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Research Article

The Impact of Wearable Technology on Median Nerve Conduction Studies: A Comparative Analysis of Smartwatch and Traditional Watch Wearers

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Abstract

Aim: Carpal tunnel syndrome (CTS) is the most common entrapment neuropathy, presenting with pain, numbness, and tingling in the hands. Factors such as occupational and lifestyle habits, repetitive movements, and external compression contribute to its development. This study aims to evaluate the relationship between continuous daily smartwatch use and median nerve electrophysiological features, comparing it with traditional watch users.

Material and Method: A total of 96 adult participants were included, comprising individuals who did not use any type of watch and those who had used either a smartwatch or a traditional watch for at least three months. Data on demographics, watch use habits, and Boston Carpal Tunnel Syndrome Questionnaire scores were collected. We performed median nerve conduction studies (NCS) and evaluated the combined sensory index (CSI) values.

Results: Ninety-six participants were enrolled: 35 without watches, 29 using traditional watches, and 32 using smartwatches. Smartwatch users demonstrated non-significant but more frequent and prolonged daily usage compared to traditional watch users ($p>0.05$). No significant differences were observed in NCS findings across the three groups ($p>0.05$). While 13.5% of participants showed median sensory NCS results compatible with CTS, this proportion increased to 41.4% when CSI>1.0 ms used as a criterion. The CSIs were similar in all three groups ($p=0.79$). No significant differences were found when comparing the frequency of CSI>1.0 ms between watch-wearing and non-wearing sides for both traditional watches (24.1% vs. 31.0%, $p=0.77$) and smartwatch users (25.0% vs. 18.8%; $p=0.76$).

Conclusion: To the best of our knowledge, our study is the first to systematically investigate the effect of smartwatch use on median nerve electrophysiological findings. Our findings suggest frequent occurrences of asymptomatic CTS-related electrophysiological changes. However, these changes were not associated with significant differences in symptoms or NCS findings among smartwatch or traditional watch users.

Keywords: Carpal tunnel syndrome, nerve conduction studies, wearable technology, median nerve, smartwatch

INTRODUCTION

Carpal tunnel syndrome (CTS) is the most prevalent focal mononeuropathy, affecting approximately 7–18.4% of the general population (1-3). Symptoms include pain, paresthesia, and, less commonly, muscle weakness in the hands (4,5). Various factors contribute to its pathophysiology, including occupational and lifestyle habits, repetitive wrist movements, and external compression (4,5).

CTS is typically diagnosed through clinical symptoms such as pain, tingling, and paresthesia in the radial 3½ digits, corresponding to the median nerve distribution (5,6). Elevated interstitial pressure within the carpal tunnel leads to sub-synovial fibrosis, median nerve demyelination, and eventual axonal degeneration (4). Management options range from preventive strategies to medical or surgical treatments, guided by electrophysiological evaluations (4,5).

Electrodiagnostic tests like nerve conduction studies (NCS) and electromyography (EMG) are pivotal in assessing the extent of median nerve damage. These tests can reveal impaired nerve conduction, prolonged latencies, and axonal degeneration (7). This study investigates the potential impact of daily smartwatch use on CTS development, comparing findings with traditional watch users and individuals not wearing watches.

CITATION

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MATERIAL AND METHOD

The study was approved by the Karabük University Clinical Research Ethics Committee and conducted in accordance with the Declaration of Helsinki (Date: 01/06/2022, Decision No: 2022/934). Informed consents were obtained from all participants. The methodology was summarized in the flowchart (Figure 1).

We included three groups of volunteers prospectively in the study: volunteers aged 18 or older who had used smartwatches or traditional watches for at least three months or who had not worn any watches or bracelets in the last six months. Exclusion criteria comprised rheumatologic, neurologic, or cardiac conditions, hypothyroidism, diabetes, upper extremity or cervical spinal surgeries, polyneuropathy, trauma, deformity, or cognitive impairment.

A total of 96 participants were included: 35 without watches, 29 traditional watch users, and 32 smartwatch users. Demographic data included age, sex, height, weight, occupation, educational level, hand dominance, and watch use habits (type, duration, frequency) were recorded.

The Boston Carpal Tunnel Syndrome Questionnaire (BCTQ), created by Lavine and colleagues (8), was used as a scoring system in this study. The BCTQ evaluates symptom severity (11 items) and functional capacity (8 items), with scores ranging from 1 (mild) to 5 (severe). The total score of the symptom severity scale and functional status scale of the questionnaires were used in this study. The visual analog scale (VAS) score is used to assess the pain level of patients.

NCS were performed using the Keypoint® Focus EMG/NCS/EP system. The median and ulnar nerve sensory NCS and radial nerve sensory NCS were performed on all participants. Sensory NCS were conducted antidromically, with recordings taken from ring electrodes. For the median nerve, the sensory distal latency upper limit was set at 3.40 ms for the 14 cm segment from the second finger to the wrist, and the lower limit for sensory conduction velocity was set at 49 m/s. Motor NCS were performed by stimulating the wrist (8 cm) and elbow. The potentials were recorded with surface disc electrodes from the abductor pollicis brevis. For the median nerve, the upper limit for motor distal latency was set at 4 ms, and the lower limit for conduction velocity was set at 50 m/s. Additionally, median mixed sensory NCS were performed including median-ulnar mixed sensory NCS for the 8 cm segment from fourth finger to wrist, median-ulnar palmar mixed sensory NCS for the 8 cm segment from palm to wrist, and median-radial mixed sensory NCS for the 10-12 cm segment from first finger to wrist. CTS was diagnosed if there was a slowing of sensory conduction velocity, prolonged sensory distal latency, and/or prolonged motor distal latency (9). We have calculated the combined sensory index (CSI) previously described by Lew et al., and CSI>1.0 ms is considered significant for CTS (10).

We compared the NCS of both upper extremities of not-watch users with those of the watch-wearing upper extremity in participants using a traditional or smartwatch. Additionally, comparisons were made between the watch-wearing and non-wearing extremities of participants using watches.

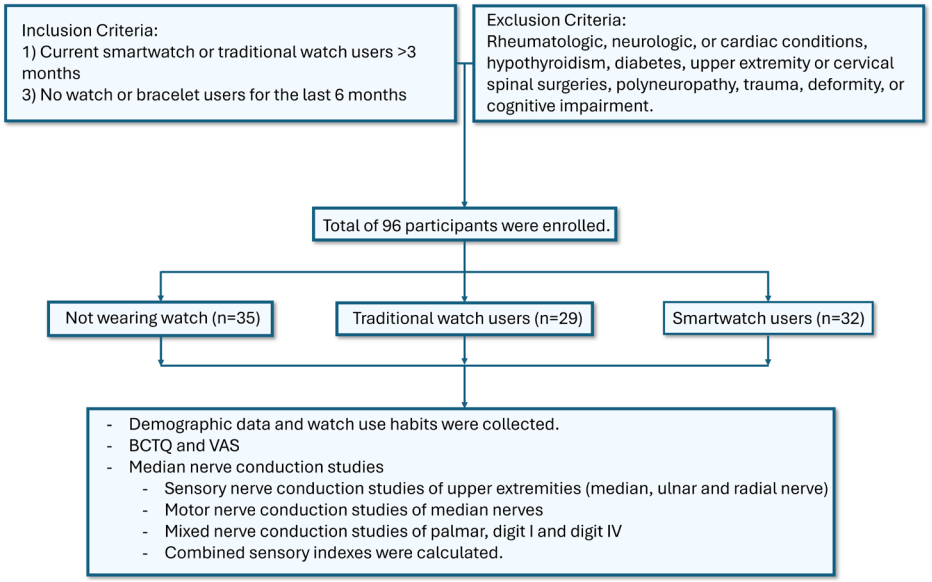

Figure 1. The flow diagram of the study

Statistical Analysis

Shapiro-Wilk tests and histograms were used to assess data normality. Categorical variables were compared using Fisher's exact test, and continuous variables using Mann-Whitney U or Kruskal-Wallis tests. Binomial logistic regression analysis was used to evaluate factors influencing CSI>1.0 ms. Multicollinearity was evaluated with tolerance and variance inflation factors. Statistical significance was set at $p<0.05$ and analyses were performed using Jamovi (v2.3.28).

RESULTS

A total of 96 participants were included: 35 without watches (24 female, 11 male), 29 traditional watch users (15 female, 14 male), and 32 smartwatch users (18 female, 14 male). Demographic and clinical characteristics are summarized in Table 1. Age, gender, height, weight, and body mass index (BMI) were comparable across the groups, though participants not wearing watches tended to be older, predominantly female, and exhibited higher BMI values. Most participants were right-handed (83% in non-watch users, 97% in both traditional and smartwatch users; p=0.08). A majority of watch wearers used their left wrist (83% in traditional watch users, 81% in smartwatch users; p=1).

Traditional watch users reported significantly longer cumulative wear duration (Table 1, p<0.01). While smartwatch users tended to use their watches more regularly and for longer periods daily, these differences were not statistically significant (p=0.46 and p=0.15, respectively). VAS pain scores and BCTQ symptom severity and functional status scores were similar across groups.

The sensory and motor median nerve NCS results did not differ significantly among the groups (Table 2, Figure 2). Combined sensory index (CSI) values were slightly higher in non-watch users, though not statistically significant (p=0.79). Mild CTS, diagnosed based on sensory latency and conduction velocity of the median nerve at digit II, was observed in four participants (11.4%) without watches, five traditional watch users (17.2%), and four smartwatch users (12.5%).

When considering CSI>1.0 ms as a criterion, 41.7% of all participants exhibited values suggestive of CTS. This included 41.3% of traditional watch users and 28.1% of smartwatch users (p=0.30). No significant differences were found when comparing the frequency of CSI>1.0 ms between watch-wearing and non-wearing sides for both traditional watches (24.1% vs. 31.0%, p=0.77) and smartwatch users (25.0% vs. 18.8%; p=0.76).

Within the traditional watch group, no significant differences in NCS findings were observed between watch-wearing and non-wearing extremities. The CSI was slightly higher on the non-wearing side, but this difference was not statistically significant (p=0.37; Table 3).

In smartwatch users, significant differences were noted between the wearing and non-wearing sides in terms of median sensory NCS latency and amplitude recorded at digit II, ulnar palmar latency, and median-ulnar palmar mixed NCS (Table 4). However, all findings were within normal limits and lacked clinical significance. Additionally, the difference in CSI between sides was not statistically significant (p=0.84).

Binomial logistic regression analysis assessed factors influencing CSI>1.0 ms. The model was statistically significant ($\chi^2(9)=21.3$, p=0.01) and accounted for 28.8% of the variance in the outcome (Nagelkerke $R^2=0.288$). No multicollinearity was observed among the included factors.

BMI was significantly associated with higher odds of CSI>1.0 ms (OR=1.25, 95% CI: 1.07–1.47, p<0.01). Other variables, including BCTQ scores, age, cumulative watch-wearing duration, daily watch-wearing time, and type of watch (traditional or smartwatch), did not show significant associations with CSI>1.0 ms.

Table 1. Demographic and clinical characteristics of the participants

	Not wearing watch (N=35)	Traditional watch users (N=29)	Smartwatch users (N=32)	p-value
Age, median (IQR)	37.0 (24.0-45.0)	30.0 (22.0-42.7)	29.5 (25.0-33.6)	0.14*
Gender, female (%)	24/35 (69%)	15/29 (41%)	18/32 (56%)	0.09**
Height (cm), median (IQR)	165 (159-175)	173 (160-176)	170 (163-183)	0.10*
Weight (kg), median (IQR)	69 (58-78)	70 (58-80)	70 (60-81)	0.81*
Body-mass index	24.6 (21.2-26.5)	23.1 (20.4-27.8)	23.2 (21.8-26.2)	0.67*
Hand preference, right	29/35 (83%)	24/25 (97%)	31/32 (97%)	0.08**
The side of the watch, left	NA	24/29 (83%)	26/32 (81%)	1**
Total wearing time, median months (IQR)	NA	60 (44-84)	24 (12-36)	**<0.01*** **
Wearing time, days in a week	0.46**			
3-4	NA	5/29 (17%)	3/32 (9%)	
5-7	NA	24/29 (83%)	29/32 (91%)	
Wearing time, hours in a day	0.15**			
0-6	NA	2/29 (7%)	3/32 (9%)	
6-12	NA	13/29 (45%)	10/32 (31%)	
12-18	NA	11/29 (35%)	8/32 (25%)	
18-24	NA	3/29 (10%)	11/32 (34%)	
Wearing during sleep	NA	13/29 (45%)	11/32 (34%)	0.44**
VAS, median (IQR)	0 (0-1)	0 (0-1)	0 (0-0)	0.90*
BCTQ-SSS, median (IQR)	11 (11-15)	11 (11-12)	12 (11-16)	0.14*
BCTQ-FSS, median (IQR)	8 (8-10)	8 (8-8)	8 (8-12)	0.48*

IQR: interquartile range, VAS: visual analog scale, BCTQ-SSS: Boston carpal tunnel syndrome questionnaire-symptom severity scale, BCTQ-FSS: Boston carpal tunnel syndrome questionnaire-functional status scale; *Kruskal-Wallis test, **Chi-square test, ***Mann-Whitney U test

Table 2. Comparison of nerve conduction study results				
	Not wearing watch (N=70)*	Traditional watch users (N=29)*	Smartwatch users (N=32)*	p-value**
Sensory nerve conduction studies				
Median nerve				
Digit I (latency, ms)	2.3 (0.3)	2.3 (0.4)	2.3 (0.2)	0.84
Digit II (latency, ms)	2.9 (0.3)	2.9 (0.5)	2.9 (0.4)	0.90
Digit II (amplitude, μv)	29.2 (10.3)	27.5 (14.1)	30.4 (8.7)	0.54
Digit II (conduction velocity m/s)	63.4 (5.5)	62.8 (7.1)	63.3 (5.1)	0.56
Digit IV (latency, ms)	2.8 (0.3)	2.8 (0.6)	2.9 (0.4)	0.76
Palmar (latency, ms)	1.6 (0.3)	1.6 (0.3)	1.6 (0.3)	0.85
Ulnar nerve				
Digit IV (latency, ms)	2.7 (0.3)	2.8 (0.5)	2.8 (0.5)	0.32
Palmar (latency, ms)	1.1 (0.4)	1.2 (0.5)	1.0 (0.2)	0.57
Radial nerve				
Digit I (latency, ms)	2.1 (0.4)	2.0 (0.7)	2.2 (0.6)	0.24
Motor nerve conduction studies				
Median nerve				
Digit II (latency, ms)	2.7 (0.4)	2.6 (0.4)	2.8 (0.4)	0.09
Digit II (amplitude, mv)	7.6 (2.4)	8.2 (1.8)	8.1 (2.3)	0.08
Digit II (conduction velocity, m/s)	58.4 (5.7)	57.1 (6.3)	57.4 (4.8)	0.38
Mixed nerve conduction studies				
Digit IV (median-ulnar) difference, ms	0.1 (0.2)	0.0 (0.2)	0.0 (0.2)	0.15
Digit I (median-radial) difference, ms	0.3 (0.5)	0.2 (0.6)	0.0 (0.6)	0.11
Palmar (median-ulnar) difference, ms	0.5 (0.5)	0.4 (0.6)	0.5 (0.3)	0.30
Combined sensory index	0.78 (0.9)	0.64 (0.7)	0.64 (0.8)	0.79
Electrophysiological findings of both upper extremities in participants not wearing a watch were compared with those of the watch-wearing upper extremity in participants using a traditional or smartwatch				
*Median (interquartile range), **Kruskal Wallis test was used				

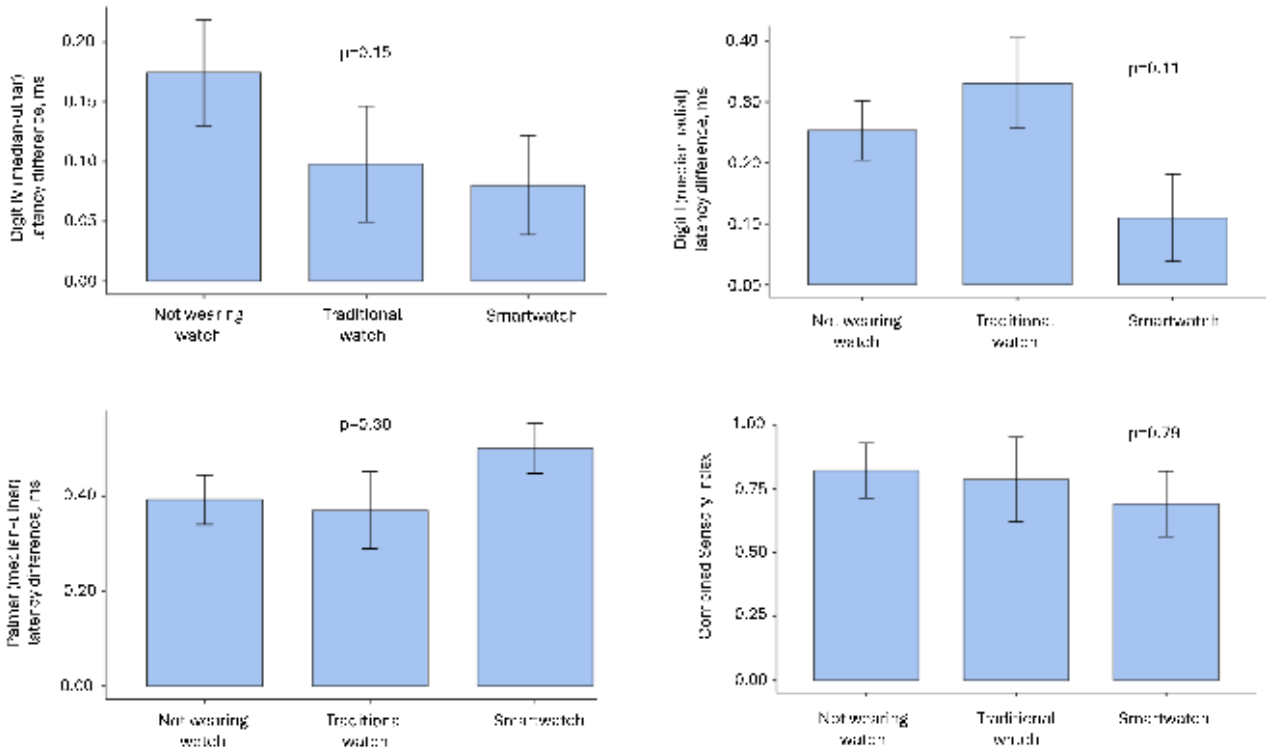

Figure 2. Mixed nerve conduction studies revealed no significant latency differences of median-ulnar nerve on digit IV, median-radial nerve on digit I and median-ulnar nerve on palmar studies between the groups (p=0.15, p=0.11, p=0.30, respectively); The combined sensory indexes were similar in all groups (p=0.79); Values are presented as mean ± standard error of the mean

Table 3. Comparison of nerve conduction studies and combined sensory indexes between the traditional watch-wearing side and the non-traditional watch-wearing side

N=29	Traditional watch-wearing side*	Non-traditional watch-wearing side*	p-value**
Sensory nerve conduction studies			
Median sensory nerve			
Digit I (latency, ms)	2.3 (0.4)	2.3 (0.4)	0.17
Digit II (latency, ms)	2.9 (0.5)	2.9 (0.7)	0.06
Digit II (amplitude, µv)	27.5 (14.1)	26.2 (9.9)	0.35
Digit II (conduction velocity m/s)	62.8 (7.1)	59.6 (8.8)	0.49
Digit IV (latency, ms)	2.8 (0.6)	2.8 (0.6)	0.78
Palmar (latency, ms)	1.6 (0.3)	1.6 (0.4)	0.31
Ulnar nerve			
Digit IV (latency, ms)	2.8 (0.5)	2.8 (0.4)	0.17
Palmar (latency, ms)	1.2 (0.5)	1.0 (0.5)	0.15
Radial nerve			
Digit I (latency, ms)	2.0 (0.7)	2.0 (0.5)	0.97
Motor nerve conduction studies			
Median motor nerve			
Digit II (latency, ms)	2.6 (0.4)	2.7 (0.6)	0.76
Digit II (amplitude, mv)	8.2 (1.8)	8.7 (2.2)	0.90
Digit II (conduction velocity, m/s)	57.1 (6.3)	57.3 (4.7)	0.52
Mixed nerve conduction studies			
Digit IV (median-ulnar) difference, ms	0.0 (0.2)	0.0 (0.2)	0.55
Digit I (median-radial) difference, ms	0.2 (0.6)	0.4 (0.5)	0.74
Palmar (median-ulnar) difference, ms	0.4 (0.6)	0.6 (0.6)	0.12
Combined sensory index, ms	0.64 (0.7)	0.79 (0.6)	0.37

*Median (Interquartile range), **Wilcoxon signed-rank test was used

Table 4. Comparison of nerve conduction studies and combined sensory indexes between the smartwatch-wearing side and the non-smartwatch-wearing side

N=32	Smartwatch-Wearing Side*	Non-Smartwatch-Wearing Side*	p-value**
Sensory nerve conduction studies			
Median sensory nerve			
Digit I (latency, ms)	2.3 (0.2)	2.4 (0.2)	0.26
Digit II (latency, ms)	2.9 (0.4)	2.9 (0.3)	**0.02**
Digit II (amplitude, µv)	30.4 (8.7)	28.3 (9.9)	**0.05**
Digit II (conduction velocity m/s)	63.3 (5.1)	63.1 (7.2)	0.90
Digit IV (latency, ms)	2.9 (0.4)	2.9 (0.3)	0.29
Palmar (latency, ms)	1.6 (0.3)	1.6 (0.2)	0.85
Ulnar nerve			
Digit IV (latency, ms)	2.8 (0.5)	2.7 (0.4)	0.42
Palmar (latency, ms)	1.0 (0.2)	1.2 (0.2)	**0.02**
Radial nerve			
Digit I (latency, ms)	2.2 (0.6)	2.2 (0.6)	0.54
Motor nerve conduction studies			
Median motor nerve			
Digit II (latency, ms)	2.8 (0.4)	2.7 (0.5)	0.53
Digit II (amplitude, mv)	8.1 (2.3)	8.1 (2.3)	0.24
Digit II (conduction velocity, m/s)	57.4 (4.8)	58.7 (5.0)	0.84
Mixed nerve conduction studies			
Digit IV (median-ulnar) difference, ms	0.0 (0.2)	0.1 (0.2)	0.17
Digit I (median-radial) difference, ms	0.0 (0.6)	0.0 (0.6)	0.86
Palmar (median-ulnar) difference, ms	0.5 (0.3)	0.4 (0.3)	**0.04**
Combined sensory index, ms	0.54 (0.8)	0.58 (0.7)	0.84

*Median (Interquartile range), **Wilcoxon signed-rank test was used

DISCUSSION

The CTS is the most common peripheral neuropathy, significantly affecting patients' functionality. It is primarily idiopathic, with female sex and increased age identified as key risk factors (2,5). Mechanical factors such as forceful gripping and repetitive wrist movements further contribute to its development by increasing carpal tunnel pressure (11). Pressure is predicted to increase tenfold with wrist extension but only eightfold with flexion (12). Other risk factors include but are not limited to rheumatological diseases, pregnancy, hypothyroidism, menopause, obesity, and amyloidosis (5,13). The underlying pathophysiology involves elevated pressure within the carpal tunnel and ischemia-induced axonal degeneration of the median nerve, manifesting as clinical symptoms (12).

Wearable technologies such as smartwatches are increasingly integrated into daily life, offering benefits like tracking vital signs, heart rhythm, and sleep quality. As a result, smartwatches may be worn for longer periods compared to traditional watches, potentially affecting carpal tunnel pressure—a key factor in CTS development (12).

Wearable devices utilize photoplethysmography to measure parameters like oxygen saturation and heart rate. This involves emitting green, red, or infrared light, which penetrates tissue to varying depths; infrared light can reach up to 5 cm (14). Although infrared radiation may have beneficial effects, its potential for heat generation and the impact of long-term exposure on peripheral nerves remain unclear (15). Additionally, LED light sources and tighter straps may increase skin temperature, potentially affecting nerve conduction. Studies have shown that temperature increases can reduce sensory amplitude in CTS patients, likely due to heat-induced conduction blocks (16). Therefore, in case of CTS, using smartwatches may alter median nerve electrophysiology. The literature search revealed only one case series in the literature has linked smartwatch use to CTS symptoms, which improved after discontinuation (17).

In our study, we extensively evaluated the median nerve in participants using traditional watches, smartwatches, or no watches at all. Demographic and clinical characteristics were similar across groups, with no differences in BCTQ scores or VAS pain scores. This finding is consistent with the fact that none of the participants had a prior diagnosis of CTS.. There was no difference in the NCS findings of all three groups in any NCS (Table 2). Based on the median sensory NCS on digit II, 11.4% to 17.2% of participants in different groups were diagnosed with CTS. In population-based studies, the frequency of CTS was found between 7% to 18.4% similar to our results (1,2). However, extensive NCS in our study showed that an increased CSI (>1.0 ms) rate may be up to 41.7%.

The CSI were similar in all groups with a slight tendency of increase in the group of participants not wearing a watch (p=0.79). The slightly higher CSI observed in participants who do not wear watches may be explained by their higher BMI, advanced age, and female predominance (18). Logistic regression analysis further supported BMI as the only significant predictor of increased CSI (OR=1.25, 95% CI: 1.07–1.47, p<0.01).

In our study, smartwatch users wear them more often during the week and longer times during the day which may increase the pressure within the carpal tunnel and compress the median nerve. Conversely, traditional watch users have a longer total wearing time which may cause continuous compression for a longer time (p<0.01). Although traditional watch users reported longer cumulative wear times compared to smartwatch users, this did not translate into differences in CSI, suggesting that duration and pressure dynamics may be less critical than other factors such as BMI or individual anatomy (p>0.05).

When comparing NCS results between the watch-wearing and non-wearing sides, no significant differences were noted in traditional watch users (p=0.37). A slight trend toward increased CSI on the non-wearing side could be attributed to the preference for wearing watches on the non-dominant hand. Among smartwatch users, statistically significant differences were found in median sensory NCS on digit II as well as ulnar palmar latency and median-ulnar palmar latency difference (Table 4). However, all measurements remained within normal limits, and these differences did not affect CSI values (p=0.84).

Several limitations should be acknowledged. The small sample size and single-center design may limit the generalizability of our findings. Additionally, as a cross-sectional study, it cannot capture participants who may develop CTS over time. Furthermore, the study lacked reliable data on strap tightness, which could influence compression levels and alter NCS results. Prospective longitudinal studies in larger, diverse populations are warranted to address these gaps.

CONCLUSION

This study examined the effects of daily smartwatch use on median NCS. To the best of our knowledge, this is the first research attempt to systematically investigate the relation between smartwatch use and median nerve electrophysiological features. Although CTS prevalence was consistent with population-based estimates, elevated CSI values were observed across all groups. Despite this, smartwatch and traditional watch use did not result in significant differences in CTS symptoms or NCS findings.

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Conflict of interest: *The authors have no conflicts of interest to declare.*

Ethical approval: *This study was approved by the Karabük University Clinical Research Ethics Committee (Date: 01/06/2022, Decision No: 2022/934).*

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