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BIOMECANICAL ANALYSIS OF THE PHYSIOLOGICAL AND ANATOMIC LIMITS DEVELOPED AT THE CERVICAL ARTICULATION LEVEL

Mihaela I. Baritz[1]
[1] Transilvania University, Brasov, ROMANIA, mbaritz@unitbv.ro

Abstract: *Increased growth in the number of people developing a cervical pathology or a limitation of the cervical movement, as well as addressing the flaws in the workplace and using the computer over extended periods of time, have led to the acute need to achieve accurate and noninvasive at this level, in order to help those with these problems. In the first part of the paper are presented some anatomical and pathological aspects related to the configuration of the cervical joint and to the physiological limits of functioning respectively. In the second part of the paper there are mentioned, in summary, other researches whose main purpose was to determine the behavior of the cervical joint, the analysis of which was the necessity of the dimensional determinations of these limits of functioning. In the third part of the paper is presented the experimental stand and the type of evaluation of cervical joint mobility. In the final part of the paper are presented the results and the conclusions regarding the methodology and the possibilities of postural rehabilitation.*
Keywords: *cervical articulation, goniometer, video image processing,*

1. INTRODUCTION

As shown in the literature, the spine and especially the cervical area are subjected to complex movements that require all three vertebrae and its muscular structure on the three axes. Seven vertebrae (C1 - C7) of the vertebral column are the smallest and lightest which involves a more complex muscular structure to support, move and position the head towards the trunk of the human body. [1] Of these seven vertebrates, the first two are atypical, and the other two are typical for the construction of the vertebrae of the spine.
The two atypical vertebrae (called *atlas* and *axis*) show a modified form of the vertebra due to specific functions performed. The *atlas* is the ring vertebra without a vertebral body on which the skull rests being formed of two lateral masses linked to an anterior bone arch and a posterior bone arch. *Axis* is the second cervical vertebra which contains a tooth that resembles a cranial bone pivot, equivalent to the atlas body. This vertebra achieves with the atlas a triple bond and with the base the skull forms a strong fibrous bond. [2]

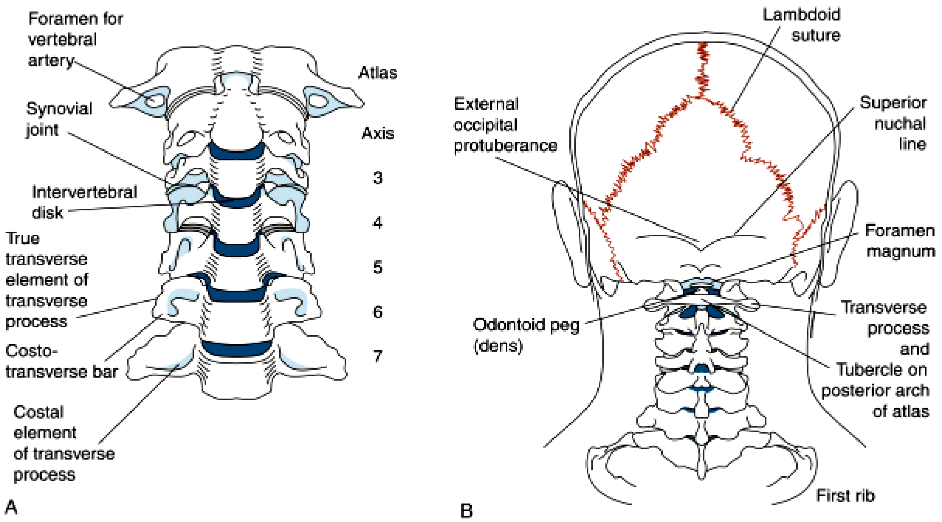

Figure 1: Cervical spine anatomy. *A*, Cervical spine. Anterior view of articulated cervical vertebrae. *B*, Posterior view of the skull, seven cervical vertebrae, and first thoracic vertebra [1]

The movements of the joints depend on the shape of the joint surfaces. Compared to the entire mobile vertebral column, the cervical column presents the greatest vulnerability to trauma.

The mobility of the area is high, but it is achieved by lowering the mechanical safety to the stabilization systems. These are overcome when the trauma transmits more energy than they are capable of dissipating.

The cervical spine's connection to the skull transforms this region into an eccentrically loaded column with mobility at the proximal end where, due to the mass of the skull, an inertial force supplement is obtained. [2]

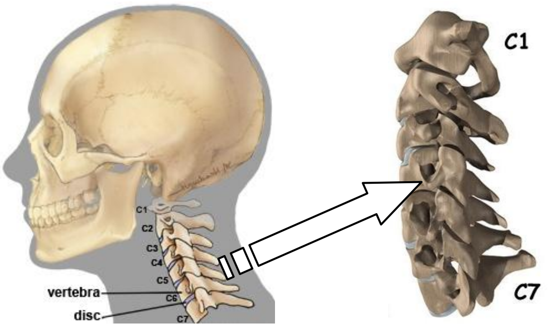

Figure 2: Cervical spine C1-C7 vertebra [5,6]

Cervical spine movement depends on certain discovery parameters such as contour, size and ratio that are directly integrated into the anatomical structure of the segment. The upper cervical column divided into the two vertebrae the *atlas* and the *axis* have a different direction and amplitude of movement due to the geometry of each. The *atlas* performs sagittal flexion movements (10˚) and extension (25˚) by combining translation and rotation movements with a transverse arc as a first-degree lever with the shorter extension arm. [7]

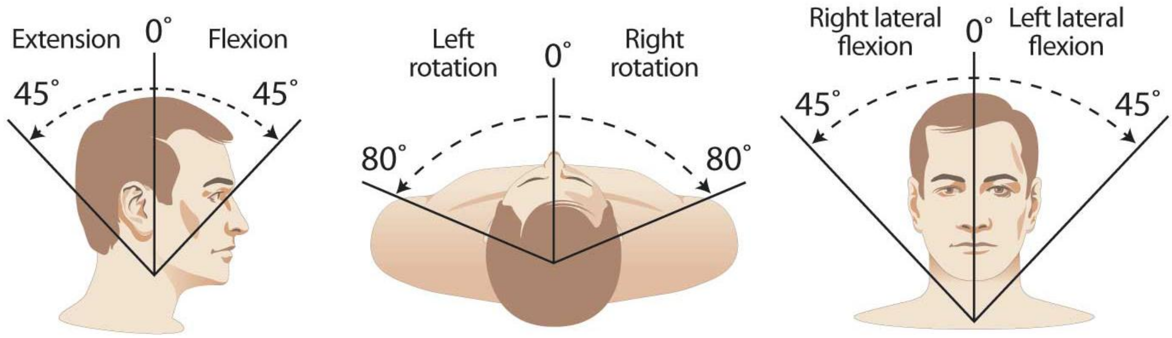

Figure 3: Cervical spine range of motion [7]

The *atlas-axis* joints take the weight of the skull and transfer it to the lower cervical spine. The basic movement is the axial rotation at 45 ° to the right or left created by the central joint, while the lateral joints produce a degree of flexion and extension of 15 ° each.

Overall, the upper cervical collar performs a 30% flexion-extension movement and 50% of the cervical spine rotation movement.

Therefore, this cervical joint is strongly required, especially in activities where the movements are repetitive and can induce a certain degree of fatigue during the activity.

As it was found from the analysis of the actions developed in the cervical spine, this is the most vulnerable segment of external traumatic action.

These lesions are the result of indirect forces acting on the neck and head. Their location as well as typology are identified by the position of the neck and head at the moment of impact.

Movements that can cause cervical lesions can be: flexion and extension, rotation, vertical compression, and shear, as well as combinations of these.

The classification of cervical traumas in which the traumatic centers of the cervical spine are considered to be C1-C2 and C5-C7 is the following: [8]

Disco-ligamental lesions: pure dislocations and fracture of articular apophyses or fracture-disclose

Disco-body injuries: compressed fractures and cominutive fractures, respectively

Mixed lesions: tear-drop fracture

Classification of lesions after the mechanism of production:

By anterior flexion-subluxation: bilateral articular joint dislocation, cervical spine fracture and Clay-Shoveler fracture

Extension-Central Spinal Syndrome: fracture in the "tear", "hanging" fracture, atlantic ankle arch fracture.

By Rotation - Unilateral Face Blanking
By vertical compression - Jefferson's fracture of the atlas: cominy fracture of the atlas, fracture by explosion.
Experimental research has also shown that cervical trauma treatment respects certain principles such as realignment of the spine, realization and maintenance of spinal stability, prevention of neurological lesions and improvement of their recovery and obtaining an early functional recovery.[8]

2. THEORETICAL ASPECTS

From the mechanical point of view, the cervical joint performs the protraction and retraction movements by combining the flexion-extension provided by the vertebrae C1-C7 (fig.4).

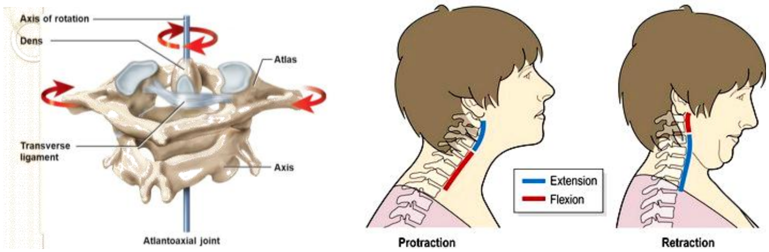

Figure 4: Cervical spine range of motion for protraction and retraction [9,11]

To determine the cervical joint motion positions, the neutral position of the cervical spine is defined relative to a tri-orthogonal axis system (fig.5).

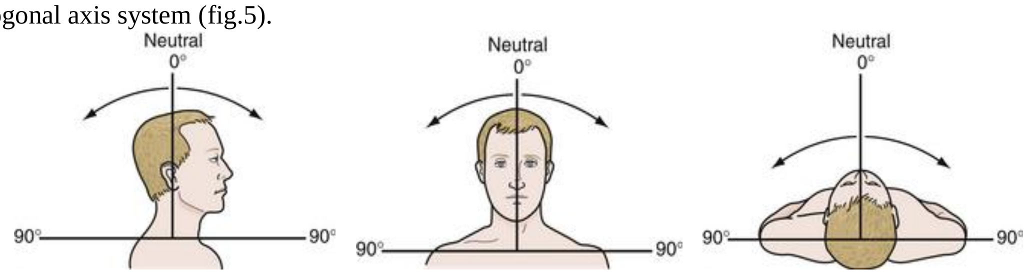

Figure 5: Neutral position for cervical spine range of motion analysis [6]

"During the bending of head it slides back and rolls forward on top of C1, in the same time the C2-7 top facet vertebra glide anterior and upward on the inferior facet. Apophyseal joints act like rails that guide movement.

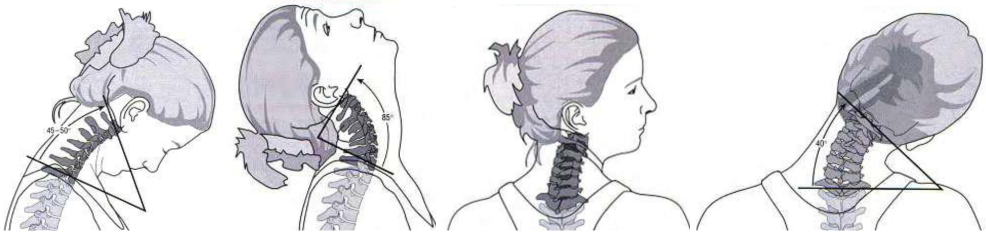

Figure 6: Natural movements for cervical spine range of motion analysis [9]

During *right rotation*, apophyseal joints do extension on the right side and flexion on the left. The opposite movement happens during left rotation.
During *right lateral flexion*, apophyseal joints do extension on the right side and flexion on the left, combined with same side rotation." [9]
Alongside the movements of the head through the cervical joint of the utmost importance is the vestibulo-ocular balance, which ensures and preserves the posture of the entire human body.
The physiological detection of the head position is as follows: if the head is in the upright position and the bag's macula is in the upright position, vertical movements will be detected: up-down movement and forward-back movement. If the head is positioned horizontally then the bag's macula is in a horizontal position and will cause horizontal movements such as left-right movement and forward-backward movement.
When the head is tilted, there is a change in the position of the eyes which would normally result in loss of image. In order for this image to be kept stable, there is an automatic movement of the eyeballs in the opposite direction to the head movement.

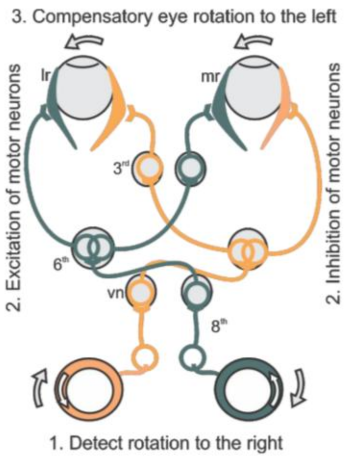

Figure 7: The neural mechanism for a horizontal VOR

Thus, the vestibulo-ocular reflex includes the following trajectory: the semicircular channels, the vestibular nerve, the longitudinal medial beam and the oculomotor nuclei (fig.7).

3. EXPERIMENTAL SETUP

A procedure to analyze head movements in the cervical area by using image acquisition and analysis was developed for the experiment. The axial movements of the head influence to a significant extent the ocular motility and the direction of sight.

Correct determinations of these movements can lead to specific, advantageous results that can be used to recognize certain pathologies or motor deficiencies of subjects exhibiting them.

The analysis of three-axis movements by correlated methods involves the simultaneous use of goniometer and experimental device based on video acquisition.

Figure 8: Equipment for experimental setup

The flexion-extension, flexion and lateral extension movements, left or right rotation are measured in a number of three different subjects, taking into account their age and gender.

The recording and analysis of these movements can highlight the pathologies they have developed or not in the cervical spine by measuring the angular limits they obtain during the execution of the actions established by the procedure.

Figure 9: Cervical flexion and extension for subject 1

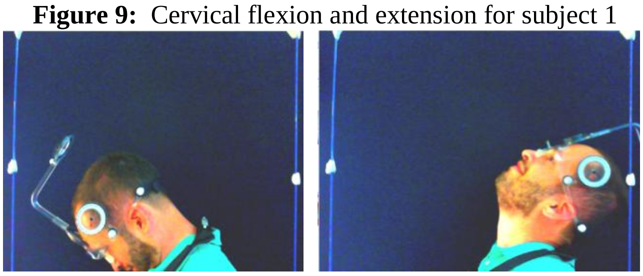

Figure 10: Cervical flexion and extension for subject 2

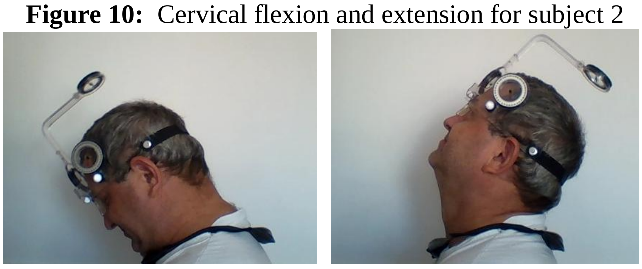

Figure 11: Cervical flexion and extension for subject 3

The experimental system includes a Cervical Range Motion Motion (CROM) goniometer [3], a Microsoft LifeCam HD-5000 1415 (a color camera with built-in audio support that captures 30 frames / sec and autofocus option and with a maximum video resolution of 1280x720 pixels that can have a 4x zoom) and a 3D calibration frame (Fig.8).

Subjects in the sample are of different age (24, 26 and 52 and female-1 and male-2)

The experiment was carried out by placing the goniometer on the face of the subject and observing the resting position of the subject.

These initial measurements at the head posture were entered in the information sheet of each subject.

Taking this information led to a first conclusion of the experiment, namely: aging leads to an increase in the inclination of the head and the position in which the subject feels comfortable.

The first subject is 24 years old and a comfortable posture at 8˚, the second subject is 26 years old and a 9˚ posture, and the last subject is 52˚ and is relaxed in a position 13˚.

The experiment continued with the measurement of flexion and cervical extension.

The subject is instructed to move the head so that it first obtains a sub-occipital flexion, and then lowers the skull until it feels comfortable.

The extension will be inversely directed to the direction of the flexion so that the subject bends the neck towards the back, up to the maximum (fig.9, 10 and 11).

4. RESULTS AND CONCLUSIONS

After the measurements, the following values are obtained for the three subjects: subject 1: flexion 80^0 and extension 81^0, subject 2: flexion 49^0 and extension 65^0 and subject 3: flexion 50^0 and extension 46^0.

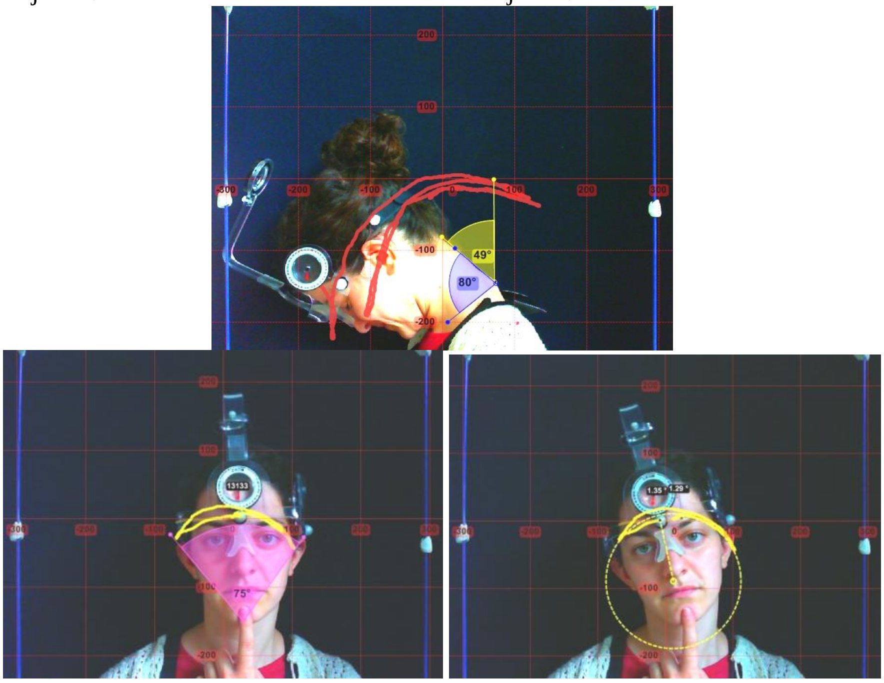

Figure 12: Measurement of cervical motion limits for subject 1 (flexion / extension and lateral flexion)

To determine the behavior of the cervical joint during the extension flexion movements, the trajectories of some physical markers mounted on the CROM goniometer (lateral - temporal right and front) were analyzed, considering the departure from the neutral position, held by the index finger held in the chin of the subject, according to the valuation standard (fig.12).

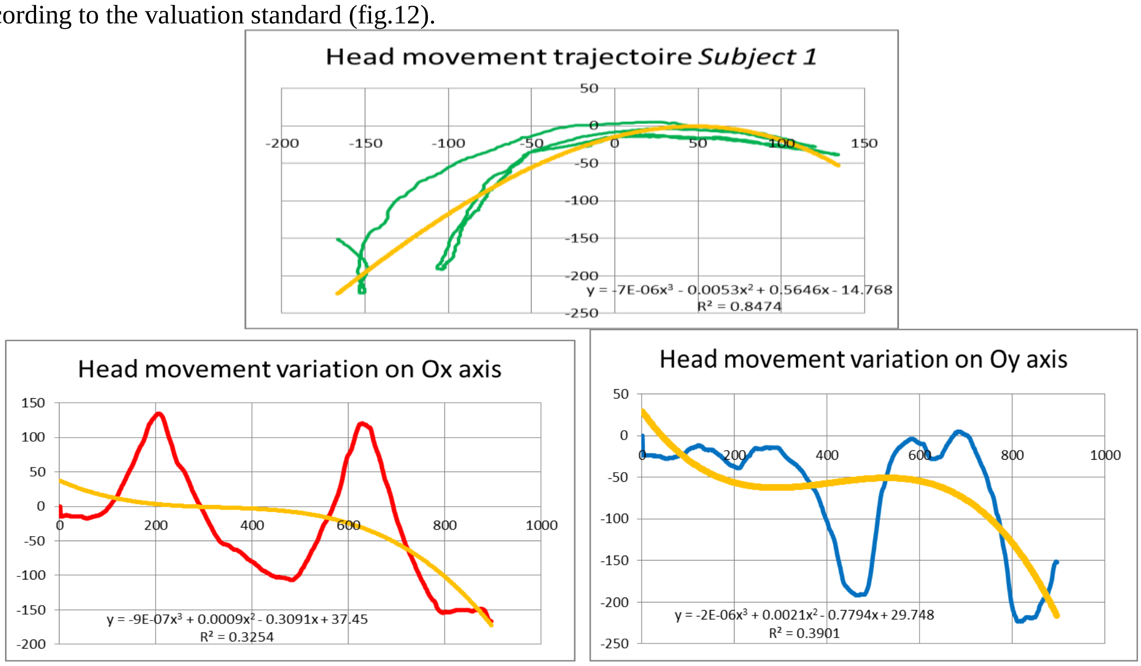

Figure 13: Head movement trajectoire in flexion/extension (full and on Ox / Oy axis) for Subject 1

These graphs reveal that the tendency of the head to move relative to the human body trunk is similar to both the Ox axis and the Oy axis, with an average R^2 coefficient of 0.3577.
Also, the motion limits of the subject's head 1 in flexion / extension are symmetrical to the neutral position. The *CvMob* software package was used to analyze the variation in speed and acceleration in the same flexion / extension movement (the use of a virtual marker superimposed over the physical marker mounted on the goniometer in the temporal area) (fig.14.)

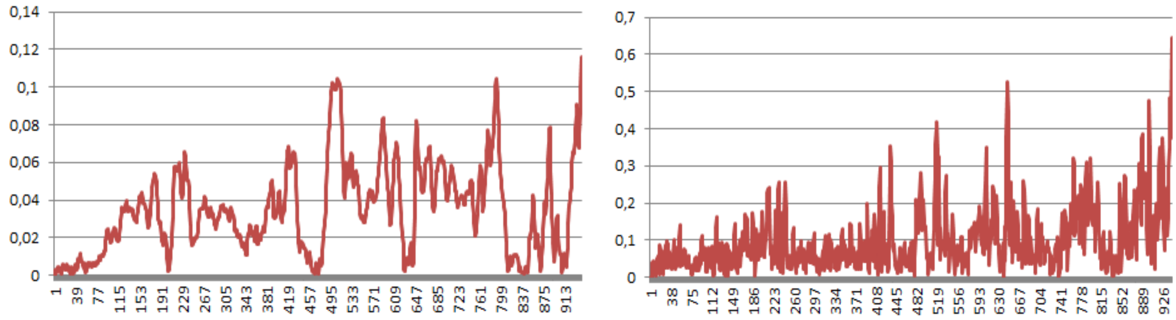

Figure 14: Head speed (left) and acceleration (right) in extension/flexion movement (Subject 1)

The lateral flexion movement reveals a slightly asymmetrical left-right trajectory traversed by a circular arc subtracted by an angle of 75^0 (Fig. 12) and also a more compact and slower variation of the speed and acceleration on average by 22% relative to the movement flexion / extension (front / back) (fig.15).

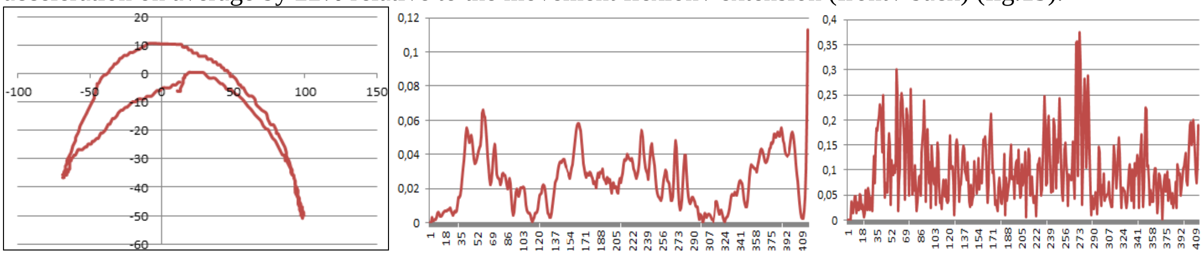

Figure 15: Head trajectoire (left), speed (midlle) and acceleration (right) in lateral flexion movement (Subject 1)

Compared to the other subjects in the experiment, there is a significant difference in anatomic limits (male subjects exhibit flexion / extension deficits: S2 of 18.5%, and S3 of 21.75%, relative to the feminine subject). These deficits are manifested by limitations of cervical movements that aggravate activity and cause painful and blocking postures. Also, many researches can be developed on the basis of this procedure for carrying out the recovery and rehabilitation processes of the cervical joint mobility. [12,13,14]

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