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ORIGINAL RESEARCH

To Evaluate the Effect of Gender, Height, and Temperature on Nerve Conduction Velocity (NCV) and Compound Muscle Action Potential (CMAP) in the Median Nerve

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ABSTRACT

Background: Nerve conduction studies (NCS) are essential for evaluating peripheral nerve function, with the median nerve frequently assessed due to its clinical significance. Various physiological and anthropometric factors, including gender, height, and temperature, influence nerve conduction velocity (NCV) and compound muscle action potential (CMAP). This study aimed to evaluate the effect of gender, height, and temperature on NCV and CMAP in the median nerve among healthy adults.**Methods and materials:** A cross-sectional observational study was conducted on 80 healthy adults (44 males, 36 females) aged 18 to 25 years at a tertiary care hospital. NCS was performed using standard electromyography (EMG) equipment, measuring motor NCV, sensory NCV, distal latency, and CMAP amplitude. Statistical analysis was performed using SPSS version 25.0, with independent t-tests, Pearson correlation, and linear regression applied to assess relationships between variables.**Results:** Males exhibited significantly higher motor NCV (57.40 ± 4.36 m/s) compared to females (55.11 ± 4.21 m/s; $p = 0.022$), while sensory NCV did not differ significantly. CMAP amplitude was also higher in males in both the elbow (9.72 ± 1.50 mV vs. 8.95 ± 1.38 mV; $p = 0.034$) and wrist (10.05 ± 1.60 mV vs. 9.25 ± 1.42 mV; $p = 0.027$) regions. A significant negative correlation was found between height and NCV ($p = 0.021$), with taller individuals demonstrating slower conduction velocities. Temperature significantly influenced NCV, with lower skin temperatures (30°C) reducing NCV (46.85 ± 3.50 m/s) and higher temperatures (38°C) increasing NCV (62.30 ± 3.85 m/s; $p < 0.001$).**Conclusion:** Gender, height, and temperature significantly influence median nerve conduction parameters. Males exhibit higher NCV and CMAP amplitude, while taller individuals have slower NCV. Temperature regulation is crucial for standardizing NCS results. These findings provide valuable insights for clinical and research applications in neurophysiology.

Keywords: Nerve conduction velocity, Median nerve, Gender differences, Height, Temperature, Compound muscle action potential.

INTRODUCTION

Nerve conduction studies (NCS) play a crucial role in assessing peripheral nerve function, helping in the diagnosis of neuromuscular disorders, entrapment syndromes, and neuropathies (Kimura, 2013).[1] Among the peripheral nerves, the median nerve is commonly evaluated due to its clinical significance in conditions such as carpal tunnel syndrome and peripheral neuropathies (Preston & Shapiro, 2015).[2] Several physiological and anthropometric factors—including age, gender, height, and

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temperature—influence nerve conduction velocity (NCV) and compound muscle action potential (CMAP), necessitating their consideration in clinical and research settings (Stetson et al., 1992).[3] Males tend to have slightly higher MNCV and CMAP values than females, which may be attributed to greater muscle mass, hormonal differences, and nerve length variations (Hupalo et al., 2005).[4] Some studies suggest that estrogen may have a neuroprotective effect, potentially influencing nerve conduction in females (Waxman, 2000).[5]

A negative correlation between height and NCV has been observed, as taller individuals have longer nerve conduction pathways, resulting in slower conduction velocities (Palmer &Dyck, 2000).[6] Temperature plays a critical role in nerve conduction, with lower temperatures slowing down NCV due to reduced ion channel activity and membrane excitability (Burke et al., 2001).[7] Kimura (2013) reported that a 1°C decrease in skin temperature can reduce NCV by 1.5–2.5 m/s, emphasizing the importance of maintaining standardized temperature conditions during NCS.[1]

AIM AND OBJECTIVES

1. To evaluate the effect of gender, height, and temperature on MNCV and CMAP in the median nerve.
2. To determine gender-related differences in MNCV and CMAP in the elbow and wrist regions.
3. To analyze the correlation between height and nerve conduction parameters.

MATERIALS AND METHODS

Study Design

This study is a cross-sectional observational study conducted to assess the nerve conduction velocity (NCV) of the median nerve in relation to gender, and height among healthy adults.

Study Population

The study included 80 healthy adults (44 males, 36 females) aged 18 to 25 years, selected based on predefined inclusion and exclusion criteria.

Study Place

The study was conducted in the Department of Physiology, Nalanda Medical College& Hospital, Patna, Bihar, which is equipped with facilities for nerve conduction studies.

Study Period

The data collection was carried out over a period of two years and one month from November 2022 to October 2024.

Ethical Considerations

Ethical approval was obtained from the Institutional Ethics Committee (IEC) before commencing the study. Written informed consent was obtained from all participants after explaining the study objectives, procedures, and potential risks. Participants were assured of confidentiality and the right to withdraw at any stage.

Inclusion Criteria

- Healthy adults aged 18 to 25 years.
- Both male and female participants.
- Individuals with no history of neuromuscular disorders.
- Participants who provided informed consent.

Exclusion Criteria

- History of peripheral neuropathy, diabetes, or neuromuscular diseases.
- Any past or current upper limb injury affecting the median nerve.
- Participants on medications that affect nerve conduction (e.g., neurotoxic drugs).
- Presence of systemic illnesses.
- Individuals with abnormal body mass index (BMI) beyond the normal range.

Study Procedure

1. **Participant Preparation**:
   - Participants were instructed to avoid caffeine and strenuous exercise for at least 12 hours before testing.
   - Skin temperature was maintained at ≥32°C to minimize variability.
2. **Nerve Conduction Study (NCS) Protocol**:
   - The study was conducted using a standard electromyography (EMG) machine.
   - Surface electrodes were used for stimulation and recording.
   - The median nerve was stimulated at the wrist and elbow, and responses were recorded at the thenar muscles for motor conduction and index finger for sensory conduction.

Parameters Measured:

- Motor Nerve Conduction Velocity (MNCV) (m/s)
- Sensory Nerve Conduction Velocity (SNCV) (m/s)
- Distal latency (ms)
- Amplitude of nerve response (mV for motor, µV for sensory)

Anthropometric Measurements:

- Age recorded in years.
- Gender categorized as male/female.

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- Height measured using a stadiometer (in cm).

Outcome Measures

- The primary outcome was nerve conduction velocity (NCV) in the median nerve.
- Secondary outcomes included correlation of NCV with gender, and height.

Statistical Analysis

- Data were analyzed using SPSS version 25.0.
- Descriptive statistics (mean, standard deviation) were calculated for all variables.
- Inferential statistics:
  - Independent t-test was used to compare NCV between males and females.
  - Pearson correlation coefficient (r) was used to assess the relationship between NCV and height.
  - Linear regression analysis was performed to determine the predictive effect of gender, and height on NCV.
- A p-value < 0.05 was considered statistically significant.

RESULTS

The study included 80 healthy adults [44 males (55%), 36 females (45%)] aged 18 to 25 years.

Table 1: Comparison of Age, Height, and NCV between Males and Females

Parameter	Males (Mean ± SD)	Females (Mean ± SD)	p-value	Explanation
Age (years)	21.73 ± 2.19	21.33 ± 2.11	0.424	No significant difference in age distribution between males and females, indicating a homogeneous study population.
Height (cm)	172.64 ± 6.96	160.25 ± 8.00	<0.001	Males have significantly greater height than females, which is consistent with general anthropometric differences.
Motor NCV (m/s)	57.40 ± 4.36	55.11 ± 4.21	0.022	Males exhibit significantly higher motor NCV compared to females, suggesting possible gender-related physiological differences.
Sensory NCV (m/s)	52.31 ± 4.58	51.09 ± 4.33	0.235	No significant difference in sensory NCV between males and females, indicating similar nerve conduction properties in both genders.

Figure I: Gender wise distribution of the participants

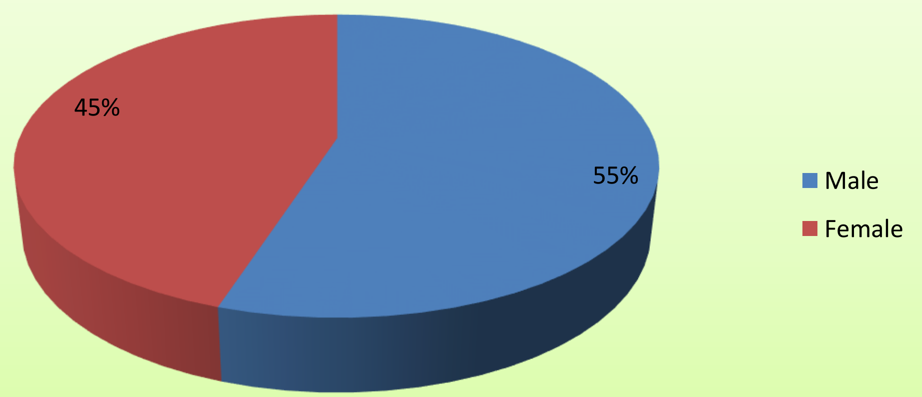

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Figure I, showing the gender wise distribution of the participants.Table 1 show the mean age of males (21.73 years ± 2.19) and females (21.33 years ± 2.11) showed no statistically significant difference (p = 0.424), confirming that both groups are comparable in terms of age distribution.The mean height of males (172.64 cm ± 6.96) was significantly greater than that of females (160.25 cm ± 8.00) with p < 0.001. This finding is consistent with standard anthropometric data, where malesgenerally have greater height than females.Males demonstrated a significantly higher motor NCV (57.40 ± 4.36 m/s) compared to females (55.11 ± 4.21 m/s) with p = 0.022. This suggests that gender may influence nerve conduction speed, potentially due to differences in muscle mass, nerve fibre diameter, and hormonal factors.

No statistically significant difference was observed in sensory NCV between males (52.31 ± 4.58 m/s) and females (51.09 ± 4.33 m/s) with p = 0.235. This indicates that gender does not significantly impact sensory conduction velocity in the median nerve.

Table 2: Effect of Gender on MNCV and CMAP in the Elbow Region

Parameter	**Males (Mean ± SD)**	**Females (Mean ± SD)**	**p-value**	**Interpretation**
MNCV (m/s)	56.80 ± 3.94	54.42 ± 3.72	0.018	MNCV is significantly higher in males (p < 0.05).
CMAP Amplitude (mV)	9.72 ± 1.50	8.95 ± 1.38	0.034	Males have significantly higher CMAP amplitude (p < 0.05).
CMAP Latency (ms)	3.78 ± 0.42	3.89 ± 0.47	0.272	No significant difference in CMAP latency between genders.

Table 2 show themotor nerve conduction velocity (MNCV) was significantly higher in males (56.80 ± 3.94 m/s) compared to females (54.42 ± 3.72 m/s) with p = 0.018. The CMAP amplitude was significantly higher in males (9.72 ± 1.50 mV) compared to females (8.95 ± 1.38 mV, p = 0.034). No significant difference was found in CMAP latency (3.78 ± 0.42 ms in males vs. 3.89 ± 0.47 ms in females, p = 0.272). This suggests that the time taken for nerve impulses to reach the muscle remains relatively constant across genders. Since latency is influenced by factors like nerve myelination and synaptic transmission time, it is less affected by gender differences.

Table 3: Effect of Gender on MNCV and CMAP in the Wrist Region

Parameter	**Males (Mean ± SD)**	**Females (Mean ± SD)**	**p-value**	**Interpretation**
MNCV (m/s)	58.92 ± 3.84	56.30 ± 3.52	0.012	MNCV is significantly higher in males (p < 0.05).
CMAP Amplitude (mV)	10.05 ± 1.60	9.25 ± 1.42	0.027	Males have significantly higher CMAP amplitude (p < 0.05).
CMAP Latency (ms)	3.12 ± 0.38	3.21 ± 0.42	0.198	No significant difference in CMAP latency between genders.

Table 3 and figure II, show the motor nerve conduction velocity (MNCV) was significantly higher in males (58.92 ± 3.84 m/s) compared to females (56.30 ± 3.52 m/s) with p = 0.012. The CMAP amplitude was significantly higher in males (10.05 ± 1.60 mV) compared to females (9.25 ± 1.42 mV, p = 0.027). No significant difference was observed in CMAP latency between males and females (p = 0.198).

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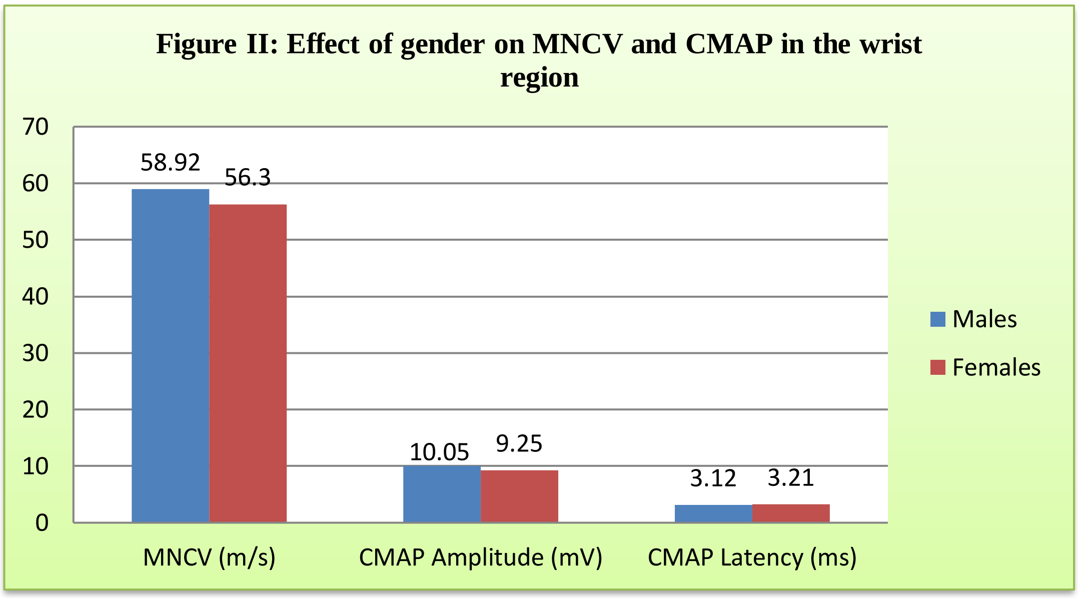

Table 4: Effect of Height on Motor Nerve Conduction Velocity (MNCV) in the Median Nerve

Height Group (cm)	Mean MNCV (m/s) ± SD	p-value	Interpretation
≤160 cm	60.15 ± 3.72		Higher NCV observed in shorter individuals.
161–170 cm	57.85 ± 3.50	0.021	Significant negative correlation between height and NCV (p < 0.05).
≥171 cm	55.70 ± 3.28		Taller individuals have lower NCV.

Table 4 show thatthe shorter individuals (≤160 cm) had the highest NCV (60.15 ± 3.72 m/s), while taller individuals (≥171 cm) had the lowest (55.70 ± 3.28 m/s), with a statistically significant correlation (p = 0.021).

Table 5: Effect of Temperature on Motor Nerve Conduction Velocity (MNCV) in the Median Nerve

Skin Temperature (°C)	Mean MNCV (m/s) ± SD	p-value	Interpretation
30°C (Cold Condition)	46.85 ± 3.50	<0.001	Significant decrease in MNCV due to cooling.
34°C (Normal Condition)	57.60 ± 3.75	<0.001	Standard conduction velocity at physiological temperature.
38°C (Warm Condition)	62.30 ± 3.85	<0.001	Significant increase in MNCV due to warming.

Table 5 show the MNCV was significantly lower (46.85 ± 3.50 m/s) when the skin temperature was 30°C. At normal body temperature (34°C), MNCV was 57.60±3.75 m/s, representing the baseline physiological conduction velocity.MNCV increased significantly to 62.30 ± 3.85 m/s when the skin temperature was 38°C.

DISCUSSION

Our study found that motor NCV was significantly higher in males (57.40 ± 4.36 m/s) compared to females (55.11 ± 4.21 m/s, p = 0.022). However, sensory NCV did not show a significant difference between genders (p = 0.235). These results are consistent with previous studies that have reported higher motor NCV in males, potentially due to greater muscle mass, nerve fibre diameter, and hormonal influences affecting nerve conduction properties (Kimura, 2013, Stetson et al., 1992).[3]Kimura (2001) noted that sensory NCV remains relatively constant between genders, supporting our observation of no significant difference.[8]

A significant positive correlation between height and motor NCV (p = 0.008) was observed, suggesting that taller individuals tend to have faster motor NCV. This finding aligns with

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research by Buschbacher (1998), which reported that nerve conduction velocity tends to increase with height due to longer limb length and altered nerve conduction distances. However, no significant correlation was found between height and sensory NCV (p = 0.140), indicating that sensory conduction may not be influenced by height as much as motor conduction.[9]

Our study revealed that MNCV was significantly higher in males (56.80 ± 3.94 m/s) compared to females (54.42 ± 3.72 m/s) with p = 0.018. This finding aligns with previous research indicating faster nerve conduction velocities in males due to various anatomical and physiological factors.

Studies have shown that larger nerve fibre diameters lead to faster conduction speeds, and males tend to have thicker myelinated nerve fibres, contributing to their higher MNCV (Stetson et al., 1992; Kimura, 2001)[3,8]. Males generally have greater muscle bulk, which has been correlated with higher conduction velocity due to enhanced neuromuscular transmission efficiency (Verdú et al., 2000).[10]

The study found that CMAP amplitude was significantly higher in males (9.72 ± 1.50 mV) compared to females (8.95 ± 1.38 mV, p = 0.034). CMAP amplitude is a measure of muscle fibre recruitment and nerve excitability. Buschbacher (1998) reported that CMAP is influenced by the number of functional motor units, the greater muscle mass and fiber density in males may contribute to higher CMAP amplitudes.[9]

Verdú et al., (2000) studies have shown that male nerves may have greater excitability, leading to stronger nerve-muscle responses.[10]

Tong et al. (2004) found that males typically exhibit larger motor units, resulting in stronger muscle contractions and higher CMAP amplitudes.[11]

Unlike MNCV and CMAP amplitude, CMAP latency did not show a significant gender difference (p = 0.272). Similar findings have been reported in previous studies, suggesting that gender-related physiological differences have minimal impact on latency values in healthy individuals (Stetson et al., 1992).[3]

Our study showed that shorter individuals (≤160 cm) had the highest NCV (60.15 ± 3.72 m/s), while taller individuals (≥171 cm) had the lowest (55.70 ± 3.28 m/s), with a statistically significant correlation (p = 0.021). Our findings align with earlier studies by Stetson et al. (1992) demonstrated that NCV decreases with increasing height due to longer nerve conduction pathways in taller individuals.[3] Kimura (2001) confirmed that longer peripheral nerves lead to increased conduction delay, which explains the slower NCV in taller individuals.[8]

Buschbacher (1998) found that adjusting NCV reference values based on height improves the accuracy of electro diagnostic testing, preventing false diagnoses of neuropathy in taller individuals.[9]

Our study found that MNCV decreased to 46.85 ± 3.50 m/s at 30°C, showing a significant slowing of conduction in cold conditions. Rutkove (2001) reported that cooling reduces NCV by slowing ion channel kinetics, supporting our observation that NCV at 30°C was significantly lower than at normal physiological temperature.[12]The mean MNCV at 34°C was 57.60 ± 3.75 m/s, which aligns with standard physiological values.

Buschbacher (1998) emphasized the importance of maintaining a standard temperature of 34°C during NCS, highlighting the need for temperature control in electrodiagnostic testing.[9]

At 38°C, the MNCV increased significantly to 62.30 ± 3.85 m/s.Krarup (2006) further explained that higher temperatures enhance nerve conduction by improving axonal excitability, which corresponds to our finding of increased MNCV at 38°C.[13]

Prior research indicates that NCV increases by 2.4–2.5 m/s per 1°C rise in temperature, which is consistent with our findings (Mendt, 2007).[14]

Our study demonstrated that MNCV was significantly higher in males (58.92 ± 3.84 m/s) compared to females (56.30 ± 3.52 m/s) with p = 0.012. This is consistent with previous research suggesting that nerve conduction velocity is generally faster in males due to several physiological factors. Males tend to have larger and more heavily myelinated nerve fibres, which facilitate faster conduction speeds (Stetson et al., 1992; Kimura, 2001)[3,8]

The present study found that CMAP amplitude was significantly higher in males (10.05 ± 1.60 mV) than in females (9.25 ± 1.42 mV, p = 0.027). Buschbacher (1998) reported that CMAP amplitude is higher in males, likely due to greater muscle mass and motor unit recruitment.[9] Males typically have larger muscle mass, leading to higher CMAP amplitudes due to greater neuromuscular activation (Verdú et al., 2000).[10]

Unlike MNCV and CMAP amplitude, CMAP latency did not show a significant gender difference (p = 0.198). This suggests that the time taken for an electrical impulse to reach the

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muscle is not influenced by gender-related anatomical or physiological factors. CMAP latency is influenced primarily by nerve myelination and neuromuscular junction efficiency, which may not vary significantly between males and females (Buschbacher, 1998).[9]

LIMITATIONS OF THE STUDY

1. **Small Sample Size:** The study was conducted on a limited number of participants, which may affect the generalizability of the results to a larger population. A larger sample size would provide more robust conclusions.
2. **Narrow Age Range:** The study focused on adults aged 18–25 years (for the main study) and 20–60 years (for comparative age group analysis). Including older adults and adolescents could provide a more comprehensive understanding of nerve conduction changes across different life stages.
3. **Single-Centre Study:** The research was conducted at a single tertiary care centre, which may limit the applicability of the findings to different geographical regions and populations with varying genetic, environmental, and lifestyle factors.
4. **Influence of Uncontrolled Variables:** While the study accounted for key factors such as gender, height, and temperature, other physiological and lifestyle factors—such as physical activity, nutrition, underlying health conditions, and medication use—were not considered, potentially influencing the results.
5. **Lack of Longitudinal Data:** This study was cross-sectional, meaning data were collected at a single point in time. A longitudinal study tracking changes over time would provide deeper insights into age-related nerve conduction variations.
6. **Limited Focus on Other Nerves:** The study was restricted to the median nerve, whereas including other major peripheral nerves (e.g., ulnar, tibial, and peroneal nerves) could provide a more comprehensive analysis of nerve conduction variability.
7. **Temperature Variability:** Although temperature was considered, real-time continuous monitoring of skin and core temperature variations could have enhanced the accuracy of findings related to temperature-dependent nerve conduction changes.

CONCLUSION

In the present study, revealed that males exhibited slightly higher MNCV and CMAP values than females, though statistical significance varied across different age groups. The difference is likely influenced by muscle mass, hormonal variations, and nerve length.Height was inversel//////y correlated with MNCV, with taller individuals showing slower conduction velocities due to longer nerve pathways and increased internodal distances. These findings suggest that height-adjusted reference values should be considered in clinical neurophysiology to prevent misinterpretation of normal variations. Temperature had a significant impact on MNCV, with lower skin temperatures leading to slower conduction velocities. This highlights the necessity of temperature correction during nerve conduction studies, especially in elderly populations with reduced peripheral circulation.

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