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Associations of Hand Function and Electrophysiological Measurements in Patients with Hand Osteoarthritis

제주대학교 대학원

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Associations of Hand Function and Electrophysiological Measurements in Patients with Hand Osteoarthritis

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ABSTRACT

Backgrounds and Objectives: Hand osteoarthritis (OA) is a common degenerative disease and deterioration of hand function in patients with hand OA affects activities of daily living, which worsens the quality of life, although its clinical and academic significance has been overlooked. Hand dysfunction in OA may be related to sensorimotor deficit, pain, disuse atrophy, aging process, or other accompanying neurological diseases. The aims of this study are to assess the relationship of the findings of the nerve conduction study with the functional outcomes in patients with hand OA and to compare each parameter of the hand function and electrophysiological test according to the presence of carpal tunnel syndrome (CTS).

Methods: The patients with hand OA (208 patients, 404 hands) were enrolled from June 2015 to June 2016. Grip strength, key pinch (KP) strength and nine-hole pegboard test (9HPT) were assessed and motor & sensory nerve conduction studies (NCS) were obtained. We compared the parameters of hand function tests and nerve conduction study according to age span, gender, and the presence of CTS. Associations of the general and clinical characteristics with electrophysiological parameters were analyzed by correlation and multivariate regression methods.

Results: There were statistical differences in all parameters of NCS, except for the distal latency of ulnar compound muscle action potential (CMAP) among age spans. All parameters of hand function showed significant differences among age spans. Male hands revealed significantly higher strength of hand grip and key pinch than female hands, while there was no difference in 9HPT between both genders. Also, CTS group revealed significantly lower strength of hand grip and key pinch and longer time of 9HPT than control group. Parameters of hand function test were correlated significantly with age, amplitude of median SNAP, median and ulnar CMAP. Multivariate regression analysis identified amplitude of median CMAP, age and male gender as independent predictors of grip strength (adjusted R_2 = 0.679), and amplitude of median CMAP and male gender as independent predictors of KP strength (adjusted R_2 = 0.603). Velocity of median CMAP, amplitude of median SNAP and age were identified as independent predictors of 9HPT (adjusted R_2 = 0.329).

Conclusions: Nerve conduction studies were significantly related with hand function test in hand OA and CTS combined with hand OA induced significant deficits in strength and performance of affected hand, which suggest the effectiveness of NCS to improve the functional outcome in hand OA through early intervention of rehabilitation program.

Keywords: electrodiagnosis, osteoarthritis, carpal tunnel syndrome, hand function, grip strength

INTRODUCTION

Osteoarthritis (OA) is a common degenerative disease and involves hand most frequently [1] and the prevalence rate of radiographic and symptomatic hand OA in Korea was 13.4% and 8.0% respectively [2]. As the hand is one of commonly used organ, repetitive use of hands can lead to degenerative arthritis that affect serious disability and functional deficits in activities of daily living [3-5]. Therefore, it is very important to assess the hand function in patients with hand OA, and the adequate rehabilitation program intervention would be essential to improve their quality of life, although hand OA has been paid less attention in the scientific literature compared with knee and hip OA.

Hand dysfunction in patients with hand OA is possibly related to the sensorimotor deficit [6-7], secondary to pain and disuse atrophy [8], or other accompanying diseases such as carpal tunnel syndrome (CTS). Although neurophysiological investigation has been rarely performed so far and there has been limited data about in patients with hand OA, it is very helpful to define the accompanying nerve impairment and CTS.

CTS is the most common peripheral entrapment neuropathy in the upper extremity [9] and can result from maladaptive changes around the wrist joint due to repetitive hand use in the ADL [9]. CTS is usually diagnosed with complex criteria including sensory and motor nerve conduction studies (NCS) [10]. Although there are wide range of reference values for both distal sensory latency and distal motor latency for diagnosis of CTS [11], Khosrawi and Dehghan suggested cut-off value of distal sensory latency as 3.6ms with a sensitivity of 87% and specificity of 91%, and cut-off value of distal motor latency as 4.2ms with a sensitivity of 70% and specificity of 100% (Appendix 1) [12], and these values have been widely used for the electromyographical diagnosis of CTS in department of rehabilitation medicine of Korea.

Hand-intrinsic muscles are innervated by the ulnar and the median nerve, and they are controlled by a delicate mechanism. Hand and finger strength and dexterity are reported to represent various hand performance abilities [13] and reflect independency in ADL [14].

Advanced CTS with the thenar muscle atrophy indicates decreased grip and pinch strengths [15] which are related to the upper extremity disability [16]. If the patients with hand OA accompany the CTS, the deterioration of hand function would be expected. However, there is the controversy about the relationship of CTS with hand OA. Some authors reported the causal link of CTS with basal thumb OA [17-18], while others suggested that basal thumb OA was not more prevalent in CTS group and the radiographic severity of basal joint arthritis of the thumb was not related to the electrophysiological severity of carpal tunnel syndrome in elderly Koreans [19].

Therefore, the primary purpose of this study is to assess the findings of the nerve conduction study in patients with hand OA and define its association with the hand function. The secondary purpose is to compare of the parameters of the hand function and the electrophysiological study according to presence and the grade of CTS with hand OA based on universal electrodiagnostic criteria.

MATERIALS and METHODS

Subject

Two-hundreds and eight patients (404 hands) who have visited the outpatient clinic and have performed nerve conduction study in the Regional Rheumatoid and Degenerative Arthritis Center of Jeju National University Hospital, from June 2015 to June 2016 were included in this study. They met the clinical criteria for symptomatic hand OA proposed by the American College of Rheumatology [20] ; 1) hand pain, aching, or stiffness, 2) hard tissue enlargement of 2 or more of 10 selected joints, 3) hard tissue enlargement of 2 or more distal interphalangeal joints, 4) fewer than 3 swollen metacarpophalangeal joints, 5) deformity of at least 1 of 10 selected joints (Appendix 2).

Carpal tunnel syndrome was confirmed by clinical symptoms such as pain, numbness, or sensory change along the median nerve distribution and electrophysiological diagnosis using AANEM guidelines [8]. Their medical charts were also reviewed.

This study was conducted in accordance with the recommendations of the institutional review board of Jeju National University hospital, which also approved the protocol used in this study. Given the retrospective study design, the need for informed consent was waived. Thus, the institutional review board of Jeju National University Hospital waived the informed consent from patients in this study (ethical approval number: JNUH-IRB 2016-06013).

Assessment of electrophysiological findings [21]

Nerve conduction studies were conducted using 'Medelec Synergy' electromyography machine (Medelec Synergy®, Oxford, UK, Figure 1) with maintaining the skin temperature of more than 32°C.

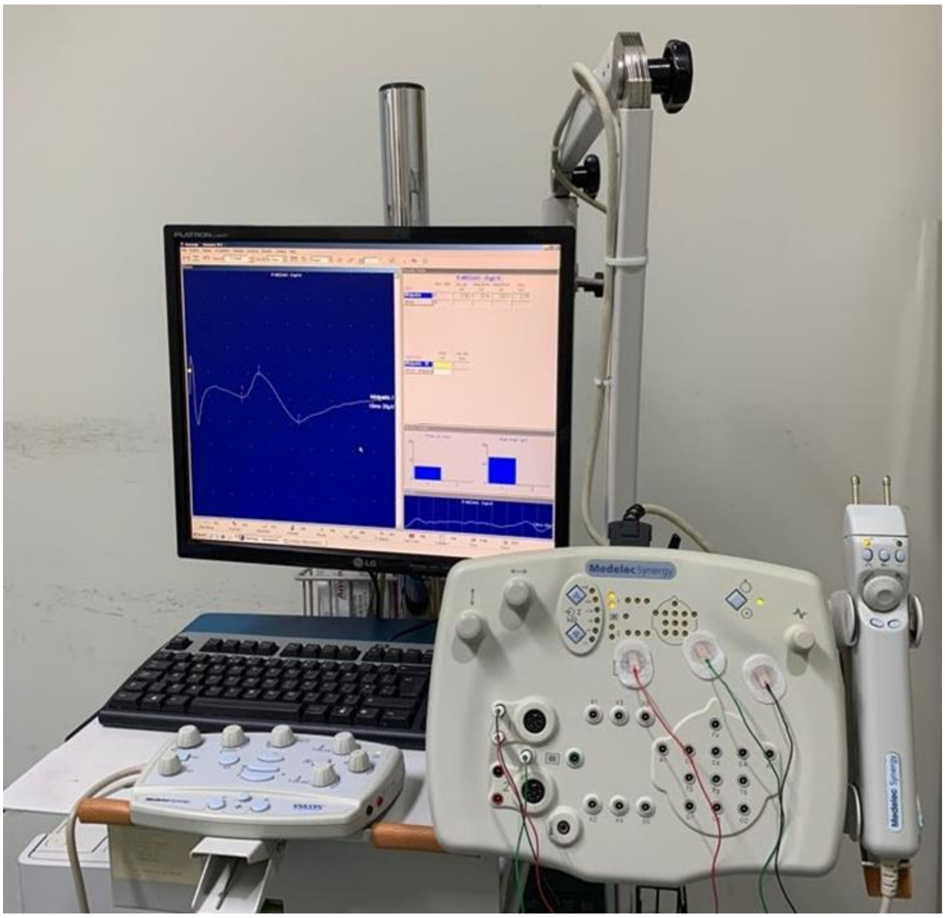

Figure 1. Electromyography Machine

Motor nerve action potential was recorded from the median nerve to abductor pollicis brevis and the ulnar nerve to abductor digiti minimi. In addition, the distal stimulation was placed above 7cm from the active recording electrode. Parameters of the distal latency, amplitude and velocity based on the compound muscle action potential (CMAP) were adopted.

Sensory nerve conduction studies were performed for the median and ulnar nerves with the placement of an active electrode at a 14 cm above position. At least ten responses were recorded and then averaged with antidromic stimulation. The latency and amplitude of the sensory nerve action potential (SNAP) were adopted.

The criteria for diagnosis of CTS in our clinic were DSL of 3.6ms and DML of 4.2ms (Table 1) [12]. The severity for CTS was classified into mild, moderate, or severe grade according to the Hang Jae LEE's Classification (Appendix 4) [22].

Table 1. Normative Values Used for Carpal Tunnel Syndrome

Nerve conduction study	
Median CMAP	Distal latency ≤ 4.2ms
	Distal amplitude ≥ 5mV
Median SNAP	Distal latency ≤ 3.6ms
	Distal amplitude ≥ 20uV

CMAP, compound muscle action potential, SNAP, sensory nerve action potential, ms, millisecond; mV, millivolt μV; microvolt

Measurement of hand function test

A portable digital hand dynamometer (Jamar dynamometer®, Sammons Preston, Bolingbrook, USA, Figure 2) was used to measure isometric grip strength of hand (in kg) [23] while the Jamar pinch gauge (PG60®, B&L Engineering, Tustin, CA, USA, Figure 3) was used to measure for key pinch (KP) strength. Participants were tested while in a sitting position. The dynamometers were calibrated prior to the first trial. The measured arm was by the side and not touching the body, and the shoulder was abducted and neutral. The elbow was flexed 90°, the forearm neutral, and the wrist extended 0–30° with ulnar deviation [24]. The participants were asked to squeeze the dynamometer with each hand for measuring grip strength and to pinch the Baseline pinch gauge with the thumb and the lateral aspect of middle phalanx of the index finger for measuring KP strength [25]. The largest values of all three measurements were recorded.

Figure 2. Measurement of Hand Grip Strength

Figure 3. Measurement of Key Pinch Strength

The wooden nine-hole pegboard test (9HPT; Jamar®, Sammons Preston, Bolingbrook, USA, Figure 4) was used for measuring hand and finger dexterity in this study. The 9HPT consists of a molded dish next to the 9-hole pegboard (31*26*4 cm) with 9 wooden pegs (0.6 cm in diameter). Participants on sitting were instructed to place and remove all 9 pegs one at a time as quickly as possible at mid-chest level; order of placement was not determined [26]. The score was the total time in seconds to complete the task. Timing began on contact with the first peg and ended with return of the final peg to the dish. The shortest time of two trials for each hand was recorded.

Figure 4. Wooden nine-hole pegboard test

Statistical Analysis

Simple descriptive statistics were used to characterize the samples and the distribution of variables. Data are presented as mean ± standard deviation (SD) for continuous variables including age, hand function test parameters, and all electrophysiological parameters. All clinical and electrophysiological parameters were analyzed using the Wilcoxon, paired-t test according to CTS presence. One-way analysis of variance (one-way ANOVA) was used to compare average values among age levels and the grades of CTS. χ^2 tests were used for categorical variables.

Pearson's correlation analysis was used to assess the relationships among clinical and electrophysiological parameters, respectively. Spearman correlation analysis was used to assess the relationships between non-parametric values.

Multivariate linear regression analysis using backward selection linear regression model was employed to determine strong predictors in NCS for each clinical functional outcome measure.

All statistical analysis was performed using the SP statistical package ver. 20.0

(SPSS Inc.®, Chicago, IL, USA). A statistically significant difference was considered with a p-value of < 0.05.

RESULTS

General characteristics of the participants and tested hands

Average age of the 208 participants was 57.3 ± 9.5 years and 74.0% (n=154) of the patients were female. Of the 404 participating tested hands, the number of female gender and right side in tested hands were 303 (75.0%) and 205 (50.7%). The 404 tested hands were divided into six groups based on age: (a) 20–29 years (n=24); (b) 30-39 years (n=44); (c) 40-49 years (n=57); (d) 50-59 years (n=130); (e) 60-69 years (n=97); (f) ≥ 70 years (n=52).

Comparison of the parameters of hand function and electrophysiological findings according to age groups and gender

The mean values of the parameters of hand function test and electrophysiological findings among age groups were indicated in Table 2. There were statistical differences of all parameters, except for the distal latency of ulnar CMAP among age group. Table 3 showed the parameters of hand function test according to gender and age span, respectively. In all age span groups, grip strength and KP strength were significantly higher in male, compared with female. There was no significant gender-specific difference of 9HPT.

Table 2. Parameters of Hand function tests and Electrophysiological Findings among Age Groups

Age group	Grip Strength (kg)	KP Strength (kg)	9HPT (sec)	Median SNAP		Ulnar SNAP		Median CMAP			Ulnar CMAP		
				DL (ms)	Amp (uV)	DL (ms)	Amp (uV)	DL (ms)	Amp (mV)	Vel (m/s)	DL (ms)	Amp (mV)	Vel (m/s)
20-29 (n=24)	32.5±13.4	7.4± 2.1	15.2±2.1	3.0±0.2	57.3±16.8	3.1±0.2	36.1±13.7	3.1±0.2	10.8±2.1	58.5±4.0	2.5±0.2	11.7±1.9	65.±3.5
30-39 (n=44)	30.1±7.2	7.2±1.7	16.1±1.9	3.2±0.6	46.5±16.6	3.1±0.2	29.4±9.5	3.2±0.6	10.9±1.8	58.3±3.8	2.4±0.2	10.5±1.8	64.±4.1
40-49 (n=57)	26.1±6.8	6.4±1.8	17.3±3.0	3.2±1.3	32.4±17.9	3.1±0.2	26.3±9.5	3.9±1.4	9.3±3.0	54.0±3.7	2.6±1.1	11.0±2.5	66.±6.2
50-59 (n=130)	22.0±6.8	6.0±1.7	17.8±2.7	3.6±1.6	24.2±17.2	3.1±0.2	23.7±9.7	4.1±1.5	8.7±3.0	52.5±9.4	2.5±0.3	10.3±1.8	63.±4.3
60-69 (n=97)	22.9±7.6	6.5±1.7	19.2±2.8	3.7±1.2	21.5±9.4	3.2±0.2	18.6±5.7	3.7±1.2	8.7±3.0	50.9±11.3	2.6±0.2	10.0±1.6	62.±5.0
≥70 (n=52)	18.5±4.8	5.5±1.4	20.7±4.9	3.6±1.1	20.3±9.4	3.3±0.2	16.8±3.7	4.0±1.3	7.8±2.4	51.4±8.7	3.4±4.5	9.2±1.9	62.±3.2
p-value	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**	<0.001*	<0.001**	<0.001*	<0.001**	<0.001**	0.136	<0.001**	<0.001*

Values are presented as mean ± standard deviation (SD), *** p <0.01*

n, numbers; KP, key pinch; 9HPT, nine-hole pegboard test; kg, kilogram; sec, seconds; m/s, meter per second; SNAP, sensory nerve action potentials; CMAP, compound muscle action potentials; DL, distal latency; Amp, amplitude; Vel, velocity

Table 3. Parameters of Hand function tests according to Gender and Age Groups

Age group (M: F)	Grip Strength (kg)			KP Strength (kg)			9HPT (sec)		
	Male	Female	p-value	Male	Female	p-value	Male	Female	p-value
All (101:303)	33.8±7.9	20.5±5.0	<0.001**	8.5±1.6	5.6±1.2	<0.001**	18.2±4.3	18.1±3.0	0.753
20-29 (8:16)	47.8±9.5	24.9±6.8	<0.001**	9.9±1.1	6.2±1.2	<0.001**	15.2±2.1	15.0±2.1	0.409
30-39 (18:26)	37.2±3.9	25.1±4.2	<0.001**	8.8± 1.2	6.0±1.0	<0.001**	16.1±1.9	16.0±2.0	0.804
40-49 (16:41)	33.1±4.8	23.3±4.8	<0.001**	8.1±1.8	5.8±1.4	<0.001**	17.3±3.0	17.0±2.4	0.391
50-59 (19:111)	34.3±6.7	19.9±4.1	<0.001**	8.7±2.1	5.6±1.1	<0.001**	17.8±2.7	17.6±2.3	0.229
60-69 (30:67)	31.3±6.5	19.1±4.3	<0.001**	8.3±1.3	5.6±1.1	<0.001**	19.2±2.8	19.5±3.1	0.108
≥70 (10:42)	24.4±4.0	17.0±3.8	<0.001**	7.5±0.8	5.0±1.1	<0.001**	20.7±4.9	20.4±3.4	0.687

Values are presented as mean ± standard deviation (SD) or (numbers of male hands: numbers of female hands), *** p <0.01*

KP, key pinch; 9HPT, nine-hole pegboard test; kg, kilogram; sec, seconds

Comparison of hand function test between CTS group and control group

Baseline comparison between CTS group and control group showed no statistically significant differences in age (mean ages, 58.1±9.8 vs 56.5±9.2, $p=0.09$).

The parameters of hand function test were compared according to presence of CTS and gender in Table 4. The average values of grip strength and KP strength of CTS group were significantly lower than those of control group in all patients (21.4±6.4 vs 26.5±9.1 for grip strength, 5.9±1.7 vs 6.8±1.8 for KP strength, $p<0.01$**). The average values of grip strength and KP strength of CTS group revealed significantly lower than those of control group in both male and female gender (Table 4, $p<0.05$*)

The mean time of 9HPT of CTS group was significantly longer than that of control group (19.1±3.7 vs 17.0±2.6, $p<0.01$**) in all patients. And the mean time of 9HPT of CTS group was significantly longer than that of control group in both male and female gender (Table 4).

Table 4. Comparison of General Characteristics and Hand Function Tests between Carpal Tunnel Syndrome Group and Control Group in All Patients and Both Genders

	All patients			Male			Female		
	CTS (n=208)	Control (n=196)	p-value	CTS (n=42)	Control (n=59)	p-value	CTS (n=166)	Control (n=137)	p-value
Grip strength (kg)	21.4±6.4	26.5±9.1	<0.001**	29.6±6.0	36.8±7.7	<0.001**	19.4±4.7	21.9±5.0	<0.001**
KP strength (kg)	5.9±1.7	6.8±1.8	<0.001**	8.0±1.8	8.9±1.3	0.006**	5.4±1.2	5.9±1.1	0.001**
9HPT (sec)	19.1±3.7	17.0±2.6	<0.001**	19.5±5.4	17.2±3.0	0.015*	19.0±3.1	16.9±2.4	<0.001**

Values are presented as mean ± standard deviation $*p < 0.05$, $**p < 0.01$

CTS, carpal tunnel syndrome; n, numbers; KP, key pinch; 9HPT, nine-hole pegboard test; kg, kilogram; sec, seconds

Comparison of electrophysiological parameters between CTS group and control group

Mean values of electrophysiological parameters including the distal latency and amplitude of median & ulnar SNAP, the distal latency, and amplitude & velocity of median & ulnar CMAP according to presence of CTS were shown in Table 5.

Distal latency of median SNAP was significantly prolonged in CTS group compared to control group (4.4±1.0 vs 3.1±0.2, $p<0.001$**) and amplitude of median SNAP was significantly decreased in CTS group compared to control group (15.4±19.9 vs 42.6±14.6, $p<0.001$**). Distal latency of median CMAP was significantly prolonged in CTS group compared to control group (4.6±1.2 vs 3.1 ±0.3, $p<0.001$**), amplitude of median CMAP was significantly decreased in CTS group compared to control group (7.9±3.2 vs 10.3 ±1.9, $p<0.001$**) and velocity of median CMAP was significantly slowed in CTS group compared to control group (50.4±11.1 vs 56.1±3.8, $p<0.001$**). For ulnar SNAP, amplitude was significantly decreased in CTS group compared to control group (19.1±6.8 vs 27.4±10.9, $p<0.001$**).

Table 5. Comparison of Parameters of Electrophysiological Findings between Carpal Tunnel Syndrome Group and Control Group

Nerve conduction studies	**CTS (n=208)**	**Control (n=196)**	**p-value**
Median SNAP			
Distal latency (ms)	4.4±1.0	3.1±0.2	<0.001**
Amplitude (μV)	15.4±9.9	42.6±14.6	<0.001**
Median CMAP			
Distal latency (ms)	4.6±1.2	3.1±0.3	<0.001**
Amplitude (mV)	7.9±3.2	10.3±1.9	<0.001**
Velocity (m/s)	50.4±11.1	56.1±3.8	<0.001**
Ulnar SNAP			
Distal latency (ms)	3.2±0.2	3.1±0.2	0.021*
Amplitude (μV)	19.1±6.8	27.4±10.9	<0.001**
Ulnar CMAP			
Distal latency (ms)	2.6±0.6	2.7±2.4	0.73
Amplitude (mV)	10.1±1.9	10.4±2.0	0.12
Velocity (m/s)	63.1±4.5	64.2±4.8	0.05

Values are presented as mean ± standard deviation (SD), $*p < 0.05$, $**p < 0.01$

CTS, carpal tunnel syndrome; n, numbers; SNAP, sensory nerve action potentials; CMAP, compound muscle action potentials; ms, millisecond; μV, microvolt; mV, millivolt; m/s, meter per second

Comparison of the parameters of hand function and electrophysiological findings according to the grade of CTS

Patents with CTS were divided into three groups according to the electrophysiological grade and the number of each group was 104 in mild, 73 in moderate and 31 in severe grade. The parameters of hand function test including grip strength, KP strength and 9HPT differed significantly among the grades of CTS. All degree of CTS groups revealed significant difference, in parameters of hand function tests and variables of median SNAP & CMAP and distal latency & amplitude of ulnar SNAP, compared with control (Table 6). However, post hoc Bonferroni comparisons of distal latency in ulnar SNAP did not show significant difference between control and each CTS grade.

Table 6. Comparison of Parameters of Hand Function Tests and Electrophysiological Findings according to Grade of Carpal Tunnel Syndrome

	Control (n=196)	Mild (n=104)	Moderate (n=73)	Severe (n=31)	p-value
Grip strength (kg)	26.5±9.1	21.6±6.3	21.7±7.2	19.7±4.7	<0.001**
KP strength (kg)	6.8±1.8	5.9±1.5	6.2±1.8	5.1±1.5	<0.001**
9HPT (sec)	17.0±2.6	18.9±3.9	18.8±2.6	20.8±4.8	<0.001**
Median SNAP					
Distal latency (ms)	3.1±0.2	3.9±0.3	4.9±1.1	6.4±0.8	<0.001**
Amplitude (μV)	42.6±14.6	22.1±7.7	12.0±5.7	1.1±2.5	<0.001**
Median CMAP					
Distal latency (ms)	3.1±0.3	3.8±0.3	5.0±0.4	7.2±1.3	<0.001**
Amplitude (mV)	10.3±1.9	9.4±2.1	7.9±2.5	2.9±2.7	<0.001**
Velocity (m/s)	56.1±3.8	53.5±3.5	52.8±5.3	34.8±21.4	<0.001**
Ulnar SNAP					
Distal latency (ms)	3.1±0.2	3.2±0.2	3.1±0.2	3.2±0.2	0.015*
Amplitude (μV)	27.4±10.9	19.1±7.3	19.3±5.5	18.5±8.3	<0.001**
Ulnar CMAP					
Distal latency (ms)	2.7±2.4	2.7±0.8	2.5±0.3	2.5±0.2	0.912
Amplitude (mV)	10.4±2.0	10.0±2.1	10.0±1.7	10.6±1.6	0.24
Velocity (m/s)	64.2±4.8	62.6±4.8	63.7±4.3	62.9±4.3	0.146

Values are presented as mean ± standard deviation (SD), *$p < 0.05$, **$p < 0.01$

N, numbers of tested hand; CTS, carpal tunnel syndrome; SNAP, sensory nerve action potentials; CMAP, compound muscle action potentials; kg, kilogram; sec, seconds; ms, millisecond; μV, microvolt; mV, millivolt; m/s, meter per second

Correlation of general and clinical characteristics and electrophysiological parameters

Table 7-9 and Figure 5 showed the correlation of age, gender, the parameters of hand function tests, and electrophysiological findings.

Grip strength was significantly correlated with age (r=-0.437**), male gender (r=0.647**), KP strength (r=0.814**), 9HPT (r=-0.270**), amplitude of median SNAP (r=0.217**), distal latency (r=-0.163**) & amplitude (r=0.387**) & velocity (r=0.185**) of median CMAP, and amplitude (r=0.247**) of ulnar CMAP.

KP strength was significantly correlated with age (r=-0.239**), male gender (r=0.643**), grip strength (r=0.814**), 9HPT (r=-0.235**), amplitude of median SNAP (r=0.130**), amplitude (r=0.383**) & velocity (r=0.211**) of median CMAP, and amplitude (r=0.166**) of ulnar CMAP.

9HPT correlated significantly with age (r=-0.437**), grip strength (r=-0.270**), KP strength (r=-0.235**), amplitude (r=-0.408**) of median SNAP, amplitude (r=-0.362**) & velocity (r=-0.404**) of median CMAP, distal latency (r=0.225**) & amplitude (r=-0.365**) of ulnar SNAP and amplitude (r=-0.206**) of ulnar CMAP.

Table 7. Correlation of Grip Strength with Electrophysiological Parameters

		Grip strength	
		Correlation coefficients (r)	p-value
Gender		-0.647	<0.001**
Age		-0.437	<0.001**
KP strength		0.814	<0.001**
9HPT		-0.270	<0.001**
Median SNAP	Latency	-0.041	0.416
	Amplitude	0.217	<0.001**
Median CMAP	Latency	-0.163	0.001**
	Amplitude	0.387	<0.001**
	Velocity	0.185	<0.001**
Ulnar SNAP	Latency	0.033	0.578
	Amplitude	0.013	0.082
Ulnar CMAP	Latency	0.015	0.793
	Amplitude	0.247	<0.001**
	Velocity	0.008	0.894

*** p<0.01*

KP, key pinch; 9HPT, nine-hole pegboard test; SNAP, sensory nerve action potentials; CMAP, compound muscle action potentials

Table 8. Correlation of Key Pinch Strength with Electrophysiological Parameters

		KP strength	
		Correlation coefficients (r)	p-value
Gender		-0.643	<0.001**
Age		-0.239	<0.001**
Grip strength		0.814	<0.001**
9HPT		-0.235	<0.001**
Median SNAP	Latency	0.049	0.323
	Amplitude	0.130	0.009**
Median CMAP	Latency	-0.066	0.187
	Amplitude	0.383	<0.001**
	Velocity	0.211	<0.001**
Ulnar SNAP	Latency	0.078	0.184
	Amplitude	-0.094	0.108
Ulnar CMAP	Latency	0.030	0.604
	Amplitude	0.166	0.004**
	Velocity	0.007	0.899

*** $p<0.01$*

KP, key pinch; 9HPT, nine-hole pegboard test; SNAP, sensory nerve action potentials; CMAP, compound muscle action potentials

Table 9. Correlation of Hand Dexterity with Electrophysiological Parameters

		9HPT	
		Correlation coefficients (r)	p-value
Gender		0.002	0.975
Age		0.437	<0.001**
Grip strength		-0.270	<0.001**
KP strength		-0.235	<0.001**
Median SNAP	Latency	0.038	0.441
	Amplitude	-0.408	<0.001**
Median CMAP	Latency	0.068	0.172
	Amplitude	-0.362	<0.001**
	Velocity	-0.404	<0.001**
Ulnar SNAP	Latency	0.225	<0.001**
	Amplitude	-0.365	<0.001**
Ulnar CMAP	Latency	0.052	0.374
	Amplitude	-0.206	<0.001**
	Velocity	-0.086	0.142

*** $p<0.01$*

KP, key pinch; 9HPT, nine-hole pegboard test; SNAP, sensory nerve action potentials; CMAP, compound muscle action potentials

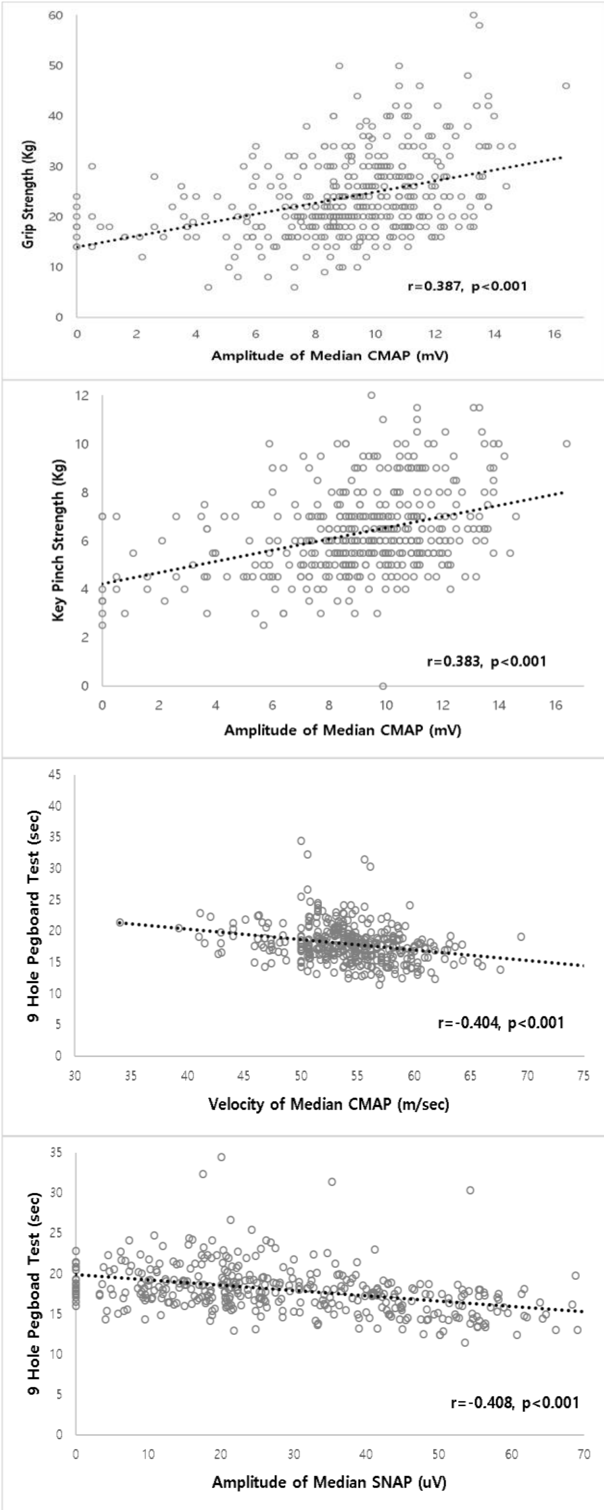

Figure 5. Correlation between Parameters of Hand Function Tests and Electrophysiologic test of Median Nerve

Multivariate regression analysis of general and clinical characteristics and electrophysiological parameters

Multivariate regression analysis identified amplitude of median CMAP ($p<0.001$**), age ($p<0.001$**) and male gender ($p < 0.001$**) as independent predictors of grip strength (adjusted $R_2 = 0.679$), and amplitude of median CMAP ($p<0.001$**) and male gender ($p < 0.001$**) as independent predictors of KP strength (adjusted $R_2 = 0.603$). Velocity of median CMAP ($p < 0.001$**), amplitude of median SNAP ($p=0.037$*) and age ($p < 0.001$**) were identified as independent predictors of 9HPT (adjusted $R_2 = 0.329$).

DISCUSSION

This study confirmed that the electrophysiological parameters, especially median motor nerve were strong predictors of hand function tests including hand grip strength, KP strength and dexterity in hand OA patients. Furthermore, the participants with CTS in this study revealed significant deterioration of hand grip & pinch strength and steadiness of hand dexterity which is compatible with recent reports [27-28].

Prevalence of hand OA ranged from 8.0 to14.9% in previous studies [2, 29-30] with various diagnostic criteria including the radiologic criteria, clinical symptoms, and the American College of Rheumatology guideline respectively or in combination. The radiologic findings are less important in diagnosing hand osteoarthritis as radiologic erosions are highly prevalent in hand osteoarthritis, which makes it difficult to distinguish OA from inflammatory arthritis and radiologic findings do not reflect true prevalence of symptomatic hand OA [20]. In addition, the ACR suggested the criteria for hand OA in two types: the traditional format with 94% of sensitivity and 87% of specificity *vs* the classification tree format with 92% of sensitivity and 98% of specificity. As the tree format were more difficult and complicated to be applied, ACR recommended the traditional format in need of simplicity and the classification tree format if both high sensitivity and high specificity are essential [20].

Hand strength plays a crucial role in carrying out activities of daily living and power grip and key pinch (or lateral pinch) are the most common type of hand strength assessment [25]. In addition, hand grip strength is an objective indicator to set the treatment goal and to evaluate the outcome of intervention [31], and is also strong predictor of muscular strength, nutritional status, disability and multimorbidity [32-33]. Also, 9HPT is a reliable test for finger dexterity which greatly impacts a person's performance in daily activities, completing work related tasks, and independent daily living (ADL) [26].

However, power grip or lateral pinch uses both intrinsic and extrinsic muscles of the hand, most of which are innervated by the proximal median nerve, the ulnar or radial nerve [34] and also may be compensated by synergistic muscles such as the flexor digitorum superficialis and flexor digitorum profundus instead of weakened APB or opponens pollicis. Thus, there is some controversy about the significance of hand function tests for assessing severity of CTS or progress after surgical decompression [10, 27].

Interestingly, while the distal latency of median sensory and motor nerve is generally used for diagnostic criteria of CTS, our results demonstrated that the amplitude of median CMAP was a strong predictor of hand strength and the velocity of median CMAP & the amplitude of median SNAP were strong predictors of hand dexterity. The amplitude of CMAP and SNAP reflects the summated axon of depolarized motor and sensory nerves and the velocity of CMAP reflect the velocity of the fastest conducting nerve fiber. Thus, our results confirmed the value of the nerve conduction studies as an objective assessment method in hand OA when the accurate functional assessment could not be possible due to severe pain or compensation. Particularly, it is noteworthy that the amplitude of ulnar SNAP was decreased in CTS group. The abnormalities of the ulnar sensory nerve conduction in CTS were observed in various researches and there was significant correlation of ulnar nerve abnormality with the severity of median nerve impairment [35].

Additionally, we also proposed the values of comprehensive functional outcome measure according to age span and gender in persons with hand OA. Hand strength and dexterity tended to decrease with age, and these were supported by the findings about the normative values in healthy Koreans [31, 36].

All parameters of nerve conduction studies except distal latency of ulnar CMAP showed significant change with age as shown in Table 2; the distal latency prolonged and the amplitude and velocity decreased with age, which are also similar to previous expert opinions [37].

As functional impairment in hand OA may be as severe as in rheumatoid arthritis, assessment and monitoring of the hand function are recommended in the systematic review [38]. In this study, we revealed significant relationship between hand function and electrophysiological findings. In addition, carpal tunnel syndrome also aggravated hand and finger strength and dexterity in patients with hand OA and these findings were significantly related with objective electrophysiological abnormality. Therefore, electrophysiological study may be useful ancillary tool in clinical field managing the patients with hand OA.

Mean hand grip strength of the dominant hand in men and women was 39.5kg and 24.2kg and the cut-off values for weak hand grip strength were <28.9 and <16.8kg in men and women, respectively in Korean adults [31]. In this study, average hand grip strength in male and female participants were 33.8 kg and 20.5kg, respectively, which revealed lower hand grip strength than those of average Korean adults but higher than the criteria of sarcopenia. Further studies might evaluate the appropriate criteria of sarcopenia in patients with hand OA.

On the other hand, it is important to identify the functional impairment and sensorimotor deficit in prescribing proper rehabilitation program. Previous studies reported that blood flow restriction training [39] and tactile discrimination training [40] could improve strength, function and pain and might increase patients' ADLs and QoL [7] in patients with hand OA. Therefore, comprehensive rehabilitation program should compose of sensory retraining as well as motor control and further study might be needed to evaluate its beneficial effects on patients' functional status, ADLs and QoL.

There are several limitations in this study. First, the study design was cross-sectional, so its association with the severity or prognosis of disease could not be investigated. Second, the control group was mainly composed of patients with osteoarthritis and their findings showed deficits of hand function tests, compared with normative values reported in previous study. So further studies should be planned to compare with healthy controls Third, we enrolled low number of male gender (male: female ratio 1:3) and could not perform subgroup analysis such as hand dominance, despite of relatively large population of patients with hand OA. But because CTS and hand OA showed higher prevalence in female gender, it might reflect the actual clinical situation of disease. Forth, the quantitative evaluation of pain severity or OA severity was not performed, because they might be considered subjective. Finally, the direct effects of OA or CTS on basic or instrumental ADL were not assessed.

To the best of our knowledge, our study is the first to analyze the correlation of hand strength and dexterity with various electrophysiological parameters using a weighted polynomial regression in relatively large number of participants, to compare according to age span, gender, and presence of CTS and to confirm the value of electrophysiological study as an ancillary test of hand dysfunction in patients with hand OA.

CONCLUSION

The results of the present study confirmed a strong relationship between the parameters of the nerve conduction studies and hand function tests in patients with hand OA. In addition, CTS induced significant decrease in strength and performance of affected hand in patients with hand OA. Therefore, the nerve conduction study may be effective test in hand OA that suggests the necessity of the rehabilitation program for functional recovery.

Although there are numerous evidences that the functional impairment limit individuals' ability to perform ADL, further longitudinal studies might be warranted to confirm its effect on the progression or prognosis of OA or CTS.

국문 초록

연구배경: 손의 퇴행성관절염은 흔한 퇴행성 질환으로, 손기능의 저하로 인해 일상생활동작 수행에 제한이 있어 삶의 질이 저하될 수 있음에도 불구하고 임상적으로나 학문적으로 그 중요성은 간과되어왔다. 손의 기능저하는 지각운동 결핍, 통증, 불용성 근위축, 노화, 그리고 동반되는 신경질환 등과 관련될 수 있다.

이 연구의 목적은 손의 퇴행성관절염 환자에서 손기능 검사와 신경전도검사의 결과 간의 관계를 알아보고 수근관증후군의 동반여부에 따른 손기능과 신경검사의 항목들의 차이를 알아보고자 한다.

방법: 2015년 6월부터 2016년 6월까지 손의 퇴행성관절염이 있는 환자들(208명, 404손)을 대상으로 손기능 검사와 신경전도검사를 실시하였다. 손기능 검사는 손의 악력과 측면 핀치의 강도의 측정과 9홀페그보드 검사를 시행하였고 신경전도검사는 상지의 운동신경과 감각신경의 잠시, 진폭, 속도를 측정하였다. 나이, 성별 그리고 수근관증후군의 유무와 중증도에 따라 신경전도검사 항목과 손 기능 검사 결과들을 비교하였고 상관분석과 다변량 분석을 통해 변수들 간의 관계를 확인하였다.

결과: 척골 운동신경의 잠시를 제외한 모든 신경검사 항목들과 손기능 항목들은 나이에 따라 통계적으로 유의한 차이가 있었다. 그리고 남성이 여성보다 손 악력과 측면 핀치 강도가 유의하게 강했으나 9홀페그보드 검사는 차이가 없었다. 또한 수근관증후군이 있는 군에서 대조군보다 손 악력과 측면 핀치 강도는 유의하게 강했으며, 9홀페그보드 검사 수행시간은 유의하게 길었다. 손기능 검사 항목들은 나이, 정중 감각신경의 진폭, 정중 운동신경의 진폭, 척골 운동신경의 진폭과 유의한 상관관계를 보였다. 또한, 다변량 회귀분석을 통해 신경전도검사의 정중 운동신경의 진폭, 나이 그리고 남성을 손 악력의 독립적인 예측변수(adjusted R_2 = 0.679)로, 정중운동신경의 진폭과 남성을 측면 핀치의 독립적인 예측변수로 확인하였고(adjusted R_2 = 0.603), 정중 운동신경의 속도, 정중 감각신경의 진폭과 나이는 9홀페그보드 검사의 독립적인 예측변수이었다 (adjusted R_2 = 0.329).

결론: 손 퇴행성관절염 환자에서 신경전도검사는 손의 기능과 유의한 관련이 있고, 특히 수근관증후군이 동반된 경우에 손기능이 더 저하되므로 신경전도검사는 유용한 검사이며, 조기 재활프로그램을 제공하여 삶의 질 향상에 기여할 수 있다.

핵심단어: 손 퇴행성관절염, 신경전도검사, 수근관증후군, 손기능, 악력

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APPENDIX

Appendix 1. Sensitivity, Specificity, and AUC of the Various Electrophysiological Diagnostic Tests of Median Nerve in CTS Patients [12]

Parameters	Abnormality Criteria	Sensitivity(%) (95%CI)	Specificity(%) (95%CI)	AUC(%) ±SE
SDL (ms)	≥3.6	87.3 (83.6-89.1)	91.2 (89-95.6)	95.4±1.1
DML (ms)	≥4.2	70.3 (65.6-71.9)	100 (96.5-100)	95±2.3
SNCV (m/s)	≤40	97.2 (94.4-98.6)	90.4 (88.5-94.2)	98±1.2
RL (ms)	>2.37	85.9 (84.4-87.5)	89.9 (89-91.1)	94.1±2.5
M-U CMAP	>0.95	84.0 (82.6-85.1)	89.9 (89-91.1)	94.9±1.3
M-U SNAP	>0.55	90.5 (88.1-93.4)	93.7 (90.2-95.6)	95.4±1.8

SDL=Sensory distal latency, DML=Distal motor latency, SNCV=Median sensory nerve conduction velocity, RL=Residual latency, M-U CMAP=Median-ulnar DML difference, M-U SNAP=Median-ulnar SDL difference, CTS=Carpal tunnel syndrome, AUC=Area under curve, SE=Standard error, CI=Confidence interval

Appendix 2. Classification Criteria for Osteoarthritis of the Hand, Traditional Format* [20]

Hand pain, aching, or stiffness
and
3 or 4 of the following features:
Hard tissue enlargement of 2 or more of 10 selected joints
Hard tissue enlargement of 2 or more DIP joints
Fewer than 3 swollen MCP joints
Deformity of at least 1 of 10 selected joints

*The 10 selected joints are the second and third distal interphalangeal (DIP), the second and third proximal interphalangeal, and the first carpometacarpal joints of both hands. The classification method yields a sensitivity of 94% and a specificity of 87%. MCP= metacarpophalangeal.

Appendix 3. Classification Criteria for Osteoarthritis of the Hand, Classification Tree Format* [20]

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1. hand pain, aching, or stiffness

and

2. Hard tissue enlargement of 2 or more of 10 selected joints

and

3. Fewer than 3 swollen MCP joints

and either

4a. Hard tissue enlargement of 2 or more DIP joints

or

4b. Deformity of 2 or more of 10 selected joints

---

* The second and third distal interphalangeal (DIP) joints may be counted in both item 2 and item 4a. The 10 selected joints are the second and third DIP, the second and third proximal interphalangeal, and the first carpometacarpal joints of both hands. This classification method yields a sensitivity of 92% and a specificity of 98%.

Appendix 4. Severity of Carpal Tunnel Syndrome by Electrodiagnostic Criteria [22]

Severity	Sensory NCS	Motor NCS	APB Needle EMG
Mild At least 3 of the following Sensory and motor nerve conduction	1. 14cm wrist stimulation peak latency>3.7ms 2. 14cm wrist stimulation, the peak latency proximal 7cm >distal 7cm 3.. Transcarpal 5cm short-segment latency (proximal latency-distal palm latency): onset>1.3msec: peak>1.5msec 4. 14cm SNAP amplitude: 16-20uV 5. Conduction block greater than 50% in wrist palm stimulation If 14cm stimulation amp≥ 20uV	6. Distal latency ＞4.2ms 7.CMAP amplitude: 4.1-4.5mV	Normal
Moderate Mild PLUS at least 2 of the following	1. Wrist stimulation SNAP amplitude 6-15uV 2. Conduction block greater than 50% at wrist & palm stimulation If SNAP ≥ 10uV with 14cm wrist stimulation	3. CMAP amplitude 2.1-4mV	4. Fibrillation (+) 5. Abnormal MUAP with intermediate interference patterns
Severe Moderate PLUS:	1. SNAP amplitude ≤ 5uV	2. CMAP amplitude ≤ 2mV	3. Fibrillation (+) 4. Abnormal MUAP with discrete activities or single unit patterns

1. Median nerve sensory conduction study with III digit recording and antidromic stimulation
2. Median nerve motor conduction study with abductor pollicis brevis (APB) muscle recording and 8 cm proximal stimulation at wrist
3. Motor CTS: Abnormal nerve conduction limited to only distal median motor nerve (wrist stimulation-APB recordings)

Appendix 5. Hand Grip Strength according to Age in Males [31]

Age(yr)	Right Hand Grip Strength (kg)		Left Hand Grip Strength (kg)		Dominant Hand Grip Strength (kg)	
	Mean(SD)	95%CI	Mean(SD)	95%CI	Mean(SD)	95%CI
10-14	23.1(8.7)	22.2-24.1	21.9(8.0)	21.1-22.7	23.2(8.8)	22.3-24.1
15-19	36.8(6.8)	36.0-37.5	35.0(6.7)	34.3-35.8	36.7(7.6)	35.8-37.6
20-24	40.0(7.5)	38.9-41.1	37.9(7.4)	36.9-38.9	40.1(7.6)	39.0-41.1
25-29	42.1(7.2)	41.1-43.1	40.1(7.2)	39.1-41.2	41.8(7.6)	40.7-42.8
30-34	44.4(7.6)	43.3-45.4	42.1(7.3)	41.1-43.1	44.2(8.2)	430.-45.4
35-39	44.7(.7.1)	43.8-45.6	42.5(6.9)	41.6-43.4	44.7(7.3)	43.8-45.6
40-44	44.1(6.9)	43.3-45.0	42.4(6.8)	41.6-43.3	44.0(7.6)	43.1-45.0
45-49	42.4(6.0)	41.6-43.3	41.1(5.8)	40.4-41.9	42.5(6.1)	41.7-43.3
50-54	41.1(6.3)	40.3-41.9	39.8(6.0)	39.0-40.5	41.1(6.2)	40.3-41.9
55-59	39.1(6.6)	38.3-40.0	37.9(6.2)	37.1-38.6	39.3(6.5)	38.4-40.1
60-64	38.2(6.3)	37.3-39.1	36.7(6.3)	35.8-37.6	38.2(6.4)	37.3-39.1
65-69	35.8(5.7)	34.9-36.7	34.5(5.6)	33.7-35.4	35.6(6.3)	34.7-36.6
70-74	32.1(6.1)	31.0-33.1	31.2(5.6)	30.1-32.2	32.1(6.7)	30.9-33.3
75-79	29.4(6.8)	28.0-30.7	28.9(6.3)	27.6-30.1	29.4(6.8)	28.1-30.7
≥80	26.2(6.8)	24.6-27.7	25.5(6.1)	24.1-26.8	26.2(6.8)	24.7-27.7

kg=kilogram; SD=standard deviation, CI=confidence interval

Appendix 6. Hand Grip Strength according to Age in Females [31]

Age(yr)	Right Hand Grip Strength (kg)		Left Hand Grip Strength (kg)		Dominant Hand Grip Strength (kg)	
	Mean(SD)	95%CI	Mean(SD)	95%CI	Mean(SD)	95%CI
10-14	18.8(5.1)	18.2-19.4	17.7(4.6)	17.1-18.3	18.8(5.0)	18.3-19.4
15-19	24.1(4.5)	23.5-24.7	22.7(4.4)	22.1-23.3	24.2(4.5)	23.6-24.8
20-24	24.2(4.6)	23.5-24.8	22.8(4.6)	22.2-23.4	24.2(4.6)	23.6-24.8
25-29	24.3(4.4)	23.7-24.9	22.8(4.4)	22.2-23.5	24.4(4.4)	23.8-25.0
30-34	25.8(4.6)	25.2-26.3	24.2(4.4)	23.7-24.8	25.8(4.6)	25.3-26.4
35-39	26.5(4.5)	26.0-27.0	25.1(4.3)	24.6-25.6	26.5(4.5)	26.0-27.0
40-44	25.8(4.5)	25.3-26.3	24.6(4.2)	24.1-25.1	25.8(4.7)	25.3-26.3
45-49	25.7(4.4)	25.2-26.2	24.0(4.3)	23.5-24.5	25.6(4.6)	25.1-26.2
50-54	25.5(4.2)	25.0-26.1	24.2(4.1)	23.7-24.7	25.6(4.3)	25.0-26.1
55-59	24.2(4.2)	23.6-24.7	22.6(4.0)	22.1-23.1	24.2(4.2)	23.6-24.7
60-64	23.5(4.4)	22.8-24.2	21.8(3.7)	21.3-22.4	23.6(4.3)	22.9-24.2
65-69	22.3(4.7)	21.4-23.1	21.1(4.1)	20.4-21.8	22.3(4.9)	21.5-23.1
70-74	20.7(4.7)	19.7-21.6	19.6(4.4)	18.7-20.5	20.5(4.8)	19.5-21.5
75-79	17.7(5.0)	16.5-18.9	17.0(4.8)	15.8-18.2	17.6(5.3)	16.3-18.9
≥80	14.6(4.2)	13.8-15.5	13.9(4.0)	13.1-14.7	14.6(4.2)	13.7-15.4

kg=kilogram; SD=standard deviation, CI=confidence interval