$  and AFO-DR:  $p=0.015$ ). Regarding temporal factors, the unaffected side single stance time was significantly shortened in the AFO-DF and AFO-DR groups compared to the without AFO group (without AFO: 0.73 [0.26] [s]; AFO-DF: 0.59 [0.15] [s], AFO-DR: 0.59 [0.17] [s]; AFO-DF:  $p=0.0024$  and AFO-DR:  $p=0.017$ ). However, the cadence and the unaffected side single stance time were not significantly different between the AFO-DF and AFO-DR groups ( $p>0.05$ ). Furthermore, the stride length, the affected side single stance time, and the double stance time of the affected limb and unaffected limb were not significantly different among the three groups ( $p>0.05$ ).

## DISCUSSION

This randomized crossover study examined the immediate effects of AFO functions with the same dorsiflexed setting of the initial angle of the ankle joint on the walking ability in individuals with chronic stroke. In comparison with the no AFO group, AFO-DF and AFO-DR groups showed a significant improvement in walking speed and spatiotemporal factors. Nevertheless, walking speed and spatiotemporal factors were not significantly different between the AFO-DF and AFO-DR



**Fig. 2.** Flow diagram for participant selection.

groups. The results suggested that different AFO functions with the same dorsiflexed setting of the initial angle of the ankle joint might not have immediately affected individuals with chronic stroke.

Walking speed, cadence, and unaffected side single stance time demonstrated a significant difference in the AFO-DF and AFO-DR groups than the without AFO group. Systematic reviews and meta-analyses<sup>14, 15</sup> have previously reported improvements in the gait speed with AFO, which is consistent with the results of this study. Although the change in spatiotemporal factors with improvement in the walking speed varies among reports<sup>15</sup>, walking speed is a combination of cadence multiplied by step length/stride length<sup>16, 17</sup>, and cadence improvement with improvement in walking speed could be predicted. The American Heart Association/American Stroke Association guidelines<sup>3</sup>) and a systematic review and meta-analysis<sup>4</sup>) have emphasized the effect of AFO on stroke patients in ensuring toe clearance. The use of AFOs has been shown to increase the ankle dorsiflexion angle during the swing phase in stroke patients, which may promote effective toe clearance and reduced compensatory movements<sup>4</sup>). In this study, the initial angle of the ankle joint of the AFO was dorsiflexed, which may have maintained toe clearance and led to a shortening of the affected side swing time (i.e., unaffected side single stance time). Our findings also suggest that using AFOs maintain toe clearance and improve walking speed in individuals with chronic stroke.

However, walking speed and spatiotemporal factors were not significantly different between the AFO-DF and AFO-DR groups. It has been reported that the ankle joint moves in the dorsiflexion direction during walking when the ankle joint rocker works in the stance phase<sup>18</sup>) and that the ankle joint rocker is an important mechanism that moves the body forward and influences the walking speed<sup>16</sup>). We expected that using AFO with mobility of the ankle joint to dorsiflexion, i.e., AFO-DR group, would improve the walking speed and prolong the single stance time of the affected limb and stride length of the unaffected limb. Therefore, we believe that the effects of AFO functions with the same dorsiflexed setting of the initial angle of the ankle joint should focus on the stance and swing phases separately; however, there was no significant difference in the spatiotemporal parameters between the AFO-DF and AFO-DR groups. Two possible reasons were attributed to the finding. First, this study included only individuals with chronic stroke and were accompanied by a limited range of motion of the ankle joint. In such individuals, even if the mobility of the ankle joint of the AFO is present, it may not be reflected in gait because of the reduced mobility of the ankle joint on the individual's side. In general, individuals with chronic stroke often have a limited range of motion of the ankle joint due to spasticity and contracture<sup>19, 20</sup>), and most of the participants in this study also had a limited range of motion of the ankle joint. Thus, the acute and subacute phases of stroke before the ankle joint mobility is limited, are considered to be important for walking with the mobility of the ankle joint in AFO. Therefore, it may be necessary to adjust the AFO to avoid the limitation of ankle joint mobility in the acute and subacute phases. Second, all the participants in this study used AFOs in daily life, and it cannot be ruled out that differences in the types of AFOs may have affected the results of this study. However, since the AFO user is the one with the greatest need for AFOs, the results of this study may have useful clinical implications even if such effects could not be fully ruled out. Detailed adjustments of AFOs may not be necessary for individuals with chronic stroke who use an AFO daily.

**Table 1.** Clinical characteristics of the individuals with stroke

Participant	Gender	Age (years)	Height (cm)	Weight (kg)	Diagnosis	Affected side	Time after onset (days)	Assistive device	Type of AFO	Passive Ankle dorsiflexion (degree, °)	MAS	SIAS-LE hip/knee/foot
1	F	50	163	61	Hemorrhage	R	619	Single-point cane	Conventional AFO (double adjustable ankle joint)	0	2	3-3-1
2	M	51	171	70	Hemorrhage	L	528	Single-point cane	APS-AFO	0	2	4-3-2
3	M	58	170	58	Ischemic	R	1,677	Single-point cane	GSD	5	2	3-4-0
4	M	78	161	55	Ischemic	R	4,383	Single-point cane	Plastic AFO	-5	2	0-3-0
5	F	67	156	39	Hemorrhage	R	2,901	Single-point cane	ORTOP AFO	0	2	3-3-0
6	M	51	162	62	Ischemic	L	5,314	No	GSD	-15	2	4-3-1
7	M	70	171	80	Ischemic	R	10,731	Single-point cane	Conventional AFO (single adjustable ankle joint)	0	2	3-3-2
8	M	52	180	66	Hemorrhage	R	211	Single-point cane	APS-AFO	0	2	4-4-1
9	M	57	161	64	Hemorrhage	L	1,133	Single-point cane	APS-AFO	0	2	4-3-1
10	M	70	180	81	Ischemic	L	631	Single-point cane	Plastic AFO (Tamarack flexure joint)	-15	2	3-3-3
11	F	62	158	53	Hemorrhage	R	1,308	Single-point cane	Conventional AFO (double adjustable ankle joint)	-15	3	3-2-0
12	M	60	168	75	Hemorrhage	L	3,908	Single-point cane	Plastic AFO (Tamarack flexure joint)	0	2	4-3-2
13	M	58	168	71	Ischemic	L	1,281	No	Plastic AFO (Tamarack flexure joint)	-20	3	4-4-1
14	M	56	175	85	Hemorrhage	L	1,820	No	Plastic AFO (Tamarack flexure joint)	0	2	3-3-0
15	M	74	171	64	Hemorrhage	L	4,923	No	Plastic AFO (Tamarack flexure joint)	0	2	4-3-2

F: female; M: male; R: right; L: left; AFO: ankle-foot orthosis; APS-AFO: adjustable posterior strut-AFO; GSD: GaitSolution Design; MAS: modified Ashworth scale; SIAS-LE: Stroke Impairment Assessment Set lower limb motor function score.

**Table 2.** Spatiotemporal data of individuals with stroke

Parameter		Without AFO	AFO-DF	AFO-DR
Walking speed (m/s) (the 10-m walk test)		0.45 ± 0.30	0.59 ± 0.22*	0.62 ± 0.24*
Walking speed (m/s) (the WalkWay MW-1000)		0.33 ± 0.15	0.42 ± 0.13*	0.43 ± 0.13*
Cadence (step/min)		68.12 ± 33.00	73.96 ± 16.70**	74.31 ± 18.67**
Stride length (m)	A	0.59 ± 0.21	0.68 ± 0.19	0.70 ± 0.18
	U	0.59 ± 0.20	0.66 ± 0.21	0.65 ± 0.18
Single stance time (s)	A	0.38 ± 0.21	0.30 ± 0.16	0.30 ± 0.17
	U	0.73 ± 0.26	0.59 ± 0.15*	0.59 ± 0.17**
Double stance time (s)	A	0.44 ± 0.29	0.38 ± 0.29	0.40 ± 0.29
	U	0.49 ± 0.48	0.34 ± 0.13	0.35 ± 0.14

AFO: ankle-foot orthosis; AFO-DF: adjustable posterior strut (APS)-AFO with fixed dorsiflexion at 5°; AFO-DR: APS-AFO set at 5–20° dorsiflexion range of motion(restricted); A: affected limb; U: unaffected limb. Data are represented as mean (standard deviation).

\*Mean of this condition differed significantly from mean of Without AFO condition. ( $p < 0.01$ ).

\*\*Mean of this condition differed significantly from mean of Without AFO condition. ( $p < 0.05$ ).

This research is characterized by the use of a seat-type foot pressure sensor to evaluate temporal and distance factors. Gait analysis can provide more objective information for the selection of AFOs. In previous studies included in the systematic review and meta-analysis<sup>14</sup>, spatiotemporal factors were measured using a three-dimensional motion analysis system<sup>21</sup> and footprint<sup>22, 23</sup>. The seat-type foot pressure sensor is easy to carry and use in clinical situations, and it can automatically measure spatiotemporal parameters that do not require any special technique<sup>24, 25</sup>. Moreover, it has been shown to be valid and reliable for measuring the spatiotemporal factors of walking<sup>26, 27</sup>. However, only a few studies<sup>28, 29</sup> have evaluated the influence of AFO on gait using this device. We believe that this device, which is easy to use in clinical situations and has high objectivity of data due to its automatic measurement, will be effective in investigating the influence of AFOs on the spatiotemporal parameters of gait.

This study had some limitations. First, the AFO used was not suitable for all participants; therefore, it is possible that those participants did not make the best use of their abilities or were afraid of falling. Second, we did not measure the kinetic or kinematic factors. Therefore, we could not examine in detail the dorsiflexion angles of the ankle joints during gait. Finally, the participants were not blinded to the three intervention conditions or the order of their allocation. However, because of the characteristics of this study, blinding was difficult. The study was conducted as a randomized crossover trial and had a short wash-out period. There is no carry-over effect because AFO affects gait only when the participant is wearing it. In addition, although not considered in this study, it is desirable to conduct a comprehensive study including factors other than walking ability, such as comparison of compliance (fits, comfortably, and acceptability in appearance) for the selection of AFO.

In chronic stroke individuals with a limited range of motion in the ankle joint, differences in AFO functions with the same dorsiflexed setting of the initial angle of the ankle joint may be less important. Further research is needed to examine the long-term effect of AFO, participant satisfaction, and the selection of AFO during the acute and subacute phases of stroke.

### Conference presentation

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### Conflict of interest

The authors declare no conflicts of interest associated with this manuscript.

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## REFERENCES

- 1) Feigin VL, Nguyen G, Cercy K, et al. GBD 2016 Lifetime Risk of Stroke Collaborators: Global, regional, and country-specific lifetime risks of stroke, 1990 and 2016. *N Engl J Med*, 2018, 379: 2429–2437. [[Medline](#)] [[CrossRef](#)]
- 2) Patterson SL, Forrester LW, Rodgers MM, et al.: Determinants of walking function after stroke: differences by deficit severity. *Arch Phys Med Rehabil*, 2007, 88: 115–119. [[Medline](#)] [[CrossRef](#)]
- 3) Winstein CJ, Stein J, Arena R, et al. American Heart Association Stroke Council, Council on Cardiovascular and Stroke Nursing, Council on Clinical Cardiology, and Council on Quality of Care and Outcomes Research: Guidelines for adult stroke rehabilitation and recovery: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke*, 2016, 47: e98–e169. [[Medline](#)] [[CrossRef](#)]
- 4) Wada Y, Otaka Y, Mukaino M, et al.: The effect of ankle-foot orthosis on ankle kinematics in individuals after stroke: a systematic review and meta-analysis. *PM R*, 2021. [[Medline](#)] [[CrossRef](#)]
- 5) Shahabi S, Shabanejad H, Kamali M, et al.: The effects of ankle-foot orthoses on walking speed in patients with stroke: a systematic review and meta-analysis of randomized controlled trials. *Clin Rehabil*, 2020, 34: 145–159. [[Medline](#)] [[CrossRef](#)]
- 6) Yamamoto S, Tanaka S, Motojima N: Comparison of ankle-foot orthoses with plantar flexion stop and plantar flexion resistance in the gait of stroke patients: a randomized controlled trial. *Prosthet Orthot Int*, 2018, 42: 544–553. [[Medline](#)] [[CrossRef](#)]
- 7) Holden MK, Gill KM, Magliozzi MR, et al.: Clinical gait assessment in the neurologically impaired. Reliability and meaningfulness. *Phys Ther*, 1984, 64: 35–40. [[Medline](#)] [[CrossRef](#)]
- 8) van Bloemendaal M, van de Water AT, van de Port IG: Walking tests for stroke survivors: a systematic review of their measurement properties. *Disabil Rehabil*, 2012, 34: 2207–2221. [[Medline](#)] [[CrossRef](#)]
- 9) Mizuno M, Saitoh E, Iwata E, et al.: The development of a new posterior strut AFO with an adjustable joint: its concept and a consideration of basic function. *Bull Jpn Soc Prosthet Orthot*, 2005, 21: 225–233.
- 10) Lamontagne A, Richards CL, Malouin F: Coactivation during gait as an adaptive behavior after stroke. *J Electromyogr Kinesiol*, 2000, 10: 407–415. [[Medline](#)] [[CrossRef](#)]
- 11) Cheng DK, Nelson M, Brooks D, et al.: Validation of stroke-specific protocols for the 10-meter walk test and 6-minute walk test conducted using 15-meter and 30-meter walkways. *Top Stroke Rehabil*, 2020, 27: 251–261. [[Medline](#)] [[CrossRef](#)]
- 12) Chino N, Sonoda S, Domen K, et al.: Stroke impairment assessment set (SIAS). A new evaluation instrument for stroke patients. *Jpn J Rehabil Med*, 1994, 31: 119–125. [[CrossRef](#)]
- 13) Bohannon RW, Smith MB: Interrater reliability of a modified Ashworth scale of muscle spasticity. *Phys Ther*, 1987, 67: 206–207. [[Medline](#)] [[CrossRef](#)]
- 14) Tyson SF, Kent RM: Effects of an ankle-foot orthosis on balance and walking after stroke: a systematic review and pooled meta-analysis. *Arch Phys Med Rehabil*, 2013, 94: 1377–1385. [[Medline](#)] [[CrossRef](#)]
- 15) Guerra Padilla M, Molina Rueda F, Alguacil Diego IM: Effect of ankle-foot orthosis on postural control after stroke: a systematic review. *Neurologia*, 2014, 29: 423–432. [[Medline](#)] [[CrossRef](#)]
- 16) Silva MR, Jacinto J: Velocity determinants in spastic patients after stroke—a gait analysis study. *Neurol Int*, 2020, 12: 48–54. [[Medline](#)] [[CrossRef](#)]
- 17) Wonsetler EC, Bowden MG: A systematic review of mechanisms of gait speed change post-stroke. Part 1: spatiotemporal parameters and asymmetry ratios. *Top Stroke Rehabil*, 2017, 24: 435–446. [[Medline](#)] [[CrossRef](#)]
- 18) Yamamoto S, Fuchi M, Yasui T: Change of rocker function in the gait of stroke patients using an ankle foot orthosis with an oil damper: immediate changes and the short-term effects. *Prosthet Orthot Int*, 2011, 35: 350–359. [[Medline](#)] [[CrossRef](#)]
- 19) Chung SG, Van Rey E, Bai Z, et al.: Biomechanic changes in passive properties of hemiplegic ankles with spastic hypertonia. *Arch Phys Med Rehabil*, 2004, 85: 1638–1646. [[Medline](#)] [[CrossRef](#)]
- 20) Thilmann AF, Fellows SJ, Ross HF: Biomechanical changes at the ankle joint after stroke. *J Neurol Neurosurg Psychiatry*, 1991, 54: 134–139. [[Medline](#)] [[CrossRef](#)]
- 21) Gök H, Küçükdeveci A, Altinkaynak H, et al.: Effects of ankle-foot orthoses on hemiparetic gait. *Clin Rehabil*, 2003, 17: 137–139. [[Medline](#)] [[CrossRef](#)]
- 22) Tyson SF, Rogerson L: Assistive walking devices in nonambulant patients undergoing rehabilitation after stroke: the effects on functional mobility, walking impairments, and patients' opinion. *Arch Phys Med Rehabil*, 2009, 90: 475–479. [[Medline](#)] [[CrossRef](#)]
- 23) Burdett RG, Borello-France D, Blatchly C, et al.: Gait comparison of subjects with hemiplegia walking unbraced, with ankle-foot orthosis, and with Air-Stirrup brace. *Phys Ther*, 1988, 68: 1197–1203. [[Medline](#)]
- 24) Webster KE, Wittwer JE, Feller JA: Validity of the GAITRite walkway system for the measurement of averaged and individual step parameters of gait. *Gait Posture*, 2005, 22: 317–321. [[Medline](#)] [[CrossRef](#)]
- 25) Menz HB, Latt MD, Tiedemann A, et al.: Reliability of the GAITRite walkway system for the quantification of temporo-spatial parameters of gait in young and older people. *Gait Posture*, 2004, 20: 20–25. [[Medline](#)] [[CrossRef](#)]
- 26) McDonough AL, Batavia M, Chen FC, et al.: The validity and reliability of the GAITRite system's measurements: a preliminary evaluation. *Arch Phys Med Rehabil*, 2001, 82: 419–425. [[Medline](#)] [[CrossRef](#)]
- 27) Vartiainen MV, Savolainen S, Alaranta HT: Reliability and agreement in gait measurements among patients with brain injury. *Adv Physiother*, 2009, 11: 22–29. [[CrossRef](#)]
- 28) Bouchalová V, Houben E, Tancsik D, et al.: The influence of an ankle-foot orthosis on the spatiotemporal gait parameters and functional balance in chronic stroke patients. *J Phys Ther Sci*, 2016, 28: 1621–1628. [[Medline](#)] [[CrossRef](#)]
- 29) Karakkattil PS, Trudelle-Jackson E, Medley A, et al.: Effects of two different types of ankle-foot orthoses on gait outcomes in patients with subacute stroke: a randomized crossover trial. *Clin Rehabil*, 2020, 34: 1094–1102. [[Medline](#)] [[CrossRef](#)]