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Original Article

How effective is the early fast treadmill gait speed training for stroke patients at the 2nd week after admission: comparison with comfortable gait speed at the 6th week

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Abstract. [Purpose] The purpose of this study was to find whether a fast treadmill gait training speed is effective for the gait training of stroke patients in the early rehabilitation stage. [Subjects and Methods] Thirty-nine stroke patients were the subjects of our investigation. They walked on a treadmill with handrail supports at a fast speed (130% of their comfortable gait speed in the 2nd week). The treadmill gaits of the patients were recorded using a 3-dimensional analysis system at two and six weeks after their admissions. Intraclass Correlation Coefficients (ICC) of the temporal and spatial parameters of the two periods were statistically analyzed. [Results] For all of the patients, the ICCs of the measured parameters were greater than 0.58. In the case of patients whose gait speeds of the two periods were close, the ICC units were greater than 0.7. [Conclusion] The fast gait speed training allowed us to expose the patients to a gait speed that they were expected to acquire at a later stage of their rehabilitation. This training method was found to be beneficial for the mildly paralyzed patients.
Key words: Stroke, Treadmill, Fast speed

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INTRODUCTION

Improvement of locomotion is one of the important goals of rehabilitation training for hemiplegic patients after stroke[1, 2)]. Many researchers have reported the usefulness of treadmill gait training[3–5)] and have established how to adjust the treadmill speed, the degree of weight bearing and other parameters for setting the level of gait training difficulty based on the patients' walking ability.

Pohl et al. evenly divided 60 hemiplegic patients into a speed-dependent treadmill (STT) group, a limited progressive treadmill training (LTT) group, and a conventional gait training (CGT) group to investigate the effect of training speed over a four-week treadmill training period. The gait training speeds of the STT and LTT groups were increased by 10% and 5% of their maximum gait speeds, respectively. Patients in the CGT group received training following the Bobath method. The STT group showed the most marked improvement in gait speed, cadence, step length, and Functional Ambulation Category scores[6)]. Sullivan et al. divided 24 chronic stroke patients with hemiplegia into 3 groups to conduct treadmill gait training at different speeds and observed notable improvement in the group which performed training at the highest treadmill gait speed[7)].

Many hemiplegic patients in sub-acute rehabilitation facilities often show improvement in their gait speed over the course of training. In order to effectively progress gait training, it is important to train at a speed that a patient will usually acquire after several weeks of training.

Many previous studies of the effects of treadmill gait training have focused on the improvement of physical function and gait parameters. However, only a few studies have focused on the increase of the expected gait speed that stroke patients usually acquire in the course of rehabilitation. Therefore, in this study we measured the temporal and spatial gait parameters of the treadmill gait of stroke patients

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Table 1. Demographic and clinical data of the subjects

		N = 39
Age	(years)	62.3 ± 10.7
Gender	(male/female)	34 / 5
Diagnosis	(Cerebral hemorrhage/Cerebral infarction/ Subarachnoid hemorrhage)	23 / 14 / 2
Side of paralysis	(Right/Left)	25 / 14
BRS*1 in 2nd week	(II/III/IV/V/VI)	5 / 8 / 15 / 10 / 1
FIM*2 walk in 2nd week	(3 /4 /5 /6 /7 points)	2 / 11 / 26 / 0 / 0
AFO use in 2nd week	(Yes/No)	31 / 8
BRS in 6th week	(II/III/IV/V/VI)	1 / 5 / 20 / 11 / 2
FIM walk in 6th week	(3 /4 /5 /6 /7 points)	0 / 1 / 12 / 19 / 7
AFO use in 6th week	(Yes/No)	30 / 9
Day of the 2nd week measurement after onset	(day)	47.2 ± 17.8

*1 Brunnstrom stage, *2 Functional Independence Measure

admitted to a sub-acute rehabilitation ward twice, at two and six weeks after admission, using a 3-dimensional analysis system. At these two times after admission, patients walked on a treadmill at 130% of their comfortable speed (fast speed) and at their comfortable speed, respectively. The measured parameters were evaluated statistically using Intraclass Correlation Coefficients (ICC).

SUBJECTS AND METHODS

The subjects were 39 first-ever stroke patients admitted to the sub-acute rehabilitation ward of Nanakuri Sanatorium, Fujita Health University (Table 1). The patients could perform supervised treadmill gait at a fast speed using handrails at two weeks after admission. Patients with difficulty in understanding instructions due to higher-cortical dysfunction, those with pain in the legs or orthopedic disorders, and those requiring body weight supports during treadmill walking were excluded.

Gait of the patients on a treadmill at two weeks and at six weeks after admission was recorded using a 3-dimensional analysis system (Kinema Tracer®, Kissei Comtec Co., Ltd.). On the basis of a previous study using a similar system[8], recording was performed at a sampling frequency of 60 Hz for 20 seconds. Comfortable level ground gait speed was defined as the mean of three trials of level ground gait at a comfortable speed. For the measurement of the comfortable level ground gait speed, the patients were asked to walk straight at a comfortable speed along a hallway and the times required for patients to cover 10 meters in the middle of the course were measured. The treadmill speeds for the gait measurements in the 2nd (2w130%) and 6th (6w100%) weeks after admission were set to 130% and 100% of the comfortable level ground gait speed, respectively.

On the basis of a previous study[8], a total of 10 markers were bilaterally placed on the acromia, hip joint (1/3 of the distance from the great trochanter on a line joining the anterior superior iliac spine and the middle of the great trochanter), knee joints (midpoint of the anteroposterior diameter excluding the patella at the height of the midpoint between the adductor tubercle of the femur and knee joint space), ankle joints (middle of the lateral malleolus) and toes (5th metatarsal head).

Initially, a few practice trials of treadmill gait were carried out by each patient to familiarize them with the task, and the actual measurements were performed afterwards. The patients used their orthoses, and were allowed to use handrails. A body support harness was used to prevent falls, but body weight was not supported.

All patients received physical and occupational therapies 7 days per week using the Full-time Integrated Treatment (FIT) program[9]. The training program consisted mainly of tasks, such as level ground gait and standing up, required for the improvement of the activities of daily living. Treadmill gait training was not part of the daily tasks of the patients and it was only used for the assessments on the 2nd and 6th weeks.

This study and the procedure of the experiment were approved by the local Ethical Committee of Nanakuri Sanatorium, Fujita Health University (approval number 92). Informed consent was received from all the subjects after explaining the purpose of this experiment, and the study was performed with the permission of their physicians in charge.

From the recorded 3-dimensional video recording, cadence, stride length, step length of the paralyzed leg, step length of the non-paralyzed leg, single support duration, double support duration, the relative parameters of the rate of single support duration and the rate of double support duration were calculated at both the treadmill gait assessment times, 2w130% and 6w100%, for all patients, the ‘Whole Group’. ICCs of each parameter were calculated using the data of the two assessment times. Then, the rates of change in the treadmill speed of the two periods (2w130% and 6w100%) were determined, and the 1st and 3rd quartiles were calculated. The number of patients within the range between the 1st and 3rd quartiles was designated as the ‘Close Group’ because the data in this range showed the least differences between the two periods. The number of patients in the Close Group was 20. ICCs were calculated again using the values of the Close Group. The results of the ICC analyses were statistically analyzed using SPSS Statistics 19 (Version 19, SPSS Co., Ltd.) software.

Table 2. Mean and SD of the temporospatial parameters of all the subjects

		N = 39		
Time-distance factor		2w130%	6w100%	ICC
Gait speed	(km/h)	2.2 ± 0.8	2.2 ± 0.8	0.77
Cadence	(steps/min)	98.2 ± 18.8	95.5 ± 16.7	0.71
Step length of paralyzed leg	(cm)	38.6 ± 11.8	38.8 ± 13.1	0.70
Step length of non-paralyzed leg	(cm)	33.5 ± 13.6	34.8 ± 15.4	0.79
Single support duration of paralyzed leg	(s)	0.4 ± 0.1	0.4 ± 0.1	0.73
Single support duration of non-paralyzed leg	(s)	0.5 ± 0.1	0.5 ± 0.1	0.72
Double support when the paralyzed leg is in the rear	(s)	0.2 ± 0.1	0.2 ± 0.1	0.83
Double support when the non-paralyzed leg is in the rear	(s)	0.2 ± 0.1	0.2 ± 0.1	0.68
Rate of single support duration of paralyzed leg	(%)	30.7 ± 5.8	30.9 ± 6.0	0.64
Rate of single support duration of non-paralyzed leg	(%)	35.7 ± 4.5	35.6 ± 4.4	0.58
Rate of double support when the paralyzed leg is in the rear	(%)	18.3 ± 5.7	17.6 ± 5.0	0.78
Rate of double support when the non-paralyzed leg is in the rear	(%)	15.3 ± 4.3	15.8 ± 4.8	0.63

Table 4. Mean and SD of the temporospatial parameters of the subjects whose gait speed of 2w130% was close to that of 6w100%

		N = 20		
Time-distance factor		2w130%	6w100%	ICC
Gait speed	(km/h)	2.1 ± 0.6	2.0 ± 0.6	0.95
Cadence	(steps/min)	97.4 ± 16.3	95.7 ± 14.0	0.92
Step length of paralyzed leg	(cm)	38.9 ± 10.3	37.9 ± 8.9	0.92
Step length of non-paralyzed leg	(cm)	32.7 ± 12.7	32.8 ± 12.4	0.92
Single support duration of paralyzed leg	(s)	0.4 ± 0.1	0.4 ± 0.1	0.79
Single support duration of non-paralyzed leg	(s)	0.5 ± 0.1	0.5 ± 0.1	0.73
Double support when the paralyzed leg is in the rear	(s)	0.2 ± 0.1	0.2 ± 0.1	0.94
Double support when the non-paralyzed leg is in the rear	(s)	0.2 ± 0.1	0.2 ± 0.1	0.80
Rate of single support duration of paralyzed leg	(%)	30.5 ± 5.6	30.9 ± 6.4	0.80
Rate of single support duration of non-paralyzed leg	(%)	35.8 ± 5.0	35.4 ± 4.4	0.73
Rate of double support when the paralyzed leg is in the rear	(%)	18.8 ± 6.1	17.9 ± 4.8	0.85
Rate of double support when the non-paralyzed leg is in the rear	(%)	14.9 ± 4.9	15.6 ± 4.5	0.79

RESULTS

The information regarding the temporal and spatial parameters of all patients is shown in Table 2. The units of the four parameters are shown in the second column, and their values at the two assessment times and ICCs are respectively shown in the 3rd, 4th, and 5th columns. The duration of the single and double supports of the paralyzed and non-paralyzed legs together with their values and ICCs are shown in the second tier of Table 2, and their relative proportions in terms of a gait cycle are shown in the third tier of Table 2. The ICCs were greater than 0.70 for the gait speed, cadence, the step length of the paralyzed leg, and that of the non-paralyzed leg. The mean values of the temporal parameters were almost the same between the two periods and the ICC values ranged between 0.68–0.83. Concerning the relative temporal parameters, the ICC of the rate of the single support duration of the non-paralyzed leg was 0.58. The other three ICC values were greater than 0.63.

The 1st and 3rd quartiles of the rate of change in treadmill speed were −13.4% and 14.6%, (Table 3). The span between the two quartiles was 28%. Table 4 shows the information of the Close Group patients whose values at the two assessment times showed the least differences compared to the values (Table 2) of the patients in the Whole Group. In each of the two tables, ICC units were calculated based on the two values at the two assessment times of each group. ICC units of the Close Group were larger and ICC units minimum was greater than 0.73.

Table 3. Quartiles of change rate of gait speed

Quartile	Change rate of gait speed
minimum	−40.0%
1st quartile	−13.4%
2nd quartile	0.0%
3rd quartile	14.6%
maximum	50.0%

DISCUSSION

In this study, the treadmill gait parameters of 2w130% and 6w100% of hemiplegic patients admitted to a sub-acute rehabilitation ward were compared and analyzed using ICCs. As patients progress through a rehabilitation course, their gait speed normally improves. Earlier exposure of the patients to a fast gait speed, one which they are expected to achieve much later in their rehabilitation, allows the patients to acquire that skill faster. As a result, a fast gait training speed may contribute to the improvement of gait training.

The ICCs of the cadence and step length of all the patients were high. For the duration and rate parameters, the ICCs were moderate. The Close Group's temporal and spatial ICCs were higher than those of the Whole Group. The ICCs of the rate parameters of the Close Group were high (ICC > 0.73). Since cadence and step length depend on gait speed, the ICCs of their values between 2w130% and 6w100% were consequently high.

From the general motor program for motor learning point of view, the relative timing as the basis of individual motor patterns has an invariant characteristic and is structurally and organizationally temporal and rhythmic and is not affected by the gait speed or gait distance[10)].

In this study, the relative temporal parameters were considered to represent the relative timing of gait, that is, the motor pattern of gait. In the results of this study, the high ICCs of the relative temporal parameters indicate the resemblance of the two periods' motor patterns. In other words, there exists the possibility of acquiring much earlier an expected motor pattern which is usually acquired later in the course of rehabilitation. The same conclusion can be drawn by considering the high ICC of the gait speeds of the two assessments.

Previous studies have shown that the gait speed of hemiplegic patients is strongly related to the muscle strength of the paralyzed leg, especially those of the hip flexor and plantar flexor muscles[10, 11)], and hemiparesis level[12–14)]. In hemiplegic patients with a low level ground gait speed in the early stage of training[15)], cooperative movements of these muscles are reported to be difficult[16)]. In addition, there is a concern that a fast treadmill training gait speed would aggravate abnormal gait patterns[17)]. On the basis of these reports, fast speed treadmill gait training should not be conducted for patients showing a slow level ground gait speed or for patients whose fast gait speed results in a markedly unstable gait. We could not conclude with a criterion to show how one should conduct fast speed treadmill gait for such patients which is one of the limitations of our study.

Other limitations were the lack of a precise and clear definition of a fast gait speed, e.g. 120% or 140% of the comfortable gait speed, and the lack of a wider range of patients, because our subjects were restricted to patients who could walk on a treadmill without assistance at the 2nd week after admission to a sub-acute rehabilitation ward. Patients requiring assistance or weight bearing training should also be evaluated.

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