Title: A Study on the Sural/Radial Amplitude Ratio in Healthy Adults: Effect of Anatomical and Demographic Variables on SRAR

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Abstract

Introduction: The sural to radial sensory nerve action potential amplitude ratio (SRAR) can serve as a criterion for diagnosing peripheral axonal neuropathy. However, different studies have revealed varying lowest values of this index. This research aimed to identify the minimum normal value of SRAR in healthy individuals and evaluate the impact of age, gender, height, weight, body mass index (BMI), forearm length, wrist circumference, ankle circumference, and leg length on the lowest normal value of SRAR to distinguish between healthy people and those with axonal polyneuropathy.

Methods: The study involved 108 individuals referred for four-limb electrodiagnostic tests with normal results. The participants were between 20 and 70 years old, and the study was conducted between July 2022 and December 2023. An electrodiagnosis test was carried out to determine the range of sural and radial sensory nerves. The data were analyzed using SPSS version 26, and a p-value of less than 0.05 was considered statistically significant .

Results: The study revealed that the lowest value of SRAR was 0.2 (mean = 0.435 ± 0.175). According to the Pearson correlation test, the SRAR has no significant correlation with age, BMI, forearm length, wrist circumference, ankle circumference, and leg length

Discussion: The study found that the SRAR was not affected by various physical characteristics such as age, gender, height, weight, forearm length, wrist circumference, ankle circumference, or leg circumference, and an SRAR value of 0.2 was the minimum normal value of SRAR in our healthy subjects .

Keywords: Radial nerve; Sural nerve; Sural/Radial Amplitude Ratio (SRAR), Healthy Volunteers

Introduction

Polyneuropathy is a type of peripheral neuropathy that leads to sensory symptoms like numbness, tingling, paresthesia, pain, and muscle weakness. It typically affects the distal portion of the lower limbs and can significantly reduce the patient's quality of life. The prevalence of polyneuropathy in the general population is usually between 1 and 3%, but it can increase to 7% in older adults. (Teunissen, L. L et al., 2000)

Due to the high prevalence of polyneuropathy in society, timely diagnosis and treatment are crucial for improving the patient's quality of life. Currently, the diagnosis of polyneuropathy is based on history, physical examination, and electrodiagnostic tests. Electrodiagnostic tests can be used to objectively diagnose axonal polyneuropathy, especially in the early stages when patients are asymptomatic. (Hanewinckel, R. et al., 2016)

Several electrodiagnostic criteria have been used to diagnose mild and subclinical cases of polyneuropathy. However, the sural nerve action potential (SNAP) amplitude criterion has some disadvantages, such as the lack of early diagnosis and accuracy in mild cases of axonal polyneuropathy. Additionally, the wide range of normal values in healthy individuals has reduced the sensitivity and specificity of this criterion. (Sreenivasan, A. et al., 2016)

The ratio of sural nerve action potential (SNAP) to radial nerve action potential (SRAR) is another electrodiagnostic criterion used in some studies to diagnose axonal polyneuropathy (Rutkove et al., 1997), (Pastore et al., 1999), (Esper et al., 2005), (Overbeek et al., 2005). Based on the length-dependent nature of nerve damage in axonal polyneuropathy and the early drop in the amplitude of sural SNAP compared to radial SNAP, it can diagnose axonal polyneuropathy in its early stages.

SRAR exhibits high sensitivity in detecting neuropathy. For instance, an SRAR cutoff of <0.4 yields a sensitivity of 100%, while a cutoff of <0.2 provides a sensitivity of 92.86%. These metrics underscore SRAR's reliability in distinguishing between normal and abnormal nerve function. (Ramanathan S et al.,2021).

Compared to other screening methods, SRAR has a sensitivity of 100%, which is higher than the sensitivity of other methods such as Michigan Neuropathy Screening Instrument (MNSI) at 64.3%, Semmes Weinstein Monofilament (SWMF) at 14.3%, and biogeometry at 78.6%. These comparisons highlight the effectiveness of SRAR, particularly in diagnosing length-dependent neuropathy, which is common in diabetic patients (Ramanathan S et al., 2021).

Despite its potential, studies on SRAR have yielded varying and sometimes contradictory results. Some research indicates that SRAR is influenced by demographic factors such as age, while other studies suggest it remains unaffected by these variables. In other words, some studies have found that the minimum normal value of SRAR is 0.4 (Rutkove et al., 1997), whereas others proposed a lower threshold of 0.21(Esper et al., 2005), (Overbeek et al., 2005).

Globally, research on SRAR is limited, and most existing studies have not adequately considered demographic variables such as age, gender, and anatomical factors. Based on the authors' search methods, no studies specifically addressing SRAR have been found in Iran. Therefore, this study aims to fill this gap by investigating the relationship between SRAR and demographic variables, and by determining the minimum normal SRAR value in healthy individuals at Shohada Tajrish and Shahid Modares medical centers. By enhancing early diagnosis of axonal polyneuropathy, this research seeks to contribute valuable insights for improving the management of this debilitating condition.

Method:

Between July 2022 and December 2023, a cross-sectional study was conducted on individuals who visited the electrodiagnosis clinics of Shohada Tajrish and Shahid Modares clinical centers to investigate the sural/radial amplitude ratio (SRAR) in healthy adults. The study was approved by the ethics committee of Shahid Beheshti University of Medical Sciences, and informed consent was obtained from all participants.

Participants included 108 healthy volunteers aged 20 to 70, comprising physical medicine and rehabilitation residents, volunteer partners of patients undergoing electrodiagnostic examination, and patients with unrelated conditions. Exclusion criteria included any electrodiagnostic abnormalities (e.g., radiculopathy, polyneuropathy, plexopathy, peripheral nerve damage), systemic diseases predisposing to neuropathy (e.g., diabetes, hypothyroidism, chronic liver and kidney diseases, autoimmune diseases, infectious diseases, malignancy), lower limb edema, history of alcohol consumption, trauma, leg or forearm surgery, drug use, or toxin exposure.

All participants underwent a neurological examination assessing manual muscle strength, pain, light touch, vibration and position sense, and deep tendon reflexes in both arms and legs.

The same examiner consecutively examined all participants using an electrophysiological protocol. The protocol included bilateral motor nerve conduction studies (NCS) of the tibial and peroneal nerves and bilateral sensory

NCS of the sural and radial nerves using surface electrodes. These initial studies were performed to rule out polyneuropathy.

An observational method was used to collect anatomical data, demographic information, and electrodiagnostic findings. Demographic information recorded included age, gender, height, and weight. Body mass index (BMI) was calculated by dividing weight (kg) by height squared (m^2). Forearm length was measured from the midpoint of the antebrachial skin fold to the styloid of the radius, and wrist circumference was measured distal to the styloid of the radius. Leg length was measured from the midportion of the popliteal fossa to the top of the medial malleolus, and ankle circumference was measured proximal to the medial and lateral malleolus.

The sensory nerve action potentials (SNAPs) of the radial and sural nerves were recorded using a Medelec Synergy electromyogram (Oxford Medical, UK) with standard settings (stimulation duration: 0.2 ms, nerve stimulation frequency: 1 Hz, frequency bandwidth: 3 Hz to 3 kHz, sensitivity: 20 mv/div, sweep speed: 20 ms/div). Before the potentials were recorded, the temperature of both upper and lower limbs was measured with a thermometer. If the temperature was below 32 degrees, a warmer was used to increase their temperature.

For radial nerve SNAP recording, participants were seated, and the active electrode was placed on the snuff box area. The reference electrode was positioned 4 cm away on the posterior surface of the first finger, and the ground electrode was placed between the stimulator and the active electrode. Supramaximal electrical stimulation was applied proximal to the active electrode at a distance of 10 cm. A physiatrist performed this procedure for both hands, and the maximum radial nerve amplitude was recorded.

For sural nerve SNAP recording, participants were positioned prone. The active electrode was placed behind the lateral malleolus, and the reference electrode was positioned 4 cm distally. The stimulator was placed 14 cm proximal to the active electrode. The procedure was performed for both legs and the maximum sural nerve amplitude was recorded.

The sural/radial amplitude ratio (SRAR) was calculated for all participants by dividing the sural nerve amplitude by the radial nerve amplitude. Additional variables recorded included gender, age, weight, height, forearm length, leg length, and wrist and ankle circumference. These values were systematically entered into a datasheet for subsequent analysis.

Statistical analysis:

Data were analyzed using Statistical Package for the Social Sciences (SPSS), version 26. The qualitative variable was described in frequency (percentage), while quantitative variables were described by mean ± standard deviation, minimum, and maximum. The normality of the data was assessed via the Shapiro-Wilks test. The Spearman correlation was used to evaluate associations, and a p-value of less than 0.05 was considered significant.

Results:

One hundred and eight individuals with normal electrodiagnostic test results and without any exclusion criteria were included in the study. The sample consisted of 69 females (64%) and 39 males (36%) with an average age of 42.46 ± 11.49 years. The mean of BMI was 25.87±4.03, and the mean of Forearm length, Wrist circumference, Leg length, Ankle circumference were 25.26±2.75cm, 16.35±7.78 cm, 37.20±2.93 cm, 22.5±1.99 cm, respectively.

Table 1 shows descriptive statistics of radial and sural SNAP amplitude and their ratio.

(Table 1)

Figures 1 and 2 present the SRAR values based on age and BMI, respectively. The average SRAR for individuals aged 20-40 years was 0.45, for those aged 40-50 years it was 0.36, and for individuals aged 50 years and older, it was 0.46. An ANOVA analysis showed no significant difference in SRAR between the three age groups ($P > 0.05$). Similarly, BMI analysis indicated no significant difference between the groups ($P = 0.368$).

(Figure 1)

(Figure 2)

The study also investigated the relationship between SRAR and other variables, such as forearm length, wrist circumference, leg length, and ankle circumference. The correlation between SRAR and other variables is shown in Table 2.

Spearman's correlation test indicated that none of the variables (forearm length, wrist circumference, leg length, and ankle circumference) had a significant relationship with SRAR.

(Table 2)

To determine a practical cut-off value for the sural/radial amplitude ratio (SRAR), we calculated the 95th percentile of SRAR values, which was 0.21. This indicates that 95% of the SRAR measurements in our study were greater than 0.21.

Discussion

Polyneuropathy is a prevalent disorder with significant impacts on patients' clinical status, socioeconomic situation, and public health. Our study identified the lowest SRAR value in normal individuals as 0.20, unaffected by demographic factors (age, sex, weight, height, BMI) or anatomical factors (forearm length, wrist circumference, leg length, ankle circumference). Based on the authors' search methods, this is the first study to explore the relationship between SRAR and anatomical variables.

Rutkove et al. (1997) found SRAR to be a sensitive method for diagnosing mild axonal polyneuropathy, reporting the lowest normal SRAR value of 0.4 with no age correlation. The discrepancy between their findings and ours (0.20) may stem from their smaller sample size (30 subjects) of Rutkove's study.

Overbeek et al. (2005) argued that an SRAR value of 0.4 is too high as a minimum normal threshold, suggesting instead a value of 0.21, which they found to be a sensitive diagnostic tool for axonal neuropathy. They also reported that SRAR is independent of age and BMI, aligning with our findings and the reports of Rajabally et al. (2009) and Zis et al. (2019).

Pinar Kahraman Koytak et al. (2017) found the medial plantar compound nerve action potential (CNAP) to radial sensory nerve action potential (SNAP) amplitude ratio (MPRAR) and medial plantar CNAP to be more sensitive than SRAR for diagnosing mild axonal neuropathy without clinical signs of large fiber involvement. They recommended a lowest normal SRAR value of 0.24 for all ages. However, MPRAR is impractical for individuals over 60 due to the

challenging and time-consuming technique of recording medial plantar CNAP, and the inability to record it in 40% of people over 60 years of age who are susceptible to neuropathy. (Hemni S et al., 2007), (Lȍseth S et al., 2007)

Mansukhani et al. (2020) found the minimum normal SRAR value to be age-dependent, reporting values of 0.23, 0.20, and 0.17 for age groups 31-40, 41-50, and 51-70 years, respectively. These findings are similar to ours, though they included individuals over 70, which we excluded to avoid confounding by the high prevalence of neuropathy in individuals over 70 years old.

Studies on the relationship between age and SRAR have yielded mixed results. Some report an inverse correlation (Overbeek et al., 2005; Esper et al., 2005; Vrancken et al., 2008; Herrmann et al., 2004; Sreenivasan et al., 2016), while others find a direct correlation (Rutkove et al., 1997). Our study found no significant correlation between age and SRAR (rho = 0.019, P = 0.842), possibly due to differences in age range and sample distribution.

Our study found no correlation between SRAR and demographic variables such as weight, height, and BMI, consistent with previous research (Rutkove et al., 1997; Pastore et al., 1999; Esper et al., 2005; Overbeek et al., 2005; Mansukhani et al., 2020). Additionally, we observed no correlation between SRAR and anatomical factors (wrist circumference, arm length, leg length, ankle circumference), a novel finding as no prior studies have explored this relationship.

Our findings suggest that SRAR is independent of both demographic (age, gender, weight) and anatomical variables (height, forearm length, wrist circumference, leg length, ankle circumference). This reinforces SRAR's robustness as a diagnostic tool.

A study by Vrancken et al. (2008) evaluated the realistic yield of lower leg SNAP amplitudes and SRAR in the routine evaluation of chronic axonal polyneuropathies. They found that while SRAR can be useful in confirming distal axonal polyneuropathy, its additional diagnostic value may be limited compared to sural and superficial peroneal SNAP measurements. The findings of this study align with our observation that SRAR is not influenced by demographic variables, reinforcing its potential utility as a supplementary diagnostic tool rather than a primary one.

In conclusion, our study found that the lowest SRAR value in normal individuals is 0.20, unaffected by demographic (age, sex, weight, height, BMI) and anatomical factors (forearm length, wrist circumference, leg length, ankle circumference).

We recommend further research with larger sample sizes, including both healthy individuals and patients with mild axonal polyneuropathy. Future studies should consider the cause of neuropathy and the time interval between onset and electrodiagnostic testing to better evaluate SRAR's sensitivity and specificity in early polyneuropathy diagnosis.

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Tables:

Table 1: Descriptive statistics of radial and sural SNAPs range and sural radial amplitude ratio.

Variable	Minimum	Maximum	Mean	Standard Deviation
Radial SNAP amplitude (mV)	12	78	45.14	15.18
Sural SNAP amplitude (mV)	١٠	90	19.29	10
SRAR (Sural/Radial Amplitude Ratio)	0.2	3.42	0.47	0.35

Table 2: Correlation between SRAR and other variables.

Variable	Correlation Coefficient	P-value
Forearm length	0.107	0.270
Wrist circumference	0.131	0.178
Leg length	0.071	0.464
Ankle circumference	0.156	0.106

Figure 1: SRAR values in different age groups

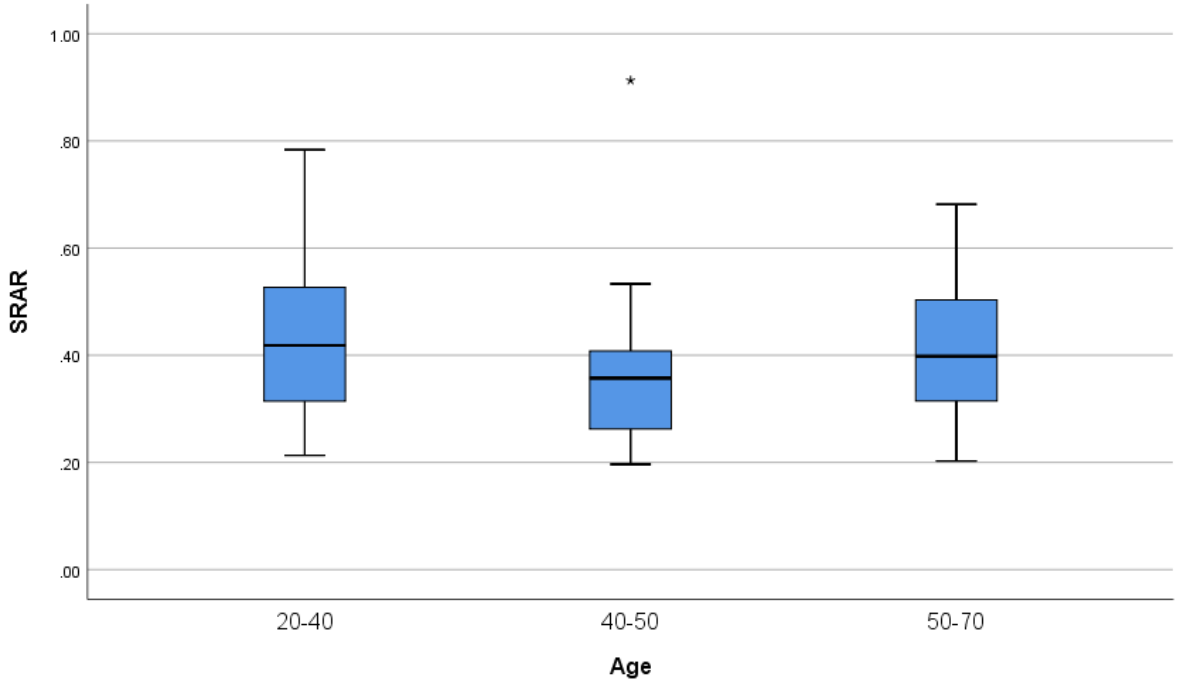

Figure 2: Correlation between SRAR and body mass index.