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Associations between Sensory of Fingertips and Hand Function in Individuals Post Stroke

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ABSTRACT

Introduction: Stroke is one of the major causes of death and disability worldwide. Sensory and motor abilities are significant contributors to ADL limitations as a consequence of stroke. The best somatosensory receptor area of the skin is the fingertip area because it has a high density of neurons. Two Point Discrimination (2PD) assesses participants' fingertips' ability, where the sensory aspect can support people's motor performance. This study investigated the association between hand sensory with 2PD, hand motor with grip strength, and hand function with FMA (UE-Hand).

Methods: This study was a cross-sectional study. Stroke individuals with a chronic phase at least three months after stroke and no more than one year after stroke onset were recruited. All subjects had a normal peripheral nerve function with no previous injury or compression syndrome.

Results: Forty-two participants aged 40-79 (64.0% of the males and only two left-handed dominants) participated in the study post stroke. All participants had a single stroke attack (57.0% left-sided brain lesion), with 43.0% having a diabetic history, and 69.0% of participants having a normal body mass index (BMI). The FMA had a high positive correlation with the grip strength test. Both assessments of the 2PD test had a negligible correlation with FMA and grip strength. 2PD was better than static 2PD.

Conclusion: Findings highlight a strong correlation between grip strength and FMA-UE hand, but there is no correlation between 2PD and grip strength, or between 2PD and FMA-UE hand in stroke patients. It may help guide health professionals, especially physiotherapists, during rehabilitation, focusing on hand motor function. Further research may focus on the clinical assessment of hand sensory, which can be used as the gold standard to evaluate the progression and correlation with other assessments.

Keywords: Hand sensory; Hand Function; Stroke

Introduction

Stroke is defined as a neurological impairment caused by sudden damage to a specific area of the central nervous system (CNS) due to vascular problems, including cerebral infarction, intracerebral hemorrhage (ICH), and subarachnoid hemorrhage (SAH). Stroke is a major cause of death and disability worldwide [1]. According to the data presented by Riset Kesehatan Dasar (RISKESDAS) 2018 from the Health Ministry of Indonesia, stroke is a disease that results in a high dependency rate as a consequence of stroke damage, leading to disability in stroke sufferers [2]. The rates for overall stroke sufferers in Indonesia were 36.3% for independence, 33.2% for mild dependence, 7.1% for moderate dependence, 9.4% for severe dependence, and 13.8% for complete dependence [3]. A high level of independence is the cause of disability due to brain damage after a stroke. In classifying disability, various related factors should depend on the lesion's localization, the level of neurological recovery, the patient's premorbid status, and the environmental support system. The most common condition in stroke patients in the rehabilitation phase is contralateral hemiparesis or hemiplegia. Neurological symptoms differ based on the location of the stroke and whether it happens in the cerebral hemisphere or brain stem. There is a large degree of specialization in the brain with different neurological functions. The manifestation of stroke is contingent upon the precise region that has incurred damage, resulting in the impairment of specific brain functions under their control. When damage occurs in a particular region of the brain, it not only affects that specific area but also leads to a loss of information from the wounded section throughout the entire brain [4].

Some previous research proved that stimulation in the sensory systems contributes to motor improvement. Motor stimulation is also processed centrally for conscious sensation, primarily for monitoring motor performance and unconscious reflex adjustment of posture and muscle tone. On the other hand, somatosensory information also gives input to the motor system. The main sources of somatosensory information that act as feedback to the motor system are muscle spindles, Golgi tendon organ (GTO), and low-threshold mechanoreceptors of the skin and tendons [5]. The best somatosensory receptor area of the skin is on the fingertip area because the fingertips have a thick density of neurons, so it is the most sensitive sensory area in the body [6, 7] and can be assessed by Two-point discrimination (2PD). The 2PD test has inter-rater reliability at an acceptable level [8]. This sensory aspect can support people's motor performance. In detecting motor performance specifically, many previous studies proved the advantages of grip strength in people post-stroke [9]. Handgrip strength assessment functions measure the ability to grip, which means the ability to carry or squeeze something. Handgrip strength assessment also has clinical results that can be a benchmark for the rehabilitation progression [10] because handgrip ability represents global upper extremity function [9]. Correlation between both systems is also found in stroke patients. Cutaneous anesthesia of the intact hand of chronic stroke patients resulted in improvements during the execution of a vigorous finger motor activity with the paretic hand [11].

In contrast, individuals with acute and subacute hemiparesis discovered moderate to significant associations between hand function and fine sensory testing (light touch and location of the thumb), but only a minor correlation in patients with chronic hemiparesis [12]. We hypothesized that fingertips' sensory function has an influence on hand function. Furthermore, patients' sensory and motor abilities are the basic needs to achieve functional ability. Therefore, it is necessary to carry out a sensory and motor assessment associated with a specific functional examination of the hand using the FMA-UE hand. Sensory and motor systems are the most significant contributors to movement or activity. The ability to execute activities of daily living is the most important in human life. It is pretty hard for stroke survivors to do activities of daily living because participants need good motor ability to execute the motion. Gaining the ability to act and move is the primary purpose of physical therapy training for patients. With a good measurement, physical therapists can assess precisely and accurately to set the training program and monitor the program's progression [13].

Methods

Study design

A cross-sectional study was conducted. The individuals after stroke were recruited from the National Brain Hospital of Indonesia.

Participants

The researcher verbally informed all selected stroke patients about the study, and those who agreed to have their data used signed a written informed consent form. Informed consent was obtained from the participants, and the study was approved by the Ethical Committee of Chulalongkorn University (COA No.251/2020) and the National Brain Hospital of Indonesia (No. LB.02.01/KEP/072/2021). Inclusion criteria of this study are male or female, more than 40 years old, who had a first stroke leading to upper limb paresis in 3-12-month post-stroke (chronic phase), and able to move the hand/finger (able to grip a handheld tool in the second position). This study excluded data from participants who reported a history of or a recent injury to the hand and cognitive problems.

Testing Procedures

The participants included in the study were asked to answer a screening questionnaire, provide a history, and provide informed consent. The screening questionnaire was used to assess the cognitive and dominant hand. The dominant hand test was assessed by the Edinburgh Handedness Inventory [14]. The participants included in this study were evaluated for their sensory perception of the fingertips by 2PD and their hand function by grip strength and FMA-Hand.
Static and moving 2PD sensations were examined using a standardized Dellon discriminator (Baseline Discrim-A-Gon Discriminator) [15]. The device comprises two plastic discs with pins separated by different distances (1 to 15 mm) [1]. Two types of 2PD measurements exist: static 2PD and moving 2PD [13, 14]. First, participants need to be seated on the chair, the foot plantar fully on the floor, and the forearm resting in a semi-pronated position on the table with elbow 90^{o} flexion, shoulder 30^{o} abduction, and wrist fully open. The participant's hand was cleaned with an alcohol swab. Static 2PD randomly touches the participant's fingertips with one or two points. Measure one finger ten times, and increase or decrease the distance between the points. For the moving 2PD, perform the test like static 2PD but start from proximal to distal on the volar distal phalanx of the fingertips. Results were recorded by the same examiner so that errors in testing would be minimized.

The examination of grip strength is performed using the Camry Hand Dynamometer (EH101; Camry, Guangdong Province, China) [16]. Grip strength was measured with the participants seated with the forearm resting in a semi-pronated position, with the shoulder abduction, the elbow flexion, and the wrist dorsiflexion. First, two trials with submaximal isometric contractions were performed to familiarize the participant with the equipment. The test is performed three times in the second handle position, as the standard position, or referring to the initial grip position for vigorous gripping. The highest voluntary contraction record was the maximal grip strength (isometric). From a previous test-retest reliability study, high Intra-class Correlation Coefficients (ICC2,1) were found for both the less affected and the more affected hand (0.95–0.96) [17]. The last assessment of hand function was examined with the Fugl-Meyer Assessment, specifically the FMA (UE-Hand) type, which only focused on the hand and wrist, approved *in 2010 by Fugl-Meyer AR* (6). Intra-and inter-rater reliability of the FMA-UE, as measured by the intraclass correlation coefficient (ICC), was excellent, with values above 0.90 for both the total and subscale levels in the chronic and subacute phases. The FMA was confirmed as a gold standard assessment in post-stroke patients [18].

Data Acquisition

The participants' data were collected from test performance and recorded on an assessment sheet (paper-based). The data from the two-point discrimination, grip strength, and FMA test sheet was copied on the datasheet by Microsoft Excel for Microsoft 365 MSO (Version 2204 Build 16.0.15128.20210).

Statistical Analysis

The distribution of the data was tested using the Kolmogorov-Smirnov test, and from all parameters, only grip strength tests were found to be suitable for parametric testing. So, to find the value of the correlation, a non-parametric test is used. Spearman tests were used to explore the correlation between groups. The statistical significance level was set at $p < 0.05$, and all testing was performed using SPSS Version 28.0 (IBM SPSS Statistics for Windows)

Results

Forty-two participants aged 40-79 (64.0% were males and only two were left-handed dominants) post stroke participated. All participants had a single stroke attack (57.0% left-sided brain lesion), with 43.0% having a diabetic history, and 69.0% of participants having a normal BMI (Table 1). All subjects had a normal peripheral nerve function with no previous injury or compression syndrome.

Table 1 Distribution of age, sex, diabetic history, dominant hand, brain lesion, and BMI of the participants

Variables	Age	n	%
Middle-aged Adults	40 – 49	7	17.0
	50 – 59	18	43.0
Old Adults	60 – 69	13	31.0
	70 - 79	4	9.0
Male		27	64.0
Female		15	36.0
Having Diabetic History		18	43.0
Have No Diabetic History		24	57.0
Right-handed Dominant		40	95.0
Left-handed Dominant		2	5.0
Right (Brain Lession)		18	43.0
Left (Brain Lession)		24	57.0
Underweight (BMI)	<23	9	2.0
Normal (BMI)	23-30	29	69.0
Overweight (BMI)	>31	4	10.0

Correlation between FMA and grip strength, FMA and static 2PD, FMA and moving 2PD, grip strength and static 2PD, grip strength and moving 2PD

The correlation between each group on the paretic side. The FMA had a high positive correlation with the grip strength test. Both assessments of the 2PD test had a negligible correlation with FMA and grip strength (Table 2).

Table 2 Correlation between each group on the paretic side

	FMA – Grip Strength	FMA – Static 2PD	FMA – Moving 2PD	Grip Strength – Static 2PD	Grip Strength – Moving 2PD
Spearman's rho	0.706	0.005	0.011	-0.128	-0.090

**Significant level at α <0.05*

Comparison between static and moving 2PD in the paretic and non-paretic hand

The moving 2PD was significantly different from the static 2PD. It shows that both static and moving 2PD had better scores in the non-paretic hand, and moving 2PD had better scores than static 2PD (Table 3).

Table 3 Mean score of static and moving 2PD in paretic and non-paretic hand

	Paretic Hand Mean (SD)	Non-Paretic Hand Mean (SD)
Static 2PD	5.6095 (1.39403)	5.4190 (1.36350)
Moving 2PD	4.8571 (1.23863)	4.7310 (1.23863)

**Significant level at* α *<0.05*

Tables 4 and 5, as in Table 3, also show that the results were better in the non-paretic hand. On the other hand, the second finger was the most sensitive finger for threshold discrimination.

Table 4 Mean score of threshold discrimination in different fingers (Paretic Hand)

Paretic Hand									
Static 2PD					Moving 2PD				
Finger 1	Finger 2	Finger 3	Finger 4	Finger 5	Finger 1	Finger 2	Finger 3	Finger 4	Finger 5
5.33	5.21	5.59	5.74	6.17	4.71	4.4	4.76	5.11	5.28

Table 5 Mean score of threshold discrimination in the different fingers (Non-paretic Hand)

Non-paretic Hand									
Static 2PD					Moving 2PD				
Finger 1	Finger 2	Finger 3	Finger 4	Finger 5	Finger 1	Finger 2	Finger 3	Finger 4	Finger 5
5.14	5.05	5.4	5.52	5.98	4.55	4.05	4.38	4.93	5.09

Both static and moving types were in paretic and non-paretic hands, and the fifth finger showed a lower result than the other fingers (Tables 6 and 7).

Table 6 Mean score of correct responses in the different fingers (Paretic Hand)

Paretic Hand									
Static 2PD					Moving 2PD				
Finger 1	Finger 2	Finger 3	Finger 4	Finger 5	Finger 1	Finger 2	Finger 3	Finger 4	Finger 5
8.09	7.95	8.14	7.74	7.62	8.19	8.09	7.95	7.83	7.66

Table 7 Mean score of correct responses in the different fingers (Non-paretic Hand)

Non-paretic Hand									
Static 2PD					Moving 2PD				
Finger 1	Finger 2	Finger 3	Finger 4	Finger 5	Finger 1	Finger 2	Finger 3	Finger 4	Finger 5
8.14	8.33	8	7.81	7.76	8.40	8.33	7.98	8.14	7.88

Discussion

This study aimed to observe the association between sensory perception of the fingertips, hand motor function, and hand function in chronic stroke patients. The participants had no experience with hand peripheral nerve injury. As described in previous research, the researchers proved the correlation between sensory and motor systems, showing a positive correlation. Anatomical function, secondary motor areas (SMA) and premotor areas (PM) respond to sensory inputs [19, 20], and the primary motor cortex (MI) is not solely a motor structure. It is involved in the processing of somatosensation [21]. So, when cutaneous stimulation is given, muscle and joint afferents can drive neurons in the primary motor cortex [22]. Different forms of sensory stimulation are applied to facilitate motor behaviour [23]. Also, other sensory modalities besides somatosensory, proprioceptive, and tactile are relevant for motor and skill acquisition; vision, auditory, and vestibular systems [24]. Correlation between both systems is also found in stroke patients. Cutaneous anesthesia of the intact hand of chronic stroke patients improved the performance of a dynamic finger motor task with the paretic hand [25]. Conversely, there are significant connections between hand function and fine sensory tests (namely, light touch and thumb positioning) in acute and subacute stroke cases. However, they found only a weak correlation in patients with chronic hemiparesis [26].

In age interval groups, the highest percentage is participants aged 50–59, around 43.0%, and the lowest percentage is around 10.0% for the 70–79-year-old group. Many previous studies showed that the higher the age group, the higher the incidence of stroke [27-29]. However, the number only shows the incidence of stroke without any information on whether the age group had a stroke for the first attack or the umpteenth attack. The result shows that the proportion of males was larger than that of females. It is in line with a previous study that proved that stroke is more common in males than females [30]. The other result of the participants was that more than 50.0% of participants had left brain lesions, normal BMI, and no diabetic history.

In this study, grip strength and FMA-UE hand were highly correlated. Adapted from Dancey and Reidy in 2004, the result was a "very strong correlation" because the score is more than 0.7 (0.706). The result supported a previous study stating that maximal voluntary grip force deficits were associated with chronic stroke subjects' motor and functional upper limb performance [31]. Thus, recovery of recordable grip strength was reported to be one of the most sensitive indicators of initial upper limb [32] recovery in acute stroke patients and a reliable predictor of later functional recovery [33]. It has also been proposed that grip strength assessments are the best way to identify upper limb motor deficits in stroke patients [34]. The study's findings indicate that grip strength assessment benefited acute and chronic stroke patients. Thus, grip strength assessment can be measured early and evaluated for each period to see the patient's motor and functional improvement.

This study also explored the correlation between hand sensory, hand motor, and hand function. Previously, researchers found moderate to strong correlations between hand function and fine sensory testing (light touch and positioning of the thumb) in acute and subacute stroke. However, they found only a weak correlation in patients with chronic hemiparesis [35]. Also, different forms of somatosensory stimulation have facilitated motor behavior [36]. In our sensory, motor, and function assessment with 2PD, grip strength, and FMA-UE hand, we found no correlation between 2PD and grip strength, or 2PD and FMA-UE hand. These findings could be due to 2PD being insufficient in this condition because previously, in the nerve repair cases, 2PD poorly tracks recovery of function following nerve injury and repair [37, 38]. Thus, motor control theory explained that the individual, the task, and the environment interact to produce movement, so this sensory assessment needs to be supplemented by other supporting examinations [39]. On the other hand, previous research has indicated that somatosensory function is important for recovery of precision grip force control after stroke, and the neurobiological processes related to the remaining integrity of the corticospinal tract (CST) play a crucial role in the restoration of precise finger motor control following a stroke [40].

Another result of this study is from 2PD tests, which were divided into static 2PD and moving 2PD. Static 2PD correlated with the patient's ability to perform tasks requiring precision sensory grip, and moving two-point discrimination was found to correlate with the ability to identify objects (tactile gnosis). Static two-point discrimination encoding by *Merkel cell-neurite* mechanoreceptors, which respond to the small impression of the skin but are *slowly* adapting. While moving, two-point discrimination encoding by *Meissner* and Pacinian corpuscle mechanoreceptors, the *Pacinian corpuscle* and *Meissner corpuscle*, is rapidly adapting. Both have different characteristics, meaning the results are not identical [35]. The results show a difference in threshold discrimination between static and moving two-point discrimination. It shows that moving two-point discrimination has a smaller threshold than static two-point discrimination. This means that participants with post-stroke detect moving two-point discrimination in more detail.

The second finger has the lowest mean score of threshold discrimination. This means that this area is the most sensitive area for sensing the lowest distance between two points in a fingertip, which is called threshold discrimination. This result is supported by a previous study in 2020, which proved that in spontaneous softness discrimination, individuals explored the offered stimuli most frequently using combinations of their index, middle, and, to a lesser extent, ring fingers. A common behaviour was to alternate between indenting with one finger and many fingers. Preferred fingers were the first or index finger, the second or middle finger, and the fourth or ring finger. The little finger and thumb were utilized least habitually [35].

The prior studies also support the results from Tables 6 and 7, which show the mean score of total correct responses in different fingers. The fifth finger, or little finger, had the lowest score for total correct responses. Several reasons that might support this result, including the analysis of the fingertips' width, showed some similarities to the performance outcome. The index and middle fingers were broader than the ring finger, and the little finger was the smallest. When investigating compliant items, they employed finger width as a gauge for contact area, which is known to be crucial [38]. It is also in line with earlier studies about the sensitivity of the fingertips, which also discussed the number of mechanoreceptors in the fingertips that come into contact with an object during exploration. The other reason discussed in the previous study is that fingers two and three are more sensitive to softness than finger four, and finger five is the least sensitive [35].

Conclusion

Findings highlight a strong correlation between grip strength and FMA-UE hand, but there is no correlation between 2PD and grip strength, or between 2PD and FMA-UE hand in stroke patients. The result of 2PD showed that moving 2PD has a better result than static 2PD. This may help guide health professionals, especially physiotherapists, during the rehabilitation phase to give an alternative that physiotherapists can only perform, moving 2PD, rather than performing both static and moving for time effectiveness. Besides, physiotherapists can use the FMA-UE Hand as a benchmark to evaluate hand function in individuals with stroke. This research has not investigated the lobes and the severity that is affected by stroke; individual CT-Scan details may support the next study. Further research may need to consider the residual corticospinal tract to see more results on the correlation between 2PD with FMA-UE hand and 2PD with grip strength.

Competing Interests

No potential competing interest relevant to this was reported.

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Author Contributions

Anchalee Foongchomcheay was responsible for developing the research questions, the study and methodological design, supervising the project, helping in data analysis, and reviewing and editing the final manuscript. Orisa Elfath helped in developing the study and methodological design, coordinated the project, conducted the experiments and data collection, performed data analysis and verified processes, prepared the initial draft of the manuscript, and reviewed and edited the final manuscript.

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