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Establishment of a normative data for cervical and lumbar spine movements using spinal column analysis system

NK Tripathy[1], MG Praveen[2], V Raghunandan[3], M Mukherjee[4], M Dahiya[5]

[1]Senior Advisor (Aerospace Medicine) & Chief Research Officer, Institute of Aerospace Medicine IAF, Bengaluru, India, [2]Specialist in Aerospace Medicine, Coast Guard Air Force Station, ICGS Daman, India, [3]Specialist in Aerospace Medicine, Department of Human Engineering, Institute of Aerospace Medicine IAF, Bengaluru, India. [4]Specialist in Aerospace Medicine, Ex Department of Human Engineering, Institute of Aerospace Medicine IAF, Bengaluru, India, [5]Specialist in Aerospace Medicine, SMC, Air Force Station Pathankot, Panjab, India.

***Corresponding author:**
Dr NK Tripathy, MBBS, MD, Senior Advisor (Aerospace Medicine) & Chief Research Officer, Institute of Aerospace Medicine IAF, Vimanapura, Bengaluru - 560 017, Karnataka, India.

nktdoc@yahoo.com

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ABSTRACT

Introduction: The current assessment of spine movements during aeromedical evaluation of aircrew is performed using the CMS 20 spinal column analysis system. However, in the present configuration, the normal ranges of cervical and lumbar spine motions depicted by the equipment are based on normative data of German population measured by goniometric method. The study was conducted to generate normative values of cervical and lumbar spine movements with respect to age-specific Indian male population.

Material and Methods: The study included a total of 225 healthy male Indian volunteers, divided into three age groups; <25 years, 25–35 years, and above 35 years, with 75 subjects in each age group. In each participant, ten cervical spine movements and six lumbar spine movements were recorded using CMS 20 S spinal column analysis system. The data were statistically analyzed to establish normative data for each of the cervical and lumbar spine movements for three age groups (<25 years, 25–35 years, and >35 years).

Results: The mean age, height & weight of the participants were 21.2, 28.3 and 39.4 years, 173.1, 171.6 and 170.6 cm, 65.9, 68.7 and 70.2 kg respectively for the three different age groups - <25 years, 25-35 years and >35 years. The mean values along with standard deviation of the ten cervical and eight lumbar spine movements were derived and presented for the three different age groups.

Conclusion: The normative data generated in the present study as per the three age groups may be used as reference values for male Indian personnel for that specific age groups for the assessment of cervical and lumbar spine movements using spinal column analysis system. The data may also be used as baseline data for aeromedical evaluation and future aviation research involving the same equipment.

Keywords: Spinal column analysis system, Normative data, Aeromedical evaluation

INTRODUCTION

Spine-related medical disorders have been reported to occur earlier and with added severity in fighter and helicopter aircrew.[1,2] Studies have shown that frequent exposure to high G forces not only causes acute in-flight cervical pain but also premature disc degeneration.[3] Studies have also revealed high prevalence of cervical disc degenerative changes among fighter pilots.[4,5] An Indian Air Force (IAF) study had revealed that disc degenerative changes were the most common (61%) incidental radiological findings during post-ejection evaluation.[6] Research in India has also indicated higher incidence of cervicalgia in MiG 29, Mirage 2000, and other fighter aircraft of the magnitude of 63.6%, 80.76%, and 54.2%, respectively.[7,8] Spine is also susceptible to injuries following ejection from aircraft and post-crash landing.[9]

Low back ache (LBA) is another common problem among aircrew. Delahaye has reviewed the incidence of LBA as between 21% and 95% in different Air Forces of the world.[10] Studies carried out in the IAF have also shown a high incidence of LBA, 46.7% in helicopter pilots and 31.3% in non-helicopter pilots.[11] The presence of pre-existing spinal disabilities would further make the spine more susceptible to injury on exposure to aviation stresses.[12] A study by Malik[11] on aircrew candidates during entry has revealed a fairly high incidence (69.9%) of spinal anomalies (on radiological surveillance) in apparently normal, healthy and asymptomatic young Indian men. Of these, 182 (15.2%) were considered unfit for flying duties.

Aeromedical assessment of spine thus becomes an important evaluation not only during the entry medicals to rule out presence of pre-existing spinal disabilities but also in trained aircrew with spinal disorders. A detailed objective evaluation of spine is carried out among all cases of post-ejection and post-crash landing at the Department of Human Engineering, Institute of Aerospace Medicine. As per the existing protocol,[13] spinal evaluation consists of a detailed clinical, radiological, and functional assessment. Assessment of range of motion (ROM) of spine is an integral part of functional assessment of spine. Until recently, cervical and lumbar ranges of movements were measured by conventional method using goniometer and indigenously designed spinal board, respectively.

A significant breakthrough in measuring spine ROM has taken place with the introduction of a dedicated three-dimensional motion analysis system that can record, calculate, and display spatial head position.[14] Such a system, known as CMS 20S spinal column analysis system, is being utilized for the assessment of spinal ranges of movements for aircrew at our Institute. However, in the present configuration, the normal ranges of cervical and lumbar ranges of motions depicted by the equipment are based on a normative data of German population measured by goniometric method. Since the procedures for measurement using goniometric method and spinal column analysis system are entirely different, the goniometric ROMs can not be taken as normal ranges to compare the results of cervical and lumbar spine motions obtained by spinal column analysis system. Further, ranges of spinal movements have strong predisposition for ethnic variation.[15] In view of the above, there was a need to establish a normative data specific to the equipment and specific for Indian population, which can be utilized for the assessment of cervical and lumbar spine movements and aeromedical evaluation of aircrew in the IAF.

MATERIAL AND METHODS

Subjects

A total of 225 healthy male Indian volunteers participated in this study. Subjects were divided into three groups based on the age; <25 years, 25–35 years, and above 35 years. 75 subjects participated in each age group. The exclusion criteria defined for the selection of subjects were clinically diagnosed cases of cervical and lumbar spine disorders, presence of radiological spinal abnormalities, and history of any spinal diseases.

Calculation of sample size

A pilot study was conducted taking 10 subjects in each age group. Cervical and lumbar spine movements were measured as per the protocol. Based on the results of the pilot study, the requirement of the total subjects in each age group was calculated using the following formula:[16]

$$n = \frac{Z^2 \times \sigma^2}{\left(\overline{x} - \mu\right)^2}$$

Where, n = sample size
Z = desired level of confidence (taken as 95 %)
σ = standard deviation of sample from pilot study
$\overline{x}$ = sample mean obtained from pilot study of 10 subjects
μ = expected population mean taken from available original equipment manufacturer (OEM) data.

Materials

Zebris(R) CMS 20S spinal column analysis system was used for the measurement of cervical and lumbar spine movements. It consists of a measuring sensor, a basic unit with power pack together with a table mounted or floor stand. The system is connected through an USB interface to a PC [Figure 1]. The measuring method is based on determination of the spatial coordinates of the ultrasound transmitters by a fixed system of three microphones whose positions are relative to a fixed system standing close by. The ultrasound transmitters send continuous pulses. Using triangulation, the measurement is derived from the time delay between the ultrasound pulses measured at a sample rate of 25 Hz, which is a standard frequency for static positions. The ultrasound pulses are then calculated and imaged through the system. Measuring and data ascertainment are achieved with the program WinSpine 2.2.3.

Experimental protocol

An informed, written consent was taken from each participant. Each participant was evaluated to rule out the presence of spinal disabilities by means of a detailed history, clinical and radiological examination. All measurements took place at least 2 h after waking up in the morning to overcome the initial diurnal stiffness of the spine and circadian variation. Subjects were made to wear minimal clothing. For each subject, 10 cervical movements (cervical flexion, cervical extension, cervical rotation [left and right], cervical lateral flexion [left and right], cervical rotation in maximum flexion [left and right], and cervical rotation in maximum extension [left and right]) and six lumbar movements (lumbar flexion, lumbar extension, lumbar lateral flexion [left and right], and lumbar rotation [left and right]) were recorded.

The data were examined for normality of distribution. The data pertaining to cervical and lumbar movements for each age group (<25 years, 25–35 years, and >35 years) were subjected to descriptive statistics and were presented as mean, median, mode, standard error of mean, standard deviation, variance, range, minimum, and maximum values.

RESULTS

The mean age, height, and weight of the participants in the three age groups are shown in Table 1.

The mean and standard deviation of 10 cervical movements in each age group (<25 years, 25–35 years, and >35 years) is presented in Table 2. Similarly, the mean and standard deviation of six lumbar movements in each age group is depicted in Table 3.

DISCUSSION

For the present study, data were collected from a total of 225 subjects. Since age-related changes in spinal movements are known,[17] the subjects were divided into three groups; (a) <25 years, (b) 25–35 years, and (c) more than 35 years. Initially, a pilot study was conducted with 10 subjects in each group. Based on the mean and standard deviations obtained on the 10 cervical and six lumbar movements, the required sample size in each age group for each of the movements was calculated.[16] Expected population mean was taken from the OEM given data and a 95% confidence level was used for calculation of the sample size. Based on the above calculation, the maximum sample size obtained was 54 for the group <25 years, 50 for age group 25–35 years, and 74 for age group more than 35 years. For the purpose of uniformity, 75 subjects were selected for each age group totaling to 225 as a whole.

In comparison with other studies using the same equipment, our study is the largest in terms of the sample size. A comparison on the sample size among the various studies is shown in Table 4.

The results of the present study were compared with those given by the OEM. It was observed that cervical extension was more than flexion in the OEM given parameters; however, in the present study, cervical flexion was found more than that

Figure 1: Spinal column analysis system.

Table 1: Mean age, height, and weight of participants.

Personal attributes	<25 years	25–35 years	>35 years
Age (years)	21.2	28.3	39.4
Height (cm)	173.1	171.6	170.6
Weight (kg)	65.9	68.7	70.2

Table 2: Mean and standard deviation cervical spine movements.

Movements (in degree)	<25 years	25–35 years	>35 year
Cervical flexion	70.4±10.9	72.5±11.3	61.0±12.2
Cervical extension	65.2±14.2	58.7±11.5	52.0±11.3
Cervical rotation (Lt)	76.4±7.8	74.4±9.2	69.7±6.7
Cervical rotation (Rt)	74.4±7.8	71.5±8.7	67.6±9.5
Cervical lateral flexion (Lt)	45.2±7.6	41.2±11.9	40.6±9.5
Cervical lateral flexion (Rt)	43.9±7.7	38.5±11.2	37.3±9.2
Cervical rotation in max. flexion (Lt)	62.0±10.8	57.4±10.0	57.2±11.6
Cervical rotation in max. flexion (Rt)	57.0±10.4	55.8±10.0	53.9±11.2
Cervical rotation in max. extension (Lt)	54.2±13.3	52.3±11.7	49.1±12.0
Cervical rotation in max. extension (Rt)	48.3±13.1	46.1±12.5	44.6±11.1

Table 3: Mean and standard deviation lumbar spine movements.

Movements (in degree)	<25 years	25–35 years	>35 year
Lumbar flexion	63.4±8.3	64.3±10.5	56.2±9.0
Lumbar extension	20.7±6.7	20.3±7.5	17.7±6.4
Lumbar lateral flexion (Lt)	22.2±7.0	26.4±8.7	27.1±7.4
Lumbar lateral flexion (Rt)	19.6±6.6	24.6±8.5	23.7±6.7
Lumbar rotation (Lt)	18.6±6.1	22.6±7.1	22.3±7.4
Lumbar rotation (Rt)	19.0±6.6	22.1±7.2	22.1±7.0

of extension in all age groups. Another noticeable difference was in lumbar rotation movements. Lumbar rotations were consistently found to be lower in the present study in all age groups in comparison with those given by the OEM. This could be due to the fact that the pelvis was stabilized by the observer while the lumbar rotational movements were recorded in our study. This was to minimize the associated pelvic movements and was as recommended by the operating manuals. It was understood from communication with the OEM that the normal ranges of cervical and lumbar spine movements given by them were based on a study by Munich University among German population by goniometric methods. The difference in the measurement methods could possibly explain the observable difference in the above movements.

Similar studies have also been carried out in other countries using the same equipment. Malmstrom *et al*., 2006,[17] have examined primary and coupled cervical movements among 120 Swedish subjects. A comparison between the findings on cervical spine movements between the two studies is given in Table 5. It is to be appreciated that the data presented in Table 5 are the analysis of overall sample of 225 subjects and not the three age groups, since the Swedish study does not include age-wise classification. However, in the absence of the raw data, no statistically meaningful comparison could be made.

The results of the present study have significant applications in aviation environment. The data are robust and specific to Indian population. The data can be used as baseline data for zebris spinal column analysis system for comparison of cervical and lumbar spine movements for aeromedical evaluation of all cases of post-ejection and crash landing, aircrew with spinal disabilities, and assessment of candidates aspiring for flying duties. The data can also be utilized as baseline data for future aeromedical research involving spinal column analysis system.

Table 4: Comparison on the sample size among the various studies.

Researcher	Population	Sample size
Strimpakos *et al*.[18]	British	35
Malmstrom *et al*.[17]	Swedish	120
Senouci *et al*.[19]	Irish	40
Cagnie *et al*.[20]	Belgium	96
Uluçam and Ciğali[21]	Turkish	100
Present study	Indian	225

Table 5: Comparison of cervical spine movements between study by Malmstrom *et al.* and present study.

Cervical spine movements (in degree)	Malmstrom *et al*., 2006 (Swedish population) *n*=120	Present study (Indian population) *n*=225
Flexion	70.1±8.6	68.0±12.5
Extension	67.6±12.2	58.6±13.5
Rotation left	78.3±9.3	73.5±8.4
Rotation right	77.0±8.2	71.2±9.1
Lateral flexion left	43.1±7.1	42.3±4.2
Lateral flexion right	40.9±6.6	39.9±9.8

CONCLUSION

The normative data generated in the present study as per the three age groups (<25 years, 25–35 years, and >35 years) may be used as reference values for that specific age groups for male Indian Air Force personnel for the assessment of cervical and lumbar spine movements using spinal column analysis system. The data may be used as baseline data for aeromedical evaluation and future aviation research involving spinal column analysis system. It is further recommended to carry out similar study to determine normative values for cervical and lumbar spine movements for Indian female population using the same equipment.

Declaration of patient consent

The authors certify that they have obtained all appropriate consent from the participants of the study.

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Nil.

Conflicts of interest

NK Tripathy is the editor of this journal. He does not have any competing interest.

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