Effects of Sensoriomotor Functions on the Ipsilateral Upper Limb According to Cane Usage in Stroke Patients; A Preliminary Study

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Purpose: The cane is one of the most popular assistive devices for stroke patients. Clinical complaints of sensorimotor functions on the ipsilateral upper limb were appealed in stroke patients who had used a cane for a long period. Therefore, we investigated whether cane usage for a long-term period affected sensoriomotor dysfunctions on the non-affected upper limb, in terms of pain presence, shoulder joint sense, a nine-hole pegboard test, and a tracking task.

Methods: We recruited 12 stroke patients, who were divided into the cane-using (CU) group or the non-cane using (NCU) group, according to cane usage experience. We evaluated joint position sense for the integrity of proprioceptive reposition sense in the shoulder joint, used a nine-hole pegboard test for upper limb dexterity evaluation, and a tracking task for visuomotor coordination.

Results: Four patients in the CU group had complained of shoulder pain none did in the NCU group. In addition, the CU group showed more reposition errors on the shoulder joint than the NCU group did. In addition, the CU group had more difficulty in proprioceptive sense perception and in performance of the nine-hole pegboard teat and tracking task, compared with the NCU group.

Conclusion: Our findings suggest that cane usage for a long period in stroke patients could give rise to trigger joint pain and decrease proprioceptive sense. In addition, complex motor performance in the ipsilateral upper limb could deteriorate. In stroke patients who had used acane for long period, careful observation and proper intervention will be necessary.

Keywords: Cane usage, Ipsilateral upper limb, Sensoriomotor functions

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Ⅰ. Introduction

Stroke is a common neurological disorder and cause of chronic disability. In addition, motor weakness, sensory impairment, and cognitive dysfunction will remain to survivors for the long-term.[1] However, the most important disability of hemiplegic patients is the difficulty of independent walking. Walking ability of stroke patients contributes to functional ability related activities of daily living. As such, restoration of walking ability is a major goal during rehabilitation.[2,3] Studies on the use of assistive devices by hemiparetic patients reported that 32% to 76% of patients use at least 1 device after a stroke, and a cane is the most widely used for hemiplegic walking training.[4-6]

A walking devices such as a cane is often used for hemiplegic patients who have balance disruption, motor weakness, or weight bearing reduction.[5] The cane enables hemiplegic patients to walk with greater stability and speed, and the supportive structure for body weight reduces pain, fatigue, and damage.[7-9] During a one leg stance in particular, a cane permits greater range of center of mass (COM) without loss of balance, as it is increasing the effective size of the base of support (BOS). Loading of the cane reduces ground reaction force (GRF) operating on the supportive limb. These may be reduced by stabilizing reaction forces to generated by the hand. Finally, the hand and upper limb as much reduced amount of GRFs will generate more forces to obtain stability.[10]

A number of studies have investigated the effect of a cane on the gait of stroke patients. Most studies examined that the use of a cane by hemiparetic patients influences temporo-spatial gait parameters, balance, and weight bearing, or kinetic analysis of the paretic leg.[6,11,12] With regard to the effect of a cane on the upper limb of sound side, there were less investigations about biomechanics and kinematic changes. Sevearal studies have measured loading of a cane during cane-assisted gait. Most studies reported that loading on a cane is supported more than 15% to 20% of patient weight.[13,14] However, loading on a cane dependson the impaired degree of the functions.[13] The major goal of hemiplegic patients is walking ability recovery[3] thus they spend more time inlocomotion training. Gait training or locomotion on cane-assisted gait in hemiplegia patients can reduce the weight acting at the support limb, but the limb using the cane will be compensated for the lower extremity for reduced weight. The patient's weight will be delivered to the upper limb that using the cane, including the wrist, elbow, and shoulder.[15] So, in this study, the following assumptionsare made: continuous cane-assisted gait will affect change in the upper extremity as well as muscular movement.

The objective of this study was to examine the changes in the proximal upper extremity of the sound side that occurs when a cane is used by hemiplegic patients.

II. Methods

1. Subjects

A total of 12 stroke patients were recruited in this study, who consisting of 6 patients who required an assistive device (cane used group: CUG) and 6 patients without an assistive device (non-cane used group: NCUG), such as a mono or quadruped cane, when walking. CUG and NCUG were determined according to whether patients had used a cane so in the three months since stroke onset. All patients understood the purpose of this study and provided their informed consent prior to participation. All subjects were verified as right-handed by the modified Edinburg Handedness Inventory (ref). Inclusive criteria were as following; (1) unilateral brain injury due to hemorrhage or infarct confirmed by MR images, (2) independent walking with or without a cane, (3) no symptoms of unilateral neglect and hemianopsia, (4) no previous neuromuscular disorder history on the non-affected upper limb, and (5) no cognitive function impairment (above 24 points with minimal status examinations). Demographic data for subjects are summarized in Table 1.

Table 1. The general characteristics of subjects

	Cane used group	Non cane used group
Sex (Male/Female)	2 / 4	3 / 3
Age	63.8±11.7	58.5±3.8
Time since onset	19.3±13.6	29.00±14.0
Stroke type (Hemorrhage/Infarct)	1 / 5	4 / 2
Damaged hemisphere (Rt/Lt)	3 / 3	3 / 3

2. Experimental methods

1) Measurement

(1) Shoulder pain perception

Shoulder pain was assessed while patients actively performed the full range of motion. At this time, a visual analogue scale (VAS) was used, which is a psychometric response scale that can be used inquestionnaires, ranging 0 to 10. Presence of shoulder pain was noted when the scores of VAS was over 1.

(2) Shoulder joint position sense

The shoulder joint position sense was evaluated with a position-reposition test. Participants held a custom-made rotator machine with a built-in potentiometer on the table using their non-affected upper limb, which was allowed to rotate at the vertical axis. The digital signal of potentiometer was transferred to a personal laptop computer, and the signal was changed to angular degrees. Patients were instructed to actively reproduce the same joint position that was passively positioned by the evaluator, in the shoulder external and internalrotation on the vertical axis. The joint reposition error between passively positioned angle and actively repositioned angle was measured. Mean value through three trials was adopted.

(3) Nine-hole pegboard test

A nine-hole pegboard test was used to measure fine motor dexterity of the non-affected upper limb. Patients were instructed to insert and remove nine dowels (9 mm in diameter and 32-mm long) from holes in the pegboard with their upper limb of the non-affected side. Time measurement begins when the first peg is placed in a hole and ends when the last peg is placed.

(4) Tracking task

Participants were seated in front of a table, with the elbow flexed at nearly 90° and held a custom-made rotator machine with a built-in potentiometer with their non-affected upper limb. The tracking task was produced by external rotation and internal rotation of the shoulder joint. The task required patients to track the target sine wave as accurately as possible while the target white wave was displayed for 15 seconds on the computer screen. Various ranges of velocity were presented by varying amplitudes within 1.5-3 Hz. The response sine wave that was performed by each subject appeared as a red line, which was drawn up toward the upper peak as the wrist was extended, and toward the lower peak as the wrist was flexed. All patients were given three practice trials after one demonstration, with a short duration of 10 seconds in between trials. Mean values through three actual trials were recorded. In the tracking task, the accuracy of performance was calculated as an accuracy index (AI).[16]

$$AI = 100(P-E)/P$$

E was calculated as the root mean square (RMS) error between the target and the response line, and P was the size of the target pattern of each individual, measured as the RMS value between the sine wave and the vertical line at the upper and lower peak. The magnitude of P was determined by the scale of the vertical axis, which is indicated as the range of wrist motion of the subject. Therefore, the AI is normalized to range of motion of each individual subject, and takes into account any differences between subjects in the excursion of the tracking target. The maximal score is 100. Negative scores occur when the response line is so distant from the target that it falls on the opposite side of the midline.

3. Statistical analysis

Chi-square was conducted to analyze the distributional difference between the two groups, in terms of sex, stroke type, damaged hemisphere, and pain presence. Mann-Whitney U tests were performed to determine which of the variables were different between the two groups, in terms of age, time since onset, joint position sense, nine-hole pegboard test, and tracking task. All statistical analyses were performed by using PASW 18.0 (SPSS Inc, Chicago, IL, US), and $p<0.05$ was used as the criterion for statistical significance.

III. Results

Table 1 indicates demographic data for the two groups. No significances were observed between the two groups, in terms of distribution of sex, stroke type, and damaged hemisphere. In addition, the two groups showed that all patients tended to be similar in age and time since onset. All patients did not have aphasia and neglect symptoms.

Table 2 shows the mean scores on the joint reposition test, nine-hole pegboard test, and tracking task as well as pain presence of the shoulder joint. Four patients who had used a cane had complained of shoulder pain, but none did in the non-cane using group. In addition, the cane using group showed more reposition errors on the shoulder joint than the non-cane using group did. In terms of the nine-hole pegboard test and tracking task, longer performance times and lower accuracy indices were observed in the cane using group, compared with the non-cane using group. However, no statisticalsignificance was detected in any dependent variables.

Table 2. Incidence of pain and mean for all parameter

	Cane used group	Non cane used group
Pain (present/no)	4 / 2	0 / 6
Joint Reposition test (°)	6.68±1.38	5.86±2.65
Nine-hole test (sec)	27.13±13.37	23.01±3.11
Tracking task	-6.07±4.29	-4.31±3.04

IV. Discussion

In the current study, we investigated whether stroke patients, who had used a cane for a long period, showed sensoriomotor dysfunctions on the non-affected upper limb, in terms of pain presence, shoulder joint sense, a nine-hole pegboard test, and atracking task. We recruited participants such that the gender ratio was the same in each of groups, for controlling the well-known effect as different motor performance between the right and the left side limbs. We evaluated joint position sense for integrity of proprioceptive reposition sense in the shoulder joint, used a nine-hole pegboard test to evaluate upper limb dexterity, and a tracking task for visuomotor coordination. As result, a higher incidence of shoulder pain was observed in the cane using group, compared with the non cane-using group. In addition, cane users had more difficulty in proprioceptive sense perception and in performance of the nine-hole pegboard teat and tracking task. On the basis of these results, we think that cane usage for long periods in stroke patients induces shoulder pain and deteriorates proprioceptive sense and complex motor performance in the upper limb ipsilateral to the damaged hemisphere. However, our result did not show statistical significance of any dependent variables. We speculate that it might be attributed to statistical issues due to small sample size, such as homogeneity of variance and normal distribution.

Our findings were accordance with many previous studies, suggesting that cane usage could affect sensoriomotor function in stroke patients.[17-20] Firstly, our results showed that cane usage for long periods increased the possibility of shoulder pain, and deteriorate the proprioceptive sense on the proximal joint that used the cane. Such findings might be attributed to the overuse syndrome or muscle fatigue due to repetitivemuscle contraction. Jones et al.[21] revealed that the physiologic cost index and heart rate at walking were observed to be higher in knee arthritis patients who had used a cane than those who had not used one. It may be possible that general fatigue on the entire body, as well as local fatigue of muscles that directly used a cane were induced to a greater degree in patients using a cane, compared with patients who had not used a cane. Several studies suggested that joint position was related with local senseand general fatigue, which affected activities of the muscle spindle and Golgi tendon organ to influence the central nervous system.[22-24] Therefore, we think that presence of shoulder pain and decreased position sense were relevant to continuous and repetitive cane usagefor long periods.

Secondly, our results showed that stroke patients who had used a cane for a long period had difficulty in performing complex visuomotor and dexterous tests with their non-affected limb (e.g., the nine hole test and tracking task). It was interpreted that cane usage could deteriorate motor control abilityto require visually hand-eye coordination involving continuous ongoing accurate motor performance. These findings might be related to the repetitive activity of contractile and non-contractile tissues around the joint by overuse of a cane. Several previous studies indicated that repetitive activity of connective tissue around the joint could lead to change of motor control ability, such as motor clumsiness and decreased co-contraction of antagonist.[25-27] Therefore, we think that the main cause of decreased motor accuracy on the ipsilateral upper limb was due to repetitive and continuous overuse activity of soft tissues around the joint.

The cane is one of the most popular assistive devicesfor independent walking in stroke patients. Our findings emphasize the necessity of clinical consideration for walking with a cane on the ipsilateral side in stroke patients. Understanding of the mechanism of this motor dysfunction provides clinicians with the careful evaluation and proper intervention on the ipsilateral upper limb that has used a cane for long time. However, we did not consider the important factors that could influence proprioceptive sense and motor performanceof the ipsilateral upper limb, in terms of time of physical activity and muscle power of the lower limbs. Many previous studies suggested that physical activity of the lower limbs was strongly related with joint pain, proprioception, and motor performance.[13,28,29] Therefore, thesefactors should be considered in future original investigations, along with a large sampling size for statistical robustness.

V. Conclusion

The cane is one of the most significant assistive devices for independent walking and daily life activity, as it provides postural stability and gait mobility in stroke patients. However, the use of a cane for long periodscould induce joint pain and deteriorate joint position sense and complex motor performance. Therefore, it is important for clinicians to make careful evaluations and intervene if necessary with stroke patients who haveused a cane for long periods. In the future, further study will be required for elucidating the more detailed mechanism and establishing generalizations of statistical issue.

Author Contributions

Research design: Son SM, Kim CS
Acquisition of data: Son SM, Kwon JW

Analysis and interpretation of data: Son SM
Drafting of the manuscript: Son SM, Kwon JW
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Research supervision: Kim CS

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