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Original Article

Kinematic analysis of head, trunk, and pelvic motion during mirror therapy for stroke patients

Jinmin Kim, PT, MS[1)], Jaehoon Yi, PhD[2)], Chang-Ho Song, PT, PhD[1)*]

[1)] *Department of Physical Therapy, Sahmyook University: 26-21 Gongneung2-dong, Nowon-gu, Seoul 139-742, Republic of Korea*
[2)] *Division of Liberal Arts and Teaching, Sungkyul University, Republic of Korea*

Abstract. [Purpose] The purpose of this study was to investigate mirror therapy (MT) condition by analyzing kinematic parameters according to mirror size and angle. [Subjects and Methods] Three hemiparesis stroke patients and five healthy adults participated in this cross-sectional study. Kinematic parameters during the MT were collected over a total of 5 trials for each subject (3 mirror angles × 3 mirror sizes). Center of pressure (COP) excursion data was collected by force plate, and other kinematic parameters by infra-red cameras. [Results] The larger the size and smaller the angle, the overall dependent variables decreased in all participants. Particularly, when virtual reality reflection equipment (VRRE) was used, the value of the flexion and the lateral tilt was the closest to the midline compared to all other independent variables. Moreover, it showed tendency of moving towards the affected side. Based on the results, MT for stroke patients has a disadvantage of shifting weight and leaning towards the unaffected side during therapy. [Conclusion] Therefore, it seems to be more effective in terms of clinics to apply VRRE to make up for the weak parts and provide more elaborate visual feedback.
Key words: Stroke, Weight-bearing, Mirror neurons

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INTRODUCTION

One of the most common problems stroke patients experience is upper limb paralysis[1)]. Accordingly, 55–75% of stroke patients complain of motor impairment[2)] and discomfort in using the affected hand in daily life[3)]. Various interventions were proposed for the recovery of upper extremity in stroke patients[4)]. Such rehabilitation in hemiparesis is well established and most often encourages the use of the paralyzed part of the body to regain function[5)].

Typically, mirror is a tool often used to provide real-time visual feedback for therapists during therapy session. However, in mirror therapy (MT), mirror is placed between a patient's limbs. Affected limb faces the non-reflective side, and by using the reflected image of the unaffected limb, patient recognizes the affected side. This gives an illusionary impression to the subject that he/she has two normal limbs[6)]. MT has been used and proven to be effective in improving the upper extremity function of stroke patients[7)]. Related studies show improvements in motor function[8, 9)], motor recovery[8, 10)], and sensory recovery[10, 11)].

Virtual reality reflection therapy (VRRT) is the technically developed version of MT concept. In some cases, VRRT similarly follows protocol of general MT by using camera recorder to record the unaffected upper limb movement and then displaying the reversed image on the monitor installed above the affected upper limb; or by using the same instrument to record the movement of the unaffected side in advance and play it to exercise the affected side asymmetrically[12)]. Virtual reality reflection equipment (VRRE) allows more complete immersion into the illusion, whereas MT requires strict focus and concentration to truly perceive the illusion as real. Also, VRRE has an advantage of using only the affected side through

*Corresponding author. Chang-Ho Song (E-mail: chsong@syu.ac.kr)

displaying to practice single-handed tasks, which is impossible in MT[13]. Above all, VRRE can be used to minimize asymmetry of trunk in sitting posture, which happens to patients during MT.

It is notable that patients tilt their trunk towards the unaffected side to view the reflected image on the mirror and the size and angle of the mirrors used in MT researches were different. These factors can cause asymmetry in sitting posture and change in weight bearing[14].

In formal studies, some researchers seemed to have considered a better posture during therapy sessions[15]. This suggests an effort to prevent asymmetry. Such attempt conveys a need for more optimal condition of the mirror used in therapy.

This study will analyze changes of kinematic parameters in patients according to mirror size and angle to suggest an optimal condition to maintain sitting posture symmetry during MT.

SUBJECTS AND METHODS

Five healthy subjects and 5 hemiparesis stroke patients were recruited. Five stroke patients were selected from the rehabilitation ward of S medical center in Seoul, who met the inclusive criteria for this study. The inclusion criteria for stroke patients were as follows: history of a stroke at least 6 months before the study; hemiparesis; able to understand and follow simple verbal instructions; a Mini-mental State Examination-Korean (MMSE-K) score of >24; dynamic sitting balance above fair level; voluntary participation and the ability to communicate effectively. The exclusion criteria included: experience of previous strokes; major hemorrhagic changes; increased intracranial pressure; hemicraniectomy or orthopedic, rheumatologic, or other diseases interfering with their ability to sit or to move either upper limb; and psychiatric disorder or dementia. In the process, 2 stroke patients failed to complete the experiment due to worsened condition. Table 1 shows general characteristics of subjects. As this study was approved by the Sahmyook University Institutional Review Board (SYUIRB 2015–092), each participant was informed about the purpose and the introduction of the research, and agreed to the procedure by signing a consent form.

For motion analysis during the experiment, 6 infra-red cameras (Oqus 1 series, Qualisys AB, Sweden, 2012) were used. These cameras were set at 100 frames/sec sampling rate. To track the motion with the infra-red cameras, 20 mm diameter spherical markers were glued directly onto the skin with bi-adhesive tape. Then, by taking personal comments into consideration, the set was made suitable for 'Visual 3D' (C-Motion, USA, 2012) analysis. In total, a set consisting of 25 markers were glued to the following spots: The head segment was defined by the markers placed right above the right and left ears (RH, LH), following up the RH and LH line which meets at the top of the head (TH), on the forehead which is transverse to the RH and LH line (AH) and the right and left zygomatic arch posterior part (RZ, LZ). The trunk segment was defined by the markers over the seventh cervical vertebra (C7), the right and left acromions (RA, LA), sagittal axis point which passes the center of the right and left should joints (RR, LL), the tenth thoracic vertebrae (T10), and the right and left sagittal axis point of T10 level (RT, LT). The pelvis segment was defined by markers placed on the right and left anterior superior iliac spines (RASIS, LASIS), the right and left posterior superior iliac spines (RPSIS, LPSIS), the right and left iliac crest point which exists on the sagittal axis (RI, LI), and the spinal process of the second sacral vertebra (S2). Also, to define femur, single markers were used on the right and left greater trochanter (RGT, LGT) and the right and left lateral epicondyles of femur (RK, LK). Furthermore, clusters of four passive-reflective markers on lateral part of the right and left thigh were attached to RGT-RK and LGT-LK in parallel. Two force plates (Type 9266AA, Kistler Instrument AG, Switzerland, 2008), sampling at 1,000 Hz, were used to collect COP excursions. Size of the big mirrors was 50 × 40 cm to reach the subject's eye level[15] and the size of the small mirrors was a conventional mirror size of 30 × 20 cm[8]. Screen as VRRE was the same virtual reality reflection equipment consisting of wooden box and an LCD monitor (width 54 ×length 34 ×height 21 cm), as suggested by D Lee, et al.[12] (Fig. 1). 'Qualisys Track Manager' (Track Manager version 2.5, Qualisys, Sweden, 2012) was used for tracking the markers, and force data were integrated by connecting infra-red cameras and A/D board with internal trigger cables.

They performed tasks according to the physiotherapist's instruction using mirrors in the following order: big mirror 90°; big mirror 60°; small mirror 90°; small mirror 60°; and VRRE. If the patient complained of discomfort, experiment was stopped immediately. Each task was repeated three times and the average value was calculated.

To classify phases, midline of the subject motioning to perform tasks was set as event 1 and the peak point to perform the tasks was set as event 2 when obtaining data values (Fig. 2). After obtaining values, the difference between the value of event 2 and event 1 was normalized.

Kruskal-Wallis test was used to determine differences in the dependent variables of each mirror angle and size in each group. For significant differences, post hoc pairwise comparisons were performed using the Least Significant Difference (LSD) to locate the differences of each mirror angle and size in each group. SPSS version 19.0 for Windows was used to perform all analyses and p values <0.05 were regarded as significant.

RESULTS

Table 2 shows stroke group's significant differences for all given dependent variables of mirror sizes ($p<0.05$), as well as mirror angles ($p<0.05$). Post hoc pairwise comparisons in mirror sizes revealed differences apart from trunk absolute angle on ML axis (T_ML). There were significant differences in head and trunk segment angle on AP axis (HT_AP), head and

Table 1. General characteristics of subjects (N=8)

Group	Subjects	Gender	Age (years)	Height (cm)	Weight (kg)	Affected side
Stroke Group (n=3)	1	Male	53	165	68	Rt.
	2	Female	60	160	45	Lt.
	3	Female	20	170	51	Lt.
Normal Group (n=5)	1	Male	31	178	78	Lt.[a]
	2	Female	26	168	56	Lt.
	3	Male	27	171	62	Lt.
	4	Female	24	162	48	Lt.
	5	Male	24	179	69	Lt.

[a]For healthy subjects, the affected side is referred as nondominant side.

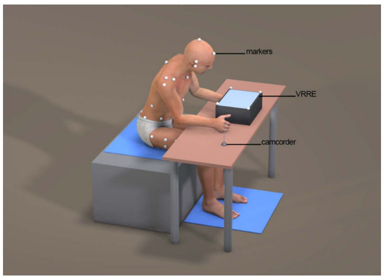

Fig. 1. Virtual reality reflection therapy

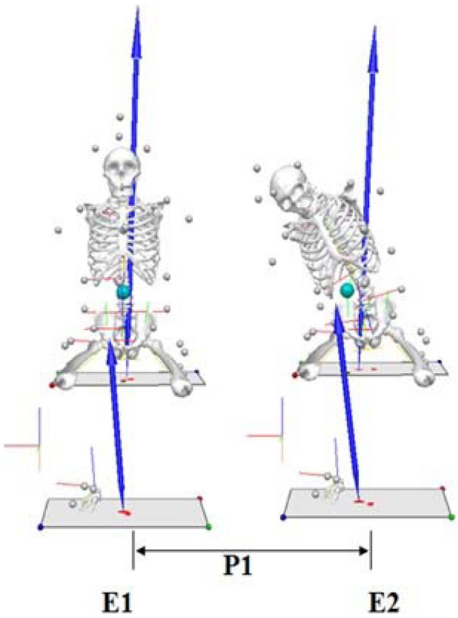

Fig. 2. Event and phase

trunk segment angle on ML axis (HT_ML), and pelvis absolute angle on AP axis (P_AP) between big mirror and VRRE, and between small mirror and VRRE ($p<0.05$). In trunk absolute angle on AP axis (T_AP) and pelvis absolute angle on ML axis (P_ML), significant differences showed only between small mirror and VRRE ($p<0.05$). Post hoc pairwise comparisons in mirror angles showed differences in all given dependent variables. HT_AP and HT_ML showed significant differences ($p<0.05$) between 90° and 0° (VRRE), and between 60° and 0°. T_AP, P_AP, and P_ML showed significant differences ($p<0.05$) between 90° and 60°, and between 60° and 0°. T_ML showed significant differences ($p<0.05$) in all angles (between 90° and 60°, between 60° and 0°, and between 90° and 0°).

Table 3 shows normal group's significant differences for all given dependent variables of mirror sizes ($p<0.05$), as well as mirror angles ($p<0.05$) apart from P_AP. Post hoc pairwise comparisons in mirror sizes revealed differences. HT_AP, HT_ML, T_ML, and P_ML showed significant differences ($p<0.05$) between big mirror and VRRE, and between small mirror and VRRE. T_AP showed significant differences ($p<0.05$) between big mirror and small mirror, and small mirror and VRRE. P_AP showed significant difference ($p<0.05$) only between small mirror and VRRE. Post hoc pairwise comparisons in mirror angles revealed differences in all given dependent variables except for P_AP. HT_ML showed significant differences ($p<0.05$) between 90° and 0° (VRRE), and between 60° and 0°. T_AP showed significant differences ($p<0.05$) between 90° and 60°, and between 60° and 0°. HT_AP, T_ML, and P_ML showed significant differences ($p<0.05$) in all angles (between 90° and 60°, between 60° and 0°, and between 90°and 0°).

Table 4 shows stroke group's significant differences in pelvis COP excursion on ML axis (PCOP_ML) and COG excursion on ML axis (COG_ML) of mirror sizes ($p<0.05$). PCOP_ML, COG excursion on AP axis (COG_AP), and COG_ML showed significant differences in mirror angles ($p<0.05$). Post hoc pairwise comparisons in mirror sizes revealed differences.

Table 2. Segment angles and absolute angles of stroke group (N=3)

		HT_AP (degree)	HT_ML (degree)	T_AP (degree)	T_ML (degree)	P_AP (degree)	P_ML (degree)
Size	Angle						
Big (A)	90 (a)	−20.86 ± 3.72	18.86 ± 11.77	−2.84 ± 0.99	5.48 ± 1.27	−1.95 ± 1.14	1.51 ± 0.76
	60 (b)	−17.13 ± 7.95	9.88 ± 8.27	−1.03 ± 1.15	1.45 ± 1.07	−0.45 ± 0.31	0.28 ± 0.36
	Total	−19.00 ± 5.92	14.37 ± 10.35	−1.93 ± 1.38	3.47 ± 2.44	−1.20 ± 1.12	0.89 ± 0.86
Small (B)	90 (a)	−32.39 ± 11.53	23.89 ± 10.32	−4.74 ± 2.01	10.13 ± 3.14	−2.20 ± 1.26	2.27 ± 1.75
	60 (b)	−17.89 ± 12.55	17.81 ± 5.47	−1.85 ± 2.01	3.29 ± 1.93	−0.69 ± 0.77	0.64 ± 1.06
	Total	−25.14 ± 13.39	20.85 ± 8.10	−3.29 ± 2.40	6.71 ± 4.41	−1.45 ± 1.25	1.45 ± 1.57
VRRE (C)	0 (c)	−0.07 ± 4.82	−6.32 ± 2.69	0.59 ± 1.36	−0.93 ± 0.47	0.69 ± 0.86	−0.44 ± 0.12
Total	90 (a)	−26.63 ± 9.93	21.38 ± 10.28	−3.79 ± 1.76	7.81 ± 3.33	−2.08 ± 1.08	1.89 ± 1.28
	60 (b)	−17.51 ± 9.41	13.84 ± 7.63	−1.44 ± 1.53	2.37 ± 1.72	−0.57 ± 0.54	0.46 ± 0.73
	0 (c)	−0.07 ± 4.82	−6.32 ± 2.69	0.59 ± 1.36	−0.93 ± 0.47	0.69 ± 0.86	−0.44 ± 0.12
	Total	−17.67 ± 13.07	12.82 ± 13.03	−1.97 ± 2.27	3.88 ± 4.19	−0.92 ± 1.35	0.85 ± 1.29
Size χ^2 (p)		7.167 (0.028)	7.817 (0.020)	6.283 (0.043)	7.817 (0.020)	6.125 (0.047)	6.900 (0.032)
Post-Hoc		A|C, B|C	A|C, B|C	B|C		A|C, B|C	B|C
Angle χ^2 (p)		8.100 (0.017)	7.567 (0.023)	8.165 (0.017)	11.567 (0.003)	8.625 (0.013)	10.017 (0.007)
Post-Hoc		a|c, b|c	a|c, b|c	a|b, b|c	a|b|c	a|b, b|c	a|b, b|c

HT_AP: head and trunk segment angle on antero-posterior axis; HT_ML: head and trunk segment angle on medio-lateral axis; T_AP: trunk absolute angle on antero-posterior axis; T_ML: trunk absolute angle on medio-lateral axis; P_AP: pelvis absolute angle on antero-posterior axis; P_ML: pelvis absolute angle on medio-lateral axis
Values are expressed as mean ± standard deviation

Table 3. Segment angles and absolute angles of normal group (N=5)

		HT_AP (degree)	HT_ML (degree)	T_AP (degree)	T_ML (degree)	P_AP (degree)	P_ML (degree)
Size	Angle						
Big (A)	90 (a)	−21.55 ± 9.80	11.06 ± 9.71	−7.06 ± 3.24	10.61 ± 9.14	−2.91 ± 2.16	3.95 ± 2.48
	60 (b)	−17.58 ± 5.19	7.70 ± 7.42	−3.72 ± 0.78	4.24 ± 1.31	−2.20 ± 1.01	1.99 ± 1.60
	Total	−19.57 ± 7.68	9.38 ± 8.34	−5.39 ± 2.83	7.43 ± 7.01	−2.56 ± 1.63	2.97 ± 2.22
Small (B)	90 (a)	−34.06 ± 10.28	14.42 ± 9.11	−17.87 ± 11.15	15.04 ± 9.10	−3.52 ± 1.84	4.73 ± 2.66
	60 (b)	−19.15 ± 7.85	7.82 ± 6.55	−6.10 ± 3.61	6.02 ± 2.81	−3.90 ± 2.32	2.44 ± 2.19
	Total	−26.61 ± 11.66	11.12 ± 8.25	−11.98 ± 9.97	10.53 ± 7.93	−3.71 ± 1.99	3.59 ± 2.59
VRRT (C)	0 (c)	−4.41 ± 4.42	−9.97 ± 5.03	−11.85 ± 6.64	−2.84 ± 2.84	−1.42 ± 1.70	−1.81 ± 1.78
Total	90 (a)	−27.81 ± 11.54	12.74 ± 9.05	−15.74 ± 9.84	12.82 ± 8.91	−3.22 ± 1.92	4.34 ± 2.46
	60 (b)	−17.37 ± 6.33	7.76 ± 6.60	−6.49 ± 4.44	5.13 ± 2.27	−3.05 ± 1.91	2.22 ± 1.83
	0 (c)	−4.41 ± 4.42	−9.97 ± 5.03	−11.85 ± 6.64	−2.84 ± 2.84	−1.42 ± 1.70	−1.81 ± 1.78
	Total	−19.35 ± 12.04	6.21 ± 11.16	−11.26 ± 8.30	6.61 ± 8.29	−2.79 ± 1.93	2.26 ± 3.05
Size χ^2 (p)		12.111 (0.002)	11.719 (0.003)	13.749 (0.001)	13.015 (0.001)	3.447 (0.178)	11.838 (0.003)
Post-Hoc		A|C, B|C	A|C, B|C	A|B, B|C	A|C, B|C		A|C, B|C
Angle χ^2 (p)		12.761 (0.002)	12.871 (0.002)	14.101 (0.001)	16.324 (0.000)	2.516 (0.284)	14.433 (0.001)
Post-Hoc		a|b|c	a|c, b|c	a|b, b|c	a|b|c		a|b|c

HT_AP: head and trunk segment angle on antero-posterior axis; HT_ML: head and trunk segment angle on medio-lateral axis; T_AP: trunk absolute angle on antero-posterior axis; T_ML: trunk absolute angle on medio-lateral axis; P_AP: pelvis absolute angle on antero-posterior axis; P_ML: pelvis absolute angle on medio-lateral axis
Values are expressed as mean ± standard deviation

COG_ML showed significant differences between big mirror and VRRE, and between small mirror and VRRE ($p<0.05$). Pelvis COP excursion on AP axis (PCOP_AP), PCOP_ML, and COG_AP showed significant difference only between small mirror and VRRE ($p<0.05$). Post hoc pairwise comparisons in mirror angles revealed differences in all given dependent variables except for PCOP_AP. PCOP_ML and COG_AP showed significant differences ($p<0.05$) between 90° and 60°, and between 60° and 0°. COG_ML showed significant differences ($p<0.05$) in all angles (between 90° and 60°, between 60° and

Table 4. COP excursions and COG excursions of stroke group (N=3)

		PCOP_AP (cm)	PCOP_ML (cm)	COG_AP (cm)	COG_ML (cm)
Size	Angle				
Big (A)	90 (a)	9.78 ± 8.50	40.35 ± 34.99	9.93 ± 3.40	16.87 ± 3.66
	60 (b)	3.19 ± 3.31	8.93 ± 6.21	2.14 ± 3.90	5.24 ± 2.46
	Total	6.49 ± 6.80	24.64 ± 28.31	6.04 ± 5.38	11.06 ± 6.96
Small (B)	90 (a)	24.19 ± 13.03	81.16 ± 42.40	15.66 ± 8.03	33.60 ± 9.96
	60 (b)	6.12 ± 0.75	34.38 ± 28.77	6.91 ± 5.74	12.34 ± 6.63
	Total	15.16 ± 12.89	57.77 ± 41.31	11.29 ± 7.87	22.97 ± 13.89
VRRT (C)	0 (c)	−0.09 ± 6.50	−13.09 ± 5.65	−1.20 ± 5.46	−5.73 ± 3.06
Total	90 (a)	16.99 ± 12.62	60.76 ± 41.33	12.80 ± 6.34	25.24 ± 11.36
	60 (b)	4.66 ± 2.68	21.66 ± 23.25	4.53 ± 5.11	8.79 ± 5.93
	0 (c)	−0.09 ± 6.50	−13.09 ± 5.65	−1.20 ± 5.46	−5.73 ± 3.06
	Total	8.64 ± 10.88	30.35 ± 40.51	6.69 ± 7.70	12.47 ± 14.37
Size χ^2 (p)		5.017 (0.081)	9.150 (0.010)	5.433 (0.066)	8.417 (0.015)
Post-Hoc			B|C		A|C, B|C
Angle χ^2 (p)		5.817 (0.055)	8.100 (0.017)	7.833 (0.020)	11.017 (0.004)
Post-Hoc			a|b, b|c	a|b, b|c	a|b|c

PCOP_AP: pelvis COP excursion on antero-posterior axis; PCOP_ML: pelvis COP excursion on medio-lateral axis; COG_AP: COG excursion on antero-posterior axis; COG_ML: COG excursion on medio-lateral axis
Values are expressed as mean ± standard deviation.

Table 5. COP excursions and COG excursions of normal group (N=5)

		PCOP_AP (cm)	PCOP_ML (cm)	COG_AP (cm)	COG_ML (cm)
Size	Angle				
Big (A)	90 (a)	9.59 ± 5.10	106.89 ± 59.61	22.59 ± 10.74	38.86 ± 21.35
	60 (b)	9.90 ± 10.01	56.27 ± 40.46	14.94 ± 6.16	19.75 ± 9.44
	Total	9.74 ± 7.49	81.58 ± 54.94	18.77 ± 9.19	29.30 ± 18.54
Small (B)	90 (a)	14.75 ± 10.59	123.11 ± 55.38	29.23 ± 11.43	52.03 ± 20.14
	60 (b)	17.11 ± 10.29	68.18 ± 47.24	25.61 ± 12.33	24.33 ± 11.48
	Total	15.93 ± 9.92	95.64 ± 56.51	27.42 ± 11.37	38.18 ± 21.26
VRRT (C)	0 (c)	11.26 ± 11.07	−44.06 ± 35.10	9.72 ± 6.16	−19.30 ± 12.76
Total	90 (a)	12.17 ± 8.29	115.00 ± 54.92	25.91 ± 11.03	45.44 ± 20.76
	60 (b)	13.51 ± 10.30	62.23 ± 41.93	20.28 ± 10.77	22.04 ± 10.20
	0 (c)	11.26 ± 11.07	−44.06 ± 35.10	9.72 ± 6.16	−19.30 ± 12.76
	Total	12.52 ± 9.31	62.08 ± 74.23	20.42 ± 11.48	23.13 ± 28.48
Size χ^2 (p)		2.442 (0.295)	11.985 (0.002)	8.027 (0.018)	12.262 (0.002)
Post-Hoc			A|C, B|C	B|C	A|C, B|C
Angle χ^2 (p)		0.116 (0.944)	15.087 (0.001)	6.402 (0.041)	15.087 (0.001)
Post-Hoc			a|b|c	b|c	a|b|c

PCOP_AP: pelvis COP excursion on antero-posterior axis; PCOP_ML: pelvis COP excursion on medio-lateral axis; COG_AP: COG excursion on antero-posterior axis; COG_ML: COG excursion on medio-lateral axis
Values are expressed as mean ± standard deviation.

0°, and between 90°and 0°).

Table 5 shows normal group's significant differences in all given dependent variables of mirror sizes ($p<0.05$) and mirror angles ($p<0.05$) except for PCOP_AP. Post hoc pairwise comparisons in mirror sizes revealed differences except for PCOP_AP. PCOP_ML and COG_ML showed significant differences between big mirror and VRRE, and between small mirror and VRRE ($p<0.05$). COG_AP showed significant difference only between small mirror and VRRE ($p<0.05$). Post hoc pairwise comparisons in mirror angles revealed differences in all given dependent variables except for PCOP_AP. COG_AP showed significant difference ($p<0.05$) between 60° and 0°. PCOP_ML and COG_ML showed significant differences ($p<0.05$) in all angles (between 90° and 60°, between 60° and 0°, and between 90°and 0°).

DISCUSSION

Healthy subjects showed symmetrical loading on body support interface while sitting and standing[16]. On the other hand, due to weaker muscles on the affected side, stroke patients showed asymmetrical posture in space and decreased weight bearing towards the contralateral part of the stroke lesion[17–19]. This causes problems in movement control and balance skills[14, 20–22]. It was suggested that the weight bearing experience would allow proprioceptive feedback for more muscle recruitment in order to meet the demand of bearing weight[17, 18]. Thus, for erect posture without collapse, improvements have been made to bear more weight on the affected side by shifting weight with manual guide on the hemiplegic side. However, in MT which is based on mirror neuron system (MNS) concept[23], conventional rehabilitation perspective on asymmetrical posture and weight bearing is not maintained. The focus of therapy is more concentrated on stimulating MNS by instructing subjects to do task-oriented hand action or observing someone and performing similar actions, and thus enabling recruit of functionally interconnected cortical structures coupling action performance and observation through the activation of MNS[24]. There are many preceding researches on MT applied on upper limb of stroke patients. However, only a few studies considered details of mirror size and angle or conditions for optimal symmetrical posture. Even among the researches that mention anything about the mirror, the sizes and angles all differed in each method[1, 8, 9, 25–27]. Yet, majority of these researches set mirror angle to 90° in front of the subject, referring it as vertical or perpendicular to the subject midline. This was the most adequate angle which provides the reflected image as real as possible to the patient. However, in order to see the reflected image on the mirror, tilting of head and trunk as well as weigh bearing towards the unaffected side was observed even with naked eyes. In one case, mirror was slightly slanted for the experiment[8]. It is true slanted mirror lets the patient perform with more symmetrical posture and better weight bearing compared to 90° condition, however, the reflected image becomes distorted, becoming unfit for creating the right illusion for the patient to carry out tasks. Recently, there have been attempts to suggest adequate vision with correct posture for taller subjects by modifying mirror size (24 × 18 × 14 inches) during MT[15]. Furthermore, in a study of applying VRRE (width 54 × length 34 × height 21 cm), which shows effect of 0° in MT, anterior pelvic tilt was assumed with the flexed hip, knee, and ankle joint to avoid postural asymmetry[12].

Therefore, the aim of this study was to investigate optimal MT condition by analyzing kinematic parameters according to mirror size and angle. Most of the dependent variable data of sizes and angles of each group in this study show significant differences. In segment angles and absolute angles of stroke group, all dependent variables showed significant differences in size and angles. From the kinematic parameters obtained from motion capture system, the larger the size and smaller the angle, the degree of flexion and tilting towards the lateral side decreased in both groups consistently. Particularly, when virtual reality reflection equipment (VRRE) was used, the value of the flexion decreased and the value of lateral tilt was the closest to the midline compared to all other independent variables. Moreover, it showed tendency of moving towards the affected side. Contrast to MT where the body moved towards the unaffected side, all the variables moved to the opposite direction. In the results of post hoc test comparisons on mirror sizes in stroke group, all dependent variables except T_ML showed significant differences between VRRE and small mirror (30 × 20 cm). In addition, there were differences between VRRE and big mirror (50 × 40 cm) in HT_AP, HT_ML, and P_AP. This conveys the biggest movement of head when patient flexes or tilts towards the lateral side according to the mirror size. Such result suggests connection to a study on trunk muscle activity[28, 29] of existing stroke patients. Pelvic functions to provide safety to support trunk mobility. However, when there is a posterior tilt, it limits trunk mobility due to fixation. Stroke patients make posterior tilt in pelvis to compensate weakness in the abdominal muscles while sitting[19]. This seems to have prompted the patient to use head more than other segments due to fixation of pelvis and weakness in trunk muscles even though the mediator instructed neutral sitting position[30] while the patient was performing tasks in sitting posture. Lee[12] also seemed to have assumed anterior tilt in the subject's sitting posture for the same reason. In the results of post hoc test comparisons on mirror angles in stroke group, all values between VRRE (0°) and 60° showed significant differences, as well as in normal groups. T_ML value shows correlation in all variables in post hoc test comparison in angles for both groups. It is observed that changes in mirror angle leads trunk to tilt towards lateral side. Among COP excursions and COG excursions, PCOP_ML and COG_ML in both groups showed similar degree of significance. Also, like other kinematic parameters, the larger the size and smaller the angle, the more excursions on AP and ML axes decreased. Particularly, when VRRE was used, the value of the excursion on AP axis decreased significantly and the value of tilting was the closest to the midline compared to all other variables, or showed values moving towards the affected side. Contrast to MT where the COP excursions and COG excursions moved towards the unaffected side, all the variables moved to the opposite direction. This implies that VRRE shifts movement from unaffected side to midline and takes weight bearing to the affected side. This effect, therefore, suggests a close connection to the kinematic parameters mentioned above. It is possible to evaluate this phenomenon as being the most symmetrical posture and the closest weight bearing condition expected to achieve in this study. Smaller movements and shorter COP excursions in patients compared to normal subject is similar to the result of S Messier, et al.[31] study. Contrast to normal subjects, stroke patients' use of head and upper trunk to change COG excursions in sitting posture is related to the changes in other kinematic parameters.

Limitation of this study includes lack of participants due to complex motion analysis procedure. Accordingly, it is difficult to make generalization because of small number of subjects. Further study will require larger number of sample sizes. Based on the results of the presented investigation, while mirror therapy is generally used as one of the upper extremity rehabilitation methods for stroke patients, it has a disadvantage of shifting weight and leaning towards the unaffected side during therapy. Therefore, it seems to be more effective in terms of clinics to apply VRRE method to make up for the weak points and provide more elaborate visual feedback.

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