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Effects of interactive metronome training on upper extremity function, ADL and QOL in stroke patients

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Abstract.
BACKGROUND: Rhythm and timing training is stimulation that substitutes for a damaged function controls muscular movement or temporal element, which has positive impacts on the neurological aspect and movement of the brain.
OBJECTIVE: This study is to assess the changes caused by rhythm and timing training using an interactive metronome (IM) on upper extremity function, ADL and QOL in stroke patients.
METHODS: In order to assess the effects of IM training, a group experiment was conducted on 30 stroke patients. Twelve sessions of IM training were provided for the experimental group three times a week for four weeks, while the control group was trained with a Bilateral arm Self-Exercise (BSE) for the same period. Both groups were evaluated by pre- and post-tests through MFT, MAL, K-MBI and SS-QOL.
RESULT: There were more statistically significant differences (<0.05) in the total score of MFT and the finger control item in the IM Group than in the BSE Group. With respect to ADL, there were more statistically significant differences (<0.05) in the total score of K-MBI and the dressing item in the IM Group than in the BSE Group.
CONCLUSION: The study proposes that IM training can be applied as an occupational therapy program in patients with various diseases who need to adjust the time for performing movements as well as stroke patients.

Keywords: Interactive metronome, rhythm and timing, Bilateral arm Self-Exercise (BSE), stroke

1. Introduction

Upper extremity function is the base of the performances such as eating, writing, washing and dressing, which also plays an important role in walking and balancing (Shumway-Cook & Woollacott, 2007). In addition, upper extremity is used as a means of communication and plays an important role in several cognitive activities (Schier & Chan, 2007). However, it is difficult for stroke patients to carry out voluntary and separating movements of the upper extremity and control the speed and direction, limitations appear in a lot of physical activities related to Activities of Daily Living (ADL) (Park, Eun, Lee, & Hong, 2010; Shumway-Cook & Woollacott, 2007).

Stroke patients have a limitation on the degree of participation in leisure activities and social activities due to damage to upper extremity function (Ensinck et al., 2002; Mayo, Wood-Dauphinee, Cote, Durcan, & Carlton, 2002; Sveen, Thommessen, Bautz-Holter, Wyller, & Laake, 2004), which consequently leads to the decrease of the quality of life (QOL) because of their life dependent on others and severe psychological distress (Almborg & Berg, 2009; Ha, Hauge, & Iversen, 2010; Pendleton & Schultz-Krohn, 2006). The reduction of their upper extremity function has negative impacts on ADL and QOL, which needs recovery through an effective rehabilitation

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program (Page, Levine, Sisto, Bond, & Johnston, 2002).

For the recovery of stroke patients' physical ability, various rehabilitation programs are implemented, such as bilateral arm exercise therapy, mirror therapy, virtual reality therapy, rhythm and timing training (Beckelhimer, Dalton, Richter, Hermann, & Page, 2011; Mamdani et al., 2010; Senesac, Davis, & Richards, 2010; Yavuzer et al., 2008). These rehabilitation programs contribute to exercise recovery through cerebral plasticity and clinical neural reorganization (Nudo, 2003; Tecchio et al., 2006). Of them, rhythm and timing training is the one in which the stimulation that substitutes for a damaged function controls muscular movement or temporal element, which has positive impacts on the neurological aspect and movement of the brain (Thaut, Demartin, & Sanes, 2008).

Interactive Metronome (IM) based on rhythm and timing training is grounded in the timing theory that human exercise is based on an inner sense of timing (Greenspan, 1997). The timing theory refers to the accuracy of a response to a given stimulus, measured by the time of the response, and it is important to expect the things that would take place in order to plan and execute the exercise and to use guidance information for movement (Wuang, Wang, Huang, & Su, 2008). This timing is essential for movement and allows a more effective organization of cognitive processes such as concentration, exercise plan and exercise order (Cosper, Lee, Peters, & Bishop, 2009; Taub, McGrew, & Keith, 2007).

IM training reduces an error in the response of movement, according to the accurate timing through the feedback provided while the subject is performing exercise tasks using hands and feet according to the metronome sound. This can activate the cerebral region by stimulating the perceptual region and exercise region through an auditory signal (Thaut & Abiru, 2010; Thaut et al., 2009), and help efficient exercise relearning and functional exercise practice performance to enhance spatio-temporal factors of movement (Luft et al., 2004; Whitall, McCombe, Silver, & Macko, 2000). Through fMRI and MRI as a result of IM training, it was found that the primary neural motor cortex, premotor cortex and cerebellum were activated and that IM increased the processing speed in nerve cells (Alpiner, 2004; Debaere, Swinnen, Beaste, & Sunaert, 2001).

IM training was conducted with children with Attention Deficit Hyperactivity Disorder (ADHD), and there were changes in physical ability, attention, concentration and learning ability (Diamond, 2003; Jeanetta et al., 2001; Libkuman, Otani, & Stegar, 2002; Shaffer et al., 2001). In addition, it was reported that there were improvements of large and small muscle techniques and accuracy of timing through the application of IM to children with problems in concentration and exercise coordination (Melinda & Robin, 2005). A study of IM training with adult golf players showed that it improved their concentration and exercise performance coordination ability (Libkuman et al., 2002). As a study with stroke patients, there was one comparing changes in the patients' arms and occupational performance by the application of IM (Beckelhimer et al., 2011; Hill, Dunn, Dunning, & Page, 2011).

However, the number of research subjects was fewer as compared to the effects and merits of IM training, or IM training was applied only to an experimental group, so limited effectiveness was reported Also, it was explained that studies conducted with the actual patients were limited (Slye, 2010). Therefore, it is necessary to examine the effect and usefulness of IM training by carrying it out with the actual stroke patients through an objective design. Thus, this study would investigate the effects of IM training by checking changes in the stroke patients' upper extremity function, ADL and QOL through the training.

2. Methods

2.1. Research period and subjects

This study was conducted with patients diagnosed with stroke at W. Rehabilitation Hospital in Daejeon for the research period from July 25 through November 5, 2015 (Hill et al., 2011; Slye, 2010).

2.1.1. Criteria for selection

(1) A person who has had the disease for more than six months after diagnosis of stroke;
(2) One who neither has any hearing disorder, hemi-neglect nor eye damage;
(3) One who can perform clapping motion; and
(4) One whose MMSE-K score is higher than 24 points.

2.1.2. Criteria for exclusion

(1) A person who has MASS Grade 3 or higher in the joint of the upper extremity,

(2) One who has a hearing disorder, hemi-neglect or eye damage; and
(3) One whose bending or outward turning of the shoulder joint, and voluntary movement of pronation of forearm <45°.

2.2. Research process and instruments

This study conducted a group experimental research in order to analyze the intervention effect of IM in stroke patients. This study provided a total of 12 sessions of IM training for the experimental group, three times a week for four weeks, and the time of each therapy session was set to 30 minutes based on the study performed in stroke patients (Hill et al., 2011). Also, for the control group, a Bilateral arm Self-Exercise (BSE) program was administered during the same sessions to provide them with a self-exercise program. The intervention effect was evaluated, using MFT, MAL, K-MBI and SS-QOL.

2.3. Interactive Metronome (IM)

This study carried out training, by referring to the preceding research on IM training in stroke patients (Slye, 2010). Out of the 13 exercise tasks in the existing protocol, six tasks were conducted, which included applying only motion using both hands, using one hand, and diagonal cross of the upper extremity and the unaffected lower extremity. IM training should consist of more than 12 to 15 sessions three to five times a week for four weeks, and the number of repetitions of the training should be 18,000 to 20,000 times or more. Therefore, in this study, training for the IM exercise tasks was carried out according to the sessions of intervention.

2.4. Statistical analysis

For the analysis of the results of the study, SPSS 20.0 (PASW Statistics 20) was employed. With respect to the general characteristics of research subjects, a frequency analysis was conducted, using descriptive statistics. For the test for homogeneity of the pre-test before the intervention in the experimental group and the control group, an independent samples *t*-test was performed. In addition, in order to compare the differences in upper extremity function, ADL and QOL between the experimental group and the control group before and after the intervention, a matched samples *t*-test was used, and in order to compare the interaction effect between the two groups, an independent samples *t*-test was conducted. The statistical significance level was set at 0.05.

3. Results

3.1. Characteristics of research subjects

As a result of the test for homogeneity in the general characteristics of research subjects according to the group, there were no statistically significant differences between the two groups (Table 1).

3.2. Test for homogeneity in the pre-test for the IM group and the BSE group

As a result of verification of homogeneity in the pre-test for both groups, there were no statistically significant differences between the two groups ($p < 0.05$).

3.3. Change in upper extremity function in the IM group and the BSE group

As a result of the comparison of upper extremity function in the IM Group, there were significant differences in finger control and the total score of MFT

Table 1
General characteristics of subjects ($N = 30$)

Variables	IM group ($n = 15$)	BSE group ($n = 15$)	Total ($n = 30$)
Gender			
Male	12	10	22
Female	3	5	8
Age (year)	50.4 ± 11.01	51.13 ± 14.37	50.77 ± 12.59
Type of stroke			
Infarction	10	11	22
Hemorrhage	5	4	9
Affected side			
Right	7	7	14
Lift	8	8	16
Marital status			
Single	3	5	8
Married	10	9	19
Divorced	2	1	3
Having children			
Yes	12	10	22
No	3	5	8
Education			
Elementary school	0	2	2
Middle school	4	4	8
High school	8	5	13
University	3	4	7

($p < 0.05$) while there were significant differences in the amount of use of the affected side and the domain of the quality of movement in MAL ($p < 0.05$). In the BSE Group, there were significant differences in upper extremity exercise and the finger control item in MFT while there were significant differences in the amount of use of the affected side and the domain of the quality of movement in MAL. In addition, as a result of the comparison of upper extremity function between the two groups before and after the intervention, there were more statistically significant differences in the finger control item and the total score of MFT in the IM Group than in the BSE Group ($p < 0.05$) while there were no significant differences in MAL (Table 2).

3.4. Change in ADL in the IM group and the BSE group

As a result of the comparison of ADL in the IM Group, there were significant differences in the scores for items including feeding, toileting, dressing and transfer from bed to chair and in the total score of K-MBI ($p < 0.05$). In the BSE Group, there were significant differences in the total score of K-MBI and the scores for items including bathing, feeding, toileting and transfer from bed to chair ($p < 0.05$). In addition, as a result of the comparison of ADL between the two groups before and after the intervention, there were more statistically significant differences in the total score of K-MBI and the dressing item in the IM Group than in the BSE Group ($p < 0.05$) (Table 3).

3.5. Change in QOL in the IM group and the BSE group

As a result of the comparison of QOL in the IM Group, there were significant differences in the total score of SS-QOL, and the scores for domains of movement, self-help activities and thinking skills ($p < 0.05$). In the BSE Group, there were significant differences in the total score of SS-QOL, and the

Table 2
Comparison of Upper extremity function between the two groups ($N = 30$)

	IM group ($n = 15$)		BSE group ($n = 15$)		t
	pre	post	pre	post	
MFT					
UF	14.73 ± 1.87	15.20 ± 1.15	14.60 ± 1.72	14.93 ± 1.44^b	0.44
GS	4.93 ± 1.34	5.07 ± 1.28	4.47 ± 1.80	4.60 ± 1.64	0.00
FM	2.20 ± 1.97	3.13 ± 2.44^b	2.40 ± 2.44	2.67 ± 2.64^b	2.80*
Total	21.87 ± 4.57	23.40 ± 4.40^b	21.47 ± 5.51	22.20 ± 5.27^b	2.41*
MAL					
AOU	68.67 ± 32.70	78.73 ± 32.74^b	79.60 ± 26.93	91.20 ± 27.01^b	–0.92
QOM	61.47 ± 30.52	73.93 ± 31.97^b	76.20 ± 29.86	86.87 ± 33.76^b	0.51

MFT: Manual Function Test, UF: Upper extremity Function, GS: Grasp strength, FM: Finger manipulation, MAL: Motor Activity Log, AOU: Amount Of Use, QOM: Quality Of Movement. ^{a}Between the two groups pre-test was statistically significant differences, $p < 0.05$. ^{b}Between the group pre-post test was statistically significant difference, $p < 0.05$. *Between the two groups post-test was statistically significant differences, $p < 0.05$.

Table 3
Comparison of ADL between the two groups ($N = 30$)

Subitem	IM group ($n = 15$)		BSE group ($n = 15$)		t
	pre	post	pre	post	
Personal hygiene	3.40 ± 0.51	3.87 ± 0.52	3.33 ± 0.82	3.67 ± 0.49	0.64
Bathing	2.33 ± 0.98	2.93 ± 0.59	2.60 ± 1.24	3.07 ± 0.96^b	–1.00
Feeding	6.00 ± 1.86	7.00 ± 1.46^b	6.80 ± 1.90	7.53 ± 1.41^b	0.53
Toilet	5.27 ± 2.74	7.13 ± 2.17^b	4.93 ± 2.37	5.93 ± 1.67^b	1.55
Stair climbing	2.80 ± 2.01	2.80 ± 2.01	3.20 ± 2.40	3.40 ± 2.41	–1.00
Dressing	5.00 ± 1.60	6.87 ± 2.07^b	5.00 ± 1.96	5.40 ± 1.55	2.97*
Ambulation (W/C)	7.63 ± 3.56	7.73 ± 3.41	7.20 ± 3.65	7.33 ± 3.54	0.27
Chair-bed transfer	8.80 ± 3.95	10.07 ± 2.74^b	7.80 ± 2.96	8.87 ± 3.54^b	0.42
Total score	59.40 ± 16.02	66.33 ± 14.08^b	58.40 ± 15.61	61.87 ± 15.10^b	2.05*

^{a}Between the two groups pre-test was statistically significant differences, $p < 0.05$. ^{b}Between the group pre-post test was statistically significant difference, $p < 0.05$. *Between the two groups post-test was statistically significant differences, $p < 0.05$.

Table 4
Comparison of Quality of life between the two groups ($N = 30$)

Subitem	IM group ($n = 15$)		BSE group ($n = 15$)		t
	pre	post	pre	post	
Mobility	18.20 ± 6.52	19.60 ± 5.74^b	14.93 ± 5.61	15.40 ± 5.28	1.58
U/E function	13.2 ± 4.30	14.33 ± 3.62	14.93 ± 3.58	15.60 ± 3.46	0.80
Self care	15.67 ± 3.85	17.73 ± 3.90^b	14.67 ± 3.27	15.53 ± 3.04^b	2.01*
Thinking	9.87 ± 2.48	10.40 ± 2.27^b	8.67 ± 2.29	9.40 ± 2.17^b	–0.64
Mood	17.07 ± 3.52	17.70 ± 3.25	16.07 ± 3,22	16.67 ± 3.27	–0.16
Total score	156.73 ± 22.98	166.20 ± 22.37^b	150 ± 19.98	157.53 ± 18.65^b	0.64

^{a}Between the two groups pre-test was statistically significant differences, $p < 0.05$. ^{b}Between the group pre-post test was statistically significant difference, $p < 0.05$. *Between the two groups post-test was statistically significant differences, $p < 0.05$.

domains of self-help activities and thinking skills ($p < 0.05$). Also, as a result of the comparison of QOL between the two groups before and after the intervention, there was a more statistically significant difference in the domain of self-help activities in SS-QOL in the IM Group than in the BSE Group ($p < 0.05$) (Table 4).

4. Discussion

This study was conducted to present the validity of the actual use of IM training as an occupational therapy program in stroke patients based on the ground of the promotion of movement performance and reaction rate of IM training. Thirty stroke patients were divided into the experimental group and the control group to examine changes in the patients' upper extremity function, ADL and QOL. For the experimental group, 30-minute IM training was carried out three times a week for four weeks, and for the control group, BSE was conducted during the same sessions.

As a result of the comparison of upper extremity function between the two groups in this study, there were more statistically significant differences in the total score of MFT and finger control item in the IM Group than in the BSE Group. This result is consistent with the result of the preceding research which reported that IM training had a greater impact on the time control in the performance of delicate movements than greater movements of upper extremity function (Slye, 2010). This supports the theory that regular rhythms like the metronome for IM training stabilize the time control of movements and the power of speed and reduce the time required for reaction according to the exercise order (Fernandez del Olmo & Cudeiro, 2003; Thaut et al., 2009). In addition, IM training was provided in children with hemiplegic cerebral palsy and normal children, and the result was similar to that of the preceding research which showed that there was shortening of the time for performance on Grooved Pegboard Test and Jebsen Hand Function Test; thus, it was found that IM training was effective for improving the alertness of the upper extremity (Jung & Kim, 2013; Shank & Harron, 2015).

In the result of the comparison of ADL between the two groups, there were more statistically significant differences in the total score of K-MBI and the dressing item in the IM Group than in the BSE Group. This result is consistent with that of the previous research on IM training carried out in stroke patients, in which ADL improved (Hill et al., 2011). In addition, this is a similar result to that of the preceding research that assessed the change in ADL through the promotion of bilateral coordination ability and upper extremity function in children with hemiplegic cerebral palsy after the IM intervention (Jung & Kim, 2013). With respect to this, a study assessing the correlation between the affected upper extremity and ADL showed that IM training had a positive impact on ADL as there is a significant correlation with the affected upper extremity since bilateral upper extremity movement and delicate movements are needed in activities of daily living (Chae et al., 1998).

As a result of the comparison of QOL between the IM Group and the BSE Group, there was a statistically significant difference in the domain of self-help activities in SS-QOL. This result is similar to that in a study, in which QOL was increased when IM training was carried out in stroke patients (Beckelhimer et al., 2011). It was reported that patients' QOL after the occurrence of stroke was affected by their functional level (Jeong & Kim, 2007). Therefore, in this study, it was noted that the promotion of the functional level through IM training had a positive impact on the patients' QOL.

On comparing the results in the groups before and after the intervention in this study, there were significant differences only in the total score of MFT and finger control item in the IM Group, while there were significant differences in the total score of MFT, upper extremity exercise and finger control item before and after the intervention in the BSE Group. These results seem to be caused by the limitation of knowledge on the range of various joints since six kinds of exercise tasks in the IM training program mainly consisted of tasks using both hands or slapping one hand and the thigh as compared to the BSE Group.

With respect to ADL, there were significant differences in the total score of K-MBI and the items including feeding, toileting, dressing and transfer from bed to chair before and after the intervention in the IM Group while there were significant differences in the total score of K-MBI and the items including bathing, feeding, toileting and transfer from bed to chair in the BSE Group. This result is according to the task-oriented approach that BSE consists of tasks that could help promotion of ADL; hence, it would be helpful for promotion of performance (Carr & Shepherd, 2003).

In addition, since the training was carried out in conjunction with the traditional occupational therapy intervention in both the IM Group and the BSE Group, it seems that this too had a positive impact on promotion of upper extremity function and ADL. Therefore, BSE according to the task-oriented approach could also be usefully applied as a patient rehabilitation program, along with IM training, and according to the intervention method, if it is provided in the patients, combining the advantage of the task-oriented approach with that of rhythm and timing training using IM, it is judged that it would have greater effects.

Based on the positive results of studies on the application of the actual IM training in stroke patients and the preceding studies (Beckelhimer et al., 2011; Hill et al., 2011; Shank et al., 2015; Slye, 2010; Thaut et al., 2009; Jung et al., 2013), this study could identify that IM training could be used as one of the rehabilitation programs for chronic stroke patients. As a result of the study, there were no statistically significant differences between the IM Group and the BSE Group. However, it was observed that IM training would be more meaningful when it is provided to promote the basic exercise ability for the activities rather than the patients' functional activities (Hill et al., 2011; Syle et al., 2010).

It is necessary to verify whether the effects of IM training remain constant through a follow-up survey in the future research. In addition, IM training has an advantage that it can be used with bringing a hand trigger to the mouth according to the metronome sound when one performs the motion of eating by including an object used in daily living or applying that for adapting to situations (Hill et al., 2011; Slye, 2010). Based on this advantage, it is judged that IM training can have a positive impact on the patients' functional activities if tasks are modified and provided to achieve activities of daily living or the task-oriented exercises like the bilateral arm exercise task applied in the BSE Group are provided together.

In addition, based on the fact that there was a difference in the result for timing improvement in studies that carried out the same sessions, it was found that the composition of exercise tasks and the amount of training for the programs had an impact on the result (Kim, Kim, & Lee, 2015). Therefore, it is suggested that IM training should be applied as a part of the occupational therapy program in more clinical trials by providing a variety of IM training programs for the patients and their situations in future studies.

5. Conclusion

This study conducted IM training and BSE in stroke patients, and compared changes in upper extremity function, ADL and QOL and assessed the effects of training. IM training reduced the time for performance of minute movements of the upper extremity than larger movements, and it was observed out that it was effective for improving the alertness of the upper extremity. In addition, the movement of bilateral upper extremities and ADL like dressing that require delicate movements were improved through promotion of the affected upper extremity function, and based on this finding, it was noted that it could also have a positive impact on the patients' QOL. Based on the results of this study, the usefulness of IM training as a therapy program in stroke patients could be confirmed. In addition, this study has a clinical significance as it provided basic data based on which IM training could be conducted by composing the amount of exercise task or training for patients who have difficulty in the application of the existing IM protocol. It can be suggested that IM training is one of the therapy programs, which can be used as one of the occupational therapy programs in patients with various diseases who require control of the time for movement performance as well as stroke patients in the future, through various studies.

Conflict of interest

None to report.

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