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Analysis of the sensory threshold between paretic and nonparetic sides for healthy rehabilitation in hemiplegic patients after stroke

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ABSTRACT

The purpose of this study was to investigate the differences in the sensory threshold between the paretic and nonparetic sides of hemiplegic patients. 28 patients who were hemiplegic post-stroke (14 men and 14 women) participated in the electrical sensory and pain thresholds study; 22 patients who were hemiplegic post-stroke (13 men, 9 women) participated in a study measureing the sensory threshold with light touch. Electrical sensory and pain thresholds were measured in the forearm via transcutaneous electrical nerve stimulation. The light-touch threshold was measured in the forearm using monofilaments. The light-touch, electrical sensory, and pain thresholds for the paretic side were significantly higher than for the nonparetic side in our population, respectively. In both the nonparetic and paretic sides, the male group generally showed higher thresholds for pain and sensation than did the female group. These results suggest that the different evaluations of sensory thresholds performed in this study for healthy rehabilitation will be a valuable clinical tool in hemiplegic patients after stroke.

Keywords: Sensory Threshold; Paretic and Nonparetic Sides; Healthy Rehabilitation; Stroke

1. INTRODUCTION

Sensory impairment is common following stroke [1]. After stroke, a loss of physical connections (synapses, dendrites, axons) linking brain regions appears from impairment to the axons to the infarct site [2]. A correlation between after stroke motor function and structural integrity of the corticospinal tract has been found [3,4]. The sensory element of the superior thalamic radiation (sSTR) contains all afferent links to the somatosensory cortex [5]. Borstad *et al*. suggested that stroke associated structural changes to the sSTR may have relation to after stroke sensory function [2]. It is important to build an understanding of discriminative sensory impairment because this type of subtle sensory disorder might be related to functional outcomes in patients who are rehabilitating after a stroke [6,7]. In many studies, it has been established that sensory impairment is detrimental to motor recovery [8,9]. Poor functional recovery may be partially result from learned nonuse phenomenon and bring about degeneration of motor function [10,11]. Tyson *et al*. found that sensory impairment was significantly associated with mobility or lack thereof, independence in recovery, and activities of daily living [12]. Also, sensory impairment indicates to predict length of hospital stay and discharge placement [2]. Measuring the prevalence and severity of sensory loss, particularly in patients who present for treatment and accurate detection of this loss, is essential [13]. Better understanding of impairments and outcomes can improve the established clinical pathways and facilitate better timing and allocation of rehabilitation [14]. However, conventional sensory testing is insufficient for exact assessment of the amount of sensory impairment in patients [15]. The word threshold refers to the points of stimulus strength at which the participant first notices the stimulation at all and as painful, respectively [16,17]. Sensory acuity is most generally determined by a threshold test. The functional part of sensory acuity is often forecast by using discrimination tests that evaluate the quality of sensation [18]. In addition, the assessment of change in a given sensory threshold could be a profitable tool in the clinical evaluation of pain [19]. The electrical sensory threshold is significant because the therapist can regulate treatment intensity from their patient's subjective sensation during use of a transcutaneous nerve electrical stimulator [20]. Recently, experimental and clinical investigations have demonstrated some parameters for the electrical sensory threshold in healthy volunteers [19,21,22]. However, there are few clinical studies demonstrating the sensory threshold in patients after a stroke. Unilateral cerebral hemisphere lesions can cause sensory impairment on the nonparetic side [23,24]. Corkin *et al*. asserted that lesion size was a demonstrable factor in sensory impairment on the nonparetic side [25]. Hemiplegic patients with ipsilateral as well as contralateral tactile impairment face considerable additional rehabilitation challenges [26]. Therefore, more study is needed to evaluate the nonparetic side of a hemiplegic patient, and in particular to focus on the comparison between the paretic and nonparetic sides. To our knowledge, no previous study of sensory and pain thresholds exists that specifically applies to the differences between the paretic and nonparetic sides of a hemiplegic patient. This study aims to evaluate three different sensory thresholds (light-touch, electrical sensory, and pain) in measuring and comparing these differences.

2. MATERIALS AND METHODS

2.1. Subjects

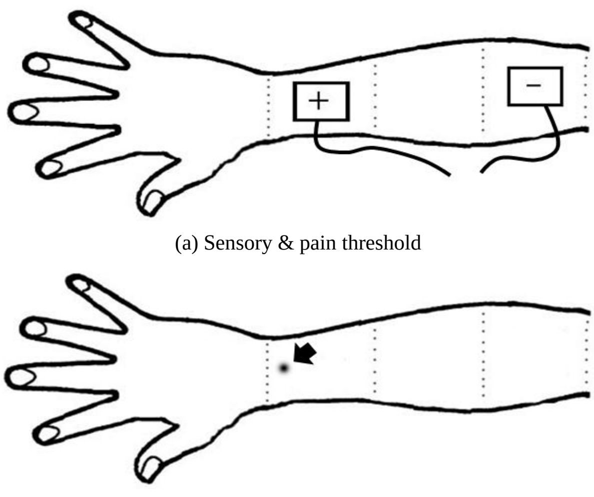
The patients were selected according to the following inclusion criteria: left or right hemisphere stroke (unilateral only); a roughly equivalent number of patients from both sexes; ability to communicate and understand instructions (**Table 1**).

2.2. Electrical Sensory and Pain Thresholds

28 patients who were hemiplegic post-stroke (14 men and 14 women) participated in the study. Patients were comfortably seated on a physical therapy treatment table or a wheelchair with their upper extremities positioned on a pillow. In each patient, the forearm was stimulated using the transcutaneous nerve electrical stimulator (HAT2000, Meditens Co. Ltd., Korea) and two surface electrodes of the same size (4.5 × 6 cm) for bipolar stimulation. The forearm was placed in a pronated position and effectively divided into thirds for the purpose of determining electrode position, with one electrode placed on the proximal aspect of the forearm at one-third of the forearm length, and the other placed at the distal aspect at one-third of the length (**Figure 1(a)**). The electrical stimulation doesn't use the heat of the electrode. The pad does get enough water during every treatment procedure. The electrical stimulation was used for 10 Hz frequency in "mode 1-tapping". The current intensity was recorded as 0% to 100% of the total output, and the sensory threshold was gradually increased by increasing the intensity. The first threshold was measured when the patients perceived the electrical stimulation without pain. The stimulus was then continuously increased in intensity until the patient felt initial pain. The stimulation was considered to be over the sensory threshold for pain when the patient felt sick or sore. This method was first performed in the paretic and then in the nonparetic side for each patient.

2.3. Light-Touch Threshold

22 patients who were hemiplegic post-stroke (13 men and 9 women) participated in the study. Touch thresholds



(a) Sensory & pain threshold

(b) Light touch threshold

Figure 1. Schematic representation of the experimental methods for measuring threshold.

Table 1. Clinical characteristics of patients with after stroke.

Gender (%)	Age (yr)	Height (cm)	Weight (kg)	BMI (kg/m^2)	Hypertension (%)
Male 22 (54)	50.2 ± 14.9	164.2 ± 7.8	62.3 ± 10.5	23.1 ± 3.0	26 (63)
			Paretic side		
Female 19 (49)	DM (%)	Time after stroke (mo)	Right (%)		Left (%)
	4 (9)	3.6 ± 2.0	15 (37)		26 (63)

BMI, body mass index; DM, diabetes mellitus.

were measured using monofilaments. The test kit consisted of 5 different filaments; bending pressure ranges for the individual filaments were 2.83 to 0.07 g, 3.61 to 0.4 g, 4.31 to 2.0 g, 4.56 to 4.0 g, and 6.65 to 300 g. To perform the test, the monofilament must be applied (that is, be pressed until it bends) perpendicular to the skin and held in place for 1 to 1.5 seconds. With the forearm in a pronated position, monofilaments were placed on the skin between the styloid process of the radius and the ulnar in the forearm (**Figure 1(b)**). Patients were required to close their eyes. Placement began through application of the smaller filaments to the skin; placement continued to the larger filaments when patients did not respond. The point at which patients perceived the contact of their forearm with the filament was measured. Measurements were first obtained from the nonparetic side.

2.4. Statistical Analysis

We analyzed the data using the Mann-Whitney U test to differentiate between the nonparetic and paretic side thresholds by gender. The differences in the nonparetic and paretic side thresholds were also analyzed with the Wilcoxon test in paired comparisons. Correlations between the electrical sensory and the light-touch thresholds were determined using Pearson's test correlation coefficient. The data are expressed as means ± standard errors (SE). A P value of <0.05 was considered statistically significant. SPSS Version 18.0 (International Business Machines, Armonk, USA) for Microsoft Windows was used for analysis in this study. The protocol for the study was approved by the Committee of Ethics in Research of the University of Yongin, in accordance with the terms of Resolution 5-1-20, December 2006.

3. RESULTS

Upon analysis of the electrical sensory threshold without distinguishing between the sexes, a significant difference existed between the nonparetic side (34.8 ± 4.8) and paretic side (50.9 ± 2.2). The electrical sensory threshold for the paretic side was also higher than for the nonparetic side (P = 0.000) (**Figure 2(a1)**). A significant difference materialized between male (37.5 ± 1.7) and female (32.1 ± 0.9) when the electrical sensory threshold was measured for the nonparetic side; this threshold was significantly higher in male than in female (P = 0.021) (**Figure 2(a2)**). A significant difference between male and female for this test also surfaced on the paretic side (male, 55.7 ± 2.9; female, 46.1 ± 2.9; P = 0.016) (**Figure 2(a2)**). Meanwhile, when the electrical pain threshold was analyzed without taking sex into account, a significant difference existed between the nonparetic side (73.2 ± 2.4) and paretic side (86.6 ± 1.9). The electrical pain threshold for the paretic side was higher than for the nonparetic side (P = 0.000) (**Figure 2(b1)**). When the electrical pain threshold was analyzed by sex, no signifycant difference existed between male (75.4 ± 1.0) and female (71.1 ± 3.5) on the nonparetic side. However, the electrical pain threshold of male was higher than that for female on the nonparetic side (P = 0.051) (**Figure 2(b2)**). When the electrical pain threshold was analyzed by sex, no significant differences existed between the male (90.0 ± 2.2) and female (83.3 ± 2.9) on the paretic side. However, the electrical pain threshold of male was higher than female on the paretic side (P = 0.10) (**Figure 2(b2)**). In an analysis of the light-touch threshold without differentiating for sex, a significant difference existed between the nonparetic side (2.9 ± 0.0) and paretic side (4.3 ± 0.4); the light-touch threshold for the paretic side was higher than that for the nonparetic side (P = 0.002) (**Figure 2(c1)**). When sex was taken into account for the light-touch threshold, no significant difference existed between the male (2.8 ± 0.0) and female (2.9 ± 0.1) on the nonparetic side, but the light-touch threshold of female was higher than that in male for the nonparetic side (P = 0.695) (**Figure 2(c2)**). There was no significant difference between the male (4.0 ± 0.4) and female (4.7 ± 0.6) on the paretic side; however, the light-touch threshold of female was higher than male in paretic side (P = 0.556) (**Figure 2(c2)**). The electrical sensory and pain threshold were significantly correlated with the light-touch threshold in paretic compared with those nonparetic side, respectively (**Figures 2(d1)** and **(d2)**).

4. DISCUSSION

The present study demonstrates for the first time that differences of sensory threshold exist between the paretic and nonparetic sides of hemiplegic patients, including the clinically important sensory assessment. Previous studies have reported the sensory threshold in healthy volunteers [19,21,22]. In our present study, the overall thresholds for sensory impairment were higher on the nonparetic side compared to the paretic side for hemiplegic patients. Differences according to sex also surfaced. Men demonstrated a significantly higher electrical sensory threshold than did women in both the nonparetic and paretic sides. The results of our present study agree with the findings of some authors who have found that men have a higher sensory threshold than woman [21,22]. Likewise, the electrical pain thresholds for both the nonparetic and paretic sides were higher for men than for women, another result that replicates results reported by previous researchers [27,28]. Even if pain is not the major focus of this study, these findings would be of interest to those who wish to further evaluate the pain threshold of electrical stimulation. Researchers have assumed that the higher sensory pain thresholds of men are related to

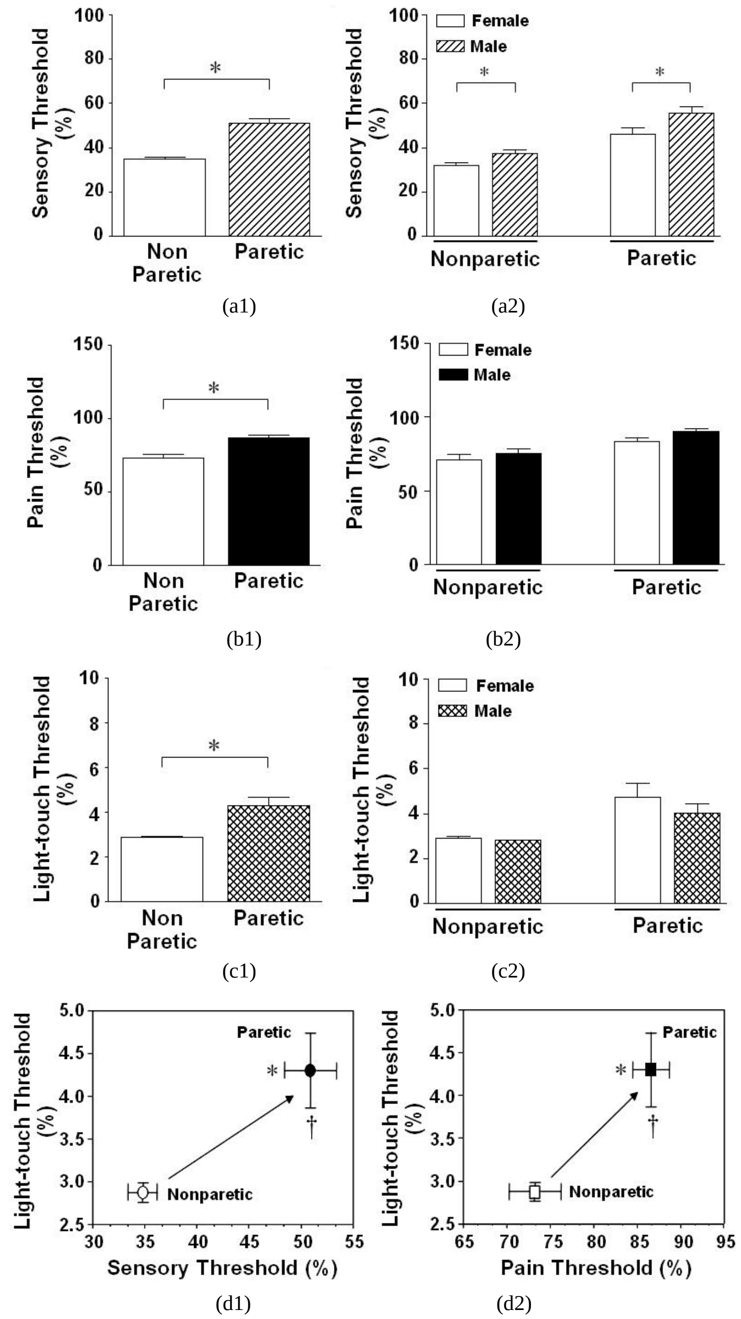


Figure 2. Difference in the stimulation-induced sensory thresholds between paretic and nonparetic sides of patients with after stroke.

the variety or type of stimulation [29], hair distribution and shaving [30], epidermal nerve fiber density [31], skin temperature, and skinfold thickness [22]. Previous studies using other types of stimulation methods suggested differences in sensory thresholds between genders associated with differences in epidermal nerve fiber density and skinfold thickness [22,32,33]. Cadaver and skin biopsy studies have reported that women have higher epidermal nerve fiber density than men [34,35]. In women, therefore, the greater sensitivity to transcutaneous electrical stimulation could be analyzed by gender differences in the morphology and/or density of epidermal nerve fibers, although gender-related differences in hormone concentrations (progesterone in particular) cannot be excluded [34,36]. Interestingly, the lower thresholds reported were correlated with greater subcutaneous fat tissue thickness in participants (more likely to be women), therefore indicating that the individual sensory response can be forecast from subcutaneous fat tissue thickness [22]. Previous studies have had results in accordance with our findings that the light-touch threshold for the paretic side was higher than for the non-paretic side, and there was no significant difference according to sex [21]. This general association between lesion size on imaging and tactile impairment has been discovered in studies of other cerebral defects [37,38]. Additionally, the density of sensory receptors can vary between individual studies, and between different ages of individuals in specific studies [39,40]. Meissner's corpuscles are located on various areas of the skin [41]. It is sensitive to light touch [42]. Meissner's corpuscles also exhibit structural modifications and general decline in amount and cross-sectional area with aging [43]. According to our results, no correlation existed between the electrical sensory threshold and the light-touch threshold. This can be explained by the fact that the sensory quality of light-touch is most related to superficial touch, while electric sensory testing is related more to subcutaneous touch. There are some limitations to this study. Data are not provided related to differences between a patient group and healthy groups for sensory and pain thresholds. However, a previous study of 30 hemiplegic patients reported a higher light-touch threshold for nonparetic hands in patients than was reported in the hands of normal subjects [20]. This study is significant because, for the first time, these tests were applied to both the paretic and nonparetic sides of hemiplegic patients. The results obtained in this study extend our previous findings and further suggest that not only electrical stimulation but also other stimulation is needed for further study of and assessment in patients after stroke. In conclusion, this study will help in the evaluation of sensory and pain thresholds for rehabilitation in hemiplegic patients.

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