Original Article

Dorsal Sural Sensory Nerve Action Potential: A Study for Reference Values

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Abstract

Background: Dorsal sural sensory nerve action potential (SNAP) could help diagnose early or subclinical peripheral neuropathy. **Objectives:** To establish reference data for dorsal sural SNAP amplitude, latency, and velocity in healthy participants. **Materials and Methods:** A prospective study was conducted in 45 nerves from healthy participants between 18 and 90 years and stratified into three age groups (a = 18–40 years, b = 41–60 years, and c ≥60 years). StataCorp 12.2 statistical program was used for all statistical analyses. Mean-2 standard deviation was used to generate reference values for the lower limit of amplitude and velocity in each age group. ANOVA with Bonferroni correction was used for intergroup comparisons of amplitude and velocity. Regression analysis was used to compute an equation for the predicted amplitude with age, height, and weight as the covariates. **Results:** The lower limit for amplitude (uv) in Groups a, b, and c was 2.57, 1.97, and 1.01, respectively. The lower limit for velocity (m/s) was 33.6, 32, and 22.8, respectively. Statistical significance was noted between the amplitudes of participants in Groups b and c ($P = 0.039$) and a and c ($P = 0.001$). Similarly, velocity was significantly different between Groups b and c ($P = 0.04$) and a and c ($P = 0.008$). Age was the covariate with maximum effect on the dorsal sural amplitude. Gender and side-to-side comparison did not show statistical significance for amplitude and velocity measurements. Linear regression analysis of the transformed amplitude gave the predictive equation as (y) =3.338 + age (−0.0167) + height in meters (−0.209) + weight (0.001). **Conclusion:** This study provides reference data for dorsal sural SNAP in Indian population stratified by age.

Keywords: Dorsal sural, Indian, reference values, sensory nerve action potential

Introduction

Dorsal sural nerve is the distal continuation of the sural nerve in the foot and is a pure sensory nerve. The sural nerve courses along a line drawn from the mid-popliteal fossa to just posterior to the lateral malleolus and then continues forward along the lateral aspect of the foot to the little toe as the lateral dorsal cutaneous nerve or the dorsal sural nerve.[1] It supplies sensation to the skin of the lateral foot and little toe. Since it is one of the distal sensory nerves, it is likely to be affected early in length-dependent peripheral neuropathies and recording its sensory nerve action potential (SNAP) would help in diagnosing very early and subclinical distal peripheral neuropathies, especially when sural and superficial peroneal SNA*P* values were obtained within the reference range.[2-5] Other distal peripheral sensory nerves such as medial plantar and interdigital nerves can also be examined but comparatively pose more technical difficulties. In our country where walking barefoot is fairly common, the sole is often very thick and that in addition to poor foot hygiene poses a problem when examining the medial plantar nerve. Recording from interdigital nerves involves using subdermal needles, which limits its utility.[3] Dorsal sural nerve is easily accessible to nerve conduction techniques because of its superficial location and is less prone to damage by local trauma or entrapment compared to the medial plantar and interdigital nerves.[6-10] Dorsal sural conduction is useful for diagnosing early peripheral neuropathy[2] and also for detecting subclinical peripheral neuropathy of impaired glucose tolerance in adults as well as children.[11,12] Higher sensitivity of dorsal sural conduction to Vitamin B12 deficiency and megaloblastic anemia has also been documented.[13] Reference

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values for nerve conduction parameters are influenced by age and anthropometric measurements.[14-17] There is scarcity of normative data and anthropometric comparisons of dorsal sural sensory action potential. No other study of the dorsal sural SNAP was found in Indian population, and hence, this study would be useful as it is designed to define the reference range for dorsal sural SNAP conductions and it is correlation with height, weight, age, limb length, and BMI in healthy Indian population.

Materials and Methods

Subject selection

Forty-five participants (24 females and 21 males) were included in this prospective study approved by the Ethics Committee of our institution. Informed consent was taken before study. Participants included in the study were:

1. Patients referred to our laboratory with restricted abnormalities localized only to the upper limb (e.g., brachial plexus disorders)
2. Healthy relatives of patients, healthy staff, and volunteers.

All selected participants had normal neurological and general examination, no sensory symptoms, and past or present history of long-term treatment, which can cause neuropathy (e.g., tuberculosis).

Exclusion criteria

Participants were excluded from the study if there was history of diabetes, lumbosacral radiculopathy, trauma to the feet, and a habit of sitting cross legged on the floor for long periods. Two participants were excluded as they had a large callus over the stimulating site possibly related to sitting cross legged on the floor, and one participant had a large pad of fat behind the lateral malleolus. In one participant, the SNAP was obtained on stimulating the superficial peroneal nerve but not the sural nerve.[18]

All selected participants had normal neurological examination with no sensory symptoms. Age, weight, height, and limb length (midpoint of fibular head to midpoint of lateral malleolus) of all participants were recorded. Body mass index (BMI) was calculated as weight (kg)/(height in m^2).

Technique of recording the sural dorsal sensory nerve action potential

The test was explained in detail to ensure maximum cooperation, and the participant was asked to lie comfortably in a lateral position with the leg to be assessed on top. The recording and stimulating sites were cleaned to reduce skin impedance. Natus electromyograph with Synergy Software and Medelec Synergy systems was used for the test. Filters were set between 20 Hz and 2 kHz, sweep duration was 20 ms, and sensitivity was 10 μV/divisions. Temperature was recorded at the lateral malleolus and was maintained at 30°C throughout the test. Trained neurophysiologists (doctors) with minimum 2 years of experience and all trained at the same center conducted the test. Self-adhesive stick on electrodes was used to record the potential by an antidromic technique,[2,6] keeping the inactive electrode (R2) in the web space of digits 4 and 5 and the active electrode (R1) 3 cm proximal to (R2) as shown in Figure 1. The stimulation site was along a line from behind the lateral malleolus to just below the tip of the lateral malleolus, varying between 8 and 15.5 cm, from the active electrode (mean = 10.6, standard deviation [SD] =1.79). The stimulator was adjusted to obtain the best-possible amplitude of the response. In some participants, maximum amplitude was obtained on stimulating the nerve just distal to the tip of the lateral malleolus. However, this resulted in shorter distances between recording and stimulating sites, which required rotating the anode to avoid a large stimulation artifact. It would have been ideal to have a fixed distance between stimulating and recording electrodes but varying foot length made this practically difficult and the distance needed to be altered to get the best-possible amplitude. The ground electrode was placed between the stimulating and recording sites. A supramaximal stimulus was used to obtain the maximum dorsal sural SNAP amplitude. Each optimal SNAP was then averaged for at least 6–8 responses to make the onset clear, and two trials were done to confirm replicability of the response. The latency in milliseconds was measured from the onset of sweep to the onset of negative peak of SNAP waveform [Figure 2]. SNAP amplitudes in microvolts were measured from peak to peak. Some participants, especially in the older age group had difficulty in relaxing the little toe and movement artifacts, were observed in the baseline. Taping the toes together or resting the entire foot on a pillow eliminated these. Overstimulation, especially distally near the tip of the lateral malleolus, was avoided as it evoked a motor response from the extensor digitorum brevis muscle.

Statistical analysis

Data were analyzed using the StataCorp 12.2 (StataCorp LP, College Station Texas, USA) statistical program. Dorsal sural SNAP parameters of the right lower limb were included for statistical analysis in 45 participants. The participants were stratified by age into three groups: Group a had participants between 18 and 40 years, Group b had participants between 41 and 60 years, and Group c had participants over the age of 60 years. Bilateral dorsal sural nerve analysis was done in 25 participants, and the side-to-side difference for latency and amplitude was found to be insignificant ($P = 0.719$ and $P = 0.47$). Unpaired *t*-test also did not show any statistical significance between the genders ($P = 0.5488$ for latency and $P = 0.9844$ for amplitude).

The latency and velocity data were normally distributed, but the amplitude data were positively skewed (Pr skewness = 0.0099) and hence was transformed by square root to bring the skewed data into more Gaussian distribution (Pr skewness = 0.37).

The upper limit of latency and lower limit of velocity were defined using mean + 2SD and mean – 2SD, respectively. The lower limit of amplitude was calculated using mean − 2SD of the transformed data and was then reconverted into original

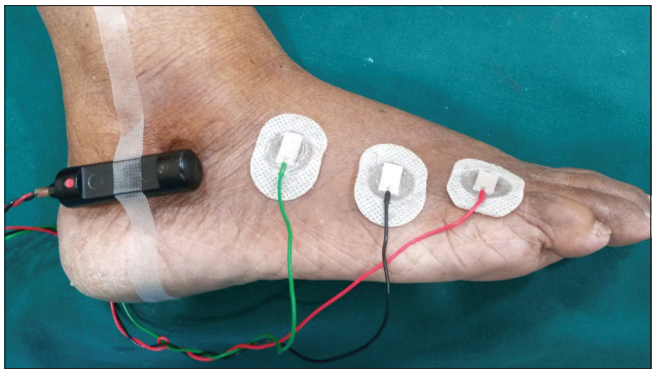

Figure 1: Placement of recording and stimulating electrodes for recording the dorsal sural sensory nerve action potential antidromically

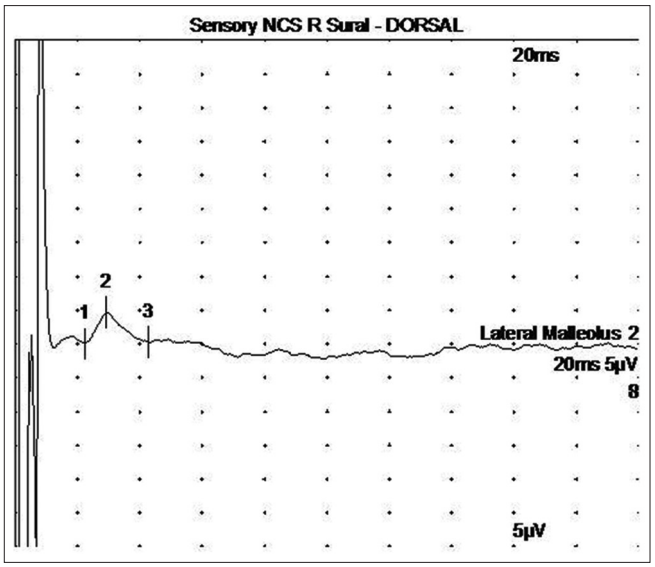

Figure 2: Dorsal sural sensory nerve action potential in a 78-year-old participant

units. ANOVA with Bonferroni correction was applied to compute the statistical difference in the dorsal sural amplitudes, latencies, and velocities between each of the three age groups specified so as to assess the effect of age on the amplitude, latency, and velocity. Linear regression analysis was done by model building to assess the effect of age, height, BMI, limb length, and distance between the stimulating and recording electrodes on the amplitude of the dorsal sural SNAP. The distance between the recording and stimulating electrodes varied from 8 to 15.5 cm (mean: 10.6, SD: 1.79). Two groups (8–10.5 cm and >10.5 cm) were made to compare the effect of distance on the amplitude. Unpaired *t*-test was applied to the groups and that did not reveal any significant effect of varying distance ($P = 0.532$). Hence, both regression and *t*-test computation showed that though the distance varied, it did not have a statistical effect on the amplitude of the dorsal sural SNAP.

Results

Forty-five nerves in 45 participants were studied, 24 were females and 21 males. The anthropometric data are summarized in Table 1. Upper limb focal neuropathies were present in nine participants, traumatic brachial plexopathies in six patients, tardy ulnar nerve palsy in one patient, and injection palsy of radial nerve in two patients. Mean, SDs, and the normative limits were calculated for the peak-to-peak amplitude and velocity for each age group and are listed in Tables 2 and 3.

Comparison of amplitudes between age groups using ANOVA with Bonferroni correction showed statistically significant difference between Groups b and c ($P = 0.039$) and a and c ($P = 0.001$) but not between a and b ($P = 0.578$). Comparison of velocity by age group using ANOVA with Bonferroni correction showed statistically significant difference between Groups b and c ($P = 0.04$) and a and c ($P = 0.008$) but not between a and b ($P > 1.0$). In 25 participants, side-to-side comparison of the amplitude ($P = 0.47$) and latency ($P = 0.72$) of the dorsal sural nerve did not reveal any statistical difference. The maximum side-to-side amplitude difference was 2.5 uv, and the maximum ratio of the difference was 45.5%. Similarly, unpaired *t*-test did not show statistical significance between genders for amplitude and latency measurements ($P = 0.5488$ for latency and $P = 0.9844$ for amplitude).

Table 1: Anthropometric parameters of participants in the study

Variable	Observations	Mean	SD	Minimum	Maximum
BMI	45	25.259	3.58	15.63	33.91
Age	45	49.34	17.05	20	90
Height	45	1.59	0.0897	1.3	1.75
Weight	45	64.42	11.746	40	98
Distance	45	10.61	1.797	8	15.5

SD = Standard deviation, BMI = Body mass index

Table 2: Age stratified lower limit of normal for dorsal sural sensory nerve action potential amplitude (in uv)

	Age group	Observations	Mean*	SD*	Lower limit of normal†
A	18-40	15	6.65	0.49	2.57
B	41-60	15	5.52	0.47	1.97
C	≥61	15	3.64	0.45	1.01

*Computed from transformed dorsal sural SNAP amplitude, †Computed as (mean−2SD) and converted back to original units. SNAP = Sensory nerve action potential, SD = Standard deviation

Linear regression of the transformed dorsal sural amplitude data also showed age as the covariate with maximum effect (adjusted R-squared = 0.2419, $P < 0.001$). Height, weight, BMI, limb length, and distance between recording and stimulating electrodes had minimal effect on the amplitude obtained (adjusted R-squared = 0.0027, 0.0101, 0.0061, 0.003, and − 0.148 and $P = 0.734$, 0.512, 0.61, 0.721, and 0.55, respectively). Correlation with body weights also showed age to be the most significant contributory with lower amplitudes of the response in older participants. Using the

Table 3: Age stratified lower limit of normal for dorsal sural sensory nerve action potential velocity (in m/s)

Variable	Observations	Mean	SD	Minimum	Maximum	Lower limit of normal (mean−2SD)
18-40	15	40.95	3.68	36.5	51	33.59
41-60	15	42.12	4.92	30.5	50	32.28
≥61	15	36.04	6.6	26.2	46.7	22.84

SD = Standard deviation

linear regression model, the predictive value for the dorsal sural amplitude would be (y) =3.338 + age (−0.0167) + height in meters (−0.209) + weight (0.001). The statistical power of our study was estimated to be 1.0.

Discussion

Reliability and ease of nerve conduction of dorsal sural nerve have been documented in previous studies.[2,6,10-13] Similarly, in the present study, dorsal sural response could be obtained in all the participants, the oldest participant being 90 years old. In two participants who had a callus below and behind the lateral malleolus, the SNAP was difficult to obtain, and the study was abandoned. This may be a unique problem in our country where a lot of people sit cross legged on the floor for long periods of time and may develop pressure effects. In a study of dorsal sural conduction in megaloblastic anemia, absent responses were found in 54% patients whereas remaining patients had mean lower amplitude, longer latency, and slower conduction velocity as compared to healthy control participants.[13] This signified the importance of cutoff values of dorsal sural conduction to identify early peripheral neuropathy rather than relying on the mere presence or absence of dorsal sural SNAP. The present study on dorsal sural conduction defined important cutoff values for lower limit of normal for amplitude and velocity in three age groups in western Indian population. An extensive study of sural and dorsal sural SNAP was done in 294 participants by Frigeni *et al*.,[6] but they did not transform the skewed amplitude data, and hence, if mean − 2SD was used to define the lower limit of normal for amplitude, the amplitude was higher in the over 70 year group as compared to the 50–59 age group for the sural nerve and similarly for the dorsal sural nerve,[6,19-21] and also the minimum amplitude values of the dorsal sural nerve in all age groups were almost the same in this study.[6] However, they gave a ratio of sural to dorsal sural amplitude which maybe a useful parameter. In the present study, we have utilized the mean ± 2SD method after transforming the skewed data.[19-21] Many studies have used the percentile method to establish the lower limit of the normal for SNAP amplitudes;[19] however, the number of participants in this study was not adequate to apply this method. Similar significant age-related decrease in dorsal sural amplitude and velocity was found in previous studies.[2,6] Effect of age on nerve conduction parameters of other nerves was also documented in other studies.[14-16] Neuronal modeling with increasing age apart from loss of nerve fiber reduced axon diameter and changes in membrane may contribute to this process.[15] In the present study, age was the single covariate with maximum effect on the amplitude of the dorsal sural SNAP (beta value of −0.524). The other parameters, BMI, limb length, height, weight, and distance between the electrodes did not contribute significantly to the variance in amplitude. The amplitude difference was significant in the age group above 60 years only.[15,16] As in another study,[17] negative correlation of BMI with amplitude of the SNAP was observed this study but was not statistically significant. Superficial and distal location of dorsal sural nerve, where distribution of adipose tissue is less, may be the reason for less significant correlation of nerve conduction parameters with the covariates such as BMI and height in the present study.[6] In one study, they observed that in 26% of their referents dorsal sural SNAP was not obtained, so they concluded that dorsal sural SNAP did not add to the diagnosis of a distal peripheral neuropathy.[22] In our population, there appears to be a risk factor of sitting cross legged on the floor for long hours, which may cause a focal neuropathy of the dorsal sural nerve. This needs to be investigated by further studies. As a precaution, we did not include such participants in this study after we found a local callus over the stimulating site in two such participants. Similarly, ankle or foot edema may pose difficulty in obtaining dorsal sural SNAP. These factors must be considered to prevent overdiagnosis of peripheral neuropathy using sural dorsal SNAPs as an indicator. Reference value for lower limit of normal conduction velocity in elderly age group is very low (22.84 m/s) because of high SD in this age group, this along with small number of participants in each group is the limitations in this study.

Conclusion

This study has helped obtain reference values for dorsal sural SNAP in western Indian population. Age seemed to be the most significant covariate and hence age-matched reference values should be used.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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