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Stiffness quantification of carpal tunnel structures during hand motion with shear wave elastography

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Introduction
Repetitive use of wrist and finger is well known cause of damage of the median nerve and the soft tissue around it and contribute to development of the carpal tunnel syndrome. The aim of this study is to unveil the stiffness variation of the structures in the carpal tunnel according to the hand and the wrist motions.

Materials and Methods
This study was designed as a prospective, cross-sectional study and 26 healthy volunteers were enrolled (Table 1). Target structures for shear wave velocity (SWV) measurement in the carpal tunnel were median nerve (MN), transverse carpal ligament (TCL), and tendon of flexor digitorum superficialis (FDS) and profundus (FDP). SWV measurement were done transversely at the carpal tunnel inlet (pisiform bone to scaphoid tubercle) of non-dominant hand in combination of the 2 wrist joint motions; wrist neutral and wrist extension(30°), and the 3 finger motions; finger neutral, finger grasp, and finger extension(30°) (Figure 1). Those six wrist-finger motion combinations were named A to F as follows; (A) wrist neutral (0°)–finger neutral (relaxed), (B) wrist neutral–finger grasp, (C) wrist neutral–finger extension, (D) wrist extension (30°)–finger neutral, (E) wrist extension–finger grasp, and (F) wrist extension–finger extension.

Results
SWV (SD, m/s) measured in different structures in the carpal tunnel from position A were as follows; MN 2.3 (0.5), FDS 2.9 (0.2), FDP 3.2 (0.3), and TCL 3.3 (0.4) (Table 2). SWV of position A were then compared with other five wrist-finger positions. MN and FDP showed significantly higher SWV (m/s) in position B to F than position A and in position D to F than A to C. FDS and TCL showed significantly higher SWV in wrist extension position than wrist neutral position and finger grasp and extension position than finger neutral position. SWV of the median nerve cross section area (CSA, mm2) showed no significance among all six positions.

Conclusions
Comparing stiffness among the all six wrist-finger joint motions shows that wrist and finger joint movement increases stiffness of the structures in carpal tunnel compared to

the wrist neutral-finger neutral position. Further study with large sample size and with carpal tunnel syndrome patients should be required to clarify these tendencies.

TABLE 1. Demographics of the participants

Sex, Male/Female(n and %)	20/6 (76.9/23.1)
Age (years, mean±SD) (range)	24.7±3.7 (19-38)
Height (cm, mean±SD) (range)	171.7±6.6 (157-185)
Weight (kg, mean±SD) (range)	69±11.8 (47-90)
Comorbidities (n and %)	
Atopic dermatitis	1/26 (3.8)
Asthma	1/26 (3.8)

TABLE 2. Ultrasonographic and ARFI parameters of the carpal tunnel structures according to the wrist-finger position

|	$Wrist_{neu}$-$Finger_{neu}$		$Wrist_{neu}$-$Finger_{grasp}$		$Wrist_{neu}$-$Finger_{ext}$		$Wrist_{ext}$-$Finger_{neu}$		$Wrist_{ext}$-$Finger_{grasp}$		$Wrist_{ext}$-$Finger_{ext}$		p-value
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
MN (m/s)	2.3	0.5	2.7	0.5	2.7	0.4	2.9	0.5	3.0	0.5	3.1	0.5	0.032
FDS (m/s)	2.9	0.2	3.1	0.4	3.2	0.4	3.3	0.4	3.4	0.6	3.4	0.4	0.084
FDP (m/s)	3.2	0.3	3.7	0.5	3.7	0.5	3.7	4.0	4.0	0.9	3.7	0.4	0.000*
TCL (m/s)	3.3	0.4	3.8	0.5	3.7	0.4	3.8	0.4	4.0	0.6	4.1	0.5	0.226
MN_CSA (mm^2)	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.285

* P value <0.05
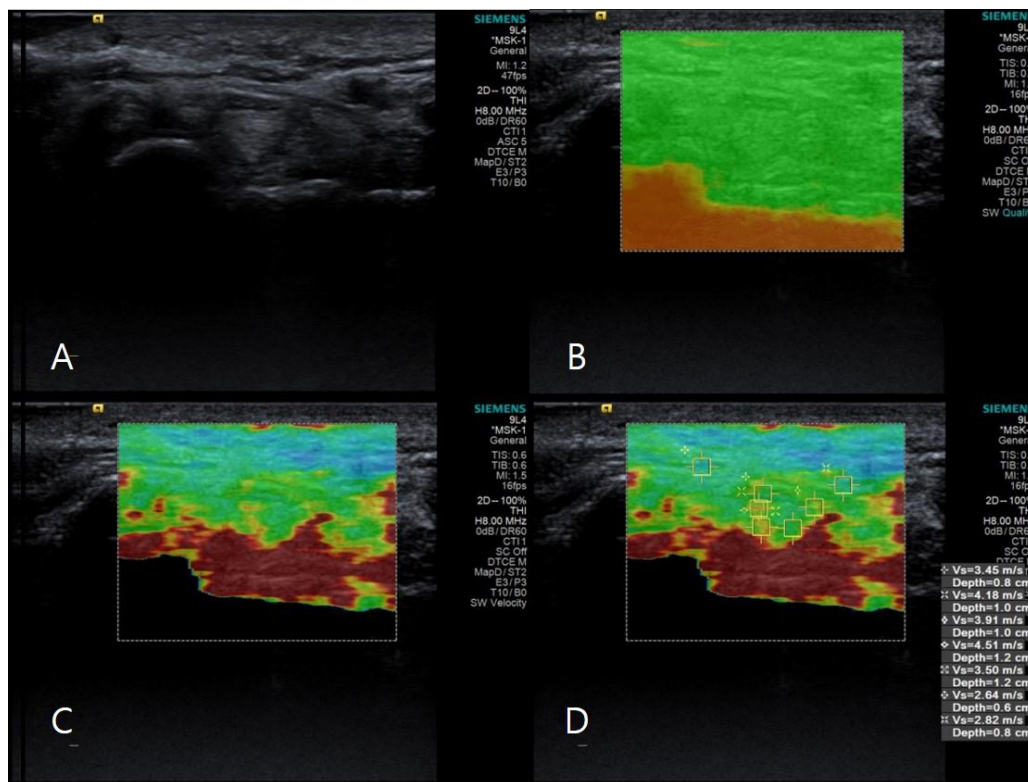
Figure 1. ARFI quantification method