



## ESTIMATION OF SPACE AVAILABLE FOR THE SPINAL CORD OF CERVICAL SPINE BY MRI IN ADULT POPULATION

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### Abstract

**Background:** Spinal stenosis may result in compression of the spinal cord and cause symptoms associated with cervical myelopathy symptoms. Space available for the cord (SAC) can be used as an indicator of spinal stenosis. This study evaluates the reference value of SAC by MRI from C3 to C7 vertebrae.

**Materials and methods:** A cross-sectional study was conducted in the Department of Radiology, Santosh Medical College, Ghaziabad, Uttar Pradesh, in collaboration with the Department of Radiology, Hind Institute of Medical Sciences, Barabanki, Uttar Pradesh. MRI-based study on the midsagittal diameter of the spinal canal, spinal cord and its SAC value of the lower cervical spine (C3-C7) were done from 320 subjects (160 males and 160 females) of 18 to 59 years of age.

**Results:** The mean value of the sagittal diameter of the spinal canal from C3 to C7 was 14.50 mm  $\pm$  1.24 in males and 14.18 mm  $\pm$  1.12 in females. The mean value of sagittal diameter of the spinal cord from C3 to C7 was 6.01 mm  $\pm$  0.69 in males and 5.85 mm  $\pm$  0.63 in females. The SAC value was 8.48 mm  $\pm$  1.22 in males and 8.33 mm  $\pm$  1.12 in females.

**Conclusion:** The SAC value was found statistically nonsignificant differences between the males and females except at the level of the C7 vertebra. The SAC value increases as age increases except in females at the level of the C3 vertebra and males at the level of the C5 vertebra.

**Keywords:** Cervical spinal canal, Spinal cord, Space available for cord (SAC), Spinal canal stenosis, Spinal cord compression.

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## INTRODUCTION

The space available for the spinal cord (SAC) is the cerebrospinal fluid space that surrounds the spinal cord.<sup>(1,2)</sup> When the diameter of the spinal canal is reduced, less space is available for the spinal cord (SAC), a condition termed cervical canal stenosis.<sup>(3)</sup> Spinal stenosis may involve any region of the spine.<sup>(4)</sup> Patients with a developmentally narrow cervical canal are prone to neurological damage after even minor cervical discopathy or trauma.<sup>(5)</sup> It has been shown that greater canal diameters reduce the probability of neurological damage secondary to cervical spine fractures or dislocation.<sup>(6)</sup> Cervical spinal stenosis is more dangerous because it involves spinal cord compression.<sup>(4)</sup> The progressive spinal cord compression may lead to spinal cord ischemia.<sup>(7)</sup> SAC value is important to understand the symptoms of spinal cord compression in cervical canal stenosis.<sup>(8)</sup> SAC is a direct indicator of spinal canal stenosis and a useful tool for prediction the risk of myelopathy and prognosis following spinal cord injury in an individual.<sup>(1,2)</sup> Evaluation of critical spinal canal stenosis using SAC enables discrimination between a patient at risk for cervical spinal cord injury and those not at risk.<sup>(9)</sup> SAC measurement is important because spinal canal stenosis can be described as encroachment of the spinal canal on the spinal cord.<sup>(10)</sup>

Most recent studies suggest the space available for the cord (SAC) is a more reliable method for determining spinal stenosis. When measured with magnetic resonance imaging (MRI), SAC has been claimed to be a reliable spinal canal stenosis indicator as compared to simple radiographs and plain computed tomography measurements.<sup>(11,12,13)</sup> The SAC value can be calculated by subtracting the spinal cord sagittal diameter from the spinal canal sagittal diameter using MRI, excluding the influence of changes in the vertebral body size.<sup>(2)</sup> Many factors, including race, sex, and age, have been demonstrated to influence the SAC.<sup>(1,14-16)</sup> Herzog et al.,<sup>(11)</sup> have mentioned that the SAC value below 5 mm is a good indicator of cervical canal stenosis. Subjects with less SAC value has less space for a spinal cord associated with herniated discs; osteophytic spurs, etc. are more susceptible to spinal cord compression.

To our knowledge, studies have yet to be conducted on the SAC value in normal adult population of Uttar Pradesh. So, this study has been designed to determine the range of SAC values in the adult population of Uttar Pradesh as a reference value.

## MATERIALS & METHODS

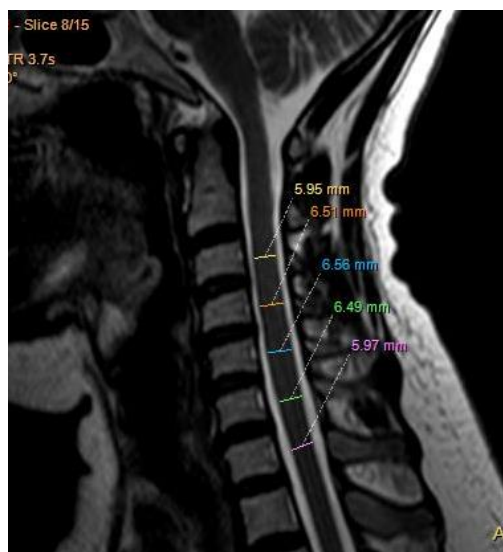
A cross-sectional study was conducted in the Department of Anatomy and Radiology, Santosh Medical College, Ghaziabad, Uttar Pradesh in collaboration with the Department of Radiology, Hind Institute of Medical Sciences, Barabanki, Uttar Pradesh India. This study was carried out over a period of four years. This study included 320 patients out of which 160 were males and 160 were females of 18 to 59 years of age group. The sample of the present study was divided into groups according to sex and then subdivided into two age groups with the following ranges: young age: 18 to 39 years old, and middle age: 40 to 59 years old. This division was based on the degenerative patterns that occur in the spine with age.<sup>(17)</sup> This study was approved by the Institutional Ethics Committee, Santosh deemed to be University, Ghaziabad.

The MRI examination of the cervical spine was performed according to standardized protocol with the help of Philips Achieva 1.5 Tesla 8 channel MRI Machine with a spinal coil and standardized neutral head and neck position. MRI was done in all routine sequences but for study purposes, only the sagittal T2-weighted turbo spin-echo (TSE) sequence was considered. All the images of cervical spine MRI were interpreted by a single radiologist. Only soft copies of virtually normal cervical spine MRIs were selected and recorded in the form of DICOM (Digital Imaging and Communications in Medicine) format. The same set of protocols was applied to every patient. The midsagittal image of the cervical spine MRI was selected. The sagittal diameters of the spinal canal and spinal cord from C3 to C7 vertebral level were traced in the image and were measured by computerized measurements on Philips DICOM viewer Release 3.0 SP3 (Software) and values of these parameters were noted in the data collection sheet. The sagittal diameter of the vertebral canal was measured as the shortest distance from the midpoint of the vertebral body's superior and inferior surfaces to the corresponding spinolaminar line [Figure 1].<sup>(18)</sup> The sagittal diameter of the spinal cord was measured at the transversal midline of the vertebral body at the appropriate level [Figure 2].<sup>(18)</sup> The SAC value was determined by subtracting the sagittal diameter of the spinal cord from the corresponding sagittal diameter of the spinal canal.<sup>(18)</sup> All the measurements were made midsagittally at each spinal level from C3 to C7 vertebra. The first and second cervical vertebrae were excluded as they have different shapes as compared with other cervical vertebrae and, also because most cases of cervical spinal stenosis

occur at the levels between C4 and C6. All these measurements were taken in millimeters (mm) in the presence of a diagnostic radiologist.



**Figure 1:** Midsagittal T2-weighted pulse sequence of the cervical spine in 51 years old female. Measurements of the sagittal diameter of the spinal canal from C3 to C7 level.



**Figure 2:** Midsagittal T2-weighted pulse sequence of the cervical spine in 51 years old female. Measurements of the sagittal diameter of the spinal cord from C3 to C7 level.

### Statistical Analyses

The Mann-Whitney U test was used to test the significance of differences between the mean of two independent groups the male and female. Total samples were divided into male and female subjects, and then the data for male and female subjects were calculated separately. For each of the four groups, the mean, standard deviation, minimum and maximum values of all the parameters were determined independently for C3–C7 cervical vertebrae. The statistical analysis was performed by using Statistical Package for the Social Sciences (SPSS) software. A p-value of 0.05 or less was considered to be statistically

significant. By using the formula “mean  $\pm$  3 S.D.” the calculated range was derived.

### RESULT

For normal values of the sagittal diameter of the spinal canal, the sagittal diameter of the spinal cord and the SAC value, cervical vertebrae from C3 to C7 level were measured in each subject. Each of the above morphometric parameters and their differences regarding sex and age are presented in three sections in this research: general and intersegmental differences, sex differences and age differences.

### Sagittal diameter of the spinal canal

#### A. General and intersegmental differences:

The sagittal diameter of the spinal canal ranged from 12.08 mm to 18.65 mm in males and 12.01 mm to 17.87 mm in females. The mean value of the sagittal diameter of the spinal canal was  $14.67 \pm 1.14$  mm (mean  $\pm$  standard deviation) at C3,  $14.14 \pm 1.07$  mm at C4,  $14.31 \pm 1.17$  mm at C5,  $14.52 \pm 1.31$  mm at C6 and  $14.85 \pm 1.36$  mm at C7 vertebral level in males while  $14.35 \pm 1.21$  mm at C3,  $14.00 \pm 1.08$  mm at C4,  $14.08 \pm 1.18$  mm at C5,  $14.12 \pm 1.12$  mm at C6, and  $14.31 \pm 0.97$  mm at C7 vertebral level in females. The sagittal diameter of the spinal canal decreased from C3 to C4 vertebral level and then increased gradually from C5 to C7 vertebral level in each and overall age group of both sexes. The sagittal diameter of the spinal canal was lowest at the level of the C4 vertebra in each and overall age group of both sexes. The sagittal diameter of the spinal canal was highest at the level of C3 and C7 vertebra in females and males respectively in each and overall age group.

#### B. Sex differences:

The sagittal diameter of the spinal canal was higher in males as compared to females at all vertebral levels and in all age groups. In the age group of 18-39 years old, statistically significant differences between males and females were found only at the level of the C7 vertebra. In the age group of 40-59 years old, statistically significant differences between males and females were found at the level of C6 and C7 vertebrae.

#### C. Age differences:

There are no statistically significant differences were found between age groups in females as well as males at any of the vertebral levels but in males at the level of the C6 vertebra. The value of the sagittal diameter of the spinal canal was higher in the age group of 40 to 59 years old than the age

group of 18 to 39 years old in both sexes at all vertebral levels except at the level of C5.

### Sagittal diameter of the spinal cord

#### A. General and intersegmental differences:

The sagittal diameter of the spinal cord ranged from 4.15 mm to 7.84 mm in males and 4.17 mm to 7.69 mm in females. The mean value of the sagittal diameter of the spinal cord was  $6.28 \pm 0.64$  mm (mean  $\pm$  standard deviation) at C3,  $6.30 \pm 0.67$  mm at C4,  $6.20 \pm 0.63$  mm at C5,  $5.92 \pm 0.58$  mm at C6,  $5.44 \pm 0.56$  mm at C7 vertebral level in males while  $6.10 \pm 0.65$  mm at C3,  $6.10 \pm 0.56$  mm at C4,  $6.00 \pm 0.56$  mm at C5,  $5.74 \pm 0.55$  mm at C6,  $5.32 \pm 0.46$  mm at C7 vertebral level in females. The sagittal diameter of the spinal cord was highest at the level of C3 to C5 vertebrae while the sagittal diameter decreased gradually from C5 to C7 vertebral level in each and overall age group of both sexes. The sagittal diameter of the spinal cord was found to be narrowest at the level of the C7 vertebra in each and overall age group of both sexes.

#### B. Sex differences:

The sagittal diameter of the spinal cord was greater in males as compared to females in each age group at all vertebral levels. The sagittal diameter of the spinal cord was statistically significant differences between males and females at all vertebral levels.

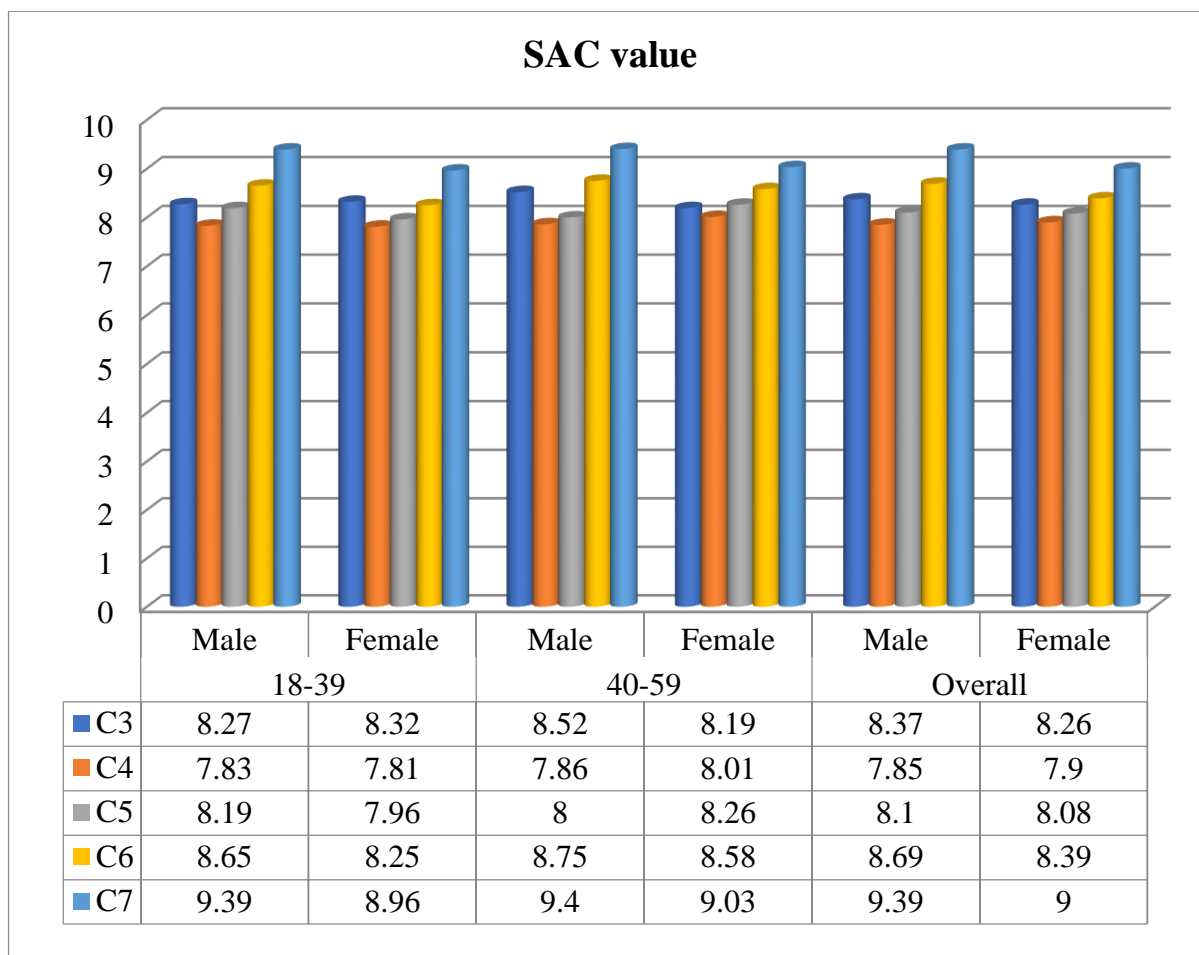
#### C. Age differences:

The sagittal diameter of the spinal cord were compared between the age group of 18-39 years old and 40-59 years old in both sexes at individual and overall vertebral levels. It was found statistically significant differences only at the level of C3 vertebra in females. In males, statistically significant differences were found at the level of C5, C6, and C7 vertebrae.

### SAC value

**Table 1:** Distribution of minimum and maximum value of SAC among various age groups in both sexes at different cervical vertebral levels

Age group (Years)	Sex	Vertebral level (Min-Max, mm)					
		C3	C4	C5	C6	C7	Overall (C3 to C7)
18-39	Male	5.51-10.23	5.85-9.55	5.93-10.67	5.95-12.14	6.64-13.55	5.51-13.55
	Female	5.59-12.74	6.07-10.56	5.43-10.36	6.39-10.55	7.02-12.27	5.43-12.74
40-59	Male	6.5-10.37	5.63-9.0	5.89-9.81	6.37-11.52	6.66-12.5	5.63-12.5
	Female	5.76-11.31	6.4-11.07	6.34-11.7	6.95-11.64	7.03-11.52	5.76-11.7
Overall (18-59)	Male	5.51-10.37	5.63-9.55	5.89-10.67	5.95-12.14	6.64-13.55	5.51-13.55
	Female	5.59-12.74	6.07-11.07	5.43-11.70	6.39-11.64	7.02-12.27	5.43-12.74



**Graph 1:** Comparison of SAC value among each vertebral level from C3 to C7 in both sexes and all age groups.

**General and intersegmental differences:**

The minimum and maximum values of SAC were obtained at each vertebral level and for each age group and sex (Table 1). The SAC value decreased from C3 to C4 vertebral level and then increased gradually from C5 to C7 vertebral level in each and

overall age group of both sexes. The SAC value was highest at the level of the C7 vertebra and lowest at the level of the C4 vertebra in each and overall age group of both sexes (Graph 1).

**Table 2:** Values of space available for the spinal cord (SAC) for each age group and vertebral level. Comparison between both sexes

Age group (Years)	Sex	Vertebral level (Mean±SD, mm)					Overall (C3 to C7)
		C3	C4	C5	C6	C7	
18-39	Male	8.27±0.92	7.83±0.87	8.19±1.06	8.65±1.28	9.39±1.33	8.47±1.22
	Female	8.32±1.24	7.81±1.04	7.96±1.05	8.25±1.01	8.96±0.98	8.26±1.13
	P-Value	0.637	0.595	0.337	0.061	0.023*	0.156
40-59	Male	8.52±1.00	7.86±0.82	8.00±0.93	8.75±1.14	9.40±1.42	8.50±1.21
	Female	8.19±1.07	8.01±1.04	8.26±1.09	8.58±1.06	9.03±0.98	8.41±1.10
	P-Value	0.093	0.948	0.275	0.285	0.076	0.243
Overall (18-59)	Male	8.37±.96	7.85±.86	8.10±1.00	8.69±1.22	9.39±1.36	8.48±1.22
	Female	8.26±1.16	7.90±1.04	8.08±1.07	8.39±1.04	9.00±.98	8.33± 1.12
	P-Value	0.181	0.734	0.929	0.051*	0.006*	0.070

\*p-value less than 0.05 was considered statistically significant

**Sex Differences:**

The SAC value was compared between males and females and found statistically nonsignificant

differences in each and overall age group at individual and overall vertebral levels except at the level of C7 vertebra in the age group of 18-39 years

old, at the level of C6 and C7 vertebrae in overall age group (Table 2).

### Age Differences:

The SAC value was compared between the age group of 18-39 years old and 40-59 years old of both sexes at individual and overall vertebral levels, found statistically non significant differences. The SAC value was greater in the age group of 40-59 years old as compared to the age group of 18-39 years old at all vertebral levels of both sexes except in females at the level of C3 vertebra and in males at the level of C5 vertebra.

## DISCUSSIONS

The space within the spinal canal determines the movements of its contents without any difficulty by tension and pressure. So, any abnormal reduction in the size of the spinal canal, particularly in the lower cervical vertebra, could predispose to neck pain. Different researchers working in various parts of the world have been attempting to determine the various dimensions of the cervical spinal canal at different vertebral levels in normal subjects. So that clinicians may be able to diagnose cervical spinal stenosis by consulting these reference values. This study has helped to establish reference values for SAC as a more direct cervical canal stenosis indicator for this study population.

### Sagittal diameter of the spinal canal

The cervical canal size in the normal Indian population was much smaller than that in other races.<sup>(8,19,20)</sup> Many authors have reported differences in the mean sagittal spinal canal diameter, our spinal canal diameters were 1 to 5 mm different from measurements reported in several studies. These differences occur as we used MRI in determining measurements, and some authors used radiographs or dried specimens or CT scans.<sup>(11)</sup>

In the study of Matveeva et al.,<sup>(18)</sup> the reported average sagittal spinal canal diameter from C3 to C7 was 14.59 mm  $\pm$  1.01 in males and 15.26 mm  $\pm$  1.11 in females. These measurements were obtained by using MRI, as we used in our study. In the present study, the sagittal diameter of the cervical spinal canal was 14.50 mm  $\pm$  1.24 in males and 14.18 mm  $\pm$  1.12 in females. In our study, the sagittal diameter of the spinal canal in males and females in every age group diminished from C3 to C4 and then gradually increased from C5 to C7 vertebrae. This result is similar to the studies reported by Morales-Avalos et al.,<sup>(17)</sup> and Lim et al.,<sup>(14)</sup> Our study showed the least value of the

sagittal diameter of the spinal canal at the level of the C4 vertebra in both sexes and in both age groups. This result is similar to other studies.<sup>(12,14,21,22)</sup> But the study of Matveeva et al.,<sup>(18)</sup> and Kathole et al.,<sup>(23)</sup> found the mean value of the sagittal diameter of the spinal canal was narrowest at the level of C5 vertebra in both sexes. The present study showed statistically significant differences in the sagittal diameter of the spinal canal between the males and females in most age groups except at the level of C4 and C5 vertebrae. Similarly, the study reported by Morales-Avalos et al.,<sup>(17)</sup> and Lim et al.,<sup>(14)</sup> found significant differences in males and females in most age groups. There are contradictions reported by other researchers who concluded that there are no significant differences in canal diameter between males and females at all cervical vertebral levels.<sup>(10,18,22, 24)</sup> In the present study, the sagittal diameter of the spinal canal increases as age increases except in males at the level of the C5 vertebra where diameter does not change with age. The sagittal diameter of the cervical spinal canal has been identified as a predictor for the development of cervical myelopathy<sup>(25,26)</sup> as well as spinal cord injury.<sup>(27)</sup> The sagittal spinal canal diameter has a major diagnostic and therapeutic decisive role in cases of degenerative stenosis.<sup>(13,28)</sup> Although the pathology of cervical spine stenosis is primarily in the sagittal plane, narrowing only in the sagittal diameter may not indicate a significant reduction in the area of the canal.<sup>(29)</sup>

Morishita et al.,<sup>(30)</sup> in their study concluded that spinal canal sagittal diameter with a value below 13mm is at increased risk of developing intervertebral disc pathologies. In our study, out of 320 subjects, about 18% showed values lower than 13 mm at various levels and all of these were normal subjects. So, we predicted that the values which are designed for the Western population might not apply to the population of Uttar Pradesh (India).

### Sagittal diameter of the spinal cord

The spinal cord is frequently exposed to numerous problems like injuries and back pains. This study took measurements at the level of midvertebral body unlike some of the other studies that took measurements at the level of intervertebral disc.

In the study reported by Matveeva et al.,<sup>(18)</sup> the mean sagittal diameter of the spinal cord was the greatest from C3 to C5 because of the cervical cord enlargement, which was 7.57 mm  $\pm$  0.42 in males and 7.67 mm  $\pm$  0.95 in females at C3. At C6 and C7 the average sagittal spinal cord diameters were

of lower values, which was  $6.43 \text{ mm} \pm 0.72$  in males and  $6.66 \text{ mm} \pm 0.73$  in females. In the present study, the sagittal diameter of the spinal cord was measured which was greatest at the level of the C4 vertebra. This enlargement might have occurred because of the increased neural tissue required for the brachial plexus. The sagittal diameter of the spinal cord was  $6.01\text{mm}\pm 0.69$  in males and  $5.85 \text{ mm} \pm 0.63$  in females. These diameters were slightly lower than the study reported by Kar et al.,<sup>(10)</sup> Anatomy dissections and imaging studies have shown that the human adult spinal cord averages 5 to 6 mm in the AP diameter.<sup>(31)</sup> The greatest sagittal spinal cord diameter was  $7.75\text{mm}\pm 0.70\text{mm}$  at C4 and the least

spinal cord diameter was  $6.15 \text{ mm} \pm 0.65\text{mm}$  at C7.<sup>(32)</sup> In the present study, the sagittal diameter of the spinal cord was compared between males and females at all vertebral levels from C3 to C7, was found statistically significant differences at all vertebral levels except at the level of C6 vertebra. Similarly, the study reported by Dag et al.,<sup>(33)</sup> also found statistically significant differences but the study reported by Gune et al.,<sup>(34)</sup> found statistically nonsignificant differences at all vertebral levels. In our study, the sagittal diameter of the spinal cord was higher in males than in females. A similar result was found in the study reported by Dag et al.,<sup>(33)</sup>

**SAC VALUE**

**Table 3:** Comparison of SAC value in different populations

Author's (Year of study)	Country	Instrumentation	Sex	No. of cases	Vertebral level				
					C3	C4	C5	C6	C7
Ndubuisi CA et al., (2017) <sup>(35)</sup>	Nigeria	MRI	Male	51	4.90±0.38	4.55±0.35	4.52±0.39	5.13±0.34	5.72±0.41
			Female	51	4.94±0.39	4.48±0.35	4.59±0.39	4.79±0.34	5.48±0.41
Chowdhury J et al., (2020) <sup>(36)</sup>	India	MRI	Male	69	4.9 ±1.58	5.0±1.03	5.2 ±1.22	5.5±1.06	6.3 ±1.37
			Female	31	5.3 ±0.74	5.3±0.80	5.4±0.64	5.7±0.98	6.3±1.07
Gwachha S et al., (2022) <sup>(32)</sup>	Nepal	MRI	Male	33	4.44±1.13	4.52±1.20	4.67±1.04	5.16±1.21	6.08±1.37
			Female	39	4.52±.97	4.38±.88	4.60±1.00	5.06±.96	5.70±.88
Gune AR et al., (2022) <sup>(34)</sup>	India	MRI	Male	36	7.27	5.01	6.79	5.58	4.91
			Female	34	6.97	4.37	5.95	5.54	4.98
Present study (2023)	India	MRI	Male	160	8.37±.96	7.85±.86	8.10±1.00	8.69±1.22	9.39±1.36
			Female	160	8.26±1.16	7.90±1.04	8.08±1.07	8.39±1.04	9.00±.98

The size of the cervical spinal canal and the space available for the cord are important determining factors to make decisions on the treatment of traumatic, degenerative, and inflammatory conditions of the cervical spine. Herzog et al.,<sup>(11)</sup> recommended that SAC is of great importance if symptomatic individuals had a Torg's ratio less than 0.80 or a sagittal spinal-canal diameter value less than 12.5 mm. Tierney et al.,<sup>(13)</sup> compared Torg's ratio and SAC and stated that SAC is a better indicator of stenosis.

In the present study, the SAC data ranged from 5.51 to 13.55 mm in males and 5.43 to 12.74 mm in females. Slightly lower range of SAC data found in a study by Matveeva et al.,<sup>(18)</sup> which was 4.82 to 12.36 mm in males and from 5.15 to 11.5 mm in females. Table 3, shows a comparison of the mean SAC value reported by various workers, including the present work. In the Macedonian population, Matveeva et al.,<sup>(18)</sup> noted that at the level of the C7 vertebra, the average SAC value was maximum,  $9.25 \text{ mm} \pm 1.76$  in males, and  $8.9 \text{ mm} \pm 1.38$  in

females. However, the SAC value was slightly higher in our study than that of the Macedonian population i.e.  $9.39\pm 1.36$  in males and  $9.00\pm 0.98$  in females. This may be due to racial differences. In the study reported by Chowdhury et al.,<sup>(36)</sup> values of SAC were greatest at the C7 level and were least at the C3 level similarly in our study, SAC value was greatest at the level of C7 but the least value was found at the level of C4 vertebra in both sexes and in all age groups.

Previous studies have demonstrated individuals with lower SAC values have an increased risk of cervical cord neuropraxia and cervical stenosis.<sup>(37)</sup> Herzog et al. have suggested that individuals with low SAC (<5mm) value and associated with herniated discs, osteophytic spurs, etc., are more susceptible to spinal cord compression.<sup>(11)</sup> Critical SAC values may predict the development of significant stenosis or may indicate an increased risk of neurological injury.

In the study of Gwachha et al.,<sup>(32)</sup> SAC value was more in males than in females at C4, C5, C6 and C7 vertebral levels. However, it was more in females than in males at the C3 level. Similarly, in my study, the SAC value was more in males than in females at the level of C3, C6, and C7 vertebra but at the level of C4 and C5 vertebra SAC value was more in females. In the present study, the SAC value was compared between males and females at all vertebral levels from C3 to C7, found a statistically significant difference only at the level of the C7 vertebra. Similarly, the study reported by

Gune et al.,<sup>(34)</sup> found a statistically significant difference only at the level of the C5 vertebra but the study reported by few authors<sup>(10,18,32,35,36)</sup> found statistically nonsignificant differences at all vertebral level.

The SAC value was compared between the age groups of both sexes at individual and overall vertebral levels, and found statistically non significant differences, similar results were reported by Gwachha et al.,<sup>(32)</sup>

**Table 4:** Showing upper and lower limits of the calculated range for SAC value, in males and females.

Vertebral level	Values suggestive of Spinal Stenosis i.e., Values < (Mean-3 S.D.)		Values suggestive of Space Occupying Lesion i.e., Values > (Mean+3 S.D.)	
	Male	Female	Male	Female
C3	<5.49	<4.78	>11.25	>11.74
C4	<5.27	<4.78	>10.43	>11.02
C5	<5.1	<4.87	>11.1	>11.29
C6	<5.03	<5.27	>12.35	>11.51
C7	<5.31	<6.06	>13.47	>11.94

From Table 4, it was observed that in both sexes the values of SAC were less than the lower limits of the calculated range which suggest spinal canal stenosis. Similarly, the values of SAC which are greater than the upper limits of the calculated range, which suggest some pathological lesion (like space-occupying lesions etc.) at the particular segmental level. Thus, the value of SAC beyond the upper and lower limit of calculated range, suggests some pathology at that particular vertebral level. Such cases need further investigations and clinical evaluation.

We believe that our findings on the reference values for the SAC value of the cervical spine derived from MRI in the adult population of Uttar Pradesh will help Doctors in the diagnosis of various clinical conditions related to the cervical spine, such as spinal canal stenosis or predicting the prognosis of cervical spinal cord injury, space-occupying lesions, etc. and also for the concerned researcher to perform different studies in future.

## CONCLUSION

Standard MRI values for the sagittal diameter of the spinal canal, the sagittal diameter of the spinal cord and the SAC value were established for the adult population of each sex and each age group by this study. These parameters can be used as reference values for evaluating various clinical conditions in the cervical spine in the adult population of Uttar Pradesh.

We can predict the narrowing or widening of the cervical spinal canal if there is a deviation from the average values of the parameters found in this study. Any value lying outside the calculated range suggests the pathological condition of the cervical spine and requires further investigations and clinical evaluation. The dimensions of the cervical spinal canal and the spinal cord in a healthy population vary according to spinal level, gender and age. The values which are designed for one geographical population might not apply to other geographical populations. So, this type of study should be conducted in every geographical population in India as well as in the world.

## Declaration

### Ethical approval

This study has been approved by the Institutional Ethics Committee of Santosh Deemed to be University, Ghaziabad, NCR Delhi, India. The reference number of ethical approval letter was SU/2021/092(28). All the data use in this study was obtained from fully consented individual.

### Conflicts of interest

All the authors declared that they have no competing interests.

### Author's contributions

SPS: Development of protocol, Collection of data, analysis, interpretation, writing the manuscript, KB: Development of protocol, collection of data, Statistical analysis of data, writing the manuscript, RK: Collection of data, guiding the work, approval



of the manuscript, NK: Topic selection, conceptualization, guiding the work, approval of the manuscript.

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### Data availability

The data used in the study are included in the result of the article. The master charts used to prepare the result are available from the corresponding author on reasonable request.

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