Abstract. [Purpose] The purpose of this study was to investigate the effect of fluidotherapy on hand’s dexterity and activities of daily living for stroke patients with upper limb edema. [Subjects and Methods] The objective of the present study was to treat 30 stroke patients with a three-week course of fluidotherapy to investigate the efficacy of such therapy for reduction of edema. For accurate baseline and post-intervention assessment of edema volume, hand edema was measured in the morning using a forearm volumeter. [Results] Mean edematous volume in the affected side measured 600.53 ± 29.94 ml prior to intervention, significantly decreasing to 533.53 ± 27.85 ml after three weeks of fluidotherapy. To investigate how such reduction may have enhanced the ability to perform activities of daily living, Korean Version of Modified Barthel Index assessment was performed. The results showed 46.10 ± 4.27 points at baseline and significantly improved to a mean score of 49.96 ± 4.34 points at the time of reassessment. Furthermore, Box and Block Test was performed to investigate hand dexterity. Before fluidotherapy, affected patients transferred 21.13 ± 3.63 blocks in one minute, increasing to 23.20 ± 3.42 blocks transferred in one minute following three weeks of treatment. Although the number of blocks transferred did increase slightly, the difference was not statistically significant. [Conclusion] These findings suggest that using fluidotherapy can reduce edema, and such a reduction can have a positive effect on activities of daily living. Based on our current findings, we hypothesize that long-term fluidotherapy treatment may be more effective in reducing edema.

Key words: Fluidotherapy, Edema, Stroke

INTRODUCTION

Over the past 6 years, the mortality rate in the Korean population has continued to increase, with 70.5% of all deaths attributable to 10 major causes, of which the third most common cause of death is cerebrovascular disease. A prevalent form of cerebrovascular disease is stroke, a disorder that is often accompanied by sudden cognitive impairment or paralysis. Frequently, stroke patients will present with hemiplegia, or paralysis on only one side of the body. Hemiplegia is characterized by significant loss of motor function, muscle weakening, and abnormal movements due to muscle tension. Importantly, immobility due to paralysis or pain may lead to edema in hemiplegic patients, with 37% of afflicted individuals developing edema of the hands.

Without clinical intervention, this chronic edema may lead to protein aggregation, producing joint contracture, as well as muscular, neural, and vascular fibrosis that can potentially lead to serious complications. Consequently, these motor impairments and edema following cerebrovascular insult may restrict the activities of daily living (ADL).
A critical component of performing ADL is proper upper limb function. Compared to lower limb function, upper limb function recovers more slowly following a stroke. Therefore, various methods have been proposed to enhance upper limb function and reduce hand edema. The shoulder elevation technique, where the hands are elevated above the elbows and shoulders, is a commonly used method that does not require specialized equipment. Other methods include electro-stimulation, massage, and hydrotherapy. Further, application of continuous passive and active exercise therapy on the finger joints has been suggested as an effective treatment modality for edema, stimulating the lymphatic vessels to act as a pump to improve lymphatic drainage and increase venous flow.

Respective articular capsule and muscle temperatures can be increased with paraffin therapy (7.5 °C and 4.5 °C) and hydrotherapy with water (6 °C and 4.3 °C). Compared to these treatment modalities, fluidotherapy has been reported to increase both articular capsule and muscle temperatures by 9 °C and 5.7 °C, respectively. Therefore, these results demonstrate that fluidotherapy may be a more effective treatment modality for reducing edema by increasing blood flow by increasing hand temperature.

The purpose of this study was to investigate the effect of fluidotherapy on hand dexterity and ADL for stroke patients with upper limb edema.

**SUBJECTS AND METHODS**

The present study was conducted over three weeks, from July 14 to August 1, 2014, on 30 stroke patients hospitalized at “W” Hospital in North Jeolla Province, Korea. The characteristics of the participants are listed in Table 1. Among the 30 participants, 19 were male and 11 were female. After receiving a detailed explanation of the objectives of the study, all patients subsequently consented to participate. Fluidotherapy was carried out for 15 sessions and 20 minutes once a day for 3 weeks. Throughout the duration of fluidotherapy, the patients did not receive any other edema-related treatments or therapies, such as massage, that may have had an effect on edema. The study design used the same measurements pre- and post-experiment. The present study selected and received consent to participate from patients diagnosed with stroke and severe edema. Edema was measured in the morning when activity levels were low by filling a forearm volumeter with room temperature water. The K-MBI (Korean Version of Modified Barthel Index) and BBT (Box and Block Test) were also administered to measure the ability to perform ADL and hand dexterity.

After placing the paralyzed hand in a chamber of finely ground corn particles heated with warm air, the upper limb was treated under low-pressure conditions with pneumatic pressure. Submersion of the paralyzed hand into the fine particles provided both tactile massage and heat transfer. The temperature of fluidotherapy was set to 48 °C for optimal skin heat absorption, with the treatment time set to 20 minutes. For objective and accurate measurement of upper limb edema, a forearm volumeter was utilized as follows: 1) a cylinder was placed on a horizontal table and filled to the top with 4,000 ml of room temperature water, 2) the patient was seated comfortably and the forearm was placed in the cylinder up to 10 cm below the elbow, and 3) overflow of water was collected in a beaker and accurately measured. Volumes from both affected and unaffected sides were measured to assess edema for each individual patient. The BBT is a tool developed for measuring and assessing hand dexterity in patients with physical disabilities. During this test, patients used each hand to transfer blocks one inch in size, from one box to another for one minute, using the number of blocks transferred as the final score. The reliability of test-retest for the left and right hand was r=0.94 and r=0.98, respectively, and inter-rater reliability for the left and right hand was r=0.99 and r=1.00, demonstrating high correlations. To investigate the function in the edematous upper limb, assessments were made before and after fluidotherapy. The K-MBI was developed to assess ADL and ADL assessment is divided into 10 categories: personal hygiene, bathing, feeding, toilet use, climbing stairs, dressing, presence or absence of fecal incontinence, presence or absence of urinary incontinence, walking/use of wheelchair, and transfer from chair to bed. Patients received scores ranging from 0 to 100 points, based on the degree of independence. Inter-rater and test-retest

| Characteristics | Number | Percentile (%) |
|-----------------|--------|----------------|
| Age             |        |                |
| ≤50 years       | 2      | 6.6            |
| 51–60 years     | 5      | 16.6           |
| 61–70 years     | 6      | 20             |
| 71–80 years     | 11     | 36.6           |
| ≤81 years       | 6      | 20             |
| ≤3 months       | 16     | 53.3           |
| 3–6 months      | 7      | 23.3           |
| ≤6 months       | 7      | 23.3           |
| Affected side   |        |                |
| Right           | 18     | 60             |
| Left            | 12     | 40             |
reliability were r=0.95 and r=0.89, respectively.\(^{14}\)

Statistical analysis was conducted using SPSS ver. 18.0. Paired t-tests were performed for comparative analysis of edema volume, K-MBI scores, and BBT scores before treatment and following fluidotherapy, with the significance level set at \(\alpha=0.05\).

**RESULTS**

The pre-experimental edema volume was 600.53 ± 29.94 ml, while the edema volume after fluidotherapy decreased significantly to 533.53 ± 27.85 ml (\(p<0.01\)). The mean K-MBI score was 46.10 ± 4.27 points prior to treatment, which significantly increased to 49.96 ± 4.34 points following three weeks of fluidotherapy (\(p<0.05\)). The mean BBT score was 21.13 ± 3.63 points prior to treatment, increasing to 23.20 ± 3.42 points at reassessment after three weeks of fluidotherapy (\(p>0.05\)). However, this difference was not statistically significant. Measured values are shown in Table 2.

**DISCUSSION**

The objective of the present study was to determine whether upper limb edema in stroke patients can be reduced by fluidotherapy, and whether such a reduction can have a positive effect on hand dexterity and relieve discomfort during ADL. Borrell et al. compared the temperatures of muscles and the articular capsules in the hands and feet when subjected to hydrotherapy, paraffin therapy, and fluidotherapy to investigate the efficacy of each type of heating modality. The results showed that hydrotherapy with a water temperature of 38.89 °C increased articular capsule and muscle temperature by 6 °C and 4.3 °C, respectively, while paraffin therapy and fluidotherapy with a temperature of 47.78 °C increased temperatures by 7.5 °C and 4.5 °C, and 9 °C and 5.7 °C, respectively.\(^{9}\) In the previous study, fluidotherapy showed an effective skin temperature increase among other thermal stimulation methods. Therefore, it was used in this study to provide continuous thermal stimulation. Also, the temperature was set to 48 °C because it proved to be the most effective way to transmit heat to the soft tissues by 46.7–48.9 °C at clinical application temperature.\(^{15}\) Thermal simulation over the threshold in the peripheral nerve generates a nerve activity potential, which propagates along the motor and sensory nerves. Kelly et al. reported a statistically significant change in skin temperature (\(p<0.001\)) and nerve activity potential (\(p<0.001\)) using fluidotherapy, suggesting the need for intervention in the form of surface heating to restore upper extremity function.\(^{10}\)

Among the various heat stimulation methods, fluidotherapy was found to be the most effective in increasing skin temperature, and as a result, fluidotherapy was used to continuously apply heat stimulation in our investigation. The present study involved 30 adult stroke patients: 19 men and 11 women with a mean age of 67.9 years. The measurement of edema in both the affected and unaffected sides prior to the experiment were obtained in the morning using a forearm volumeter under conditions that would not affect the edema. The mean arm volume in the unaffected and affected sides was 566.52 cc and 659.73 cc, respectively, in men, with a difference of 93.21 cc. In women, those respective values were 404.09 cc and 498.27 cc, with a difference of 94.18 cc. Reassessment following three weeks of fluidotherapy (1 session per day) using the same method as the pre-experimental assessment demonstrated that mean arm volume on the affected side was 598.52 cc in men, a decrease of 61.21 cc from three weeks earlier, while the value was 421.27 cc in women, a decrease of 77 cc from three weeks earlier. A K-MBI assessment was performed to determine the capacity to perform ADL, while BBT was performed to investigate hand dexterity on the affected side. The mean K-MBI score was 46.10 ± 4.27 points prior to treatment, interpreted as “in need of maximal assistance”, whereas the mean score following three weeks of therapy was 49.96 ± 4.34 points, indicating an improvement in clinical interpretation to “in need of partial assistance.” With respect to BBT, the mean number of blocks transferred in one minute was 21.13 ± 3.63 prior to treatment and 23.20 ± 3.42 following three weeks of therapy, showing a slight, but statistically insignificant improvement after fluidotherapy.

Previous studies using fluidotherapy showed the same results as decreasing upper limb volume, but some other results were also confirmed. Kim reported that the tactile function and upper limb volume reduction were significantly improved in the experimental group that applied fluidotherapy and occupational therapy.\(^{16}\) Lee also showed a upper extremity volume, upper extremity function and ADL were statistically significant.\(^{17}\) Outcomes in upper extremity function and ADL are presumed to be due to differences in general characteristics of the subjects. In this study, half of the subjects were over 70 years old and those who had a period of 3 months or more. Therefore, early intervention of fluidotherapy is expected to be more

| Variables       | Pre     | Post     | p       |
|-----------------|---------|----------|---------|
| Edema Volumeter (ml) | 600.5 ± 29.9 | 533.5 ± 27.8 | 0.00**  |
| ADL K-MBI       | 46.1 ± 4.2 | 49.9 ± 4.3 | 0.04*   |
| Hand dexterity BBT | 21.1 ± 3.6 | 23.2 ± 3.4 | 0.22    |

ADL: activities of daily living; K-MBI: Korean version of Modified Barthel Index; BBT: Box and Block Test. *\(p<0.05\), **\(p<0.01\).
effective for patients with relatively young and short duration of illness.

A limitations of this study was that it did not compare the experimental group with the control group. The number of subjects was insufficient and various evaluation tools related to the function of the hand were not used. Therefore, future studies should be conducted to prove the effect of reducing the edema and improving the hand function by using the control design and more various evaluation tools.

In conclusion, our findings indicate that fluidotherapy was effective in reducing edema, and such reduction in edema had a positive impact on reducing discomfort in performing ADL in afflicted patients. Although some participants showed positive outcomes with respect to hand dexterity, these improvements were not statistically significant. In the clinical setting, fluidotherapy should be considered for patients with stroke and edema to improve comfort when performing ADL. In the future, studies should build on our results by examining the efficacy of fluidotherapy for enhancing sensation in the hands.

ACKNOWLEDGEMENT

This paper was supported by Research Funds of Kwangju Women’s University in 2017 (KWUI17-074).

REFERENCES

1) Han YA: Analysis of in daily activities, family support, and depression in hemiparesis patients due to stroke. Unpublished master's thesis, Yonsei University, Seoul, 2004.
2) Leibovitz A, Baumochl Y, Roginsky Y, et al.: Edema of the parietic hand in elderly post-stroke nursing patients. Arch Gerontol Geriatr, 2007, 44: 37–42. [Medline] [CrossRef]
3) Olszewski WL: Lymphstasis: pathophysiology, diagnosis, and treatment. Florida: CRC Press, 2000.
4) Lee SE, Lee HY: The effect of the meridian massage on the hand and function of the hemiplegic patient. J Korean Adult Nurs Acad, 2003, 15: 520–530.
5) Laseter GF: Management of the stiff hand: a practical approach. Orthop Clin North Am, 1983, 14: 749–765. [Medline]
6) Kottke FJ, Lehmann JO: Krusen's handbook of physical medicine & rehabilitation, 4th ed. Philadelphia: W.B. Saunders Company, 1990, pp 671–672.
7) Vasudevan SV, Melvin JL: Upper extremity edema control: rationale of the techniques. Am J Occup Ther, 1979, 33: 520–523. [Medline]
8) Borrell RM, Parker R, Henley EJ, et al.: Comparison of in vivo temperatures produced by hydrotherapy, paraffin wax treatment, and fluidotherapy. Phys Ther, 1980, 60: 1273–1276. [Medline] [CrossRef]
9) Borrell RM, Henley EJ, Ho P, et al.: Fluidotherapy: evaluation of a new heat modality. Arch Phys Med Rehabil, 1977, 58: 69–71. [Medline]
10) Kelly R, Beech C, Hansford A, et al.: Effect of fluidotherapy on superficial radial nerve conduction and skin temperature. J Orthop Sports Phys Ther, 2005, 35: 16–23. [Medline] [CrossRef]
11) DeVore GL, Hamilton GF: Volume measuring of the severely injured hand. Am J Occup Ther, 1968, 22: 16–18. [Medline]
12) Trombly CA, Radomski M: V: Occupational therapy for physical dysfunction, 5th ed. Baltimore: Lippincott Williams & Wilkins, 2002.
13) Cromwell FS: Occupational therapist’s manual for basic skills assessment or primary pre-vocational evaluation. California: Fair Oaks Print, 1976.
14) Granger CV, Albrecht GL, Hamilton BB: Outcome of comprehensive medical rehabilitation: measurement by PULSES profile and the Barthel Index. Arch Phys Med Rehabil, 1979, 60: 145–154. [Medline]
15) Kelly R, Beech C, Hansford A, et al.: Effect of fluidotherapy on superficial radial nerve conduction and skin temperature. J Orthop Sports Phys Ther, 2005, 35: 16–23. [Medline] [CrossRef]
16) Kim EJ: The effects of fluidotherapy for stroke patients on the tactile sensory function and edema reduction on hands. Unpublished master’s thesis, Daegu University, Gyeongbuk, 2016.
17) Lee MJ: Effect of fluidotherapy for edema reduction on upper extremity function and activities of daily living for stroke patients. J Korea Entertain Ind Assoc, 2016, 10: 237–244. [CrossRef]