Japanese Journal of Comprehensive Rehabilitation Science (2016)

Original Article

The game task level of a balance exercise assist robot achieved by chronic stroke patients with hemiplegia is correlated with balance ability after training

Tetsuya Tsunoda, MD,[1] Satoshi Hirano, MD, DMSc,[1] Eiichi Saitoh, MD, DMSc,[1] Shigeo Tanabe, RPT, PhD,[2] Ryuzo Yanohara, RPT,[3] Miho Tanahashi, OTR,[3] Ryuki Kondoh, RPT,[3] Noriaki Muramatsu, RPT,[3] Ikuko Fuse, MD,[4] Hitoshi Kagaya, MD, DMSc[1]

[1]Department of Rehabilitation Medicine I, School of Medicine, Fujita Health University, Toyoake, Aichi, Japan
[2]Faculty of Rehabilitation, School of Health Sciences, Fujita Health University, Toyoake, Aichi, Japan
[3]Department of Rehabilitation, Fujita Health University Hospital, Toyoake, Aichi, Japan
[4]Department of Rehabilitation Medicine II, School of Medicine, Fujita Health University, Tsu, Mie, Japan

ABSTRACT
Tsunoda T, Hirano S, Saitoh E, Tanabe S, Yanohara R, Tanahashi M, Kondoh R, Muramatsu N, Fuse I, Kagaya H. The game task level of a balance exercise assist robot achieved by chronic stroke patients with hemiplegia is correlated with balance ability after training. Jpn J Compr Rehabil Sci 2016; 7: 87−94.
Objective: The balance exercise assist robot (BEAR) is a balance training system that utilizes robot technology. The purpose of this study was to use BEAR on chronic stroke patients with hemiplegia and to elucidate the correlation between balance indices and BEAR game task levels.
Methods: The subjects were 15 chronic stroke patients with hemiplegia. The Berg Balance Scale (BBS), Timed Up and Go Test (TUG), and other balance indices as well as leg muscle strength and paralysis were assessed before and after the BEAR training period. The relationship between the achieved game task levels (tennis, skiing, and rodeo) and balance indices after training was investigated using Spearman's rank correlation coefficient.
Results: After training, TUG, Functional Reach Test (FRT) and comfortable walking speed showed a significant improvement. Furthermore, BBS, FRT, and comfortable walking speed showed a significant correlation with the achieved game task levels.
Conclusions: The results of this study suggest that balance training using BEAR contributes to an improvement in dynamic postural control ability. The levels achieved for all BEAR game tasks are thought to reflect the balance ability of the subjects after training.
Key words: robot, rehabilitation, hemiplegia, balance training, game task level

Correspondence: Tetsuya Tsunoda, MD
Department of Rehabilitation Medicine I, School of Medicine, Fujita Health University, 1−98 Dengakugakubo, Kutsukake-cho, Toyoake, Aichi 470−1192, Japan.
E-mail: tsunoda@fujita-hu.ac.jp
Accepted: September 20, 2016.
This study was performed by a research grant from Toyota Motor Corporation.

doi.org/10.11336/jjcrs.7.87

Introduction

In recent years, developments in the field of robot engineering have led to the adoption of robot technology in rehabilitation medicine. Balance training using robot technology is expected to be used as a type of postural control training. As one of these types of robot, we developed the balance exercise assist robot (BEAR), which combines dynamic games with the "Winglet," a personal mobility device ridden in the standing position. This device employs inverted pendulum control, and moves when the user on it shifts his or her center of gravity (COG) forward or backward and left or right. We believe that feedback of the shift of COG as the robot's movement could be useful in motor learning. It has been conjectured that the games would be experiential [1], and promote the desire to train. In addition, because the game tasks and robot parameters are adjustable, the system can always ensure that training is performed at the optimum level of difficulty.

Ozaki [2] et al. performed three types of balance training using BEAR in eight patients with central nervous system diseases (e.g., hemiplegia, ataxia, and paraplegia) and reported that both dynamic balance and leg muscle strength were improved after the tasks as compared with before the tasks. Ishihara [3] et al. performed three types of balance training using BEAR in seven healthy subjects, and elucidated the muscle activity characteristics of all the games using surface electromyography. However, no studies on the usefulness of BEAR have focused exclusively on stroke patients with hemiplegia. Similarly, the relationship between game task levels and balance indices has never been investigated. Therefore, in the present study, we assessed the effectiveness of BEAR training on stroke patients with hemiplegia by comparing their balance-related indices before and after training and investigating the relationship between all indices and BEAR game task levels.

Methods

1. Subjects

From the patients referred to the rehabilitation department at our university, 16 chronic stroke patients with hemiplegia who were able to walk under supervision, or without any assistance and supervision (with at least 6 months after the onset) performed BEAR exercises. After the exclusion of one subject whose psychotropic medication was adjusted during the BEAR training period, 15 subjects were included in the analysis. The clinical characteristics of the 15 subjects are shown in Table 1. Ten subjects had right hemiplegia and five had left hemiplegia. There were 12 men and three women; the mean age ± standard deviation was 62 ± 13 years and the mean period ± standard deviation from onset to BEAR training was 44 ± 46 months. Seven of the 15 subjects were able to walk without the use of any walking assistive device during balance assessments. Five subjects required both a T-cane and ankle foot orthosis (AFO), two required only a T-cane, and one required only AFO. This study was conducted with the approval of the Institutional Review Board of this hospital, and written informed consent of all the subjects was obtained.

2. BEAR

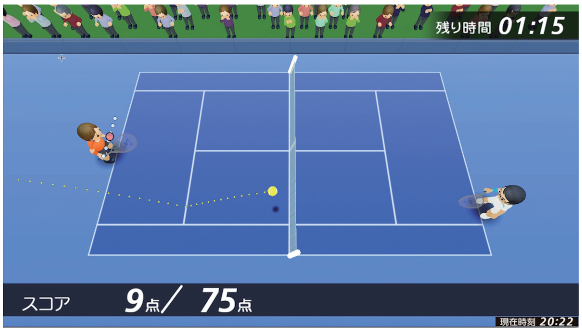
The BEAR is a balance training system based on the "Winglet," which is a personal mobility device ridden in the standing position developed by Toyota Motor Corporation. It is composed of a robot, a monitor, and a safety suspension device (Figure 1). Because the computer that controls the monitor and the robot communicate via a wireless local area network (LAN), the robot's movements can be displayed on the monitor. The robot has two in-wheel motors (one on the left and one on the right) which are used for inverted pendulum control. Sensors detect the user's posture and the motors use this data to maintain the user's posture. The user grips the robot's handle, and with both feet positioned on steps on the left and right sides of the device, the user controls the robot by shifting his or her COG. In particular, when the user moves his or her COG forward or backward, the robot also moves forward or backward. In addition, when the user moves his or her COG to the left or right, the robot rotates. Because the robot's movements reflect shifts in the COG, shifts in the user's COG are made apparent, providing an effective form of feedback for the user. In order to ensure safe use of the robot, it is fixed in place using an auxiliary bar while the user is getting on or off. The height and angle of the handle

Table 1. Patient characteristics.

Subject	Age (years)	Sex	Disease	Side of hemiplegia	Assistance for gait	AFO	TAO (months)	Leg SIAS-M
A	67	M	CI	Right	T-cane	none	86	4-4-2
B	73	M	ICH	Right	T-cane	RAPS-AFO	47	3-3-3
C	63	M	ICH	Left	T-cane	P-AFO	37	3-3-3
D	81	M	CI	Left	none	none	136	4-4-4
E	73	M	CI	Right	none	none	25	4-4-4
F	74	M	CI	Left	none	none	27	4-4-2
G	46	M	ICH	Right	none	none	20	3-3-3
H	59	M	ICH	Right	none	none	6	4-3-3
I	63	F	ICH	Left	T-cane	RAPS-AFO	144	3-3-2
J	71	M	ICH	Right	T-cane	RAPS-AFO	10	3-3-2
K	61	M	ICH	Right	none	none	18	4-4-4
L	70	M	ICH	Right	T-cane	none	83	4-3-0
M	44	F	ICH	Left	none	P-AFO	7	4-4-4
N	58	M	ICH	Right	none	none	14	3-2-2
O	34	F	ICH	Right	T-cane	RAPS-AFO	6	3-3-1

CI, Cerebral infarction; ICH, Intracerebral hemorrhage; AFO, Ankle foot orthosis; P-AFO, Plastic-ankle foot orthosis; RAPS-AFO, Remodeled Adjustable Posterior Strut-ankle foot orthosis; TAO, Time after onset; Leg SIAS-M, The scores of hip-flexion, knee-extension, and foot-pat test in the motor items of the Stroke Impairment Assessment Set (SIAS-M) [7].

Figure 1. Configuration of the balance training assist (BEAR) system.
The BEAR is a balance training system based on the "Winglet," which is a personal mobility device ridden in the standing position developed by Toyota Motor Corporation. It consists of a robot, a monitor, and a safety suspension device. Because the computer that controls the monitor and the robot communicate via a wireless local area network (LAN), the robot's movements can be displayed on the monitor. The user grips the robot's handle, and with both feet positioned on steps on the left and right sides of the device, the user controls the robot by shifting his or her COG. The BEAR has a safety suspension system that consists of a user harness and specialized suspension frame. The user can adjust the harness to the optimum height in relation to his or her height.



A) For tennis, the subjects actively move the characters forward or backward to hit a ball coming toward them. The goal is to reach the ball at the proper time in order to hit it.

B) For skiing, the subjects move the characters to the left or right on the screen which is scrolling forward. The goal is to pass through the middle of the gates on the course.

C) For rodeo, the subjects keep the characters at the center of the screen in response to disturbances that are created irregularly.

Figure 2. Screens used in the games.

are adjustable so that the user can maintain an optimum position while riding. To prevent falls, the BEAR has a safety suspension system that consists of a user harness and specialized suspension frame.

3. Training tasks

We developed three types of specialized game tasks to ensure that the subjects could both enjoy and maintain concentration during their balance training. COG shift training consisted of tennis with anteroposterior motion, and skiing with lateral motion, while disturbance-coping training consisted of rodeo (Figure 2). One game lasted for a total of 90 seconds. The difficulty level of the training was adjusted by the parameters of the game task and robot. Based on a preliminary study of healthy individuals (not published), each game task had 40 levels of specific difficulty.

The tennis task requires that the subjects actively move the characters forward or backward to hit a ball coming toward them. The goal is to reach the ball at the proper time in order to hit it. The difficulty level is adjusted by changing the speed of the ball (number of balls in one game) and width of the racket. The skiing task requires that the subjects move the characters to the left or right on the screen which is scrolling forward. The goal is to pass through the middle of the gates on the course. The difficulty level is adjusted by changing the speed of the gliding (number of gates per unit hour). The rodeo task irregularly creates disturbances 16 times during the 90 seconds playtime.

The goal is for the user to stop at the start position. The difficulty level is adjusted by changing the size of the disturbance (angle of the foot plates and length of time for which the foot plates are angled). In the present study, for cases in which the task success rate was at least 70%, the difficulty level for the following game was increased by one step, and for cases in which the task success rate was 50% or lower, the difficulty level was decreased by one step.

4. Training protocol

One training session included four attempts in each game (1.5 min × 12 games = 18 min) as well as a practice training session (2 min), equaling a total of 20 min/session. Sessions were held twice a week for eight weeks.

5. Outcome measures

Before and after the training period, the Berg Balance Scale (BBS) [4], Timed Up and Go Test (TUG) [5], Functional Reach Test (FRT) [6], comfortable walking speed, tandem gait speed, and number of continuous tandem gait steps were measured as indices of balance ability. TUG required the subjects to stand up from a seated position in a chair, walk for 3 m with a 180° turn, return to their seat, and sit down. The test measured the time required (seconds) to complete this series of tasks. FRT required the subjects to start from a position with their shoulders flexed at a 90° angle and then extend their arms as far forward as possible, and the maximum distance (cm) was then measured. The comfortable walking speed (km/h) test required the subjects to walk a 10 m course, during which their walking speed was measured.

During tandem gait, the subjects were instructed to "walk as quickly as possible on the line with their toes aligned with their heels." One successful step was defined as that in which "the heel in the swing phase contacts the toes in the stance phase and the COG shifts from the rear foot to the front foot." If the rear foot moved because of loss of balance, the step was considered a failure. Tandem gait speed (m/min) was calculated from the time required to walk 5 m in tandem gait. When the maximum number of continuous tandem gait steps was two or less, the subject was determined to be unable to walk in tandem gait and the walking speed was listed as "0" (m/min). For cases in which the number of continuous tandem gait steps was less than two steps within one min after the start of walking, measurement was concluded and the walking speed was also listed as "0" (m/min).

Regarding leg muscle strength, the strength of the iliopsoas, gluteus medius, quadriceps femoris, hamstrings, tibialis anterior, and triceps surae (6 muscles) were measured on both the affected and unaffected sides. Isometric muscle strength was measured for 5 seconds using a hand-held dynamometer (Anima Corp.), and the maximum muscle strength (kgf) was adopted. We used the motor items of the Stroke Impairment Assessment Set (SIAS-M) [7] as our index for

Table 2. Changes in indices before and after training.

		Before training	After training	p
		Median (IQR)	Median (IQR)	
BBS		53 (46−54)	54 (46−55)	0.086
TUG (s)		16.5 (12.8−28.1)	14.9 (12.8−25.7)	0.028*
FRT (cm)		30.0 (28.0−33.8)	33.0 (28.2−35.0)	0.037*
Comfortable walking speed (km/h)		2.3 (1.7−2.8)	2.6 (1.6−3.2)	0.022*
Tandem gait speed (m/min)		0 (0−11.8)	5.0 (0−9.1)	0.642
Number of continuous tandem gait steps		0 (0−5)	3 (0−5)	0.344
Iliopsoas (kgf)	unaffected side	25.4 (19.7−31.9)	24.0 (20.1−33.3)	0.934
	affected side	20.0 (13.1−22.7)	16.2 (14.3−24.0)	0.679
Gluteus medius (kgf)	unaffected side	22.4 (17.7−25.1)	23.0 (19.1−26.7)	0.173
	affected side	17.5 (12.8−20.1)	18.0 (16.0−27.0)	0.026*
Quadriceps femoris (kgf)	unaffected side	32.3 (25.2−40.4)	33.5 (27.5−39.5)	0.629
	affected side	26.5 (14.6−30.0)	23.1 (17.8−30.6)	0.571
Hamstrings (kgf)	unaffected side	14.9 (12.3−20.2)	15.0 (13.5−20.5)	0.629
	affected side	9.5 (5.7−12.4)	10.2 (6.9−14.6)	0.071
Tibialis anterior (kgf)	unaffected side	18.1 (14.8−21.7)	20.6 (14.2−24.5)	0.147
	affected side	7.5 (3.5−16.4)	11.5 (5.9−15.7)	0.026*
Triceps surae (kgf)	unaffected side	53.8 (44.4−63.9)	62.0 (42.7−71.7)	0.330
	affected side	26.9 (10.0−35.7)	21.9 (15.3−30.9)	0.241

Wilcoxon signed-rank test, *$p < 0.05$; IQR, Interquartile range.

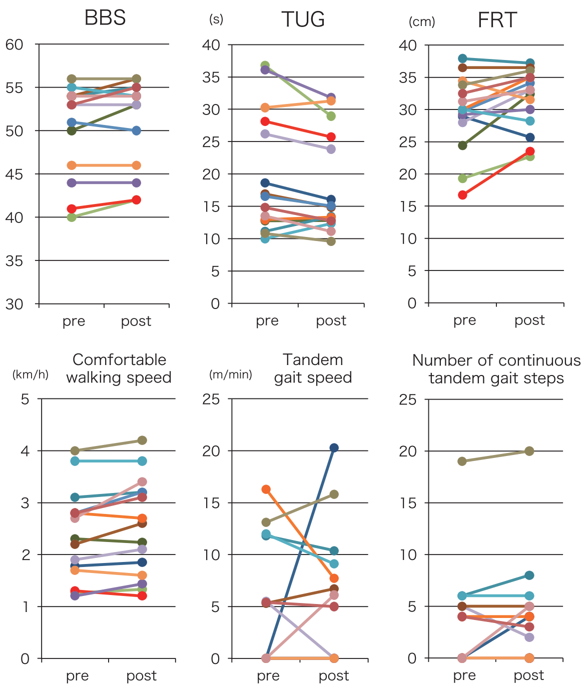


Figure 3. Changes in balance ability.
There was a significant improvement in TUG, FRT, and comfortable walking speed after BEAR training.

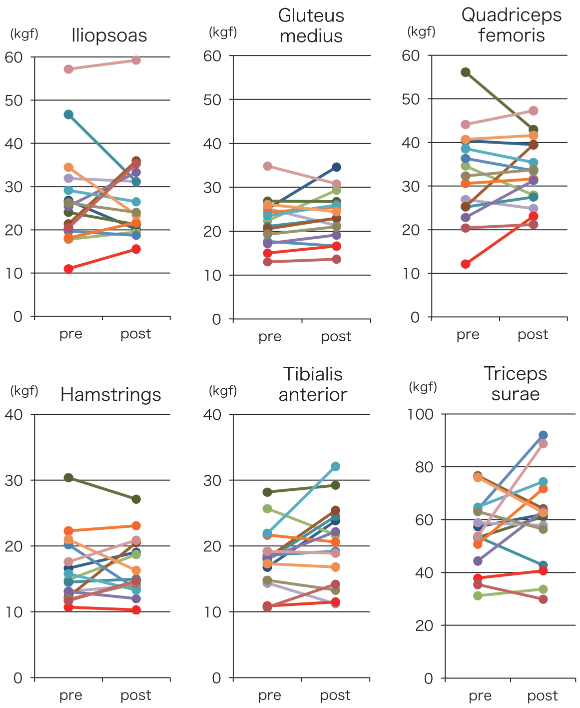


Figure 4. Changes in leg muscle strength on the unaffected side.
There were no significant differences in strength between any of the six measured muscles before and after BEAR training.

evaluating leg paralysis. We evaluated the hip-flexion, knee-extension, and foot-pat test scores and calculated the total leg SIAS-M score. Measurements other than BBS and SIAS-M were conducted two times, and the best score was used.

6. Statistical analysis

We compared all items before and after the training period using the Wilcoxon signed-rank test. Correlations between all the game task levels and the balance index after BEAR, muscle strength, and total leg SIAS-M scores were analyzed using Spearman's rank correlation coefficient. The statistical level of significance was set at 5%. Statistical processing was performed using JMP 12.2.0.

Results

Changes in the balance index and leg muscle strength before and after BEAR are shown in Table 2 and Figures 3–5. TUG showed a significant improvement after BEAR training (p = 0.028). Although FRT (p = 0.037) and comfortable walking speed (p = 0.022) showed a significant improvement, there were no significant differences between BBS, tandem gait speed, and number of continuous tandem gait steps. Six of the 15 subjects were unable to perform tandem walking. Investigation of muscle strength on the unaffected side indicated that there were no significant differences between any of the six measured muscles

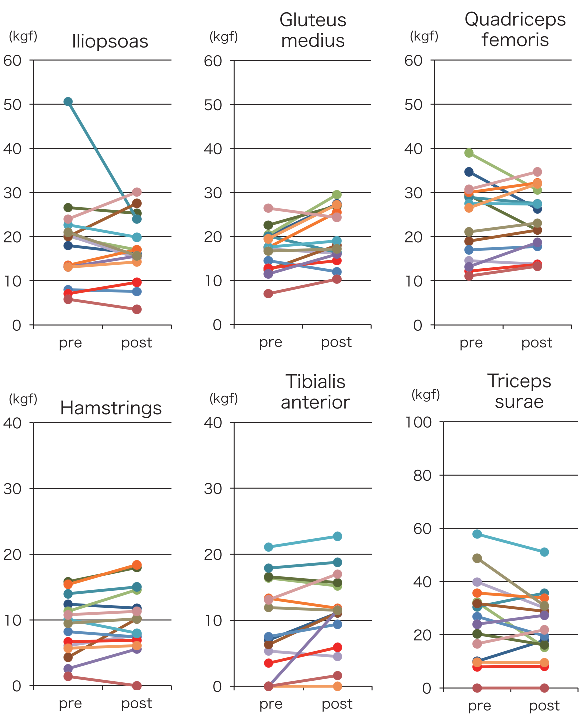


Figure 5. Changes in leg muscle strength on the affected side.
There was a significant improvement in the gluteus medius and tibialis anterior muscles.

before and after BEAR. Investigation of leg muscle strength on the affected side indicated that the gluteus medius and tibialis anterior muscles showed a significant improvement but the other muscles did not show significant differences. Our investigation of leg SIAS-M indicated that there were no differences between the indices among all the subjects.

The achieved game task levels of all the subjects are shown in Table 3. Only one subject achieved the maximum difficulty level of 40 in the tennis and rodeo game tasks.

The correlation between all the achieved game task levels and post-BEAR indices are shown in Table 4. BBS, FRT, and comfortable walking speed showed a significant positive correlation with all the achieved tennis, skiing, and rodeo game task levels ($p < 0.05$). TUG showed a significant correlation with skiing ($p < 0.05$).

Our investigation of leg muscle strength on both the affected and unaffected sides indicated that there was a significant correlation between skiing and the triceps surae muscle but not between any of the other muscles. There was no significant correlation between the total leg SIAS-M score and the achieved game task levels.

Table 3. The achieved game task levels of all the subjects.

Subject	Tennis	Skiing	Rodeo
A	20	19	21
B	3	7	1
C	18	27	18
D	24	19	20
E	20	17	20
F	19	35	36
G	28	33	32
H	30	39	21
I	17	11	17
J	24	16	19
K	18	18	15
L	2	16	17
M	40	37	40
N	27	34	23
O	29	16	20

Discussion

Our result indicated that the BEAR training for chronic stroke patients with hemiplegia led to a significant improvement in dynamic balance-related indices such as TUG, FRT, and comfortable walking speed. The three types of BEAR games were tasks that required constant dynamic control of the COG; therefore, we think that the games have high transferability as dynamic balance ability tasks. There were no significant differences in tandem gait speed and continuous tandem gait steps. Ozaki et al. [2] performed three types of balance training using BEAR in eight patients with central nervous system diseases (e.g., hemiplegia, ataxia, and paraplegia) and reported a significant improvement in tandem gait speed. However, all four hemiplegia patients in that study

Table 4. The correlation between all the achieved game task levels and post-BEAR indices.

		Tennis	Skiing	Rodeo
BBS		0.52*	0.61*	0.66**
TUG		−0.50	−0.62*	−0.44
FRT		0.61*	0.61*	0.71**
Comfortable walking speed		0.59*	0.62*	0.54*
Tandem gait speed		0.37	0.46	0.47
Number of continuous tandem gait steps		0.41	0.52*	0.50
Iliopsoas	unaffected side	0.32	0.21	0.31
	affected side	−0.13	0.43	0.13
Gluteus medius	unaffected side	−0.34	0.18	−0.14
	affected side	−0.44	0.08	−0.24
Quadriceps femoris	unaffected side	−0.16	0.48	0.22
	affected side	−0.13	0.24	−0.03
Hamstrings	unaffected side	0.01	0.46	0.24
	affected side	0.00	0.45	0.13
Tibialis anterior	unaffected side	−0.31	0.10	−0.15
	affected side	−0.02	0.21	−0.09
Triceps surae	unaffected side	0.18	0.57*	0.34
	affected side	0.34	0.54*	0.31
Total leg SIAS-M score		0.16	0.39	0.21

Wilcoxon signed-rank test, $^*p < 0.05$, $^{**}p < 0.01$.

were cases that did not require ankle foot orthoses (AFOs) or canes. On the other hand, eight out of the 15 subjects in the present study required AFOs or canes, and so a simple comparison of these studies is not possible.

Although paralysis did not change, there was a significant improvement in muscle strength in the gluteus medius and tibialis anterior muscles on the affected side after BEAR training. It is possible that lateral COG movement in the skiing and rodeo tasks contributed to the improvement of gluteus medius muscle strength, and anteroposterior COG movement in the tennis and rodeo tasks contributed to the improvement of tibialis anterior muscle strength.

Dettmann et al. [8] and Turnbull et al. [9] reported that hemiplegic stroke patients have a reduction in the ranges of weight shift toward the affected side, and Dodd et al. [10] reported that the amplitude of lateral pelvic displacement of the affected side is correlated with walking ability. Geurts et al. [11] reported that visual, vestibular, and somatosensory information, which is plantar pressure sensation and ankle proprioception, is necessary for hemiplegic stroke patients to control their standing posture. Oliveira et al. [12] reported that abnormal sensory integration, which makes it difficult to select the most appropriate sensory information to achieve postural stability, impacts balance control in hemiplegic stroke patients.

Balance training using BEAR enables shifting of the COG toward the affected side under dynamic conditions and dynamic control of the COG in the backward and forward directions as well as to the left and right. We think that the aforementioned improvements in muscle strength of the gluteus medius and tibialis anterior muscles contributed to the improvement in the subjects' ability to control posture; however, it is possible that this was not just because of the effect on muscle strength. BEAR also activates vestibular sense, plantar pressure sensation, ankle proprioception, and sensory integration, and may thus have led to improvements in the ability to control dynamic posture.

We also considered the relationship between all the achieved game task levels and indices, as measured at the end of BEAR training. In the present study, only one subject achieved the maximum difficulty level of 40 in the tennis and rodeo tasks, which indicates that there was no influence of ceiling effect in the game task levels.

BBS, FRT, and comfortable walking speed were significantly correlated with the achieved game task levels of all the three games. In particular, FRT had a high correlation with the rodeo game ($p < 0.01$). Because the rodeo game required several seconds of continuous coping with a disturbance, we think that this had a high degree of similarity with the reach movement in FRT. Comfortable walking speed had a significant correlation with skiing, tennis, and rodeo (in descending order), and TUG was significantly correlated with skiing. In comparison with the rodeo game, which required continuous coping with a disturbance, the tennis and skiing games required dynamic movements in the backward and forward directions as well as to the left and right. Walking was a periodical movement that required shifting the COG in the backward and forward directions as well as to the left and right, and we think that this accounted for the high degree of correlation with tennis and skiing. It is possible that TUG showed a high degree of correlation with skiing which requires lateral COG movement, because TUG is a task that includes both walking movements and directional change in movements. The number of continuous tandem gait steps was significantly correlated with the achieved skiing level only. Tandem gait is a task that requires more control of the leg on the affected side in the single support phase than normal walking. We think that the correlation was due to the fact that skiing requires the affected side to bear a significant burden during lateral shifting of COG.

In the present study, we elucidated that all the achieved game task levels (which were achieved as the result of using BEAR on chronic stroke patients with hemiplegia) reflected the post-BEAR balance ability of the subjects. This suggests that all the BEAR game levels correspond to balance ability. We also confirmed that there was a tendency for the three types of games to show correlations with all the balance-related indices, with different degrees of correlation with each. Therefore, by combining the three types of games, we believe that the BEAR training contributes to an improvement in different aspects of balance ability.

The limitations of the present study were that we investigated only a small number of subjects (15) and that it was conducted at a single facility. Another limitation was the fact that we did not compare our results with those of a control group. Therefore, only a limited interpretation of the present results is possible.

Acknowledgements

We sincerely thank Toyota Motor Corporation for permitting the use of BEAR. This research was supported in part by JSPS KAKENHI Grant Number 25350637.

References

1. Norman, DA. Things that make us smart: Defending human attributes in the age of the machine. Reading, MA: Addison Wesley Publishing Company; 1993. p. 31–42.
2. Ozaki K, Kagaya H, Hirano S, Kondo I, Tanabe S, Itoh N, et al. Preliminary trial of postural strategy training using a personal transport assistance robot for patients with central nervous system disorder. Arch Phys Med Rehabil 2013; 94: 59–66.
3. Ishihara K, Hirano S, Saitoh E, Tanabe S, Itoh N, Yanohara R, et al. Characteristics of leg muscle activity in

three different tasks using the balance exercise assist robot. Jpn J Compr Rehabil Sci 2015; 6: 105−12.
4. Berg K, Wood-Dauphinee S, Williams JI, Gayton D. Measuring balance in the elderly: preliminary development of an instrument. Physiother Can 1989; 41: 304−11.
5. Podsiadlo D, Richardson S. The timed "Up and Go": a test of basic functional mobility for frail elderly persons. J Am Geriatr Soc 1991; 39: 142−8.
6. Duncan PW, Weiner DS, Chandler J, Studenski S. Functional reach: a new clinical measure of balance. J Gerontol 1990; 45: M192−7.
7. Chino N, Sonoda S, Domen K, Saitoh E, Kimura A. Stroke Impairment Assessment Set (SIAS) —a new evaluation instrument for stroke patients. Jpn J Rehabil Med 1994; 31: 119−25.
8. Dettmann MA, Linder MT, Sepic SB. Relation among walking performance, postural stability, and functional assessments of the hemiplegic patient. Am J Phys Med 1987; 66: 77−90.
9. Turnbull GI, Charteris J, Wall JC. Deficiencies in standing weight shifts by ambulant hemiplegic subjects. Arch Phys Med Rehabil 1996; 77: 356−62.
10. Dodd KJ, Morris ME. Lateral pelvic displacement during gait: abnormalities after stroke and changes during the first month of rehabilitation. Arch Phys Med Rehabil 2003; 84: 1200−5.
11. Geurts AC, de Haart M, van Nes IJ, Duysens J. A review of standing balance recovery from stroke. Gait Posture 2005; 22: 267−81.
12. Oliveira CB, Medeiros IR, Greters MG, Frota NA, Lucato LT, Scaff M, et al. Abnormal sensory integration affects balance control in hemiparetic patients within the first year after stroke. Clinics 2011; 66: 2043−8.