Rehabilitation Practice and Science

Volume 1
Issue 1 *Taiwan Journal of Physical Medicine and Rehabilitation (TJPMR)*

Article 14

12-1-1973

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Recommended Citation

Kuo, Andrew W. L. (1973) "The Effect of Varying Skin Temperature on Sensory Nerve Conductive Velocity," *Rehabilitation Practice and Science*: Vol. 1: Iss. 1, Article 14.
DOI: https://doi.org/10.6315/3005-3846.1502
Available at: https://rps.researchcommons.org/journal/vol1/iss1/14

皮膚温度對感覺神經傳導速度之影響 *

郭 文 隆

THE EFFECT OF VARYING SKIN TEMPERATURE ON SENSORY NERVE CONDUCTIVE VELOCITY

ANDREW W. L. kUO, RPT

INTRODUCTION

"More than 110 years ago Von Helmholtz was probably the first to determine the velocity of motor nerve impulse by stimulation on the nerve muscle preparation."[1] Since then numerous studies of nerve conduction velocity have been done both on animal experiments and in man. Today ; the results of nerve conduction velocity studies have been applied to clinical use as a tool in diagnosing neurological disorders. For this reason researchers and clinicians have been interested in determining " norms " of peripheral nerves.

In dealing with determinations of " norms " for peripheral nerves, it is important to study extrinsic factors as they relate to varying conduction rates. This pilot study is a part of a larger study which has been designed to increase the reliability and reproducibility of nerve conduction studies. This study centers on the question. " Is there any correlation between skin temperature and nerve conduction velocity ? " This paper deals with sensory nerve conduction velocities of the right ulnar nerve. The motor nerve conduction velocity portion of this study has been investigated by Reddien and Swertfager.[2] We are interested in skin temperature measurement for it is an accessible, practical and a simple technique. If the results of this pilot study prove a positive correlation between temperature and sensory conduction

* This is a pilot Study of Mr. Andrew W.L.Kuo, RPT with the affiliation of U.S. Public Health Service Hospital, Carville, Louisiana, U.S.A. Mr. Kuo now serves as Chief of Physical Therapy Section, Changhwa Christians Hospital, Changhwa, Taiwan, Republic of China

velocities, it could have significant clinical application.

Review of Literature :

Several animal experiments have demonstrated that environmental temperatures exert an influence on nerve conduction velocity. "The sciatic nerve of frogs was exposed to a temperature range of 2.6 to 3.5°C by Rosenberg and Sugimoto (1925), who noted that with the fall in temperature the conduction velocity decreased from 33 to 6 meters per second(M/sec), the change occurring slowly above 12°C and rapidly below this level."[3] Tasaki and Fujita (1948)[4] studied the isolated single nerve fiber of the toad and found that the relationship between ambient temperature and logarithm of conduction could be expressed by the straight line in the temperature range between 5 and 20°C. However, above 20°C the temperature coefficients showed a tendency to decrease.

After Dawson and Scott (1949)[5] described the use of surface electrodes for recording the nerve action potentials in man, there were several reports concerning the correlation of nerve conduction velocity and temperature. "Henriksen (1956)[6] observed that motor nerve conduction velocity was decreased 2.4 M/sec for each 1 degree Centigrade drop in muscle temperature range between 29° and 38°C. His study utilized buman ulnar and median nerves."[3] De Jong et al (1966)[7] stated that motor nerve conduction velocity decreased linearly at a rate of 1.84 M/sec per degree C between 36° and 23° C of measured nerve temperature.

Abramson et al (1966)[8] reported that in the bath temperature range of 34° to 4° C, the measurements of median and ulnar motor nerve conduction velocity in the forearm were increased by an experimentally produced rise and decreased by an experimentally produced fall in tissue temperatures.

Peroneal nerve conduction velocities as studied by Currier and Nelson (1969)[9] were found to have a tendency to increase with a rise in body temperature brought about by active and passive heating.

Most of the above studies dealt with the correlation between motor nerve conduction velocity and temperature. The study of median nerve by Abramson et al (1969)[3] included sensory latency. He stated that lowering bath temperature below a physiological level caused a progressive increase in orthodromic and antidromic sensory latencies.

Objectives and Hypotheses :

The above studies have no clear statement on the correlation between sensory nerve conduction velocity and skin temperature. This pilot study was done in an attempt to supply the clinician with a correction factor to interpret the sensory conduction velocities he obtained.

The null hypothesis in this study is that the correlation between skin temperature and sensory nerve conduction velocity is zero.

Method on Materials :

The study was performed on nine male and four female subjects between ages of 21 and 40 years of age with 31 years being the mean age. Among these subjects ten were right-handed and three left-handed. All subjects had no previous history of neurologic abnormalities or deficiencies.

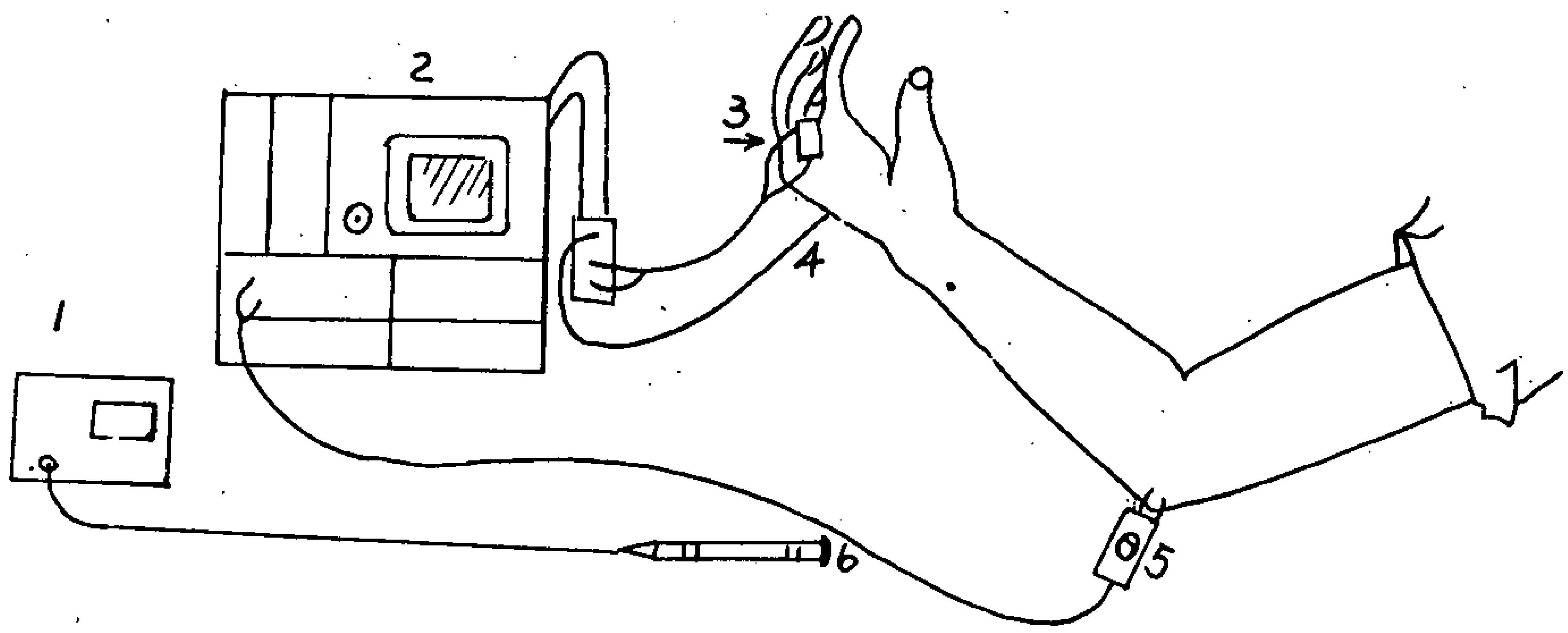
All testing was done between 8:00 A.M. and 4:00 P.M. Instructions were given to the subjects not to smoke for at least one-half hour prior to the experiment and during the experiment. Subjects were also asked to abstain from strenuous exercise prior to testing since Currier and Nelson (1969) reported that motor nerve conduction velocities tended to increase with a rise in body temperature caused by exercise.

Room temperature for all studies was between 21.4°C and 25.0°C with the average being 23.4°C. The air conditioner was left off prior and during the experiment, thus minimizing temperature variation and drafts.

In this study, a TE-4 Electromyograph (TECA) was used to pick up action potentials of sensory nerve fibers by the antidromic method. Stimulation was done with the NS6 Nerve Stimulator. Prior to the study, the reproducibility of the Electromyograph was tested. Skin temperature was monitored by a Model 46 TU Tele-thermometer. Prior to each experiment the accuracy of the thermometer was tested.

The study was performed on the right ulnar nerve of each subject. The active pick-up and reference electrodes (ring-like spring electrodes) were placed with the active pick-up around the proximal phalanx and the reference electrode around the distal phalanx of the fifth digit. Stimulation took place over the ulnar nerve at the wrist and elbow (see Diagram 1.) This gave nerve conduction velocities for the elbow-wrist segment and a latency from the wrist to the pick-up electrodes.

Diagram 1. Shown is a diagrammatic representation of the setup used and the electrode placement on the subject's right arm.



1. 46 TU Tele-thermometer
2. TE-4 Electromyograph
3. Reference and active Pick-up electrode

4. Ground
5. Stimulator
6. Themister

The subjects were placed in a supine position on the testing table, with the right arm supported at the shoulder, external rotated and abducted to approximately 60 degrees. The elbow was positioned in 60 degrees of flexion, with the forearm in slight supination. The wrist was supported in neutral position, with fingers in relaxed position.

No initial cleansing of the skin was done as it might have produced changes of skin temperature. A dot of non-water soluble ink was made on the lateral side of the proximal phalanx of the little finger, at the wrist 140 mm from the first dot and at the elbow just between medial epicondyle and olecranon process.

The pick-up electrodes were then put in place with a small amount of electrode paste. A ground electrode with electrode paste was placed on the dorsum of the hand being tested.

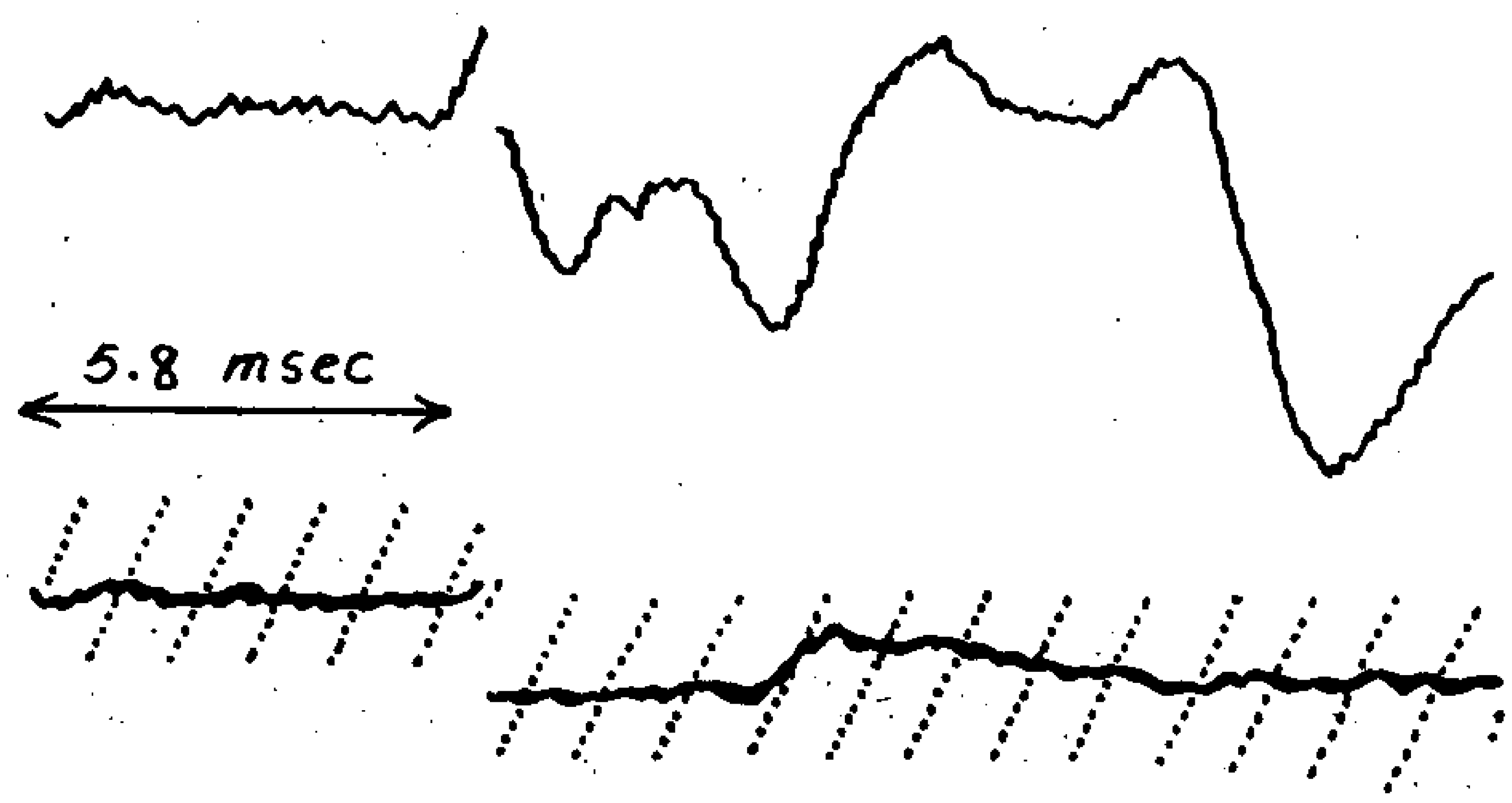
Skin temperatures were taken prior to the stimulation over the exact dot where the cathode of the stimulator was applied. A thermister prode taped onto the end of a pencil was used for temperature measurements. While applying the probe with a constant light pressure the hand of the experimenter was kept five inches from the subject's skin to minimize any possible influence of the examiner's body temperature on the temperature reading.

The NS6 Nerve stimulator was used with its constant fixed distance of 20 mm set between the anode and cathode. The cathode was used as the active electrode which was the distal electrode of the stimulator.

All cathode stimulation was performed exactly over the previously mentioned dots at the wrist and at the elbow.

The frequency of stimulation was set at one per second and the duration of a stimulus was 0.1 millisecond (m/sec). The intensity was gradually increased until the sensory potential became properly displayed on the oscilloscope, as shown in Diagram 2.

Diagram 2. This is an example of a photograph taken representing the millisecond measurement



Sweep Velocity 2 msec/div.
Sensitivity 20 uv/div.

This procedure was repeated at each point of stimulation. The entire testing procedure was immediately repeated to check evaluation repeatability. Distance measurements were taken in millimeter(mm) and recorded between the points of stimulation. This gave a "normal" conduction velocity for each subject. The pick-up and ground electrodes were then removed.

The subjects were treated in an arm whirlpool with a water temperature of 70°F (21.1°C) for 15 minutes. The tested arm was immersed 2 to 3 inches above the elbow. The whirlpool agitator was on to maintain an even temperature in the whirlpool bath. The subjects were instructed not to exercise the tested arm in the whirlpool.

At the end of 15 minutes, the subject's right arm was dried and wrapped with a towel. The subject was returned to the testing table and the electrodes were immediately replaced as in the initial testing procedure. The dots remained visible so that the distance between points of stimulation remained constant. Two trials were again performed as rapidly as good technique and recording accuracy would permit.

The procedures which followed were the same as after the initial "normal" test but this time the subject immersed the tested arm into a whirlpool bath of 110°F (43.3°C). After 15 minutes the subject was returned to the examination room to repeat sensory measurements as previously described. This completed the study of the subject.

For each subject six trials were taken in three different treatments, and data for each trial included: The skin temperature, the measurement of distances between dots, and the time for stimulation to the peak of sensory nerve active potentials seen on the oscilloscope. Two trials were used for data analysis.

Findings:

The data was statistically analyzed using a Treatment x subject Design of Analysis of Variance (ANOVA). With this method, the differences of temperature treatments (normal, cooling, heating) and of individual subjects with respect to nerve conduction velocity were found highly significant as shown on Diagram 3.

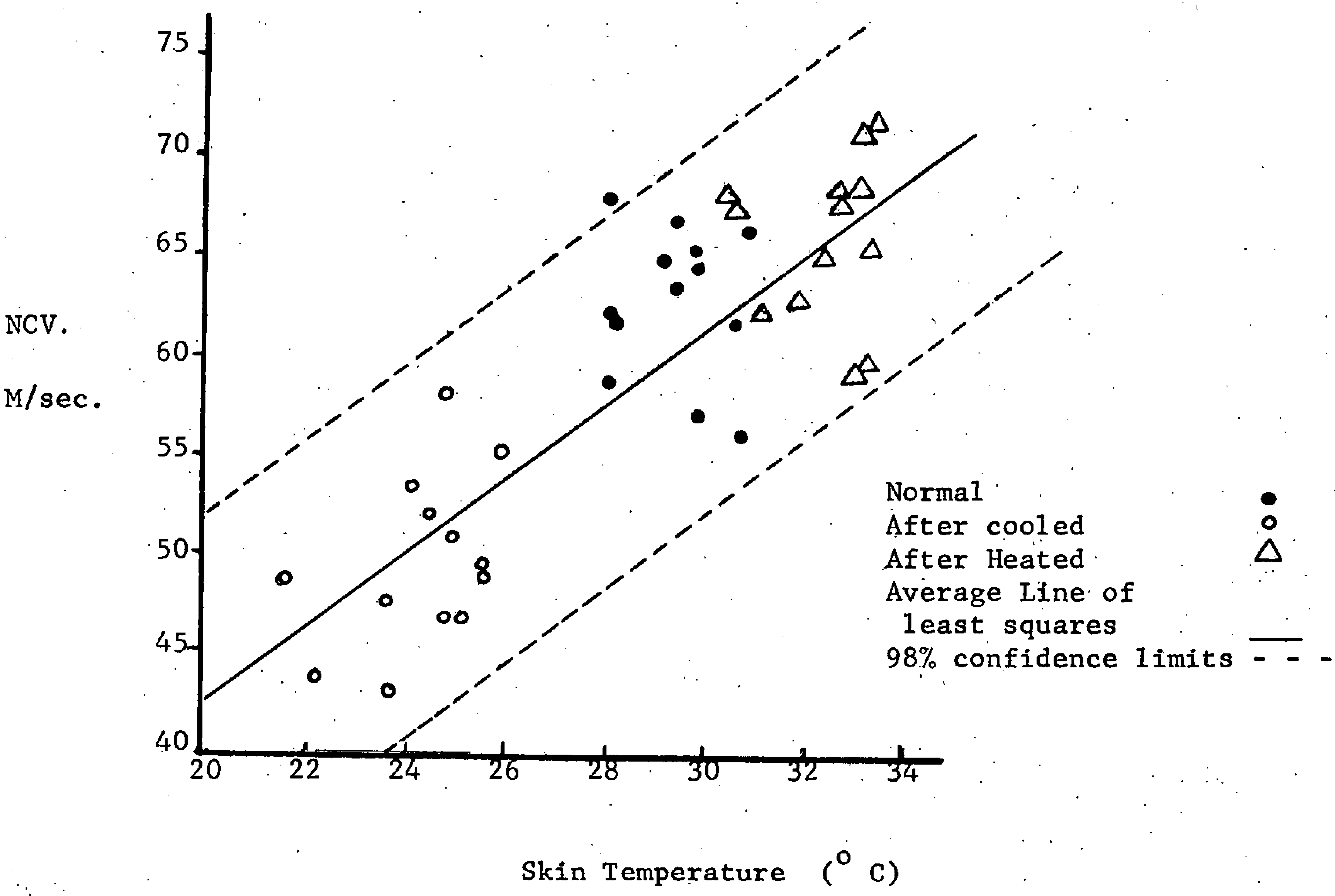
Diagram 3. Analysis of Variance Summary with Nerve Conduction Velocity.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square (Variance)	F-Ratio
Temperature Treatments (A)	2	1708.38	854.19	199.11 *
Subjects (S)	12	480.99	40.08	9.34 *
AS	24	102.03	4.29	
TOTAL	38	2292.30	60.32	

*Highly Significant, P=< .01

A scatter plot (see figure 1) of the varying skin temperatures obtained for specific nerve conduction valocities was plotted. From this information the correlation coefficient and the coefficient of determination were calculated. For further calculation see Diagram 4 and the Appendices.

Figure 1. Correlation scatter plot between skin temperature and sensory nerve conduction velocity



SUMMARY OF CORRELATION STATISTICS BETWEEN TEMPERATURE AND SENSORY NERVE CONDUCTION VELOCITY

Diagram 4.

Correlation Statistics Wrist- Elbow Of Ulnar Nerve		
Correlation coefficient	0.84	P=<0.01 *
Coefficient of determination	70.6 %	
Mean temperature	28.6°C	

Mean nerve conduction velocity (NCV)	59.1 M/sec.
Standard deviation of temperature	3.45
Standard deviation of NCV.	7.77
Slope of NCV on temperature	1.9 M/sec/ °C.

* Null Hypothesis Rejected

Results :

1. From the ANOVA significant NCV differences were noted among three temperature treatments and individual subjects.
2. The correlation coefficient was 0.84 ($P<0.01$) which means a high correlation between the NCV and the skin temperature exists.
3. The coefficient of determination was 70.6% which states that 70.6% of the variation of sensory nerve conduction velocities was associated with the variation of skin temperature.
4. Standard deviations for skin temperature was 3.45, and for the NCV was 7.77.
5. The slope of the line was 1.9, meaning that for each degree C change of skin temperature the sensory nerve conduction changed 1.9 M/sec.
6. All information shows that there is a significant relationship between skin temperature and sensory nerve conduction velocity.

Discussion :

Since the antidromic method has the advantage of producing a larger nerve action potential with less current and is less painful for the subjects being tested, this method was chosen for use in this study.

The technique for measurement of skin temperatures included immediate wrapping of the extremity in an attempt to control the influence of evaporation on the temperature of the skin following whirlpool immersion. No attempt was made to control for influence of the towel on skin temperature, but it was on the extremity for a very brief time and it was felt that its influence was minimal. Also any influence the towel may have had on skin temperature was not directly influencial on the results of this study since the only recorded temperatures were taken immediately before the NCV testing.

Abramson et al (1966)[10] observed that from prolonged heating (bath temperature 4°C) for 155 minutes by immersion, the correlation coefficient between motor conduction velocity of the ulnar nerve and cutaneous temperature was 0.889. Reddien and Swertfager applied the same method as this study described and found the correlation coefficient was 0.76 for the motor nerve fibers and this study showed the correlation coefficient of sensory nerve fibers was 0.84. There is a significant correlation between skin temperature and both sensory and motor conduction velocity of the ulnar nerve.

In comparing the slope with the results which Reddien and Swertfager found, 1.9 M/sec/°C of sensory nerve was steeper than 1.7 M/sec/°C of motor nerve of wrist-elbow segment. This difference might be related to the fact that all subjects in this study were cooled before heating. In the study by Reddien and Swertfager half of the subjects were cooled first and half heated first.

For clinical interpretation of a correction factor relating to skin temperature and nerve conduction velocities more extensive studies are indicated. Because of the different specific heat of water and air, it is suggested that cold and warm air be used instead of immersion to be able to imitate a more natural situation. It is felt that continual evaporation from the moist skin around the thermometer probe may have influenced the temperature recordings.

Since there is a difference in anatomical location of each nerve and nerve segment it is necessary to study each individually.

Summary and Conclusions :

The determination of a skin temperature correction factor for

sensory conduction of the Right Ulnar Nerve of wrist-elbow segment has been performed by a simple, practical method. It is by taking skin temperature at the ulnar notch over the point to be stimulated prior to stimulation. The finding of this correction factor of the Ulnar Nerve was 1.9 M/sec for each degree C.

In evaluating sensory conduction velocity of ulnar nerve, actual skin temperatures of the part must be considered. After further investigation and larger samplings of normal subjects, it should be possible to make a temperature correction table which would be used in establishing more accurate results in sensory conduction velocity studies.

APPENDICES

1. Study of Sensory Conduction Velocity of the Right Ulnar Nerve by the Antidromic Method

NAME ___ AGE ___ SEX ___

TESTING DATE ___ RIGHT HANDED ___ LEFT HANDED ___

ROOM TEMPERATURE ___

NORMAL		MSEC	MM	SKIN TEMP	ORAL TEMP		M/SEC
Trial #1.	Wrist…pick-up	___	___		___		
	Elbow…pick-up	___				NCV#1	___
	Elbow…Wrist	___	___	___			
Trial #2.	Wrist…pick-up	___	___		___		
	Elbow…pick-up	___				NCV#2	___
	Elbow…Wrist	___	___	___			
			MEAN	___	___		___

COOLING							
Trial #1.	Wrist…pick-up	___	___		___		
	Elbow…pick-up	___				NVC#1	___

	Elbow···Wrist	____	____	____		
Trial #2.	Wrist··· pick-up	____	____		____	
	Elbow··· pick-up	____				NCV#2 ____
	Elbow···Wrist	____	____	____		
			MEAN	____	____	____

HEATING

Trial #1.	Wrist··· pick-up	____	____		____	
	Elbow··· pick-up	____				NCV#1 ____
	Elbow···Wrist	____	____	____		
Trial #2.	Wrist··· pick-up	____	____		____	
	Elbow··· pick-up	____				NCV#2 ____
	Elbow···Wrist	____	____	____		
			MEAN	____	____	____

2. Tabulation Skin Temperatures and Nerve Conduction Velocities (NCV) of 13 Subjects.

Subj.	COOLINS		NORMAL		HEATING	
No.	Skin Temp°C	NVC M/Sec	Skin Temp°C	NCV M/Sec	Skin Temp°C	NVC M/Sec
1	25.5	49.2	30.9	65.0	32.4	67.4
2	24.9	47.8	30.2	60.7	30.8	61.4
3	23.7	43.0	30.7	56.0	33.0	58.2
4	25.5	49.8	29.6	56.5	33.1	58.6
5	26.0	55.2	29.5	63.8	33.1	71.0
6	23.7	48.5	29.5	63.3	30.8	66.3
7	21.3	47.7	28.3	61.7	30.7	67.1
8	22.1	43.7	29.3	62.0	31.7	62.0
9	24.8	47.8	28.1	59.0	33.3	64.7
10	24.4	53.8	28.2	62.3	32.2	64.8
11	25.5	58.8	28.3	68.9	32.9	70.3
12	24.7	52.3	29.1	63.4	32.4	67.6
13	24.9	50.7	29.3	65.7	32.7	67.7

3. Analysis of Variance Summary with Nerve Conduction Velocity as the Criterion Measurement.

A.

Subj. No.	Cooling NCV	Normal NVC	Heating NCV	Ti
1	49.2	65.0	67.4	181.6
2	47.8	60.7	61.4	169.9
3	43.0	56.0	58.2	157.2
4	49.8	56.5	58.6	164.9
5	55.2	63.8	71.0	190.0
6	48.5	63.3	66.3	178.1
7	47.7	61.7	67.1	176.5
8	43.7	62.0	62.0	167.7
9	47.8	59.0	64.7	171.5
10	53.8	62.3	64.8	180.9
11	58.8	68.9	70.3	198.0
12	52.3	63.4	67.6	183.3
13	50.7	65.7	67.7	184.1
Tj	648.3	808.3	847.1	$\Sigma X=2303.7$
$\bar{X}j$	49.87	62.18	65.16	$\Sigma X^2=138370.09$
ΣX^2j	32561.29	50411.51	55397.29	$N=39$
Sj	4.39	3.58	4.07	$(\Sigma X)^2/N=136077.79$

B.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square (Variance)	F-Ratio
Temp Treats(A)	2	1708.38	854.19	199.11 *
Subjects (S)	12	480.99	40.08	9.34 *
AS	24	102.93	4.29	
TOTAL	38	2292.30	60.32	

*Highly Significant, $P=<.01$

4. Correlation Statistics

Skin Temperature X		NCV Y	
ΣX	1117.1	ΣY	2303.7
ΣX^2	32450.99	ΣY^2	138370.09
$\bar{X}$	28.64	$\bar{Y}$	59.07
S_x^2	11.93	S_y^2	60.35
S_x	3.45	S_y	7.77

N	39
ΣXY	66842.65
byx	1.9
bxy	0.4
ayx	4.65
axy	5.01
Syx	4.2
Sxy	1.9
r	+ .840 , P =< .01
r^2	.7059
$Y^2(100)$	70.59%

Regression equation for prediction of $\hat{Y}$	$\hat{Y}=ayx + [byx(X)]$
1 $\hat{Y} = 4.65+(1.9)(22)=$	46.45
2 $\hat{Y} = 4.65+(1.9)(28)=$	57.85
3 $\hat{Y} = 4.65+(1.9)(33)=$	67.35

Upper 98% confidence limit of a $\hat{Y} = 2.33(Syx) + \hat{Y}$

Lower 98% confidence limit of a $\hat{Y} = \hat{Y} - [2.33(Syx)]$

FOOTNOTES

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ABSTRACT

The purpose of this study was to determine if a direct correlation exists between skin temperature and sensory nerve conduction of the right ulnar nerve by utilizing a simple, practical method. Skin temperatures were monitored with a Model 46 TU Tele-Thermometer at the points of nerve stimulation, namely, the wrist and the elbow. Instrumentation used in this study for recording sensory action poten-

tials was The TECA TE-4 Electromyograph. Nerve stimulation was performed using the antidromic method at the points mentioned above and with pick-up electrodes placed around the fifth digit.

The subjects were comprised of thirteen individuals with no history of neurological disease. Each subiect's right ulnar nerve was tested under three different environmental conditions.

A. Normal arm temperature

B. After cooling

C. After heating

Cooling was performed by immersing the subject's right arm in a whirlpool bath for 15 minutes, at a temperature of 70°F (21.1° C). Heating was performed in a similar manner with the whirlpool bath temperature at 110°F (43.3°C).

Findings of this study indicated a statistically significant correlation between skin temperature of the right arm and sensory nerve conduction of the right ulnar nerve. For each rise or fall of 1°Centigrade of skin temperature the mean sensory nerve conduction velocity changed 1.9 meters/second.

中文摘要

這個研究的目的是以簡單實用的方法來決定右臂尺骨神經之感覺神經傳導速度與皮膚溫度之間有無直接相互之關係。

皮膚溫度是以 46 TU 型皮膚溫度計在腕部與肘部測定。用來記錄感覺神經傳導的是TECA，TE—4 肌電圖描繪器。神經的刺激是以反傳導方法於上述之兩點刺激；摘取電極放在小指上。

試驗對象包括 13 位過去沒有神經系統疾病的人。每一對象右手臂尺骨神經在三種不同周圍環境下測定，即：A.通常手臂溫度 B.在冷却之後 C.在受熱之後

冷却是對象將右手臂放入華氏 70°（攝氏 21.1°）的旋渦浴中 15 分鐘。受熱是以相似的方法在華氏 110°（攝氏 43.3°）的水中。

研究所發現在統計學上右手臂皮膚溫度和右手臂尺骨神經之感覺神經傳導速度有意義的相互關係。每升高或降低皮膚溫度攝氏 1 度，感覺神經之平均速度改變了 1.9 米／每秒。