Original Article

Electrodiagnostic reference data for sensory nerve conduction studies in Saudi Arabia

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ABSTRACT

الأهداف: إنشاء مرجع لقيم تخطيط الأعصاب الحسية الشائعة بالاستعانة بمجموعة من الأفراد الأصحاء في المجتمع السعودي.

المنهجية: تم تسجيل سعة كامن الفعل للعصب الحسي، سرعة التوصيل، ووقت الإستجابة القصوى. قياس العلاقة ما بين هذه المتغيرات والعوامل المصاحبة (العمر، الجنس، الطول، الوزن، ومؤشر كتلة الجسم) تم بإستخدام معامل إرتباط بيرسون. تم بعد ذلك استخلاص مرجع القيم بإستخدام أدنى نسبة مئوية تقديرية موثوقة تم استخراجها لسعة كامن الفعل للعصب الحسي وسرعة التوصيل. مرجع القيم لوقت الإستجابة القصوى تم استخراجها بإستخدام أقصى نسبة مئوية.

النتائج: تم إقامة تخطيط الأعصاب الحسية للأعصاب الطرفية العلوية والسفلية تباعاً على 127 و137 متطوع. كان العمر العامل الوحيد الذي احتاج الى تعديل عند تقدير سعة كامن الفعل للعصب الحسي. لهذا السبب، تم عمل نموذج تنبؤ لكل عصب. لم تحتاج النسبة المئوية التقديرية لكلاً من وقت الإستجابة القصوى وسرعة التوصيل إلى تعديل أي من العوامل المصاحبة. لذلك، تم جمعها لجميع الأفراد سويةً.

الخلاصة: مرجع قيم تخطيط الأعصاب الحسية كان مشابه لقيم الدول الأخرى. ومع ذلك، تم ملاحظة اختلافات بسيطة. هناك حاجة لدراسات إضافية مع التركيز على المسنين.

Objectives: To estimate reference data for the commonly performed sensory nerve conduction studies (NCS) using a cohort of healthy subjects from Saudi Arabia

Methods: This is a cross-sectional study conducted between May 2015, and June 2019. Sensory nerve action potential (SNAP) amplitude, conduction velocity (CV), and peak latency (PL) were recorded. Associations between these parameters and the covariates (age, sex, height, weight, and body mass index) were tested with Pearson correlations. Reference data were then derived using the lowest percentile that could be reliably determined for SNAP amplitude and CV. Reference data were derived using the highest percentile for PL.

Results: Upper and lower limb sensory NCS were performed in 127 and 137 participants, respectively. Age was the only covariate that required adjustment for estimation of SNAP amplitude. Therefore, a prediction model was generated for each nerve. Percentile estimation for PL and CV did not require adjustment for any of the covariates. Hence, it was derived for all the subjects pooled together.

Conclusion: The sensory NCS reference data were comparable to the data from other countries. However, minimal differences were observed. Further studies are required with a focus on the older age group.

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Nerve conduction studies (NCS) are commonly performed procedures during the diagnostic workup for peripheral nervous system disorders. Distinguishing normal NCS values from the abnormal values is a key to accurately interpreting the test, and to guiding further management. However, it requires comparison of patients' NCS values with an established reference. Moreover, NCS values could vary in healthy individuals. Intrinsic factors that might affect NCS values include temperature, age, height, weight, body mass index (BMI), sex, and handedness.[1-4] Conflicting evidence exists regarding the influence of ethnicity on the NCS values.[5-8] Electrodiagnostic laboratories may use different protocols including filter setting and stimulation distance. Therefore, it has been suggested that the individual laboratories generate reference data for their own NCS protocol.[9,10] However, it is a daunting process methodologically and statistically. In reality, most laboratories use reference data derived elsewhere, which is considered reasonable when the same technical standards as those from where the reference data were generated, are employed.[11,12] However, it might not be suitable to use the reference data derived from the Western populations for Arabs living the Gulf region. We are not aware of any NCS reference data published from Saudi Arabia until now for the commonly performed nerve conduction studies.

In the present study, we reported the reference data for sensory NCS parameters. This study aimed to estimate the reference data for the commonly tested sensory nerves in healthy Saudi Arabian adults, and to identify the influence of age, sex, height, weight, and BMI.

Methods.

Participants and setting. The study was conducted at King Saud University Medical City, Riyadh, Saudi Arabia between May 1, 2015 and June 30, 2019. The details of the inclusion and the exclusion criteria are listed in the recently published article about motor NCS reference data in the same journal.[13] We included healthy adults who had no known current or previous neurological diseases, systemic diseases, or neurological symptoms. Neurological examination was performed for participants aged ≥ 50 years to exclude asymptomatic sensory deficit. Participants were recruited from the clinic waiting areas. We focused on recruiting patients' family members, hospital staff, and medical students. Since the King Saud University Medical City is a tertiary hospital and accepts referral from the rural areas, a considerable number of the participants were from the rural areas and from different tribes.

NCS protocol. In our laboratory, NCS are performed following the standardized techniques published elsewhere.[3,14,15] A trained technician with more than 20 years of experience in the field performed all the studies. Dr. MHA and Dr. NMK assessed the quality of the studies and reviewed the NCS waveforms. All the sensory studies were performed antidromically with the exception of the mixed palmar study, which involved orthodromic recording. The median nerve was stimulated at the wrist between the tendons of the flexor carpi radialis and the palmaris longus and was recorded slightly distal to the metacarpo-phalangeal joint of D2 (index finger) and D4 (ring finger). The ulnar nerve was stimulated just lateral to the flexor carpi ulnaris tendon and was recorded just distal to the metacarpo-phalangeal joint of D4 and D5 (little finger). The superficial radial nerve was stimulated on the distal radius and was recorded at the base of the thumb over the anatomical snuffbox. The medial antebrachial cutaneous nerve (MAC) was stimulated at the midpoint between the biceps tendon and the medial epicondyle and was recorded on the medial side of the forearm. The lateral antebrachial cutaneous nerve (LAC) was stimulated just lateral to the distal biceps tendon and was recorded on the lateral side of the forearm. The sural nerve was stimulated slightly lateral to the midline of the calf muscle and was recoded posteroinferior to the lateral malleolus. The superficial fibular nerve was stimulated on the anterolateral part of the lower leg and was recorded between the tendon of the tibialis

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Table 1 - The characteristics of the study participants are identical to that listed in the recently published article for the motor NCS reference data.[13]

	Upper limb study (n= 127)	Lower limb study (n = 137)
Age (years)		
Mean ± SD	**31.9±10.4**	**33.7±11.1**
Range	20 – 65	20 – 66
20 – 29	64	60
30 – 39	31	36
40 – 49	25	28
50 - 59	5	10
≥ 60	2	3
Sex, n (%)		
Male	40 (31.5)	46 (33.6)
Female	87 (68.5)	91 (66.4)
Height (cm)		
Mean±SD	163.4±9.1	163±9.4
Range	131–189	131-189
Weight (kg)		
Mean±SD	72.0±15.8	74.3±17.9
Range	37–130	37-130
BMI		
Mean±SD	26.9±5.4	27.9±6.2
Range	15–50.8	15–50.8

Table 2 - Summary of the sensory NCS data presented as mean ± standard deviation.

Nerve	N	Absent	Amplitude (μV)	Peak latency (ms)	Conduction velocity (m/s)
Median sensory D2	118	0	61.6±20.3 (23 – 130)	3.0±0.23 (2.6 – 3.5)	62.0±4.9 (52 – 71)
Median sensory D4	109	0	32.6±11.3 (10 – 62)	3.1±0.25 (2.5 – 3.7)	59.5±5.4 (50 – 74)
Ulnar sensory D4	109	0	14.7±34.1 (2.0 – 92)	3.0±0.24 (2.4 – 3.6)	62.1±5.0 (52 – 74)
Ulnar sensory D5	118	0	53.0±17.9 (18 – 108)	3.0±0.26 (2.5 – 3.7)	61±5 (50 – 74)
Median mixed palmar	100	0	___	1.8±0.16 (1.4 – 2.1)	___
Ulnar mixed palmar	100	0	___	1.7±0.14 (1.3 – 2.1)	___
Radial sensory	111	0	49.2±12.9 (24 – 91)	2.1±0.21 (1.6 – 2.7)	67.6±7.6 (50 – 91)
Medial antebrachial sensory cutaneous	71	0	14.1±7.0 (4 – 42)	2.1±0.23 (1.7 – 2.8)	62.8±8.8 (48 – 94)
Lateral antebrachial sensory cutaneous	71	0	19.7±8.9 (4 – 44)	2.1±0.17 (1.4 – 2.5)	65±7.4 (49 – 83)
Sural	134	0	18.2±7.7 (4.0 – 53)	3.5±0.3 (2.5 – 4.5)	51.9±5.7 (40 – 70)
Superficial fibular	134	8 (6%)	15.7±8.6 (0.01 – 55)	3.3±0.3 (2.5 – 4.2)	56.9±6.3 (44 – 78)

D2 - index finger, D4 - ring finger, D5 - little finger

anterior and the lateral malleolus. A distance of 14 cm was maintained between the stimulating cathode and the recording electrode for the median, the ulnar, the superficial fibular, and the sural nerves. A distance of 10 cm was maintained for the superficial radial, the MAC, and the LAC. A distance of 4 cm was maintained between the recording and the reference electrodes for all the sensory nerves. For the mixed palmar orthodromic study, the ulnar and median nerves were stimulated over the medial and lateral sides of the palm, and were recorded 8 cm proximally over the anatomic sites of the ulnar and the median nerves, just proximal to the wrist joint, respectively. Hand temperature was maintained at ≥ 32 °C and foot temperature was maintained at ≥ 30°C. All the sensory nerve action potentials (SNAP) were measured after a supramaximal stimulation had been achieved. The recorded parameters included the SNAP onset-to-peak amplitude, the peak latency (PL), and the conduction velocity (CV).

Instrument setting. The NCS were performed using Nicolet Viking version 11.1 (VIASYS Healthcare Inc., USA). Low and high frequency filters were set at 20 Hz and 3 kHz, respectively. Sweep speed was set at 2 milliseconds/division (ms/div). Gain was set at 10 microvolts (μV)/div. The study was approved by the institutional review board at the King Saud University Medical City. Signed informed consent was obtained from all the participants

Analysis. Descriptive statistics were used to summarize the data. Pearson correlation coefficients were calculated to evaluate the correlations of age, sex, height, weight, and BMI with the SNAP amplitude, the PL, and the CV. Quantile regression analyses were employed on the log-transformed data to identify the covariates that significantly contributed to the variance in the SNAP amplitude and the CV for each nerve. The goal was to determine and adjust for the covariates that showed significant associations with the NCS parameters of the related nerves. The covariates with inconsistent statistical significance across the NCS parameters of the related nerves may have been subjected to numerical artifacts rather than variations in the biology.[16] A *p*-value <0.05 was considered statistically significant. We adjusted our reference data for age as recommended by the Normative Data Task Force (NDTF) of the American Association of Neuromuscular and Electrodiagnostic Medicine.[12] We computed the third percentile for the SNAP amplitude and the CV, and the 97th percentile for PL. The 95% confidence intervals for these percentiles were generated to provide estimates of the upper and the lower reference limits, as deemed appropriate. Data were analyzed using Stata software version 12 (Stata Corp., College Station, Texas, USA).

Results. Upper and lower limb sensory NCS were performed in 127 and 137 participants, respectively. The number of participants was variable for each nerve. The characteristics of the study participants are identical to that listed in the recently published article for the motor NCS reference data (**Table 1**).[13] A summary of the sensory NCS responses is presented in **Table 2**. The predicted reference data for the SNAP amplitude, the PL, and the CV are shown in **Table 3**. Correlations between the covariates (sex, height, weight, and BMI) and the NCS parameters were generally weak to moderate (**Online**

Supplementary Table S1). Except age, none of the other covariates showed constant association with the sensory NCS parameters of related nerves in the quantile regression models (**Online Supplementary Table S2**). BMI, height, and sex were significantly associated with the ulnar SNAP amplitude, but not with the median SNAP amplitude, suggesting that these associations were probably due to numerical artifacts rather than due to differences in biology of the tested nerves. The MAC and the LAC SNAP amplitude, and the sensory CV and PL of all the nerves were not influenced by age, or by the other covariates. Therefore, the percentile estimations for these parameters were reported for the all participants pooled together.

For the SNAP amplitudes in which age contributed significantly to their prediction model, we estimated reference values for ages 20, 40, and 60 years (**Table 3**). The regression coefficients generated in the quantile regression model for the third percentile can be used to estimate the log (predicted SNAP amplitude) for other ages. For example, the predicted third percentile of the ulnar SNAP amplitude for a 50-year-old subject would be estimated as follows:

log (ulnar SNAP amplitude) = $\beta0 + \beta1 * age$; where $\beta0$ is the constant coefficient and $\beta1$ is the coefficient for age.

$= 4.125 + (– 0.027) * 50$

$= 4.125 – 1.35$

$= 2.775$

Hence:

ulnar SNAP amplitude = exp (2.775) = 16 μV

The predicted lower limit of the normal amplitude for the third percentile can also be estimated using $\beta0$ and $\beta1$ of the lower bound of the 95% confidence intervals (**Table 3**). The effect of age on the SNAP amplitudes was variable for different nerves. Comparing the SNAP amplitudes for the age of 60 years with those for the age of 20 years, it was observed that the SNAP amplitudes decreased by approximately 50-80% for the sural and the superficial fibular nerves, 67-75% for the ulnar nerve, 30-46% for the median nerve, and 24-34% for the superficial radial nerve.

Table 3 - Reference values for the sensory NCS parameters in the upper and the lower limbs.

Nerve N	Age	Amplitude (μV) 3rd percentile (LLN)†	Peak latency (ms)‡ 97th percentile (ULN)	Conduction velocity (m/s) 3rd percentile (LLN)†
Median sensory D2				
118	20	31 (24)	3.5 (3.5)	52 (52)
	40	27 (18)		
	60	22 (13)		
β_0*		3.613 (3.444)		
β_1*		– 0.008 (–0.014)		
Ulnar sensory D5				
118	20	36 (24)	3.5 (3.7)	51 (50)
	40	21 (12)		
	60	12 (6)		
β_0*		4.124 (3.853)		
β_1*		–0.027 (–0.034)		
Median D2 – (minus) ulnar D5 PL difference				
118	20 – 65	___	0.4 (0.4)	___
Median – (minus) ulnar D4 PL difference				
109	20 – 65	___	0.4 (0.5)	___
Median – (minus) ulnar mixed palmar PL difference				
100	20 – 65	___	0.3 (0.4)	___
Superficial radial sensory				
	20	29 (24)		
111	40	25 (20)	2.6 (2.7)	53 (50)
	60	22 (16)		
β_0*		3.493 (3.378) †		
β_1*		– 0.007 (– 0.01) †		
Medial antebrachial cutaneous				
71	20 - 65	4 (4) §	2.7 (2.8)	49 (48)
Lateral antebrachial cutaneous				
71	20 - 65	8 (4) §	2.5 (2.5)	51 (49)
Sural				
134	20	9 (4)		
	40	6 (2)		
	60	4 (1)	4.3 (4.5)	41 (40)
β_0*		2.678 (2.223) †		
β_1*		– 0.023 (– 0.037) †		
Superficial fibular				
126 ¥	20	10 (5)		
	40	7 (3)	3.9 (4.2)	48 (44)
	60	5 (1)		
β_0*		2.629 (2.186) †		
β_1*		– 0.018 (– 0.029) †		

Data are combined for NCS parameters with no age effect. *Regression coefficients obtained from the quantile regression model: log (predicted value) = $\beta0 + \beta1$ (age). †LLN - the lower limit of the 95% confidence interval at minimum values in the sample. ‡ULN - represents the upper limit of the 95% confidence interval at maximum values in the sample. §Reference values for the median and the lateral antebrachial cutaneous nerves were calculated at the 5th percentile due to the small sample size. ¥Eight out of 134 participants had unrecordable superficial fibular sensory amplitudes. Those were excluded from the analysis as recommended by the NDTF. PL - Peak latency; D2 - index finger, D4 - ring finger, D5 - little finger

Discussion. The present study followed the recommendations of the NDTF. More than 100 healthy participants were recruited for the majority of the nerves to support the reliability of the generated data.[12] We presented our data as mean±2 standard deviations and derived the cut-off values using percentiles. Researchers have discouraged the use of mean ± 2 standard deviations to generate NCS reference data. This statistical approach is hampered by the inherent skewness (non-Gaussian distribution) of the NCS values, whereby the lower limit of normal (e.g., for amplitude) would not be meaningful in a heavily right-skewed curve. The same holds true for the upper limit of normal (e.g., for latency) in a heavily left-skewed curve.[17] On the contrary, percentile analyses produce a more reliable reference data regardless of the shape of the data distribution curve. Thus, it has been considered a preferred method for NCS reference data estimation.[12]

The reference data generated in this study were comparable to those of previous studies that fulfilled the NDTF criteria.[3] However, minor differences were observed in the generated data for some of the NCS parameters. The 97th percentile reference limit for the PL of the median, the ulnar, the radial, and the sural sensory nerves were 3.5 ms, 3.5 ms, 2.6 ms, and 4.3 ms, respectively. These latencies are slightly shorter than the previously reported values of 4.0 ms, 4.0 ms, 2.8 ms, and 4.5 ms, respectively.[1,2,18,19] Direct comparison of the SNAP amplitude was not considered feasible as we used a prediction model with age as a covariate, while the previous reports were stratified for different age ranges. However, the SNAP amplitudes of the median, the ulnar, the radial, and the sural nerves in this study had higher mean amplitudes, resulting in slightly higher cut-off values. The antebrachial cutaneous nerves are not commonly studied in the electrodiagnostic laboratory. However, their assessment is crucial, especially when a lesion of the brachial plexus if suspected. For the MAC nerve, the PL was 2.7 ms, and the amplitude was 4.0 µV. These values are almost identical to the values of 2.6 ms and 4.0 µV reported by Prahlow and Buschbacher.[20] For the LAC nerve, the PL was 2.5 ms, and the amplitude was 8.0 µV. The reported reference limits for the LAC nerve by Buschbacher et al[21] were 2.5 ms, and 5.0 µV, respectively.

Notably, we implemented the same NCS protocol described in the previous studies. The differences in the results may be in part due to the younger age, the disproportionate sex ratio, and the lower average height of our study population. Height, male gender, and age have been shown in some studies to have positive associations with sensory distal latency.[22,23] Fujikama et al[24] reported that women have greater SNAP amplitudes in the upper limbs than men. On the other hand, Stetson et al. did not find any correlations between sex and NCS parameters except the ones that could be explained by physiological factors such as height and finger circumference.[23] Salerno et al[25] observed that, after adjusting for finger circumference, women still had higher median SNAP amplitudes. Ethnicity might have contributed to the differences seen in the present study as all the participants in this study were Arabs. However, the role of ethnicity might be controversial.

The 97th percentile of the PL difference between median D2-ulnar D5, median D4-ulnar D4, and median-ulnar mixed palmar studies were 0.4 ms, 0.4 ms, and 0.3 ms, respectively. These tests, in addition to the lumbrical-interossei study (not assessed in the present study), are important for evaluating patients with carpal tunnel syndrome. Our findings are consistent with the median-ulnar digit SNAP comparison study reported by Grossart et al[26] and the median-ulnar mixed palmar PL difference reported by Buschbacher.[27] Another study reported a slightly larger median-ulnar D4 PL difference (0.5 ms) than the values in our study.[28]

In this study, all the SNAPs of the tested nerves were recordable except 6% of the superficial fibular SNAPs were absent. While unrecordable potentials from the sural nerve have been reported in 2.6% of healthy subjects, it seems that this phenomenon is more frequently encountered with the superficial fibular nerve (8%).[29] It is not known whether an unrecordable potential reflects a truly absent response, or whether the response is present but is below the threshold of detection. Although we did not plan to investigate this a priori, further analysis of our data revealed that patients with absent superficial fibular SNAP had a higher mean BMI (36.3±8.7) than those with recordable potentials (27.5±5.7, $p<0.001$). Therefore, it is possible that failure to record the superficial fibular potentials was due to physical factors such as adipose tissue interfering with the ability to achieve supramaximal nerve stimulations and to record the provoked potentials. As suggested by the NDTF,[12] participants with absent responses in this study were not included in the analysis. Caution is still required while interpreting the NCS values of a nerve that could have an unrecordable response in healthy subjects.

Among the covariates, only age had a significant negative association with the SNAP amplitudes. The effect was seen in all the studied sensory nerves except the MAC and the LAC. We did not find any significant association between sex (adjusted for height) and sensory NCS parameters. These findings are consistent with the findings of the study by Stetson et al[23] but not consistent with the findings of other studies.[7,22,24,25]

One limitation of this study is that the side-to-side differences were not accounted for. This could potentially affect the accuracy of the reference values, since side-to-side differences have been reported in several publications including those with absent responses.[1,2,19] Although we did not find a correlation between sex and any of the NCS parameters, the relatively small number of male participants (≈30%) could have potentially influenced our conclusion. Moreover, the older age group was underrepresented due to difficulties with recruitment. The study had several strengths. It is the first study of normative sensory NCS data in Saudi Arabia. The study had an adequate total sample size of more than 100 healthy adults. NCS were performed following the standardized protocol of previous studies. The data were reported using percentiles and the covariates were accounted for. Future studies should focus on obtaining the NCS reference data in the older age group.

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Supplementary Table 1 - Correlations of age, sex, height, weight, and BMI with sensory nerve action potential amplitude, peak latency, and conduction velocity.

	M2snap-p	U5snap-p	Rsnap_-p	Medant-sp	Latant-sp	age	sex
M2snap_amp	**1.0000**						
U5snap_amp	**0.7292**	***1.0000***					
Rsnap_amp	**0.4067**	**0.3815**	***1.0000***				
Medante_amp	**-0.0397**	**-0.0003**	**0.0217**	***1.0000***			
Latante_amp	**0.0650**	**0.0679**	**0.2508**	**0.1842**	***1.0000***		
age	**-0.4977**	**-0.4206**	**-0.1432**	**-0.1571**	**0.0366**	***1.0000***	
sex	**-0.3120**	**-0.3421**	**-0.4096**	**-0.0323**	**0.1882**	**0.1466**	***1.0000***
Ht	**-0.2194**	**-0.2389**	**-0.3767**	**-0.0609**	**0.0907**	**-0.1159**	**0.6716**
Wt	**-0.3760**	**-0.3890**	**-0.2355**	**-0.3091**	**0.1272**	**0.3166**	**0.4925**
BMI	**-0.3110**	**-0.3018**	**-0.0433**	**-0.3748**	**0.0903**	**0.4155**	**0.1592**
BMI	**-0.3110**	**-0.3018**	**-0.0433**	**-0.3748**	**0.0903**	**0.4155**	**0.1592**

	M2snap-t	U5snap-t	Rsnap_-t	MedanI-t	LaIanI-t	sex	age
M2snap_lat	1.0000						
U5snap_lat	**0.6906**	**1.0000**					
Rsnap_lat	**0.5139**	**0.5091**	***1.0000***				
Medante_lat	**0.0154**	**0.2244**	**0.1906**	**1.0000**			
Latante_lat	**0.3596**	**0.2842**	**0.0535**	**0.0376**	***1.0000***		
sex	**0.0499**	**0.1707**	**0.1037**	**0.1309**	**0.0120**	***1.0000***	
age	**0.3250**	**0.1161**	**0.1062**	**0.0536**	**-0.0012**	**0.1466**	**1.0000**
Ht	**0.0181**	**0.1991**	**0.1731**	**0.2239**	**0.0248**	**0.6716**	**-0.1159**
BMI	**0.1064**	**0.0075**	**-0.0627**	**0.2253**	**-0.1356**	**0.1592**	**0.4155**
BMI	**0.1064**	**0.0075**	**-0.0627**	**0.2253**	**-0.1356**	**0.1592**	**0.4155**

	Sural_-p	surat_-k	SupP_Amp	SupP_P-k	age	sex	Ht
Sural_Amp	***1.0000***						
surat_Peak	**-0.0904**	***1.0000***					
SupP_Amp	**0.4186**	**-0.0394**	**1.0000**				
SupP_Peak	**-0.2803**	**0.4293**	**-0.2692**	***1.0000***			
age	**-0.2698**	**0.0261**	**-0.3332**	**0.2546**	**1.0000**		
sex	**-0.0655**	**0.1064**	**-0.0826**	**0.2344**	**0.0892**	***1.0000***	
Ht	**-0.1640**	**0.2387**	**-0.0632**	**0.3278**	**-0.2076**	**0.6223**	***1.0000***
Wt	**-0.3297**	**0.0249**	**-0.3629**	**0.2532**	**0.3015**	**0.3971**	**0.3934**
BMI	**-0.2875**	**-0.0767**	**-0.3905**	**0.1211**	**0.4420**	**0.1009**	**-0.1078**
BMI	**-0.2875**	**-0.0767**	**-0.3905**	**0.1211**	**0.4420**	**0.1009**	**-0.1078**

Supplementary Table 2 - Quantile regression analysis output (3rd percentile unless otherwise indicated).

1. Median SNAP amplitude

M2_snap_log	Coef.	Std. Err.	t	P>|t|	[95^{9} Conf.	Interval]
age	—.0226158	.003348	—6.76	*0.000*	—.0292487	—.0159829
BMI	—.0175226	.0105759	—1.66	0.100	—.0384753	.0034301
Ht	.0056459	.0139544	0.40	0.687	—.0220003	.0332921
sex	—.135719	.1011429	—1.34	0.182	—.3361014	.0646634
cons	3.730818	2.196502	1.70	0.092	—.6208482	8.082485

M2_snap_log	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval.]
age	**—.0083333**	**.0029359**	**—2.84**	**0.005**	**—.0141482**	**—.0025184**
_cons	**3.613334**	**.0855324**	**42.25**	**0.000**	**3.443926**	**3.782741**

2-Ulnar SNAP amplitudes

Usnap_log	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
age	—.0244541	.0028474	—8.59	0.000	—.0300948	—.0188135
BMI	—.0257745	.0041519	—6.21	0.000	—.0339993	—.0175496
Ht	—.0138853	.0018977	—7.32	0.000	—.0176447	—.0101259
sex	.2340236	.0616957	3.79	0.000	.111805	.3562423
_cons	6.971722	.3444768	20.24	0.000	6.289316	7.654128

Usnap_log	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
age	—.0268421	.0036165	—7.42	0.000	—.0340044	—.0196798
_cons	4.124737	.137247	30.05	0.080	3.852926	4.396548

3-Superficial radial SNAP amplitude

Rsnap_log	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
age	**—.000749**	**.0035756**	**—0.21**	**0.834**	**—.0078379**	**.0063399**
BMI	**.0019485**	**.0027657**	**0.70**	**0.483**	**—.0035347**	**.0074318**
Ht	**—.0093068**	**.0021753**	**—4.28**	***0.000***	**—.0136196**	**—.004994**
sex	**—.1561534**	**.0325046**	**—4.80**	**0.000**	**—.220597**	**—.0917099**
_cons	**4.978477**	**.3481969**	**14.30**	***0.000***	**4.288143**	**5.668812**

Rsnap_log	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
age	—.0068182	.0015801	—4.32	0.000	—.0099498	—.0036865
_cons	3.493636	.0582263	60.00	*0.000*	3.378234	3.609039

1. Median antebrachial SNAP amplitude

Mante_log	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
age	—.0005159	.0141204	—0.04	0.971	—.0287082	.0276764
BMI	—.0334374	.0260603	—1.28	0.204	—.0854686	.0185937
Ht	.0197315	.0256201	0.77	0.444	—.0314208	.0708838
sex	.28859	.6344127	0.45	0.651	—.9780558	1.555236
_cons	—.525155	3.940147	—0.13	0.894	—8.391913	7.341603

1-Lateral antebrachial SNAP amplitude.

Lante_log	Coef.	Std. Err.	t	P>|t|	[95%	Conf.	Interval]
age	.0070564	.0097405	0.72	0.471	—.0123912		.026504
BMI	—.0048636	.0183935	—0.26	0.792	—.0415874		.0318603
Ht	.0191673	.0192922	0.99	0.324	—.0193509		.0576854
sex	—.1087629	.4096582	—0.27	0.791	—.9266719		.709146
_cons	—1.004466	2.952763	—0.34	0.735	—6.899847		4.890915

2-Sural amplitude

sural_log	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
age	**-.0113835**	**.0045237**	**-2.52**	**0.013**	**-.0203337**	**-.0024333**
BMI	**-.0183425**	**.0076491**	**-2.40**	**0.018**	**-.0334763**	**-.0032086**
sex	**-.154742**	**.1177951**	**-1.31**	**0.191**	**-.3878025**	**.0783184**
Ht	**-.0043393**	**.0054096**	**-0.80**	**0.424**	**-.0150422**	**.0063637**
_cons	**3.593453**	**1.151149**	**3.12**	**0.002**	**1.315876**	**5.87103**

sural_log	Coef.	SId. Err.	t	P>|t|	[95% Conf.	Interval]
age	**—.0147019**	**.0038068**	**—3.86**	***0.000***	**—.0222326**	**—.0071712**
BMI	**—.01478**	**.0221214**	**—0.67**	**0.505**	**—.0585415**	**.0289814**
_cons	**2.850454**	**.5890914**	**4.84**	***0.000***	**1.685091**	**4.015818**

sural_log	Coef.	5d. Err.	t	P>|t|	[95% Conf.	Interval]
age	—.0227778	.0070709	—3.22	0.002	—.0367648	—.0087908
_cons	2.678333	.2298178	**11.65**	***0.000***	2.223731	3.132936

3-Superficial fibularamplitude

. qreg supP_log age, quantile (3)
Iteration 1: WLS sum of weighted deviations = 29.298231

Iteration 1: sum of abs. weighted deviations = 34.19511

Iteration 2: sum of abs. weighted deviations = 16.343988 Iteration 3: sum of abs. weighted deviations = 7.5662585 Iteration 4: sum of abs. weighted deviations = 6.7079784 Iteration 5: sum of abs. weighted deviations = 6.6780002

.03 Quantile regression Raw sum of deviations Min sum of deviations 8.141 (about1.79) 6.678

Number of obs = 126

Pseudo R2= 0.1797

supP_log	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
age	—.0178788	.0058591	—3.05	0.003	—.0294755	—.0062821
cons	2.629091	.2240852	11.73	0.000	2.185563	3.072618

4-Conduction velocity (97rd percentile unless otherwise indicated)Median

M2snap_cv	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
age	**0**	**.0022617**	**0.00**	***1.000***	**—.0044812**	**.0044812**
sex	**0**	**.0657444**	**0.00**	**1.000**	**—.1302641**	**.1302641**
BMI	**0**	**.0048518**	**0.00**	**1.000**	**—.0096132**	**.0096132**
Ht	**0**	**.0035005**	***0.00***	***1.000***	**—.0069357**	**.0069357**
_cons	**52**	**.5969065**	**87.12**	***0.000***	**50.81731**	**53.18269**

M2snap_cv	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
age	0	.0098232	0.00	1.000	—.0194578	.0194578
_cons	52	.3269304	159.06	0.000	51.35241	52.64759

95th percentile

M2snap_cv	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
age	—.0511092	.0966613	—0.53	0.598	—.2426312	.1404128
sex	—1.843168	2.071921	—0.89	0.376	—5.948413	2.262078
BMI	—.2452919	.1614079	—1.52	0.131	—.5651008	.0745171
Ht	.0072057	.1325654	0.05	0.957	—.2554557	.2698672
_cons	61.28131	22.35548	2.74	0.007	16.98678	105.5758

M2snap_cv	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
age	—.0909091	.0599642	—1.52	0.132	—.2096866	.0278685
_cons	56.81818	1.950963	29.12	0.000	52.9537	60.68266

5-Ulnar

U5snap_cv	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
age	—.2386299	.0148324	—16.09	0.000	—.2680184	—.2092413
sex	—1.047073	1.124887	—0.93	0.354	—3.275893	1.181746
BMI	.2215983	.0217025	10.21	0.000	.1785976	.264599
Ht	—.0506651	.0176017	—2.88	0.005	—.0855407	—.0157895
_cons	62.50312	2.981172	20.97	*0.000*	56.59631	68.40993

U5snap_cv	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
age	—.2	.037503	—5.33	0.000	—.2742862	—.1257138
_cons	58.2	1.4810e5	39.30	0.000	55.26641	61.13359

6-Superficial radial

Rsnap_cv	Coef.	Std.Err.	t	P>|t|	[95% Conf.	Interval]
age	—.0001111	.0171423	—0.01	0.995	—.0340973	.0338751
BMI	.1929142	.0502046	3.84	*0.000*	.0933788	.2924497
Ht	—.4519257	.0978202	—4.62	*0.000*	—.6458637	—.2579877
sex	5.298252	.4251608	12.46	*0.000*	4.455329	6.141174
_cons	121.4385	17.03552	7.13	0.000	87.66393	155.2131

7-Sural

Sural_cv	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
age	—.0384616	.0630254	—0.61	0.543	—.163132	.0862089
_cons	42.19231	2.875846	14.67	*0.000*	36.5036	47.88102

8-Superficial fibular

SupP_CV	Coef.	Std. Err.	t	P>|t|	[95%Conf.	Interval]
age	—.2489812	.015982	—15.58	0.000	—.2806218	—.2173407
BMI	—.0351896	.0233381	—1.51	0.134	—.0813936	.0110144
sex	5.56312	.7867994	7.07	0.000	4.005443	7.120797
Ht	—.3511868	.0212466	—16.53	0.000	—.39325	—.3091236
_cons	113.6365	3.224366	35.24	*0.000*	107.253	120.02

SupP_CV	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
age	—.1818182	.0233049	—7.80	0.000	—.227945	—.1356913
_cons	54.36364	1.13218	48.02	*0.000*	52.12274	56.60454