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Original Article

Difference in independent mobility improvement from admission to discharge between subacute stroke patients using knee-ankle-foot and those using ankle-foot orthoses

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Abstract. [Purpose] To verify differences in independent mobility improvements between people with subacute stroke with knee-ankle-foot orthoses (KAFOs) and those with ankle-foot orthoses (AFOs) from admission to discharge, and to identify the relationship between mobility improvements and their characteristics. [Participants and Methods] This study included 381 hospitalized patients with subacute stroke who required complete mobility assistance at admission and for whom KAFOs (KAFO group) or AFOs (AFO group) were prescribed after admission. The functional independence measure (FIM) score at admission and discharge, FIM gain, age, Brunnstrom stage (BS) of the paretic lower limb at admission, and the period from admission to prescription for lower limb orthoses were investigated. [Results] Repeated-measures two-way analysis of variance revealed a significant group × time interaction in the walk/wheelchair and stair-climbing items of the FIM. Improvements in the scores in the KAFO group were significantly lower than those in the AFO group. Age, BS, FIM at admission, and period from admission to lower limb orthosis prescription significantly correlated with FIM gain in the walk/wheelchair and stair-climbing items. [Conclusion] A more effective intervention using lower limb orthoses with consideration of the influence of age, motor paralysis, and activities of daily living at admission is required to promote the improvements of people with subacute stroke prescribed KAFOs or AFOs.

Key words: Stroke, Lower-limb orthosis, Mobility

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INTRODUCTION

Impairments resulting from stroke lead to long-term disabilities in activities of daily living (ADL). In particular, mobility functions such as walking, stair-climbing, and transferring are frequently impaired by stroke[1], and impaired mobility functions leads to reduced life space. Moreover, mobility disorders decrease one's overall physical activity and may increase risk for recurrent stroke and cardiovascular disease[2]. Thus, more effective interventions to regain independent mobility are required for patients with subacute stroke.

Recent reviews of exercise interventions to improve mobility have reported that those using equipment such as body weight-supported treadmill training and robot-assisted gait training improve the walking abilities of people with stroke[3, 4]. In

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each training method, compensating for motor impairments in the paretic lower limb using an external device enables people with stroke to walk with less therapist assistance. However, because both devices can be used only in specific environments, they have not yet been widely used.

Lower-limb orthoses have been used for many years, and several stroke rehabilitation guidelines recommend their use by people with stroke to improve walking ability[5–10]. Lower-limb orthoses are easily used in many different settings without the need for special equipment and have the potential to be widely used. Ankle-foot orthoses (AFOs) and knee-ankle-foot orthoses (KAFOs) are representative lower-limb orthoses used for stroke rehabilitation. The use of AFOs has been recommended for people with stroke who experience loss of control or muscle function impairments around the ankle[5–10]. The use of AFOs for people with stroke has been reported to immediately improve walking independence[11], speed[12], endurance[13], step length[14], and standing balance ability[15]. Moreover, the long-term AFO versus no AFO use improved functional independence measure (FIM) score at discharge[16].

On the other hand, KAFOs have been used by people with stroke who experienced knee collapse while standing and walking. In the clinical situation, AFOs and KAFOs have been used with the expectation of affecting mobility, and we have observed KAFOs improving the mobility abilities of people with stroke. However, previous reports on the effects of KAFOs on mobility are limited. Furthermore, little is known about factors that contribute to mobility improvements in people prescribed lower-limb orthoses. Age, stroke severity, and motor paresis of paretic limb at admission reportedly affect ADL abilities and independent walking at discharge[17, 18]. However, it is unclear whether patient characteristics at admission such as age, motor paralysis, and ADL disability influence improvements in independent mobility in people after moderate to severe stroke who require lower-limb orthoses.

The purposes of this study were to verify differences in independent mobility improvements between people with subacute stroke who were prescribed KAFOs and AFOs from admission to discharge, and to identify relationship between mobility improvements and patient characteristics at admission. In clinically, compared with AFOs, KAFOs are often prescribed for people with more sever stroke. We hypothesized that the improvements in independent mobility are poorer in people with subacute stroke prescribed KAFOs than in those prescribed AFOs, and previously reported factors influenced independent walking at discharge[17, 18] would relate to the improvements. Studying improvement characteristics of mobility independence and factors that contribute to mobility improvements of people who are prescribed lower-limb orthoses allow us to provide more efficient rehabilitation using lower-limb orthoses.

PARTICIPANTS AND METHODS

The participants of this study were 381 people with subacute stroke (mean age, 71 years; mean post stroke interval at admission, 35 days; mean hospital stay, 126 days). The patients were hospitalized at the rehabilitation hospital between 2006 and 2011. Inclusion criteria were: (1) post-stroke interval at admission within 60 days; (2) length of hospital stay within 180 days; (3) prescribed a KAFO or an AFO after admission; and (4) requirement for complete assistance for mobility (score of 1 at admission in walk/wheelchair and stair-climbing items of the FIM mobility subscale) at admission. This study excluded people who were diagnosed with subarachnoid hemorrhage. All participants received conventional rehabilitation of approximately 1–3 hours per day, including physical therapy, occupational therapy, and speech therapy similar to other institutions[19]. These therapies were delivered at amounts of 1–6 units each (one unit is 20 minutes; total of 3–9 units).

This study was approved by the Ethics Committee of Kyorin university (28-4) and Hatsudai Rehabilitation Hospital (H27-85). All participants provided written informed consent.

Primary outcome measures were FIM scores at admission and discharge. The FIM consists of 18 items divided into motor and cognitive domains[20]. The motor domain includes 13 items composed of four subscales: self-care, sphincter control, transfers, and mobility. The cognitive domain includes five items composed of two communication and social cognition subscales. All items are scored using a seven-point ordinal scale. A score of 1 equals complete dependence, while a score of 7 equals complete independence. Higher FIM scores indicate higher levels of independence.

The total functional independence measure (t-FIM) score, which is the sum of all scores for the 18 items, and the motor domain of functional independence measure (m-FIM) subscore, which is the sum of the scores of the 13 items of the motor domain, cognitive domain of functional independence measure (c-FIM) subscore, which is the sum of the scores in five items of the cognitive domain, were calculated. The number of people who moved independently at discharge (two items scores of FIM mobility subscale at discharge≥6) was derived from discharge FIM scores. The FIM gain in two items of the FIM mobility subscale were calculated as discharge FIM score minus admission FIM score.

Secondary outcome measures were basic characteristics (age, gender, stroke type, lesion side, Brunnstrom stage (BS) of the paretic lower limb at admission[21], post-stroke interval at admission or lower-limb orthosis prescription, period from admission to a lower-limb orthosis prescription, and length of hospital stay).

All assessments were performed by medical staff (nurse, care worker, physical therapist, occupational therapist, or speech therapist) trained on these assessments.

In the comparison of basic characteristics, to compare gender, stroke type, lesion side, and BS of the paretic lower limb at admission between the participants who were prescribed KAFOs (KAFO group, n=263) and those who were prescribed AFOs (AFO group, n=118), a χ^2 test was performed. To compare age, post-stroke interval at admission, or lower-limb

Table 1. Comparison of basic characteristics between KAFO group and AFO group

	KAFO group	AFO group
Age (years[a,b])	74 ± 11	65 ± 14*
Gender female/male (n)	132/131	34/84*
Stroke type, infarction/hemorrhage (n)	150/113	59/59
Lesion side, left/right (n)	104/159	60/58*
Post stroke interval at admission (days[a,b])	35 ± 13	34 ± 12
Post stroke interval at lower-limb orthosis prescription (days[a,b])	46 ± 18	47 ± 18
Period from admission to lower-limb orthosis prescription (days[a,b])	11 ± 4	13 ± 6
Length of hospital stay (days[a,b])	127 ± 28	123 ± 26
BS of paretic lower limb at admission, I/II/III/IV/V/VI (n)	14/149/82/14/4/0	0/24/84/8/2/0*

[a]Data provided as mean ± SD; other items indicated number of participants. [b]Two-sample t-test was used to compare differences in characteristics between KAFO group and AFO group; other items used χ^2 test. *p<0.05. KAFO: knee–ankle–foot orthosis; AFO: ankle–foot orthosis; BS: Brunnstrom stage.

orthosis prescription, the periods from admission to lower-limb orthosis prescription, and length of hospital stay between two groups, a two-sample t-test was also performed.

In the comparison of time courses of t-FIM, m-FIM, c-FIM, three items (bed, chair, wheelchair; toilet; tub, shower) of FIM transfer subscales and two items (walk/wheelchair; stair-climbing) mobility subscale scores from admission to discharge between the two groups, repeated two-way analysis of variance (ANOVA) with main factors of type of leg orthosis (KAFO/AFO) as a between-participant factor and admission/discharge as a within-participant factor was used. When a major or interaction effect was found, post hoc analyses were performed using the Bonferroni method. Furthermore, to compare the number of people who moved independently at discharge between two groups, the χ^2 test was conducted.

Spearman correlation coefficients were calculated to examine the correlation between age, each FIM score (t-FIM, m-FIM, and c-FIM) at admission, BS of the paretic lower limb at admission, period from admission to lower-limb orthosis prescription, and FIM gain in two items of the FIM mobility subscale.

The statistical significance level was 0.05. All analyses were conducted using IBM SPSS version 23.0.

RESULTS

In the comparison of basic characteristics between the two groups, a two-sample t-test revealed that the participants in the KAFO group were significantly older than those in the AFO group. The χ^2 test revealed that the proportion of participants who were female, had left hemisphere brain damage, and BS I and II were more common in the KAFO group, while the proportion of participants who were male, had right hemisphere brain damage, and had a BS III were more common in the AFO group (Table 1).

In two items of the mobility subscale, repeated two-way ANOVA showed significant main effects of the within-participant factor, while the post hoc analysis showed that the KAFO and AFO groups had significantly higher scores on two items of the mobility subscales at discharge than at admission. However, repeated two-way ANOVA showed a significant main effect of between-participant factor and interaction effect, and the improvement of two items of the mobility subscale scores were significantly lower in the KAFO group than in the AFO group.

Also, in the three items of transfer subscale, t-FIM and m-FIM, repeated two-way ANOVA showed significant main effect of within-participants factor and interaction effect, improvement of three items of transfer subscale, t-FIM and m-FIM scores in KAFO group were significantly lower than in AFO group. On the other hand, post hoc analysis showed that participants in KAFO group had significantly lower scores than those in AFO group at admission.

In c-FIM, repeated two-way ANOVA showed significant main effects of between-participant and within-participant factors, while the post hoc analysis showed that the KAFO and AFO groups had significantly higher two items of mobility subscale scores at discharge than at admission (Table 2). Furthermore, the proportion of people who were able to independently transfer and ambulate at discharge was significantly lower in the KAFO group (Tables 3, 4).

The Spearman correlation coefficients showed that FIM gains in walk/wheelchair and stair-climbing items were significantly correlated with age; BS of the paretic lower limb; t-FIM, m-FIM, and c-FIM at admission; and period from admission to lower-limb orthosis prescription. The t-FIM, m-FIM, and c-FIM scores were moderately positively correlated with FIM gains in walk/wheelchair and stair-climbing items. A moderately negative correlation was found among age and FIM gain in the walk/wheelchair and stair-climbing items. The BS of paretic lower limbs was only slightly positively correlated with FIM gains in the walk/wheelchair and stair-climbing items. The period from admission to lower-limb orthosis prescription was slightly negatively correlated with FIM gains in the walk/wheelchair and stair-climbing items (Table 5).

Table 2. Comparison of time courses of FIM scores from admission to discharge between KAFO group and AFO group

	Admission		Discharge	
	KAFO group	AFO group	KAFO group	AFO group
Mobility (point)				
Walk/wheelchair*, †, **	1.0 ± 0.0 [a]	1.0 ± 0.0 [b]	2.4 ± 1.7 [d]	4.2 ± 2.0
Stair-climbing*, †, **	1.0 ± 0.0 [a]	1.0 ± 0.0 [b]	1.8 ± 1.4 [d]	3.6 ± 1.7
Transfer (point)				
Bed, chair, wheelchair*, †, **	1.7 ± 0.7 [a, c]	2.8 ± 1.1 [b]	3.4 ± 1.5 [d]	5.1 ± 1.5
Toilet*, †, **	1.6 ± 0.7 [a, c]	2.7 ± 1.1 [b]	3.5 ± 1.5 [d]	5.1 ± 1.5
Tub, shower*, †, **	1.4 ± 0.6 [a, c]	2.1 ± 0.9 [b]	2.3 ± 1.1 [d]	3.6 ± 1.2
m-FIM*, †, ** (point)	20.9 ± 8.2 [a, c]	34.2 ± 11.9 [b]	37.6 ± 17.7 [d]	61.0 ± 19.1
c-FIM*, † (point)	13.6 ± 7.2 [a, c]	19.5 ± 8.2 [b]	18.6 ± 8.0 [d]	24.5 ± 7.6
t-FIM*, †, ** (point)	34.5 ± 14.0 [a, c]	53.7 ± 18.0 [b]	56.2 ± 24.0[d]	85.5 ± 25.0

Data provided as mean ± SD. [a]Significant differences between admission and discharge in KAFO group.
[b]Significant differences between admission and discharge in AFO group.
[c]Significant differences between KAFO group and AFO group at admission.
[d]Significant differences between KAFO group and AFO group at discharge.
*Significant main effect (admission/discharge).
†Significant main effect (KAFO/AFO).
**Significant interaction effect. KAFO: knee–ankle–foot orthosis; AFO: ankle–foot orthosis; BS: Brunnstrom stage; t-FIM: total functional independence measure; m-FIM: motor domain of functional independence measure; c-FIM: cognitive domain of functional independence measure.

Table 3. Comparison of the number of people who moved independently at discharge between KAFO group and AFO group

		Walk/wheelchair item			Stair-climbing item		
		KAFO group	AFO group	All participants	KAFO group	AFO group	All participants
Dependent	n	245	77	322	258	105	363
	%	93	65	85	98	89	95
	Adjusted residuals	6.96	−6.96		3.88	−3.88	
Independent	n	18	41	59	5	13	18
	%	7	35	16	2	11	5
	Adjusted residuals	−6.96	6.96		−3.88	3.88	
All participants	n	263	118	381	263	118	381

Walk/wheelchair item, $p<0.001$, $\chi^2=48.452$.
Stair-climbing item, $p<0.001$, $\chi^2=15.037$.
KAFO: knee–ankle–foot orthosis; AFO: ankle–foot orthosis.

Table 4. Comparison of the number of people who transferred independently at discharge between KAFO group and AFO group

		Transfer (bed, chair, wheelchair) item			Transfer (toilet) item			Transfer (tub, shower) item		
		KAFO group	AFO group	All participants	KAFO group	AFO group	All participants	KAFO group	AFO group	All participants
Dependent	n	236	65	301	238	65	303	260	111	371
	%	90	55	79	91	55	80	99	94	97
	Adjusted residuals	7.68	−7.68		7.92	−7.92		2.71	−2.71	
Independent	n	27	53	80	25	53	78	3	7	10
	%	10	45	21	10	45	21	1	6	3
	Adjusted residuals	−7.68	7.68		−7.92	7.92		−2.71	2.71	
All participants	n	263	118	381	263	118	381	263	118	381

Transfer (bed, chair, wheelchair) item, $p<0.001$, $\chi^2=58.951$.
Transfer (toilet) item, $p<0.001$, $\chi^2=62.729$.
Transfer (tub, shower) item, $p=0.012$, $\chi^2=7.317$.
KAFO: knee–ankle–foot orthosis; AFO: ankle–foot orthosis.

Table 5. Spearman correlation coefficient among FIM gain in walk/wheelchair and star-climbing items, characteristics at admission and period from admission to lower-limb orthosis prescription

	FIM gain	
	Walk/wheelchair item	Stair-climbing item
Age	−0.552	−0.582
BS of paretic lower limb at admission	0.217	0.277
Period from admission to lower-limb orthosis prescription	−0.211	−0.157
t-FIM	0.613	0.584
m-FIM	0.650	0.621
c-FIM	0.449	0.425

All significance level was $p<0.001$. The FIM gain in walk/wheelchair and star-climbing items were calculated as discharge FIM score minus admission FIM score.
BS: Brunnstrom stage; t-FIM: total functional independence measure; m-FIM: motor domain of functional independence measure; c-FIM: cognitive domain of functional independence measure.

DISCUSSION

This study investigated differences in independent mobility improvements between people with subacute stroke who were prescribed KAFOs and AFOs from admission to discharge, and examined the correlations among independent mobility improvements, characteristics at admission and, period from admission to lower-limb orthosis prescription. Our results indicated that mobility independence improved in the KAFO and AFO groups; however, age, motor paralysis of the lower limb, ADL disabilities at admission, and period from admission to lower-limb orthosis prescription might affect the improvement in mobility independence since it was lower in the KAFO group than in the AFO group.

Motor function of the lower limb is an important factor in walking performance. Severe motor paralysis makes it difficult to support one's body weight and swing one's leg and inhibits mobility. Veerbeek et al.[18] and Hirano et al.[19] reported that hemiparetic leg strength affected independent walking in people with stroke, and our results agree with those reports. Therefore, differences in the severity of motor paralysis of the paretic lower limb among people with subacute stroke who were prescribed KAFOs or AFOs might affect the improvement in independent mobility. In addition, participants in the KAFO group had more severely impaired motor and cognitive functions assessed by FIM than those in the AFO group. Because people with severe stroke mostly have impaired motor function, they may be recommended to acquire compensatory movements. However, because severe motor dysfunction may decrease training amount and severe cognitive dysfunction may restrict training type, motor learning may be limited. Wandel et al.[22] reported that ADL disabilities assessed by the Barthel index at admission predicted independent walking after stroke. Therefore, ADL disability might have also affected improvements in independent mobility in the present study.

Patient characteristics at admission as well as the period from admission to lower-limb orthosis prescription were related with mobility improvements seen in people with subacute stroke prescribed KAFOs or AFOs in the present study. Stroke typically leads to physical inactivity[23], so increasing physical activity is an important factor that facilitates recovery from post-stroke disability in people with stroke[24]. Most people with subacute stroke prescribed KAFOs or AFOs required physical assistance to stand and walk at admission and tended to have a poor ability to do so with assistance. Using KAFOs and AFOs enables people with subacute stroke to stand and walk with less assistance by compensating for the decreased motor function of the paretic lower limb and may promote physical activity. Thus, the early prescription of lower-limb orthoses might be a considerable factor that promotes improvements in independent mobility.

In the present study,<10% of patients in the KAFO group and 10–30% of patients in the AFO group moved independently at discharge. Few reports have investigated the proportion of people with stroke who are able to walk independently, while several studies examined patients who could not walk independently and observed walking independence from the acute phase to 6 months after stroke. Veerbeek et al.[18] reported that 79% of people with stroke were able to walk independently at 6 months after stroke, while Kwah et al.[25] reported that 70% of people with stroke achieved independent ambulation at 6 months after stroke. In present study, because the participants could not walk independently and had more severe walking disability in the subacute phase, the proportion of them who were able to move independently at discharge would be very low. Using lower-limb orthoses to improve the walking and standing capacity of people with stroke has been recommended[5–10]. However, how to use lower-limb orthoses in stroke rehabilitation has not been reported. A more effective intervention using lower-limb orthoses is required to promote improvements in mobility independence among people with subacute stroke prescribed KAFOs or AFOs, and it was also needed to consider the impact of age, motor paralysis of paretic lower limb and ADL at admission on the improvements.

The limitation of the present study was that it did not address the influence of cognitive and emotional disabilities on improvement after stroke despite their ability to negatively influence ADL recovery[26]. Additionally, comorbidities were not investigated, while we were unable to identify whether any particular comorbidities might affect improvements in independent mobility.

Conflict of interest

None.

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