Original Article

Medial Plantar Sensory Nerve Action Potential: A Study for Reference Data in Indian Subjects

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Abstract

Context: The medial plantar nerve (MP) sensory nerve action potential (SNAP) has been shown to be a sensitive indicator for detecting a length-dependent axonal peripheral neuropathy. However, literature survey shows paucity of age stratified data. This study was undertaken to obtain age stratified reference data for MP SNAP amplitude and latency. **Aim:** To establish age-stratified reference data in Indian subjects for the MP SNAP. **Study Setting and Design:** The study was conducted in the electrodiagnostic laboratory of a tertiary city hospital and is retrospective study. **Materials and Methods:** A retrospective study was conducted using the nerve conduction study reports of 173 patients with only upper limb symptoms and findings. Patients were between the ages of 18 and 86 years, stratified into six groups, a = 18-30 years, b = 31- 40 years, c = 41-50 years, d = 51- 60 years, e = 61-70 years, f ≥70 years. **Statistical Methods:** Stata 12.1 statistical program was used. Lower limit of the SNAP amplitude was obtained using mean-2SD of transformed data. Analysis of variance defined the intergroup variability, linear regression and Pearson's correlation assessed the statistical significance. **Results:** The lower limit of normal MP SNAP amplitude for each age group is as follows: a: 8.7uv b: 7.5uv c: 3.7 uv d: 2.9uv e: 2.0 uv f: 1.4uv. The amplitude difference between the groups b & c, c & d and e and f using analysis of variance with Bonferroni correction and Tukey post-hoc test was not significant, but the other groups showed statistically significant variance. The equation of regression for the predicted amplitude value with age was defined as $Y^{\wedge} = \{3.5 + \text{age } (-.0233) - 2\ (0.389)\}^3$. **Conclusion:** This study provides age stratified reference data for MP SNAP. There is evidence to suggest that MP SNAP amplitude varies with age hence age stratified data should be used to define abnormality.

Keywords: Age-stratified, Indian population, Medial-plantar -SNAP, reference data

Introduction

Sural sensory nerve action potential (SNAP) is the commonly utilized electrodiagnostic test for the diagnosis of a length dependent sensory-motor peripheral neuropathy.[1-5] However, sural nerve is not the distal most nerve in the foot and by the time its SNAP amplitude is affected, the patient may have lost significant sensory motor function in the feet. To aid early diagnosis of a peripheral neuropathy, more distal SNAPs are studied and they include the dorsal sural and medial plantar (MP) SNAPs.[6-17] Dorsal sural SNAP can be affected due to local foot injuries, ill- fitting foot wear, and callus formation due to sitting cross- legged on the floor.[6] MP SNAPs could be technically difficult to obtain, especially in persons with poor foot hygiene but in this study which included elderly subjects; we were able to obtain MP SNAPs in all our subjects. MP SNAP is also useful in the diagnosis of a focal tibial or medial plantar neuropathy due to local causes e.g., tarsal tunnel syndrome, trauma or leprosy[18,19] The tibial nerve divides into its terminal branches, medial and lateral plantar nerves in the tarsal tunnel or just proximal to it, below the flexor retinaculum, at the medial malleolus-calcaneal axis.[20-23] The medial plantar nerve runs in the foot deep to the abductor hallucis brevis, supplies motor innervation to it and divides into one proper digital nerve to great toe and three common digital nerves [Figure 1]. The SNAP recorded in our study is from stimulation of the first common digital nerve. Though many studies have been previously done for reference data of the MP SNAP- none are available for Indian subjects and most do not have an age stratified lower limit of normal value for the amplitude. Hence, this study was undertaken to obtain these values.

Subjects and Methods

This was a retrospective, study using nerve conduction study reports from patients over a period of 4 years. It was cleared by the Institutional ethics committee of our hospital. The subjects included in this study were patients referred to the department with unrelated conditions, which did not affect the peripheral nerves and with no symptoms of paraesthesiae or numbness in the feet

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Subjects with any history suggestive of recent or past symptoms of a peripheral neuropathy, family history of an inherited neuropathy, frequent alcohol consumption (more than two drinks per day for more than 4 weeks) diabetes mellitus, treatment for tuberculosis, local trauma in the ankle or foot region, surgery on the back, or leg were not included in this study. Subjects with normal ankle jerks in the younger age group and preserved ankle jerks with preserved position sense in the older age group were included in this study.

One hundred and eighty patients were included between 18 and 86 years, seven patients were later eliminated due to local causes at recording and or stimulating sites (odema and injury) anthropometric parameters of all subjects included age, weight, height and BMI [Table 1].

Sensory nerve conduction study technique.

The Ponsford technique[24] for studying the orthodromic MP SNAP was followed. The test procedure was explained to the subject who was then made to lie in a lateral position (left lateral for left medial plantar nerve study). Recording and stimulating sites were thoroughly cleaned with spirit and the skin temperature was measured over the medial malleolus using a " Testo'" digital skin thermometer (before, during and after the recording). The temperature was maintained at about 30°C, by warming the foot using an electric hair dryer. The active electrode (E1) was placed just behind the medial malleolus; just posterior to tibial artery and the reference electrode (E2) was placed 3-4 cm proximal to E1. The ground electrode (E0) was placed between recording and stimulating electrodes. The stimulating electrode was held 12 -16 cm distally in the foot (depending on the foot length) along a line drawn from the recording electrodes to the first web space (the wire of the bipolar stimulating electrode could be used to mark this line) [Figure 2]. The SNAP was recorded using a Synergy ultra-pro electromyograph (Natus Medical Inc). Recording and acquisition parameters were: filter settings: 3Hz to 2 kHz, sweep speed: 20 millisecond (msec) amplitude gain setting: 10 microvolts per division (μv/div) stimulus duration: 0.1 msec to 0.2 msec, with supramaximal intensity, 8-10 responses were averaged after obtaining the best amplitude SNAP. Onset latency and peak to peak amplitudes were measured of the SNAPs bilaterally. Some points worth mentioning here are -the stimulating site needs to be thoroughly scrubbed – especially in patients with bad foot hygiene and needs to be adjusted according to the size of the foot such that there was no muscle twitching or a motor response seen along with the sensory response. Some studies call it the "mixed nerve action potential" as the motor branch to the abductor hallucis/flexor hallucis brevis maybe inadvertently stimulated- however in this study care was taken to avoid that by moving the stimulator more distally and/or reducing the stimulus intensity when there was a motor response, hence the distance was not kept constant.

Statistical analysis

The data was analyzed using the Stata Corp 12.2 (StataCorp LP, College Station, Texas) statistical software program. Summary statistics of the variables were obtained. The mean side-to-side amplitude was compared using a Student's t test and it did not show a statistical difference (t-statistic = 1.1924, degrees of freedom = 129. P =0.23), hence right sided nerves were used for analysis. Similarly, there was no difference in the amplitude between the genders (t = -0.7121 Satterthwaite's degrees of freedom = 170.796, P = 0.4774) hence male and female data was pooled (male = 91, female = 82). The subjects were stratified by age into 6 groups: a = 18- 30 years, b = 31- 40 years, c = 41-50 years, d = 51- 60 years, e = 61- 70 years and f >70 years. The amplitude of the MP SNAP was not in a gaussian distribution [Skewness/Kurtosis tests for Normality: Pr (Skewness) 0.0000, Pr (Kurtosis) 0.0492 adj chi2 (2) 22.95, Prob > chi 2 0.0000]. Of all the transformations applied, cube root best corrected the

Table 1: Anthropometric details of the subjects

	n	Mean	Std. Deviation	Min	Max
Age years	173	47.35	17.06	18	86
Weight kg	173	62.67	9.4	40	92
Distance cm	173	12.86	1.06	10	16
Height m	173	1.61	0.08	1.45	1.82
BMI	173	23.97	3.47	15.62	40.88

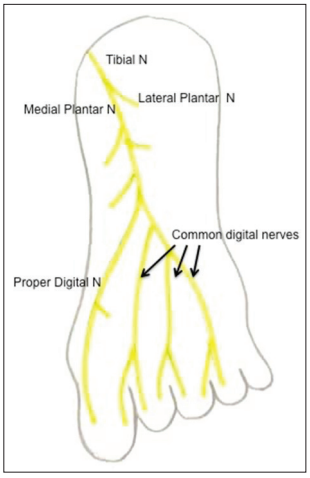

Figure 1: Branches of the medial plantar nerve

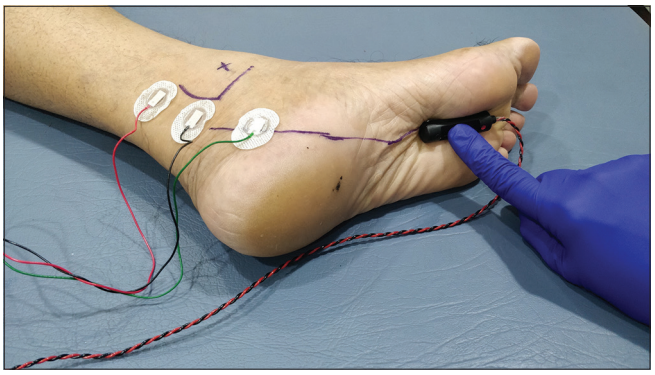

Figure 2: Technique of recording the medial plantar SNAP

skew [Pr (Skewness) 0.0461 Pr (Kurtosis). 2121 adj chi2 (2) 5.46 Prob > chi2 0.0651], hence for calculating the lower limit of normal for the amplitude in each age group (a to f) the formula applied was: mean minus 2 standard deviations (SD) of the transformed data and re-conversion by obtaining the cube of the value obtained, as suggested by Robinson *et al*.[25] Scatter plot of age against the amplitude showed a linear correlation and the regression analysis equation obtained for age.

A Pearson's product-moment correlation was run to assess the relationship between amplitude of the MP SNAP amplitude and age. One- way ANOVA with Bonferroni correction and also a Tukey post-hoc test was run to look for the significance of the age groups on the amplitude. Linear regression analysis was done to determine the statistical significance and effect and of age, height, distance between recording and stimulating electrodes (d) and BMI on MP amplitude. All pre- requisite assumptions for the above statistical tests were satisfied, prior to applying the tests.

Results

One hundred and seventy -three healthy subjects (91 males and 82 females) between the ages of 18 years and 86 years were included in this study. The anthropometric details are shown in Table 1.

The lower limit values for age -stratified MP SNAP latency, amplitude and sensory conduction velocity are listed in Table 2.

The amplitude values were transformed to a normal distribution by using the cube root function as it best reduced the skew in the distribution.[25,26] Mean minus 2 standard deviations (SD) and re- conversion of the values gave the normal lower limits for each group. A Pearson's product-moment correlation test showed strong negative correlation between age of the subject and the MP amplitude, r (171) = -0.72; P <.001with age explaining 52% (r^2) of the variation in the amplitude. Non parametric Spearman's correlation was also run to assess the relationship between age and the not- transformed MP SNAP amplitude data. There was a strong negative correlation which was statistically significant r^s = --0.7067, P <.001. A one-way ANOVA was conducted to determine the amplitude variability with age. There was statistically significant difference between groups {F (5,167)} = 36.23, P <.001 Bonferroni and Tukey correction (post- hoc test) further revealed the inter-group statistically significant variation with age except between groups b and c, c and d, and e and f. There was significant inter- group variation of the MP SNAP amplitude between the age group a (18-30 years) and all other age groups. Linear regression analysis established that age could statistically predict the MP SNAP amplitude F (1,171) = 186.91 P <.001, adjusted R^2 = 0.5133 i.e., age accounted for 51% of the explained variability in amplitude. The regression equation was: predicted MP amplitude = {3.5 + age (-.0233) – 2 (0.389)}^{3}. Linear regression model of BMI with MP SNAP amplitude showed statistical significance for F (1,171) = 28.96; P <.001 but the effect measured by R-squared was only 12% and a model with both age and BMI increased the R^2 value by only 3%

Table 2: Age stratified MP SNAP latency, amplitude & conduction velocity

Age groups	18-30 years	31-40 years	41-50 years	51-60 years	61-70 years	>70 years
#Latency ms ULN	2.98	2.75	3.1	2.85	2.94	3.0
@Amplitude uv LLN	8.7	7.5	3.7	2.9	1.9	1.4
SNCV m/s LLN	43.8	42.5	42.9	43.7	44	40

#Onset latency measured in milliseconds. @Peak to peak amplitude in micro volts. SNCV=sensory nerve conduction velocity in meters per second. ULN=upper limit of normal (calculated using mean +2SD). LLN=lower limit of normal (calculated using mean – 2SD of the transformed data and re-converting it)

Linear regression model of height with MP SNAP amplitude did not show any statistical significance. (F (1,171) = 1.24; P = 0.28.) Linear regression model of distance with MP SNAP amplitude showed a statistical significance. (F (1,171) = 8.11; P =0.04.) but the effect measured by R^2 (0.04) was not significant suggesting that distance contributed to only 4% of variability in the amplitude.

Discussion

This study has helped in obtaining age- stratified reference values for MP SNAPs in healthy Indian subjects, even above the age of 70 years. Further it has statistically demonstrated that age has a negative, significant correlation on the amplitude and hence age-stratified data alone should be used to define abnormality. Reeves *et al*.[13] in 1984 were the first to suggest that MP SNAP could be used as a sensitive indicator for demonstrating early diabetic peripheral neuropathy. Since then multiple studies have been done to show the sensitivity of the MP SNAP in diabetic neuropathy and Tarsal tunnel syndrome. Iyer *et al*.[27] in 1984, first demonstrated recording techniques for medial and lateral plantar nerve SNAPs and since then many studies with different techniques using antidromic and orthodromic methods have been published, including distal conduction from the big toe.[9-11,13,20,24,27,28] We have used the method described by Ponsford *et al*.[24] who studied the SNAP distributed over eight groups with a total of 100 subjects. However, they did not classify the lower limit of normal for the amplitude and their values of standard deviation were high (as we have seen that the amplitude does not fall into a Gaussian distribution). They also found that stimulating the sole yielded better amplitude responses than stimulating the big toe and they too were able to record the SNAP in subjects in their 9th decade as we have in our study. They have also demonstrated a significant negative correlation with age and suggested the use of age-stratified values to define abnormalities.

Hemmi *et al*.[9] also studied the MP SNAP over age-stratified groups (total 64 subjects) but mean values were described,

not the lower limit of normal. No Indian reference data has been published to provide age-stratified normative data for the MP SNAP

Limitations of our study: Our study could have been made stronger by including more subjects in each group, planning a prospective study and by studying patients with confirmed peripheral neuropathy and applying the age-stratified values, this could be planned as a follow-up study

Conclusion

This is the first study to provide age stratified reference values for the lower limit of normal for medial plantar sensory nerve action potential amplitudes in Indian subjects. This study shows that age has a significant effect on the amplitude, while height, BMI, gender, and site of stimulation do not. Using a single value for the lower limit of normal for all ages may not be advisable. MP SNAP would be useful for determining a peripheral neuropathy, tibial neuropathy and medial plantar neuropathy. Further studies on patients would validate this claim.

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Conflicts of interest

There are no conflicts of interest.

References

1. Sreenivasan A, Mansukhani KA, Sharma A, Balakrishnan L. Sural sensory nerve action potential: A study in healthy Indian subjects. Ann Indian Acad Neurol 2016;19:312-7.
2. Lai Y-R, Huang C-C, Chiu W-C, Liu RT, Tsai NW, Wang HC, *et al*. Sural nerve sensory response in diabetic distal symmetrical polyneuropathy. Muscle Nerve 2020;61:88-94.
3. Herrmann DN, Ferguson ML, Pannoni V, Barbano RL, Stanton M, Logigian EL. Plantar nerve AP and skin biopsy in sensory neuropathies with normal routine conduction studies. Neurology 2004;63:879-85.
4. Vinik AI, Bril V, Litchy WJ, Price KL, Bastyr EJ, 3rd MBBQ Study Group. Sural sensory action potential identifies diabetic peripheral neuropathy responders to therapy. Muscle Nerve 2005;32:619-25.
5. Mansukhani K, Dhonde M, Sreenivasan A, Sharma A, Balakrishnan L, Chavan P. Sural radial amplitude ratio: A study in healthy Indian subjects. Ann Indian Acad Neurol 2020;23:255-60.
6. Chaudhari SC, Mansukhani KA, Sharma A, Balakrishnan L, Sreenivasan A. Dorsal sural sensory nerve action potential: A study for reference values. Ann Indian Acad Neurol 2017;20:127-31.
7. Cinar N, Sahin S, Sahin M, Okluoglu T, Karsidag S. Effects of anthropometric factors on nerve conduction: An electrophysiologic study of feet. J Am Podiatr Med Assoc 2013;103:43-9.
8. An JY, Park MS, Kim JS, Shon YM, Lee SJ, Kim YI, *et al*. Comparison of diabetic neuropathy symptom score and medial plantar sensory nerve conduction studies in diabetic patients showing normal routine nerve conduction studies. Intern Med 2008;47:1395-8.
9. Hemmi S, Inoue K, Murakami T, Sunada Y. Simple and novel method to measure distal nerve conduction of the medial plantar nerve. Muscle Nerve 2007;36:307-17.
10. Løseth S, Nebuchennykh M, Stålberg E, Mellgren SI. Medial plantar nerve conduction studies in healthy controls and diabetics. Clin Neurophysiol 2007;118:1155-61.
11. Guiloff RJ, Sheratt RM. Orthodromic sensory nerve conductions of the medial and lateral plantar nerves. J Neurol Neurosurg Psychiatry 1977;40:1168-81.
12. Herrera E, Camargo DM, Delgado DC, Salvini TF. Reliability of superficial peroneal, sural, and medial plantar nerve conduction studies: Analysis of statistical methods. J Clin Neurophysiol 2009;26:372-9.
13. Reeves ML, Seigler DE, Ayyar DR, Skyler JS. Medial plantar sensory response. Sensitive indicator of peripheral nerve dysfunction in patients with diabetes mellitus. Am J Med 1984;76:842-6.
14. Abraham RM, Abraham RR. Absence of the sensory action potential of the medial plantar nerve: A sensitive indicator of diabetic neuropathy. Diabet Med 1987;4:469-74.
15. Uluc K, Isak B, Borucu D, Temucin CM, Cetinkaya Y, Koytak PK, *et al*. Medial plantar and dorsal sural nerve conduction studies increase the sensitivity in the detection of neuropathy in diabetic patients. Clin Neurophysiol 2008;119:880-5.
16. Nodera H, Logigian EL, Herrmann DN. Class of nerve fiber involvement in sensory neuropathies: Clinical characterization and utility of the plantar nerve action potential. Muscle Nerve 2002;26:212-7.
17. Sylantiev C, Schwartz R, Chapman J, Buchman AS. Medial plantar nerve testing facilitates identification of polyneuropathy. Muscle Nerve 2008;38:1595-8.
18. DeLisa JA, Saeed MA. The tarsal tunnel syndrome. Muscle Nerve 1983;6:664-70.
19. Oh SJ, Sarala PK, Kuba T, Elmore RS. Tarsal tunnel syndrome: Electrophysiological study. Ann Neurol 1979;5:327-30.
20. Im S, Park JH, Kim HW, Yoo SH, Kim HS, Park GY. New method to perform medial plantar proper digital nerve conduction studies. Clin Neurophysiol 2010;121:1059-65.
21. Torres AL, Ferreira MC. Study of the anatomy of the tibial nerve and its branches in the distal medial leg. Acta Ortop Bras 2012;20:157-64.
22. Inthasan C, Vaseenon T, Mahakkanukrauh P. Anatomical study and branching point of neurovascular structures at the medial side of the ankle. Anat Cell Biol 2020;53:422-34.
23. De Maeseneer M, Madani H, Lenchik L, Kalume Brigido M, Shahabpour M, *et al*. Normal anatomy and compression areas of nerves of the foot and ankle: US and MR imaging with anatomic correlation. Radiographics 2015;35:1469-82.
24. Ponsford SN. Sensory conduction in medial and lateral plantar nerves. J Neurol Neurosurg Psychiatry 1988;51:188-91.
25. Robinson LR, Temkin NR, Fujimoto WY, Stolov WC. Effect of statistical methodology on normal limits in nerve conduction studies. Muscle Nerve 1991;14:1084-90.
26. Dorfman LJ, Robinson LR. AANEM minimonograph #47: Normative data in electrodiagnostic medicine. Muscle Nerve 1997;20:4-14.
27. Iyer KS, Kaplan E, Goodgold J. Sensory nerve action potentials of the medial and lateral plantar nerve. Arch Phys Med Rehabil 1984;65:529-30.
28. Adam JK, Bechoo R, Rmaih WS. A comparative study evoking a sensory action potential from the medial and lateral plantar nerves using the probe and ring method of stimulation. Neurol India 2010;58:277-9.