Title:

Upper extremity disability is associated with pain intensity and grip strength in women with bilateral idiopathic carpal tunnel syndrome

Authors:

Akihito Yoshida,[a,b] Shigeru Kurimoto,[a] Katsuyuki Iwatsuki,[a] Masaomi Saeki,[a] Takanobu Nishizuka,[a] Tomonori Nakano,[a] Hidemasa Yoneda,[a] Tetsurou Onishi,[a] Michiro Yamamoto,[a] Masahiro Tatebe,[a] Hitoshi Hirata[a]

Affiliation:

[a]Department of Hand Surgery, Graduate School of Medicine, Nagoya University, Nagoya, Japan

[b]Department of Rehabilitation, Nagoya University Hospital, Nagoya, Japan

Corresponding author: Akihito Yoshida

Full postal address: Department of Hand Surgery, Nagoya University Graduate School of Medicine

65 Tsurumai-chou, Showa-ku, Nagoya 466-8550 Japan

Telephone number: +81 52 744 2957

Fax number: +81 52 744 2785

E-mail address: yosh.akihito@med.nagoya-u.ac.jp

Abstract

Background: The upper extremity disability in patients with carpal tunnel syndrome (CTS) is related to dysfunction due to the median nerve damage. However, there is no report on which dysfunctions affect the upper extremity disability.

Purpose: This study aimed to investigate which clinical factors influence upper extremity disability in women with CTS.

Methods: We analyzed 60 hands of women with bilateral idiopathic CTS. Upper extremity disability was assessed using Hand10, a validated and self-administered tool. Pain intensity was measured using the Japanese version of the Short-Form McGill Pain Questionnaire (SF-MPQ-J). We performed nerve conduction studies, assessed physical and psychological parameters, and collected demographic data. Physical parameters comprised grip strength, pinch strength, tactile threshold, static 2-point discrimination sensation, and severity of numbness. Psychological parameters include depression, pain anxiety, and distress.

Results: The bivariate analysis revealed that Hand10 was significantly correlated with age, symptom duration, SF-MPQ-J, grip strength, pain anxiety, and distress. Multiple regression analysis demonstrated that SF-MPQ-J and grip strength were related to Hand10 score.

Conclusions: Pain intensity and grip strength were dysfunctions affecting the upper extremity disability in women with bilateral idiopathic CTS. Rehabilitation approaches for CTS should be considered based on the adaptive activities of the neural networks.

Key words. Idiopathic carpal tunnel syndrome; Bilateral carpal tunnel syndrome; Women; Upper extremity disability; Pain intensity; Central sensitization

1. Introduction

Carpal tunnel syndrome (CTS) is one of the most common entrapment neuropathies (Bland, 2007). Given that the median nerve in the carpal tunnel is irritated, patients with CTS may experience pain and paresthesia in the thumb, index, middle, and radial side of the ring finger (Atroshi et al., 1999). Advanced CTS symptoms include decreased grip and pinch strengths, resulting in the atrophy of the thenar muscle (Keir et al., 2005). These dysfunctions are related to the upper extremity disability in patients with CTS (Jerosch-Herold et al., 2008), but there is no report on which dysfunctions affect the upper extremity disability. In general, the severity of median nerve damage is evaluated through nerve conduction studies (NCS) (Werner & Andary, 2011). Symptoms of CTS can be relieved by orthosis or carpal tunnel release (Page et al., 2012; Brown et al., 1993; Phalen, 1966). However, the significant correlation between the NCS result and the severity of the upper extremity disability has not been shown (Itsuboet al., 2009). The findings indicate that treating the damaged median nerve is important, but there are also other causes of upper extremity disability.

Recent studies report that CTS patients show functional changes in not only the median nerve but also the central nervous system. Specifically, CTS patients showed the presence of functional disinhibition with destruction of the somatotopic organization in the primary somatosensory cortex compared with healthy controls (Iwatsuki et al., 2016), although inhibitory neurons in the central nervous system played an important role in regulating neural network activity (Froemke, 2015). The pain causes poor behavioral performance resulting in pain-related fear and avoidance (Vlaeyen & Linton, 2000). The non-use of the hand results in the deterioration in motor performance and changes in motor cortical excitability within days (Facchini et al., 2002) and even hours of immobilization (Avanzino et al., 2011). In addition, CTS patients may have psychological symptoms, such as depression (Shin et al., 2018), pain anxiety (Shin et al., 2018), and distress (Yoshida et al., 2018). These findings indicate that the pathology of CTS includes the central nervous system, and besides, the adaptive or maladaptive changes are affected by the frequency of hand use in the activity of daily living (ADL). We are currently investigating a paradigm shift in the concept of CTS.

As described previously, the upper extremity disability in CTS patients is affected by various factors. However, the dysfunctions affecting the upper extremity disability has not been elucidated yet. Thus, a study involving a homogeneous group is required and valuable for CTS. Epidemiological studies found that CTS is more frequent in women than in men (Atroshi et al., 1999). Most cases of CTS are idiopathic (Middleton & Anakwe, 2014). The proportion of patients who develops CTS in their bilateral hands in 73%, although they may not manifest concurrently (Bagatur & Zorer, 2001; Hoogstins et al., 2013). The objective of this prospective cohort study was to clarify which factors influence the upper extremity disability in the ADL of women with bilateral idiopathic CTS.

2. Methods

2.1. Study design and patients

This study was conducted as a subanalysis of our ongoing research project elucidating the mechanism between clinical outcomes and brain plasticity after CTS treatments. We included 68 hands of women with bilateral idiopathic CTS who underwent open or endoscopic carpal tunnel release from December 2012 to March 2018. Eight hands were excluded because of Parkinson's disease (one hand), syringomyelia following Arnold-Chiari malformation (one hand), and incomplete assessments (six hands). Ultimately the data of 60 hands were analyzed. Patients were diagnosed with CTS based on a history of dysesthesias in the distribution of the median nerve and a positive provocative test, such as Phalen's wrist flexion test, carpal tunnel compression test or Tinel's sign (Iwatsuki et al., 2016; Iwatsuki et al., 2014).

2.2. Ethics statement

All patients provided informed consent and agreed to participate in the study. The research was approved by the ethics committee of our institution (2012-0312-6).

2.3. Assessments and outcome measures

Hand assessments were at one week prior to their scheduled operation. Given that some outcomes were to be measured in the bilateral hands, each hand was divided into operative and non-operative sides. Patients' characteristic data consisted of age, body mass index (BMI), symptom duration, operative side, dominant side, coexistence of trigger finger, and Padua classification, which showed neurophysiological severity of the median nerve based on the NCS (Padua et al., 1997). Hand10 was used as an upper-extremity disability assessment tool (Kurimoto et al., 2011). The patient-reported outcome measure consists of 10 short, easy-to-understand questions, and explanatory illustrations. Hand10 had high acceptability and reliability among elderly patients because of the use of explanatory illustrations (Kurimoto et al., 2013). Pain was measured using the Japanese version of the Short-Form McGill Pain Questionnaire (SF-MPQ-J) (Melzack, 1987; Yamaguchi et al., 2007).

The physical assessments comprised grip strength, key pinch strength, pulp pinch strength, tactile threshold as measured using the Semmes-Weinstein monofilament test (SWT) (Klein et al., 2016), static 2-point discrimination sensation (S2PD) (Hsu et al., 2015; Dellon, 1981), and numerical rating scale (NRS) for numbness. All sensorimotor function tests were performed by three well-trained occupational therapists.

The psychological assessment tools, which were self-reported questionnaires, used were the Japanese version of the Self-rating Depression Scale (SDS) (Fukuda & Kobayashi, 1983; Zung, 1965), the Japanese version of the Pain Anxiety Symptom Scale-20 (PASS-20) (Matsuoka & Sakano, 2008; McCracken & Dhingra, 2002), and the Stress Response Scale-18 (SRS-18) (Suzuki et al., 1997).

2.4. Statistical analysis

The dependent variable was Hand10. The independent variables were age, BMI, symptom duration, the Padua classification, SF-MPQ-J score, grip strength, key pinch strength, pulp pinch strength, SWT, S2PD, NRS for numbness, SDS, PASS-20, and SRS-18. The independent variables that were significantly associated with Hand10 scores in the bivariate analysis (Pearson's correlation test, or Spearman's rank correlation test, as appropriate) were entered into a multivariate analysis. A multiple regression analysis was used to identify factors that were independently associated with Hand10 scores. In addition, we did multiple regression analysis with the force-on method for the existence of trigger finger, because trigger finger often coexisted in the same patient (Wessel et al., 2013). All statistical analyses were conducted using the Statistical Package for Social Science version 22.0J software (SPSS, Tokyo, Japan). The significance level was set at $p < 0.05$.

3. Results

Patients' characteristics are shown in Table 1. Trigger finger was found in thirteen hands. According to the Padua classification, neurophysiological severity of 9, 12, 30, and 9 hands was “extreme”, “severe”, “moderate”, and “mild”. Most hands had abnormal or absent digit-wrist sensory and motor responses.

In the bivariate analysis, Hand10 was significantly correlated with age (r = 0.33, p = 0.00), symptom duration (r = -0.27, p = 0.04), the SF-MPQ-J (r = 0.53, p = 0.00), grip strength at operative side (r = -0.46, p = 0.00), grip strength at non-operative side (r = -0.29, p = 0.03), PASS-20 (r = 0.32, p = 0.01), and SRS-18 (r = 0.47, p = 0.00) (Table 2). The other assessments did not show any statistically significant correlation. Multiple regression analysis revealed that the SF-MPQ-J (β = 0.47, p = 0.00) and grip strength (β = -0.34, p = 0.00) were significantly correlated variables for Hand10 score, whereas the other variables were not (Table 3). Multiple regression analysis adjusted for the existence of trigger finger also showed the same independent variables.

4. Discussion

We investigated the factors that influenced the Hand10 score in women with bilateral idiopathic CTS. The bivariate analysis revealed that the Hand10 score was significantly correlated with age, symptom duration, the SF-MPQ-J (pain intensity), grip strength at operative and non-operative sides, PASS-20 (pain anxiety), and SRS-18 (distress). In the multiple regression analysis, the significantly correlated factors for Hand10 were the SF-MPQ-J and grip strength at the operative side.

Patients with CTS have limited ADL, such as writing, buttoning of clothes, holding a book while reading, opening of jar lids, and carrying of grocery bags (Levine et al., 1993), which are due to the CTS-specific symptoms (Jerosch-Herold et al., 2008). Although there were various symptoms, we showed that the upper extremity disability in the ADL in women with bilateral idiopathic CTS was significantly influenced by pain intensity and grip strength. Origin of pain is regarded as the impaired sensory fiber in the median nerve. Decreased grip strength is due to the muscle atrophy following the impaired motor fiber in the median nerve. Our results supported a described report previously (Jerosch-Herold et al., 2008) and showed that the median neuropathy at the wrist level is among the causes of ADL limitations in the patients.

Our results showed that pain intensity and grip strength at the operative side affected the upper extremity disability in women with bilateral idiopathic CTS, whereas, the Padua classification, pinch strength, and SWT did not affect the upper extremity disability. These findings suggested that the cause of the upper extremity disability in the women with bilateral idiopathic CTS could not explain the peripheral neuropathy only. In other words, the disability is influenced by the central nervous systems. In particular, pain after the peripheral nerve damage is believed to be due to both peripheral and central nerves (Haroutounian et al., 2014). It is well known that pain is modulated by the central sensitization (Woolf, 2011; Woolf & Salter, 2000). We found that the primary somatosensory cortex in patients with CTS showed functional disinhibition compared with that in healthy subjects (Iwatsuki et al., 2016). Moreover, we suggested that the disinhibitory change induced a maladaptation of the central nervous system, which was related to chronic dysesthesia or pain. Therefore, pain intensity in this study was also perceived as a maladaptive response under the influence of the central nervous system.

In the multiple regression analysis, the Padua classification, pinch strength, SWT, S2PD, and NRS for numbness were not associated with the upper extremity disability, although these outcomes were widely used in patients with CTS. The pinch strength is one of outcomes when assessing hand function in CTS patients (Fernandes et al., 2013). The SWT evaluates the tactile threshold and the localization of the tactile sensation (Ylioja et al., 2004). The 2PD reflects the ability of tactile spatial acuity (Hsu et al., 2015). A previous report found that altered brain morphometry in CTS was associated with median nerve pathology (Maeda et al., 2013). However, these findings were not associated with our results in the multiple regression analysis. As a result of the adaptive structural changes in the brain of CTS women to symptoms, there was a possibility that the Padua classification, pinch strength, SWT, S2PD, and NRS for numbness had a small influence on the upper extremity disability.

This study had four limitations. First, we could not show the results after the surgical operation. However, our unpublished data in a research project show at least improvements of the central nervous system in patients with CTS. Second, we could not show the evidence that grip strength was influenced by not only the peripheral nerve but also the central nervous system. Decreased grip strength might be caused by physical inactivity due to pain (Smuck et al., 2017; Teichtahl et al., 2015), behavioral change to avoidance due to pain (Vlaeyen & Linton, 2000; Clark et al., 2014), and the poor motor performance due to dysfunction of sensory and motor systems (Lundborg, 2000; Lundborg, 2003). Thus, the study investigating the outcome of such amount of daily physical activity in the upper extremity with wearable devices is warranted (Schrack et al., 2016). Third, our findings are not always applicable to men or young women with CTS. However, our findings are clinically valuable, because the participants in this study are a typical cohort in CTS patients. Finally, our participants did not include CTS women, who preferred to not undergo a surgery. We assume that these women have symptoms but are not that concern with how the disability affects their ADL. Given that a homogenous cohort is important in this study, this consideration was irrelevant with our findings.

Our results showed that rehabilitation in women with bilateral idiopathic CTS should be targeted at symptoms of both the peripheral and central nervous systems. Desensitization maneuver (Fernández-de-Las Peñas et al., 2015) is considered to decrease amplified pain intensity. It is important that CTS patients undergo general treatment for the neuropathic pain (Magrinelli et al., 2013), because mounting evidence indicates that it is required for the desensitization strategies targeting symptoms of the peripheral and central nervous systems (Baron et al., 2013); the treatments are desirable to be started preoperatively or immediately and continuously postoperatively. Grip exercises are effective in improving the patients' grip strength, if the decreased grip strength is caused by the disuse of the hand. In general, exercises are recommended to improve muscle strength to set up high loading (1-12 repetitions with 1- to 2-minutes of rest periods between sets at a moderate velocity) (Kraemer et al., 2002). However, when patients experience discomforts, such as pain during grip exercise, patients may have difficulty in performing the optimal grip exercise. When the pain intensity is adaptively modulated by treatments, patients can easily perform the optimal grip exercise. Adaptive modulated pain intensity is expected to enhance both of the performance of grip exercises and the amount of physical activity of the upper extremity in the ADL.

5. Conclusions

We investigated the clinical factors that influenced upper extremity disability in women with bilateral idiopathic CTS. Pain intensity and grip strength were significantly correlated factors of upper extremity disability in the ADL. Our findings suggest that the upper extremity disability in the ADL of women with CTS is influenced by not only inherent symptoms of the peripheral neuropathy but also maladaptive response of the central nervous system. Rehabilitation approaches for CTS should be considered based on the adaptive activities of the neural networks.

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Conflict of interest:

None

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Table 1. Patients' characteristics (n = 60)

Age (years), mean ± SD	60.1 ± 14.5
Body mass index (kg/m^2), mean ± SD	24.8 ± 4.8
Duration of symptom (months), mean ± SD	42.2 ± 53.0
Operative side (right), number	28
Dominant hand (right), number	58

Table 2. Correlation between upper extremity disability and independent variables by means of bivariate analysis (n = 60)

Variables	Side	*r*	*p*
Age		0.33	0.00*
Body mass index		-0.18	0.17
Symptom duration		-0.27	0.04*
Padua classification	Operative	0.03	0.83
	Non-operative	-0.04	0.76
SF-MPQ-J		0.53	0.00*
Grip strength	Operative	-0.46	0.00*
	Non-operative	-0.29	0.03*
Key pinch	Operative	-0.20	0.13
	Non-operative	0.08	0.53
Pulp pinch	Operative	-0.14	0.28
	Non-operative	0.00	0.99
SWT (thumb)	Operative	0.02	0.87
	Non-operative	-0.01	0.96
SWT (index)	Operative	0.06	0.66

	Non-operative	0.06	0.65
SWT (middle)	Operative	0.10	0.45
	Non-operative	-0.05	0.72
S2PD (thumb)	Operative	0.13	0.33
	Non-operative	0.06	0.67
S2PD (index)	Operative	0.13	0.33
	Non-operative	0.04	0.78
S2PD (middle)	Operative	0.20	0.13
	Non-operative	0.00	0.98
NRS for numbness	Operative	0.22	0.09
	Non-operative	0.06	0.64
SDS		0.21	0.11
PASS-20		0.32	0.01*
SRS-18		0.47	0.00*

SF-MPQ-J, Japanese version of Short-Form McGill Pain Questionnaire; SWT, Semmes-Weinstein monofilament test; S2PD, static 2-point discrimination; NRS, numerical rating scale; SDS, Self-rating Depression Scale; PASS20, short version of Pain Anxiety Symptom Scale; SRS-18, Stress Response Scale-18 *r*, correlation coefficient; *p*, probability value

$^{*}p < 0.05$

Table 3. Significantly correlated variables for Hand10 score by means of multiple regression analysis (n = 60)

Dependent variable	Independent variables	*β*	*p*	R^2
Hand10				0.40
	SF-MPQ-J	0.47	0.00	
	Grip strength at operative side	-0.34	0.00	

β, standardized regression coefficient; *p*, probability value; R^2, multiple correlation coefficient adjusted for the degrees of freedom; SF-MPQ-J, Japanese version of Short-Form McGill Pain Questionnaire