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Araştırma Makalesi / Research Article

Intra- and Inter-Observer Variability in Sonographic Measurement of the Cervical Nerve Roots of Healthy Volunteers

Sağlıklı Gönüllülerin Servikal Sinir Köklerinin Sonografik Ölçümünde Gözlemci İçi Ve Gözlemci Arası Değişkenlik

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Abstract

Aim: The aim of our study is to determine the normal values of mean cervical (C) nerve root diameter in millimeters (mm) in healthy volunteers and to show its relationship to age, gender, height, weight, body mass index (BMI), and the dominant hand.

Material and Method: Two observers measured the mean nerve root diameter of the bilateral C5, C6, and C7 nerve of all volunteers. Before the procedure, the age, sex, height, weight, BMI, and the dominant hand of all the participants were noted. Two measurements were taken by each of the two observers without one knowing about the other's noted values. The intraclass correlation coefficient (ICC) test was used to analyze intra-and inter-observer reliability.

Results: There was no statistically significant relationship between gender and dominant hand, and mean nerve root diameter. Moreover, when we compared the mean nerve root diameter for the nerves in the right and left sides of each participant, no significant statistical differences were identified. The mean diameter of the C6 nerve root was higher than that of C7, which was higher than that of C5 on both sides ($p < 0.001$). The ICC values for intra- and inter-observer were good or excellent for all diameter measurements (ICC > 0.8).

Conclusions: The normal range of cervical nerve root diameters should be determined to distinguish pathological conditions. In our study, the measurement of mean nerve root diameters of C5, C6, and C7 nerves is highly reproducible with excellent intra-observer and inter-observer agreement. Therefore, the measurement of nerve root diameter can be confidently performed in daily clinical practice.

Keywords: Brachial plexus; cervical nerve root; ultrasonography; diameters; healthy volunteers

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Amaç: Çalışmamızın amacı sağlıklı gönüllülerde ortalama servikal (C) sinir kökü çapının normal değerlerini milimetre (mm) olarak belirlemek ve yaş, cinsiyet, boy, kilo, vücut kitle indeksi (VKİ) ve dominat el ile ilişkisini göstermektir.

Materyal ve Metod: İki gözlemci, tüm gönüllülerin bilateral C5, C6 ve C7 sinirinin ortalama sinir kökü çapını ölçtü. İşlem öncesi tüm katılımcıların yaş, cinsiyet, boy, kilo, VKİ ve dominant eli not edildi. Biri diğerinin not edilen değerleri bilmeden, iki gözlemcinin her biri tarafından iki ölçüm yapıldı. Gözlemci içi ve gözlemciler arası güvenilirliği analiz etmek için sınıf içi korelasyon katsayısı (ICC) testi kullanıldı.

Bulgular: Cinsiyet ile dominant el ve ortalama sinir kökü çapı arasında istatistiksel olarak anlamlı bir ilişki yoktu. Ayrıca, katılımcıların sağ ve sol taraf ortalama sinir kökü çap ölçümleri arasında istatistiksel olarak anlamlı farklılık izlenmedi. C6 sinir kökünün ortalama çapı, her iki tarafta da C7'den C7 ise C5'ten yüksekti ($p <0.001$). Gözlemci içi ve arası ICC değerleri tüm çap ölçümleri için iyi veya mükemmeldi (ICC> 0.8).

Sonuç: Patolojik durumları ayırt etmek için normal servikal sinir kökü çapları aralığı bilinmelidir. Çalışmamızda, C5, C6 ve C7 sinirlerinin ortalama sinir kökü çaplarının ölçümü, mükemmel gözlemci içi ve gözlemciler arası uyum göstermekte olup yüksek tekrarlanabilik göstermektedir. Bu yüzden servikal sinir kökü çap ölçümü, günlük klinik pratikte güvenle yapılabilir.

Anahtar Kelimeler: Brakiyal pleksus; servikal sinir kökü; ultrasonografi; çaplar; sağlıklı gönüllüler

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INTRODUCTION

Brachial plexus (BP), consisting of the roots of the cervical (C) nerve, provides sensorimotor innervation of the upper extremity (1). Anatomically, the nerve roots of C5 and thoracic (T) 1 usually form a brachial plexus, and the C4 or T2 nerve roots may also contribute to the formation of BP (2). The brachial plexus has four anatomical regions: paravertebral, interscalene, periclavicular, and retropectoral regions (3, 4). Ultrasonographic evaluation of the cervical nerve root is optimal during the anatomical course between anterior scalene and middle scalene muscles (5, 6).

Cervical nerve roots may possess pathological findings due to various systemic diseases, such as trauma, tumoral lesions, entrapment neuropathies, inflammatory-infectious causes, and secondary to radiation (7, 8). Ultrasound (US) and magnetic resonance imaging (MRI) methods can be used to evaluate the cervical nerve roots (9). MRI imaging is superior to the US with higher spatial resolution and high soft-tissue resolution (10). Ultrasound is an alternative imaging method to evaluate the roots of the cervical nerve as it is cheap, easily accessible, reproducible, and dynamic (5, 6).

Our aim in this study is to examine the normal values of cervical mean nerve root diameter in healthy volunteers and to show its relationship to age, gender, height, weight, body mass index (BMI), and dominant hand.

MATERIAL AND METHODS

The study period was from June 2019 to January 2020. A total of 84 participants were included in the study, of which 50 were women and 34 were men. All procedures performed in our study were in accordance with the ethical standards.

We included volunteers aged 18-60 years without any known disease. The exclusion criteria were receiving radiotherapy to the neck for any reason, previous neck surgery-trauma history, cervical disc herniation, brachial plexopathy finding on physical examination, and body mass index >35. Two observers participated in this study and both of them used the same ultrasound system (LOGIQ S8, GE Medical Systems, Wisconsin, USA) with a 9-11 MHz linear transducer. The first observer (Observer 1, IA, 10 years' experience in radiology and Head - Neck Imaging) and second observer (Observer 2, EG, 6 years' experience in musculoskeletal radiology and Head - Neck Imaging) performed the B-mode ultrasound and measured the mean nerve root diameter of bilateral C5, C6 and C7 nerves of all volunteers at the level of the root. The observers were blind to the participant's results. Participants were examined consecutively during the same visit. Two measurements were taken by each observer at a 1-hour interval in two separate settings.

Before the procedure, age, sex, height, weight, BMI, and the dominant hand of all participants were noted. The examination was performed in the supine position with the arms in anatomical position. In the posterior part of the longus colli muscle, between the anterior and posterior tubercles of the transverse process, the probe was moved up and down to identify the C5, C6, and C7 nerve roots, respectively. The C7 nerve root was recognized at this level by the absence of the anterior tubercle in the transverse process and being just inferior to C6. Nerve roots were scanned in the axial-longitudinal plane up to the truncus and cords. Two measurements, anteroposterior and mediolateral, were taken at the root level of the axial plane and their arithmetic mean was obtained (Figure 1). Imaging of the C8 and T1 was problematic due to the sternoclavicular joint and was not included in the analysis.

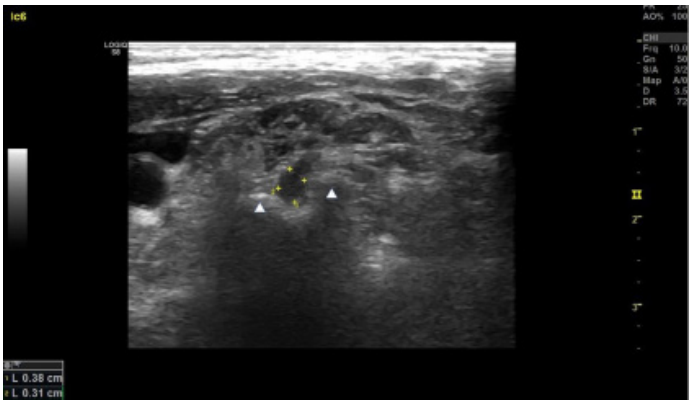

Figure 1. 44 years old healthy female volunteer. The mean diameter of the left C6 nerve root (yellow oval shape) was measured between the anterior and posterior transverse tubercles (arrowheads) of the C6 transverse process

Statistical analysis was performed via the SPSS v.22 package program (IBM SPSS Statistics, Chicago, IL, USA). The compatibility of the variables to normal distribution was examined using the Kolmogorov-Smirnov test. Mean and standard deviation values were used for descriptive statistics. The relationship of the nerve diameters to gender and dominant hand was evaluated using the Man Whitney U test. The correlation between the bilateral mean nerve root diameter and age, weight, BMI, and height was calculated with the Spearman correlation coefficient test. Friedman test was used to evaluate the within-group differentiation of nerve root diameter values. We used Wilcoxon's signed tests on different combinations of interest groups to analyze where the variations exist. The intraclass correlation coefficient (ICC) test was used to analyze intraobserver reliability for repeated measurements. Interobserver agreement regarding the diameter measurements between the two observers was assessed using the ICC with a 95% confidence interval in a two-way random model. ICC was interpreted as follows: below 0.50: poor, between 0.50 and 0.75: moderate between 0.75 and 0.90: good above 0.90: excellent. It was considered that $p<0.05$ was significant.

RESULTS

A total of 84 participants were included in the study. The demographic data of the participants are presented in Table 1. In 8 patients, the measurement could not be

obtained due to technical reasons, such as the short neck, deep localization of the nerve root, and the absence of rudimentary anterior tubercle, which is the anatomical landmark of the C7 nerve root. There was no statistically significant relationship between gender, hand dominance, and mean nerve root diameter (p=0.76). Besides, no statistically significant differences were identified when we compared the mean nerve root diameter at the right and left sides in each participant (p=0.12).

Table 1. The demographic characteristics of the participants

Variables	Participants (N = 84)
Age (range)	42.06±6.73(18-60)
Gender (male:female)	34:50
Weight (kg)	64.06±7.73
Height(cm)	166.61±6.30
Body mass index (kg/m²)	23.13±3.25
Dominant hand (right:left)	76:8

Data are expressed as the mean± standard deviation

The mean nerve root diameters of both sides of the first and second observers are shown in Table 2.

The ICC values for all diameter measurements were>0.80-0.90, indicating good and excellent agreement (Table 3a, b).

Spearman correlation analysis was performed for comparison of mean nerve root diameters and height, weight, BMI, and age. There was no statistically significant difference between C5, C6 and C7 mean nerve roots and weight, height, BMI, and age(p>0.05) (Table 4).

There was a statistically significant difference in the within-group differentiation of mean nerve root diameters ($\chi 2=278.225$, p<0.001, Friedman test). Post hoc analysis with Wilcoxon signed-rank tests was conducted with a Bonferroni correction applied to were used to compare subgroups. The mean diameter of the C6 nerve root was higher than C7 and the mean diameter of the C7 nerve root was higher than C5 on both sides, according to both observer measurements (p<0.001) (Table 5).

Table 2. Measurement of cervical mean nerve root diameters(mm)

	Observer 1		Observer 2	
	Right	Left	Right	Left
C5	2.68 ±0.40	2.88±0.41	2.63 ± 0.38	2.66±0.42
C6	3.29 ± 0.56	3.15±0.56	3.30 ± 0.56	3.26±0.61
C7	2.88 ± 0.48	2.86±0.52	2.86 ± 0.52	2.90±0.50

Data are expressed as the mean± standard deviation

Table 3 a,b: Intraclass correlation coefficient for intra-observer(a) and inter-observer(b) measurement of mean nerve root diameters(mm).

Table 3a. Intraobserver variability

	Observer 1			Observer 2		
	ICC Value	%95 CI	P-Value	ICC Value	%95 CI	P-Value
R C5	0.901	0.845-0.936	<0.001	0.890	0.795-0.921	<0.001
R C6	0.935	0.901-0.957	<0.001	0.903	0.850-0.930	<0.001
R C7	0.905	0.858-0.937	<0.001	0.901	0.846-0.929	<0.001
L C5	0.823	0.702-0.911	<0.001	0.841	0.751-0.898	<0.001
L C6	0.870	0.788-0.919	<0.001	0.884	0.791-0.922	<0.001
L C7	0.870	0.806-0.914	<0.001	0.874	0.794-0.924	<0.001

R: Right, L: Left

Table 3b. Interobserver variability

	ICC Value	%95 CI	P-Value
R C5	0.948	0.916-0.967	<0.001
R C6	0.966	0.948-0.978	<0.001
R C7	0.950	0.923-0.968	<0.001
L C5	0.839	0.752-0.896	<0.001
L C6	0.931	0.881-0.958	<0.001
L C7	0.930	0.893-0.955	<0.001

ICC: Intraclass Correlation Coefficient; CI: Confidence Interval; p value significant at 0.05. R: Right, L: Left

Table 4. Spearman Rho correlations between age, weight, height, and body mass index

			Observer 1						Observer 2					
			RC5	RC6	RC7	LC7	LC6	LC7	RC5	RC6	RC7	LC5	LC6	LC7
Spearman's rho	Age(years old)	Correlation Coefficient	.183	-.031	.118	-.021	.103	-.061	.173	.028	.007	.037	.128	-.050
		Sig. (2-tailed)	.096	.782	.284	.850	.351	.581	.116	.804	.947	.738	.246	.651
	Weight(kg)	Correlation Coefficient	-.027	-.093	-.242*	-.171	-.062	-.125	-.054	-.102	-.174	-.047	-.007	-.143
		Sig. (2-tailed)	.810	.400	.056	.119	.574	.256	.626	.355	.114	.668	.953	.195
	Height(cm)	Correlation Coefficient	-.079	.014	.067	-.108	.138	.097	-.131	.050	.064	.066	.127	.117
		Sig. (2-tailed)	.477	.896	.545	.329	.211	.379	.236	.654	.564	.550	.249	.287
	BMI (kg/m2)	Correlation Coefficient	-.073	-.184	-.196	-.086	-.018	-.209	-.024	-.167	-.201	-.071	-.004	-.184
		Sig. (2-tailed)	.512	.095	.074	.434	.871	.057	.829	.129	.067	.524	.973	.094
		N	84	84	84	84	84	84	84	84	84	84	84	84

Correlation is significant at the 0.05 level (2-tailed).

Table 5. Wilcoxon test for mean nerve root diameters

	Observer 1		Observer 2	
	Z-Value	P-Value	Z-Value	P-Value
R C6 – R C5	-7.257[b]	<0.001	-7.273[b]	<0.001
R C7 – R C6	-5.884[c]	<0.001	-5.502[c]	<0.001
R C7 – R C5	-3.530[b]	<0.001	-3.677[b]	<0.001
L C6 – L C5	-6.802[b]	<0.001	-6.977[b]	<0.001
L C7 – L C6	-6.037[c]	<0.001	-5.268[c]	<0.001
L C7 – L C5	-3.272[b]	<0.001	-3.824[b]	<0.001

a. Wilcoxon Signed Ranks Test b. Based on negative ranks c. Based on positive ranks R: Right, L: Left

DISCUSSION

Cervical nerve roots may be affected with some systemic diseases, such as tumors, neuropathies, inflammation, infection, and radiation (7, 8). Magnetic resonance imaging (MRI) and ultrasound (US) are commonly preferred imaging methods in the evaluation of cervical nerve roots (11). The main disadvantages of MRI are the long imaging times, the need for contrast material, they are expensive, and they are prone to motion artifacts (7). With its outstanding soft-tissue resolution and multiplanar examination characteristics, MRIs are still the most preferred method for evaluating the peripheral nervous system, and US can be used as a complementary method in selected cases (12).

In this prospective study, 84 healthy participants were recruited. To determine the reference values for the mean nerve root diameters of the cervical nerve roots, including the C5, C6, and C7 nerves, measurements were made immediately after their exit from the spinal foramina. The mean nerve root diameters of C5, C6, and C7 nerves were obtained on both sides. The association between the measurements and age, height, weight, body mass index (BMI), and hand dominance were then evaluated.

An important finding of this study was that the mean nerve root diameters of C5, C6, and C7 nerves could be evaluated by ultrasonography with an excellent intra- and interobserver reliability.

Sugimoto et al. (13), found no statistically significant correlation between C5, C6, and C7 mean nerve root diameters and sex in 60 healthy volunteers. In the same study, the relationships between the C6 and C7 nerve roots and the dominant hand were higher than

those of the non-dominant hand. Moreover, there was a statistically significant correlation between BMI and C6, while the same correlation with the C5 and C7 nerves could not be demonstrated (13). Perez et al. (14) found no statistically significant correlation between BMI and nerve root cross-sectional area (CSA) in 100 healthy volunteers. Moreover, they could not find a statistically significant relationship between the CSA values of the nerve roots and the dominant hand.

A correlation between age and mean nerve root diameter in the control group was not observed in the study conducted by Nodera et al. (15) in 35 patients with amyotrophic lateral sclerosis. They also failed to find a significant relationship between sex and mean nerve root diameters. A study by Boehm et al. (16) with 56 healthy subjects reported a weak negative correlation between the C6 mean nerve root diameter and age. Furthermore, there was no significant correlation between the C5 and C7 mean nerve root diameters and age. They also could not find a significant correlation between the C5, C6, and C7 nerve roots and height or weight. In another study by Takeuchi et al. (14), a correlation between the C5 nerve root transverse diameters and CSA values and height were observed bilaterally; however, no correlation was observed between the C6 and C7 measurements and height on either side. In our study, there were no significant relationships between the mean nerve root diameters of C5, C6, and C7, hand dominance, and sex. There were also no correlations between BMI and age and the mean diameters of the C5, C6, and C7 nerve roots. Therefore, there was no significant relationship between the diameters of the nerve roots of the C5, C6, and C7 and height on the right and left sides. Our study differs from other studies due to its interobserver structure and the fact that it included more participants and a wider range of ages. As a result, we consider our findings to be more accurate.

Takeuchi et al. (17) measured 219 cases of C5, C6, and C7 nerve root diameters, transverse diameters, and CSAs. They found that the nerve diameter of C5 was less than those of C6 and C7 on both the right and left sides. Similarly, in nerve root CSA measurements, the C5 nerve root was smaller than the C6 and C7 nerve roots. The C7 CSA was less than that of C6. Perez et al. (14) reported that the C5 nerve root CSA was less than that of C6 and C6 less than C7. Matsuoka et al. (18) examined 30 healthy volunteers and found the mean diameter of the C5 nerve roots was smaller than those of C6 and C7. Moreover, the mean C7 nerve root diameter was also greater than C6 in the same study. In our study, in accordance with Takeuchi et al. (17), the mean C6 nerve root thickness was greater than that of C7; however, the mean C7 nerve root thickness was greater than that of C5. We believe our study provides more accurate data on mean nerve root diameters due to its wider age range and the greater number of participants and interobserver assessments.

There were some limitations of our study. First, the number of cases was not sufficient to reach a definitive result. Second, the C8 and T1 nerve root measurements could not be included in the study due to technical problems. Third, as degenerative changes and osteophyte formations increase with older age, participants over 60 years of age were not included in the study. Finally, since our measurements were made only at the level of the nerve root, the measurements of the diameter at the fascicle and trunk levels may vary.

In summary, the normal range of cervical nerve root diameters should be determined to distinguish pathological conditions. In our study,the measurement of mean nerve root diameters of C5, C6, and C7 nerves is highly reproducible with excellent intra-observer and inter-observer agreement. Therefore, the measurement of nerve root diameter can be confidently performed in daily clinical practice.

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Conflict of Interest: *The authors declare that they have no competing interest.*

Ethical approval

The study was approved by the ocal ethics committee (approval number: 2019/1901). All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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