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Original Article

Does hot pack application change the morphology of the median and ulnar nerves?

Fatima Yaman[1], Merve Akdeniz Leblebicier[1], Aysun Özlü[1], Emine Cihan[2], Dilan Bulut Özkaya[1]

[1]Department of Physical Medicine and Rehabilitation, Kütahya Health Sciences University, Faculty of Medicine, Kütahya, Türkiye
[2]Department of Therapy and Rehabilitation, Selçuk University, Physiotherapy Program, Vocational School of Health Sciences, Konya, Türkiye

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ABSTRACT

Objectives: This study aims to investigate the effect of the hot pack application on the morphology of healthy median and ulnar nerves.

Patients and methods: Between August 2021 and September 2022, a total of 54 healthy volunteers (17 males, 37 females; mean age: 31.9±9.4 years; range, 21 to 63 years) were included in the study. The cross-sectional area (CSA) and depth of the right median and ulnar nerve were measured using ultrasonography before and after 20-min hot pack application. The right median nerve CSA and depth from the level of the scaphoid bone (at the level of the carpal tunnel) and from the mid-forearm were also measured. The right ulnar nerve CSA and depth from the level of the hook of hamate and the mid-forearm were evaluated. The depth measurements between the skin and the outer hyperechoic border of the nerve were performed.

Results: After the hot pack application, there was an increase in both the median nerve CSA at the carpal tunnel (from 0.06±0.01 to 0.09±0.02 cm^2) and forearm (from 0.06±0.02 to 0.09±0.02 cm^2) levels ($p<0.001$) and the ulnar nerve CSA at the hook of hamate (from 0.04±0.03 to 0.06±0.01 cm^2) and forearm (0.05±0.01 to 0.08±0.02 cm^2) levels ($p<0.001$). No statistically significant difference was observed between the pre- and post-application depth measurements ($p>0.05$).

Conclusion: Our study results show that the hot pack application leads to acute swelling of the median and ulnar nerves. In future studies, the relationship between morphological changes in healthy and pathological nerves and electrodiagnostic findings should be investigated.

Keywords: Cross-sectional area, hot pack, median nerve, morphology, ulnar nerve, ultrasonography.

Hot pack application is one of the treatment methods used to increase local tissue temperature. Heat provides an increase in local blood flow in tissues, increases tissue metabolism, muscle relaxation, and fibrous tissue flexibility, thereby reducing pain and extending joint range of motion.[1] Due to these physiological effects, researchers have added hot pack application to many treatment methods, such as isometric and neuromobilization exercises to support functional recovery.[2,3]

Temperature is one of the important factors affecting nerve conduction parameters in healthy and pathological nerves.[4] This occurs through changes in the transmembrane ion balance. The increase in temperature facilitates both the opening and closing of the Na+ channel, which accelerates depolarization and repolarization.[5,6] In electrodiagnostic (EDX) evaluations, an increase in temperature increases the nerve motor and sensory conduction velocity and decreases the latency and amplitude.[7] In a previous study, hot pack application increased the median and ulnar nerve conduction velocity and decreased the amplitude in both patients with carpal tunnel syndrome (CTS) and healthy individuals.[8]

Corresponding author: Fatima Yaman, MD. Kütahya Sağlık Bilimleri Üniversitesi Tıp Fakültesi, Fiziksel Tıp ve Rehabilitasyon Anabilim Dalı, 43100 Civli, Kütahya, Türkiye.
E-mail: fatimacakir84@hotmail.com

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Ultrasonography (USG) is widely used in the imaging of musculoskeletal diseases, particularly in detecting entrapment neuropathies.[9,10] In USG evaluation, nerve cross-sectional area (CSA) measurements provide important information concerning the structure of peripheral nerves. Therefore, during the imaging of a peripheral nerve, its dimensions should be evaluated, as well as its relationship with nearby anatomical structures.[11,12] There are studies showing the effects of heat on EDX findings in healthy and/or pathological nerves.[5,13] However, to the best of our knowledge, no study has investigated morphological changes in healthy nerves following hot pack application frequently undertaken as part of physiotherapy.

In this study, we aimed to investigate the effect of 20-min hot pack application on the morphology of the median and ulnar nerves *in vivo* using USG.

PATIENTS AND METHODS

This pilot study was conducted at Kütahya Health Sciences University, Faculty of Medicine, Department of Physical Medicine and Rehabilitation between August 2021 and September 2022.

Participants were selected based on compliance with the study criteria among healthy individuals that volunteered to participate in the study after seeing the related posters in our outpatient clinic. All the participants were informed in advance about the procedures and assessments to be performed in the study. Inclusion criteria were as follows: age between 18 and 65 years; volunteering to participate in the study; and having right upper extremity dominance. Exclusion criteria were as follows: presence or clinical manifestation of entrapment neuropathy in both upper extremities; presence of any disease that can cause polyneuropathy; presence of a disease that affects the central nervous system; presence of disability in upper extremity; presence of a systematic inflammatory disease; having a skin disease; diagnosis of Raynaud's syndrome; having a history of malignancy; presence of peripheral vascular disease; having self-reported nicotine and/or alcohol dependence. Finally, a total of 54 healthy volunteers (17 males, 37 females; mean age: 31.9±9.4 years; range, 21 to 63 years) were included in the study.

Procedures

Healthy volunteers were asked to wait at room temperature (approximately 22°C) for 30 min. Then, they were placed in the sitting position on the examination table, with the right elbow flexed to 90 degrees, the wrist neutral, and the fingers slightly semi-flexed. We measured the skin surface temperature before and after hot pack application using an infrared thermometer (Medishop DT-8806, PRC) three times in a row and recorded the average. We used a USG device with a multifrequency (7 to 15 MHz) linear probe (Mindray-UMT 200, NJ, United States) for the median and ulnar nerve CSA and depth measurements. We determined the anatomical localizations to be measured in light of the literature.[14,15] Mid-forearm measurements were made from the distal wrist crease and the midpoint of the medial epicondyle.[14,15] The depth of the median and ulnar nerves was measured from the skin surface through the upper border of the nerves. We measured CSA (cm^2) by marking the inner hyperechoic trace of the nerve section. We measured the CSA and depth of the median nerve distally at the level of the scaphoid bone (wrist; carpal tunnel level) and the mid-forearm. We measured the ulnar nerve CSA and depth from the level of the hook of hamate and the mid-forearm. Before hot pack application, we also marked the locations where we performed the measurements with a pencil. The measurements were undertaken by a physiatrist with six years of musculoskeletal USG experience. Considering that hot pack application routinely used in physiotherapy require a temperature of 38 to 42°C, we confirmed the temperature of the hot pack before the application by measuring it with an infrared thermometer (Medishop DT-8806, PRC). Then, we applied a hot pack to the volar face of the right wrist and forearm for 20 min. Immediately after the application, we placed the USG probe on the marked anatomical areas and measured the CSA and depth of the nerves again.

Statistical analysis

Study power and sample size calculation were performed using the G*Power version 3.1 software (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany). To examine differences in the post-application median and ulnar nerve CSA values compared to the baseline values, the required sample size was calculated as 54, and the power of the study was found to be 0.94 with an effect size (d) of 0.5 and significance level (p) of 0.05 at 95% confidence interval (CI).

Statistical analysis was performed using the IBM SPSS for Windows version 24.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were expressed in mean ± standard deviation (SD), median (min-max) or number and frequency, where

TABLE 1
Demographic data of healthy volunteers

	Participants (n=54)				
Data	n	%	Mean ± SD	Median	Min-Max
Age (year)			31.9±9.4	28.50	21-63
Sex					
Female	37	68.5			
Male	17	31.5			
Weight			67.62±13.59	65	43-104
Height			167.62±9.84	164	153-193
Body mass index			23.86±2.85	24.50	17.2-28.7

SD: Standard deviation.

applicable. The conformity of the variables to the normal distribution was examined with visual (histogram and probability graphs) and analytical (Shapiro-Wilk test) methods. The paired-samples t-test was used to evaluate normally distributed parameters, and related-samples t-test (Wilcoxon test) to evaluate non-normally distributed parameters. A *p* value of <0.05 was considered statistically significant.

RESULTS

Demographic characteristics of the patients are shown in Table 1.

After the hot pack was applied to the healthy volunteers, there was a statistically significant increase in the median nerve CSA at the levels of the carpal tunnel and mid-forearm (p<0.001). Similarly, ulnar nerve CSA increased at the levels of the hook of hamate and mid-forearm (p<0.001) (Figure 1). The median and ulnar nerve depth measurement values were similar to the values before and after hot pack application (p>0.05). Skin temperature increased at carpal tunnel level and forearm level after hot pack application (p<0.001) (Table 2).

DISCUSSION

In the present study, we attempted to objectively evaluate changes in the morphology of the median and ulnar nerves following hot pack application. After applying a hot pack for 20 min, we detected an increase in the CSA values at the level of the scaphoid bone in the median nerve, at the level of the hook of hamate in the ulnar nerve, and at the level of the mid-forearm in both nerves.

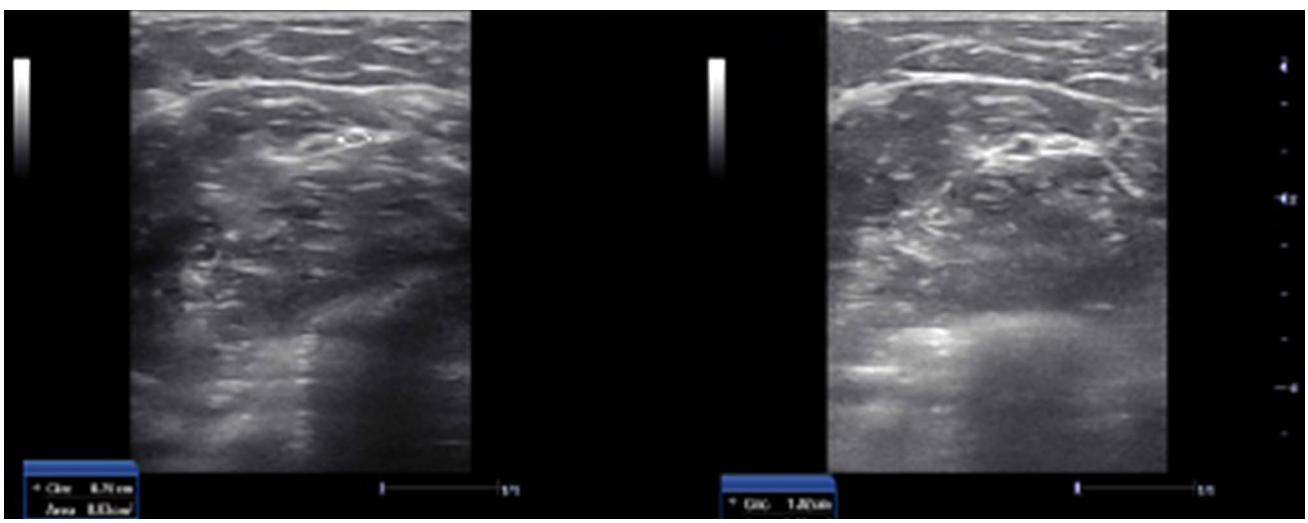

Figure 1. Ulnar nerve cross-sectional area measurement at the mid-forearm level (before and after hot pack application).

TABLE 2
Cross-sectional area, depth, and temperature values before and after hot pack application

Data	Participants (n=54)			Analysis	
	Mean±SD	Median	Min-Max	t, z	*p*
Median nerve CSA at carpal tunnel (cm^2)					
Before hot pack	0.06±0.01	0.06	0.040-0.110	-6.022	<0.001
After hot pack	0.09±0.02	0.09	0.06-0.19		
Median nerve depth at carpal tunnel (cm)					
Before hot pack	0.36±0.11	0.36	0.23-0.90	1.461	0.150
After hot pack	0.34±0.07	0.33	0.18-0.54		
Median nerve CSA at mid-forearm (cm^2)					
Before hot pack	0.06±0.02	0.06	0.04-0.12	-5.435	<0.001
After hot pack	0.09±0.02	0.08	0.06-0.19		
Median nerve depth at mid-forearm (cm)					
Before hot pack	1.17±0.25	1.12	0.69-1.78	0.825	0.413
After hot pack	1.15±0.24	1.18	0.49-1.66		
Ulnar nerve CSA at hook of hamate (cm^2)					
Before hot pack	0.04±0.03	0.04	0.03-0.30	-5.080	<0.001
After hot pack	0.06±0.01	0.06	0.04-0.11		
Ulnar nerve depth at hook of hamate (cm)					
Before hot pack	0.45±0.10	0.45	0.15-0.82	-1.750	0.080
After hot pack	0.48±0.13	0.48	0.18-0.88		
Ulnar nerve CSA at mid-forearm (cm^2)					
Before hot pack	0.05±0.01	0.05	0.03-0.12	-6.255	<0.001
After hot pack	0.08±0.02	0.08	0.05-0.16		
Ulnar nerve depth at mid-forearm (cm)					
Before hot pack	0.95±0.28	0.97	0.34-1.53	-0.402	0.689
After hot pack	0.96±0.30	1	0.28-1.51		
Skin Temperature-carpal tunnel (°C)					
Before hot pack	32.52±1.76	32.45	28.90-35.70	-6.395	<0.001
After hot pack	39.32±1.40	38.85	36.80-41-90		
Skin temperature- mid-forearm (°C)					
Before hot pack	32.68±1.75	33	29-36	-27.659	<0.001
After hot pack	39.32±0.88	39.20	37.20-41		

SD: Standard deviation; CSA: Cross-sectional area; t: T-test; z: Wilcoxon test, p<0.05.

Due to its physiological effects, hot pack application is used in musculoskeletal pathologies to create an analgesic effect and/or prepare the muscle for exercise. Although it is frequently included in treatment protocols, the effect of hot pack application on healthy nerve morphology still remains unclear. Therefore, in our study, we visualized the effect of hot pack application on the morphology of the median and ulnar nerves using USG. On USG, the neural fascicles of healthy nerve tissue are seen as hypo/anechoic and the interfascicular epineurium as hyperechoic. However, the sonographic appearance of a nerve with an impaired structure is swollen and wide.[16,17] Physiological changes, such as vasodilatation, increased vascular permeability, and fluid increase in the intercellular space occur after heat application.[18] Edema that develops as a result of these changes can change the structure of the tissue. In our study, we attributed the increase in the CSA values of the median and ulnar nerves after hot pack application

to edema due to increased intraneural vascularity. In addition, to optimize measurements, we marked the measurement areas before hot pack application and measured the depth between the skin and the outer hyperechoic border of the nerves before and after this application. Therefore, we believe that our results clearly show changes in the morphology of the median and ulnar nerves in our measurements.

Most EDX laboratories emphasize that the temperature of the extremity should be in a narrow range, such as 32 to 34°C to obtain normative data.[7] Therefore, it is recommended to immerse the cold extremity in hot water or warm it with a hot pack before evaluation.[19,20] Burnham and Burnham[13] found that the median sensory and motor conduction velocity increased more significantly in the transcarpal tunnel, after they increased hand temperature by an average of 33.5°C using a heat pad for 20 min in patients with CTS. In another study, increased temperature decreased the median sensory amplitude by 32.1% in patients with CTS and by 10.7% in healthy individuals.[8] As a result, increased temperature changes EDX parameters in healthy individuals, particularly in pathological nerves.[21,22] Therefore, we consider that the effect of heat on morphological changes in nerves should be investigated in different anatomical localizations (such as carpal tunnel level and forearm) in USG studies. Review of the literature reveals only one study investigating the effect of increased temperature on the median nerve CSA at the carpal tunnel level in both patients with CTS and healthy individuals. However, in that study, the median nerve CSA measurements were made at 30°C, 32°C, and 34°C by providing a controlled temperature increase.[23] Although 34°C did not provide significant results in either group, an increase in the median nerve CSA was noted. In our study, we attributed the increase in the median and ulnar nerve CSA at both the carpal tunnel and forearm levels to the skin temperature being measured to be higher than 34°C in all participants following the 20-min hot pack application.

Neuromobilization, which is frequently applied in entrapment neuropathies, is added to routine physical therapy programs.[24,25] Peripheral nerve excursion in nerve mobilization is not only related to the tissues surrounding the nerve, but it also depends on the fascicles and fibrils of the nerve to slide against one another.[26] The demonstration of an increase in the nerve CSA following the 20-min hot pack application in our study may be evidence that possible short-term intraneural edema may facilitate the sliding of the nerve. Therefore, whether neuromobilization with or without hot pack application may have an effect on the nerve CSA should be further elucidated.

The main limitation to our study is that evaluation was unable to be performed blinded, although it is difficult to ensure that a USG evaluator is blinded. In addition, we did not measure intramuscular temperature, repetitive measurements were not made during the cooling stages after the hot pack application, and we did not examine the EDX measurements and the morphological change together. Future studies are needed to confirm the relationship between morphological and EDX findings by applying heat to both healthy and pathological nerve tissues.

In conclusion, while studies in the literature add hot pack application to rehabilitation protocols, we focus on the effect of hot pack application on healthy nerve tissue. Our study results show acute nerve swelling in the median and ulnar nerves with the use of a hot pack for 20 min in physiotherapy practice. Nevertheless, there is a need for further studies based on objective methods to provide valid and reliable data on morphological changes in both healthy and diseased tissues following the use of physiotherapy agents.

Ethics Committee Approval: The study protocol was approved by the Kütahya Health Sciences University Interventional Research Ethics Committee (date: 12.07.2021, no: 2021-03/07). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each participant.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: The study design: F.Y., M.A.L.; Data collection: F.Y., D.B.Ö., M.A.L., A.Ö.; Analysis and interpretation of the data: F.Y., E.C., A.Ö., D.B.Ö.; Literatüre review, writing the article and references: F.Y., E.C, M.A.L., A.Ö.; Supervision of the article: M.A.L., A.Ö., E.C.

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