

Association Between Self-Perceived General Human-Likeness During Walking and Walking Speed in Stroke Patients: A Preliminary Study

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Kazuki Hayashida^{1,2}, Ryota Nakazono², Nami Yamamichi³,
Masa Narita⁴, Koichiro Onishi⁵ and Shu Morioka¹

¹Neurorehabilitation Research Center, Kio University, Koryo, Japan. ²Department of Rehabilitation, Fujikai Rehabilitation Hospital, Higashiosaka, Japan. ³Department of Rehabilitation, Fukuoka Rehabilitation Hospital, Fukuoka, Japan. ⁴Department of Rehabilitation, Hokuyukai Neurological Hospital, Sapporo, Japan. ⁵Department of Rehabilitation, Home-visit Nursing Rehabilitation Station Yuyu, Himeji, Japan.

ABSTRACT: The difference between the walking speeds of stroke patients and the general population may influence the self-perception of patients, who perceive their walk as lacking general human-likeness. Perception toward human-likeness during walking is defined here as the feeling that one can walk as intended, just like healthy people. Such negative subjective experiences may curb their social participation. However, the perception associated with walking speed in stroke patients is poorly understood. The main purpose of this study was to investigate the relationship between walking speed and perception toward general human-likeness during walking in stroke patients. Thirty-two post-stroke patients were enrolled in this cross-sectional study. Patients performed 10-m walk tests at comfortable and fast speeds and answered questions about their perceived human-like walking after completing the walk (“How much did you feel your walking resembled the human-likeness during walking of general people?”). We found a significant positive correlation between perception toward human-likeness during walking and walking speed at both comfortable and fast speeds. To the best of our knowledge, this report is the first to suggest that walking speed may correlate with self-perception. Our findings may help understand the underlying mechanism in patients perceiving less human-likeness during walking.

KEYWORDS: Human-like walking, walking, stroke, walking speed, subjective experience

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CORRESPONDING AUTHORS: Kazuki Hayashida, Neurorehabilitation Research Center, Kio University, Koryo 635-0832, Japan. Email: kazuki_aka_linda@yahoo.co.jp

Shu Morioka, Neurorehabilitation Research Center, Kio University, Koryo 635-0832, Japan. Email: s.morioka@kio.ac.jp

Introduction

For most individuals, independent functioning in the community presupposes the ability to walk. Therefore, investigations of patients participating in rehabilitation have shown that these patients prioritize the recovery of their walking ability.^{1,2} Walking abnormalities commonly result from stroke, which affects daily activities and social participation,^{3–5} and walk reconstruction is one of the main purposes of rehabilitation. It is necessary to have a range of abilities to walk practically and increase walking speed according to any given purpose.^{6,7} Perry et al³ established walking speed as a valid predictor of community walking status: >0.8 m/s predicts unlimited community walking. This benchmark has been used by many previous studies as an index of the social participation of patients with stroke.^{8–10} Additionally, even if walking ability can be acquired, it is often difficult for stroke patients to walk at the same speed as their healthy counterparts because of motor paralysis. In clinical practice, such slow-walking patients often describe their complaints with terms related to body awareness of human-likeness during walking,¹¹ such as “non-human-like walking” or “like a robot.” Perception toward human-likeness during walking is defined here as the feeling that one can walk as intended, just like healthy people. Furthermore, this perception may be related to the walking capacity of activity according to the International Classification of Functioning. Because

differences between the walking speeds of post-stroke patients and the general population may manifest a decrease in the subjective experience of human-like walking, such negative subjective experiences may curb social participation. In other words, as per the International Classification of Functioning, the subjective experience of human-like walking may have a negative impact on activity as well as participation. Therefore, we hypothesized that slow walking speed reduces self-perception toward general human-likeness during walking. In addition, this perception may be reinforced by psychological states, such as depression and apathy. Depression may cause bias in the evaluation of self, and apathy may distort its validity. These negative psychological states may also affect the subjective experience of the stroke patients during walking. For example, patients may continue to have negative emotions about walking in such negative psychological states, even if walking fast. This is because depression is known to be associated with self-attribution of negative outcomes (in this case, slow walking speed).¹² Such psychological traits may, in no small part, affect body perception during walking and influence the self-perception of “human-like.” Thus, depression and apathy must be assessed to ensure the validity of any subjective self-evaluation during walking. While the subjective experience of being able to walk like a healthy human may have a direct impact on the quality of life of stroke patients and should be prioritized in



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Table 1. Demographic data of the stroke patients.

	VALUES
Age (years), mean \pm SD	63.43 \pm 11.15
Sex (n): male/female	23/9
Type of stroke (n): infarction/hemorrhage/both types	16/15/1
Affected side (n): right/left	16/16
Time since stroke (days), mean \pm SD	187.84 \pm 337.21
Comfortable walking speed in 10 MWT (m/sec), mean \pm SD	0.75 \pm 0.38
Fastest walking speed in 10 MWT (m/sec), mean \pm SD	0.98 \pm 0.52
Difference between comfortable and fastest speeds	0.23 \pm 0.19
Human-likeness in comfortable speed, mean \pm SD	-0.19 \pm 1.97
Human-likeness in fastest speed, mean \pm SD	-0.25 \pm 1.97
FMA (lower extremity): max=34, mean \pm SD	28.62 \pm 4.77
Apathy scale: max=42, mean \pm SD	13.50 \pm 6.44
SDS: max=80, mean \pm SD	36.81 \pm 7.23

Abbreviations: 10 MWT, 10 m Walk Test; FMA, Fugl-Meyer assessment; n, number; SD, standard deviation; SDS, Self-Rating Depression Scale.

rehabilitation research, the subjective perception toward human-likeness during walking associated with walking speed in stroke patients is poorly understood. Rehabilitation professionals need to be aware of the patient's subjective experience during walking and improving it may promote their social participation. The main purpose of this study was, therefore, to investigate the relationship between walking speed or psychological states and subjective self-perception toward general human-likeness during walking in stroke patients by using Perry et al's³ walking speed classification to determine differences in the perception of stroke-induced disturbances in walking ability.

Materials and Methods

Participants

Thirty-two post-stroke patients (mean \pm standard deviation, 63.43 \pm 11.15 years; stroke onset, 187.84 \pm 337.21 days) were enrolled in this cross-sectional study (see Table 1 for demographic information). The stroke patients meeting the following criteria were recruited at the 4 collaborating hospitals for a period of 6 months, starting September 20, 2019. The exclusion criteria were as follows (1): inability to walk independently without the assistance of physical therapists, (2) Mini-Mental State Examination score of <24 points, (3) history of orthopedic disease, and (4) pain in the lower limbs. The ethics committee of Kio University approved the study procedures (approval number: H30-40), and the experiments were conducted in accordance with the Declaration of Helsinki. All participants

provided written informed consent before participating in the study.

Experimental set-up and procedures

Participants were asked to walk across a 10 m walkway with a supplementary 2 m walkway twice, at a comfortable speed and their fastest walking speed. Physical therapists were available to minimize the risk of falling. Whether the participants were asked to walk at the comfortable or fastest walking speed was counterbalanced across all patients, and participants were allowed sufficient rest to avoid fatigue between trials. Participants could use a cane and orthosis as necessary during the assessments. Walking speed was measured using a stopwatch from the crossing of the start line to the end line of the 10-m.¹³ Patients answered questions about subjective perception toward human-likeness during walking after walking at each speed ("How much did you feel your walking to have resembled the human-likeness during walking of general people?") and reported their subjective experience on a 7-point Likert scale ranging from "-3" (totally disagree) to "+3" (totally agree), with "0" indicating neither agreement nor disagreement ("uncertain"): the lower the value, the less perceived human-likeness during walking.

Clinical evaluation

The Fugl-Meyer et al¹⁴ assessment (FMA) was used to measure the severity of paralysis. To measure the severity of

depressive states, we used the Zung Self-Rating Depression Scale in the form of a self-report questionnaire.^{15,16} Higher scores indicated more severe depressive states (cutoff score: 40 points). To measure the severity of apathy states, we used the Apathy Scale in the form of a self-report questionnaire.^{17,18} Higher scores indicated more severe apathy states (cutoff score: 16 points).

Statistical analysis

The relationship between each walking speed and FMA was analyzed using Spearman's rank correlation coefficient because the severity of motor paralysis strongly affects walking speed post-stroke.¹⁹ Since the results of the Shapiro–Wilk test were not normally distributed, we used Spearman's rank correlation coefficient. The mean of the 2 trials was used for the value of each walking speed. The relationships between perception toward human-likeness during walking and walking speed, FMA, Zung Self-Rating Depression Scale, and Apathy Scale were analyzed using Spearman's rank correlation coefficient. Additionally, the range of ability to freely increase walking speed was calculated as the difference between the comfortable and fastest speed.²⁰ A low value indicated that the range of ability to freely increase walking speed was narrow. The relationship between the perception at each speed and the range of ability to freely increase walking speed was analyzed using Spearman's rank correlation coefficient. Next, at each walking speed, participants were divided into a fast- ($>.8$ m/s) or slow-walking group (≤ 0.8 m/s); the difference in the perception was compared between the groups. Patients who were classified in the slow group at the comfortable walking speed may be classified in the fast group at their fastest walking speed. If the samples were divided into slow and fast groups only at the comfortable walking speed, the interpretation of the results would be arbitrary. Therefore, the analyzed samples were divided into the slow group and fast group for both comfortable walking speed and fastest walking speed. Thereafter, FMA, age, time from stroke onset, Apathy scale, and Zung Self-Rating Depression Scale were compared between the groups.

The Shapiro–Wilk test was used to evaluate the normality of the data distribution. Parametric statistics were used to analyze normally distributed data, while non-parametric comparisons were applied for the non-normally distributed variables. Statistical significance was set at $P < .05$. SPSS Statistics for Windows (version 24, IBM, Tokyo, Japan) was used for the analysis.

Results

The clinical test scores are summarized in Table 1, and the correlation analysis results are summarized in Table 2. At a comfortable speed, FMA and walking speed showed a significant correlation ($\rho = .71$, $P = .000005$). Human likeness was significantly correlated with walking speed ($\rho = .61$, $P = .0002$)

(Figure 1) and FMA ($\rho = 0.62$, $P = .0002$). There was no significant correlation between human likeness and the Zung Self-Rating Depression Scale ($\rho = -.15$, $P = .43$) or the Apathy scale ($\rho = -.23$, $P = .20$). At the fastest speed, FMA and walking speed showed a significant correlation ($\rho = .76$, $P = .000001$). Human likeness was significantly correlated with walking speed ($\rho = .54$, $P = .002$) (Figure 1) and FMA ($\rho = 0.59$, $P = .0004$). There was no significant correlation between human likeness and the Zung Self-Rating Depression Scale ($\rho = -.18$, $P = .33$) or the Apathy scale ($\rho = -.29$, $P = .12$). A significant correlation between the range of ability to freely increase walking speed and human likeness of the comfortable speed ($\rho = 0.57$, $P = .0006$) and the fastest speed ($\rho = 0.49$, $P = .005$) was observed.

Participants were divided into a fast- ($n = 15$) or slow-walking group ($n = 17$) according to their speeds while walking at a comfortable pace. Human likeness was significantly higher in the fast-walking group than in the slow-walking group (mean difference = 1.98, SE = 0.61) (t -value = 3.24, $df = 30$, 95% CI = 0.73–3.23, $P = .003$). Participants were divided once again into a fast- ($n = 21$) or slow-walking group ($n = 11$) according to their speed while walking at their fastest pace. The Mann–Whitney U test revealed that perceived human likeness was significantly higher in the fast-walking group than in the slow-walking group ($U = 52$, $z = 2.52$, $P = .01$). After grouping based on each speed, FMA was significantly higher in the fast-walking group than in the slow-walking group at each based on their walking speed. However, the other parameters (Zung Self-Rating Depression Scale and Apathy Scale) were not significant (Table 3). At a comfortable speed, human likeness was significantly correlated with walking speed ($\rho = 0.61$, $P = .0002$). At the fastest speed, a significant correlation was identified between human likeness and walking speed ($\rho = .54$, $P = .002$).

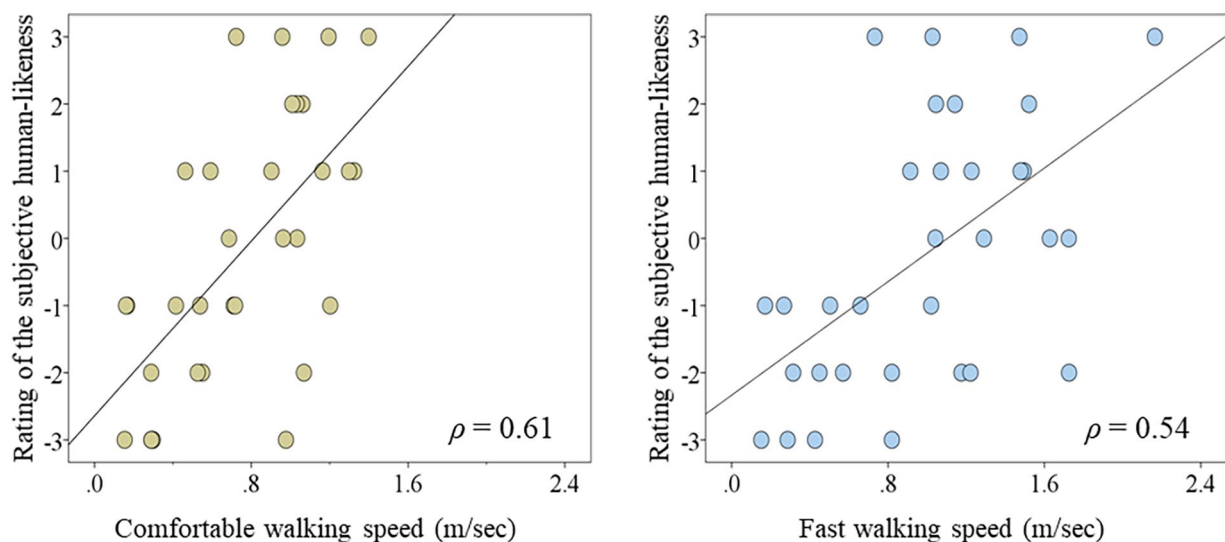
Discussion

This study aimed to investigate the participant's self-perception of the human-likeness of their walking after stroke according to walking speed. Our results showed that both the comfortable and fastest walking speeds had a significant positive correlation with the subjective perception. In addition, there was a significant positive correlation between the range of ability to freely increase walking speed and the perception. Since the Zung Self-Rating Depression Scale and the Apathy Scale were below the cut-off scores (Table 1), we proceed with the discussion considering that the effects of negative psychological states may be minimal. In previous studies, the range between the comfortable and fastest speeds in healthy older adults was approximately 0.45 m/s¹⁸; the range identified among the patients in this study (0.23 m/s) was smaller. Thus, our study suggests that patients with stroke have a limited range of walking speeds and that being unable to freely select their walking speed might reduce their subjective perception toward the human-likeness of their walking. Furthermore, the logic between these 2 findings further suggests that being able

Table 2. Correlation analysis.

SPEARMAN'S RANK CORRELATION COEFFICIENT FOR THE COMFORTABLE WALKING SPEED					
	WAKING SPEED	HUMAN-LIKENESS	FMA	SDS	APATHY SCALE
	ρ (P-VALUE)	ρ (P-VALUE)	ρ (P-VALUE)	ρ (P-VALUE)	ρ (P-VALUE)
Walking speed	1				
Human-likeness	0.61 (.0002)	1			
FMA	0.71 (.000005)	0.62 (.0002)	1		
SDS	0.23 (.21)	-0.15 (.43)	0.15 (.41)	1	
Apathy scale	0.009 (.96)	0.23 (.20)	0.14 (.43)	0.24 (.18)	1
SPEARMAN'S RANK CORRELATION COEFFICIENT FOR THE FASTEST WALKING SPEED					
	WALKING SPEED	HUMAN-LIKENESS	FMA	SDS	APATHY SCALE
	ρ (P-VALUE)	ρ (P-VALUE)	ρ (P-VALUE)	ρ (P-VALUE)	ρ (P-VALUE)
Walking speed	1				
Human-likeness	0.54 (.002)	1			
FMA	0.76 (.000001)	0.59 (.0004)	1		
SDS	0.29 (.11)	-0.18 (.33)	0.15 (.41)	1	
Apathy scale	0.008 (.97)	-0.29 (.12)	0.14 (.43)	0.24 (.18)	1
SPEARMAN'S RANK CORRELATION COEFFICIENT FOR THE RANGE AND EACH HUMAN-LIKENESS					
	HUMAN-LIKENESS				
	COMFORTABLE SPEED	FASTEST SPEED			
	ρ (P-VALUE)	ρ (P-VALUE)			
Range	0.5 (.0006)	0.49 (.005)			

Abbreviations: FMA, Fugl-Meyer assessment; Range, the range of ability to freely increase walking speed; SDS, Self-Rating Depression Scale.

**Figure 1.** Scatter plot of the relationship between the perception of human-likeness during walking and the 2 walking speeds.

to make decisions freely and being able to choose actions might impact the perception.

According to Perry et al's³ classification, the slow-walking group perceived a lower human-likeness of their walking than

the fast-walking group. Since a fast-walking speed can maintain the subjective perception toward human-likeness, it might be possible for patients with relatively faster walking speeds to participate in their communities. The present study suggests

Table 3. Scores after grouping based on speed at each pace.

	FAST-WALKING GROUP		SLOW-WALKING GROUP		T-VALUE	95% CI	U	Z	P
	MEAN	SE	MEAN	SE					
<i>Based on comfortable pace</i>									
Time since stroke (days)	68.00	6.25	293.59	106.95	-2.11	-452.58-1.40			.05
Apathy scale	14.6	6.03	12.53	6.81	0.90	-2.60-674			.37
SDS	39.00	6.40	34.88	7.56	1.65	-0.98-9.21			.11
Age	62.87	3.06	63.94	2.63			126	-0.06	.96
FMA	31.87	0.47	25.76	1.16			33.5	-3.56	.0001
<i>Based on fastest pace</i>									
Time since stroke (days)	76.76	7.23	399.91	158.09	-2.04	-675.57-29.28			.07
Apathy scale	14.05	1.36	12.45	2.10	0.66	-3.35-6.53			.51
SDS	38.33	1.44	33.91	2.35	1.69	-0.92-9.77			.10
Age	64.52	2.36	61.36	3.62			91.0	-0.97	.33
FMA	30.76	0.86	24.55	1.05			22.5	-3.71	.00006

Abbreviations: FMA, Fugl-Meyer assessment; SDS, Self-Rating Depression Scale; SE, standard error.

that the likelihood of community participation partially depends on both the physical ability to move from place to place and the social-psychological factors of maintaining the perception of human-like walking.

Although walking speed strongly impacts activities of daily living and quality of life³⁻⁵ how walking speed affects a patient's subjective experience has not been investigated. Elucidating this subjective patient experience will allow an insight into the inner world of the patients, which is a great asset in clinical practice. Ueda and Okawa²¹ have explained the importance of understanding the subjective experiences of patients and provided a definition of the subjective dimension of functioning and disability in the International Classification of Functioning, Disability, and Health Perspectives. They suggested that the patient's subjective experience influences social participation. Our study suggests that perception toward human-likeness during walking may be related to the subjective aspect of activity limitation in the International Classification of Functioning. Moreover, since the perception of human-likeness could be reduced by comparing activities with healthy people, we suggest that environmental factors (ie, healthy people) may influence the patient's perception toward human-likeness during walking and restrict their social participation. Understanding the potential possibility of restricted participation due to negative subjective experiences during walking can be useful information for encouraging patients to participate in community activities. In recent years, the illness narrative of the body of amputated patients has been reported.²² We suggest that measuring the subjective experience of walking in stroke patients

may contribute to the development of future research in the field of rehabilitation.

The motor learning approach may enhance the perception toward human-likeness during walking in stroke patients. Since a comparison to healthy people (ie, the environmental aspects in the ICF) may reduce the experience of human-likeness, it is necessary to reduce the harm caused by the comparison. Therefore, we first need to investigate factors that enhance or reduce human likeness. We hypothesized that spatial laterality, joint angle, and gait rhythm are factors affecting the perception of human-like walking. Considering these factors (eg, the angle of the knee during walking), if motor learning can bring the patient's walking closer to that of a healthy person, we believe that the subjective perception toward human-like walking may also be improved. From our results, we can deduce that if the motor learning approach by physical therapy can increase the walking speed of stroke patients with slow-walking speed, it may improve their subjective perception.

Several possible limitations of the study should be considered. First, our data are only part of the explanation for the perception toward human-likeness during walking of stroke patients and should be discussed carefully. FMA was significantly higher in the fast-walking group than in the slow-walking group based on each walking speed. Additionally, the time from stroke onset was shorter in the fast-walking group than in the slow-walking group based on each walking speed, although there was no statistically significant difference. There may be other confounding factors, such as spatial laterality, joint angle, gait rhythm, neglect, or change in sensation. Second, the

mechanism by which walking speed is related to the perception is unknown. One possible connection might be the involvement of speed-dependent visual information (ie, optic flow).^{23,24} We speculate that the integration of vision and somatosensory perception might affect cognition during walking. Third, it is unclear to what extent a negative perception affects limitations in activity and social participation because this study included patients in both the acute and chronic phase of stroke. Fourth, a previous study that investigating the perception during the observation of asymmetric walking patterns (ie, third-person perspective) reported that stride length and knee position affect perception.²⁵ Since asymmetry is a characteristic of post-stroke walking, it may be necessary to investigate the interrelationship between the first- and third-person perspectives. Fifth, it remains unclear what performance aspects (eg, balance, upper limb movement, lower limb movement) made each participant perceive human likeness because our participants were simply asked whether or not they perceived their walking to have the human-likeness of a general person. Future research is required to clarify the factors that influence patients' perceptions of human-like walking. Finally, our results do not necessarily imply a causal relationship between human likeness and walking speed. In this cross-sectional study, it was not possible to answer the question of whether improving self-perception using psychological therapies could improve walking speed. To explore this possibility, a prospective interventional study would be useful, which would also be able to demonstrate the potential impact of this research. This is a preliminary study, and further research on ways to improve walking ability in stroke patients is warranted.

We conducted a preliminary study on the relationship between self-perceived general human-likeness during walking and walking speed after stroke. To the best of our knowledge, this report is the first to suggest that walking speed may correlate with the perception toward general human-likeness during walking. A high degree of the perception is important for the patient's quality of life. This study is expected to inform future studies on the mechanisms underlying patient complaints of "non-human-like walking," and our findings will contribute to the development and practice of rehabilitation approaches to promote social participation.

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Author Contributions

All authors contributed to the development and design of the studies. KH, RN, NY, MN, and KO conducted the experiments and analyzed the data. KH drafted the manuscript. All

authors contributed to the article and approved the submitted version.

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