Validation of Vertebral Metrics: A Mechanical Instrument to Evaluate Posture of the Spinal Column

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Abstract— **The purpose of this study is to verify the validity of the instrument Vertebral Metrics, designed to identify X, Y, and Z positions of - each vertebral apophyses, by comparing the results obtained from this instrument with those from an optoelectronic system of Stereophogrammetry, composed of 10 infrared cameras with a sampling frequency of 200 Hz. Methodology: The sample consisted of 11 women aged between 14 and 39 years. After marking the various points in the spinal column, from the 1st cervical vertebra to the 1st sacral vertebra, each woman's backbone was first measured with Vertebral Metrics and then measured with the optoelectronics system. Later, the results obtained with the two instruments were compared. Results: For our analysis we used an ANOVA model with 3 factors (Instrument, Subject and vertebrates) for the intervertebral distance. Conclusion: The Vertebral Metrics proved to be a reliable and valid apparatus when compared with the optoelectronics system.**

Keywords— **Spine, Instrumentation, Validation, Biomechanics.**

I. Introduction

Rachialgiae constitute a relevant problem in modern society [1]. Najm at al. [2] reported that about 80% of people experience rachialgiae at some point in their lives and, from those, 80 to 90% are caused by mechanical changes in the spine.

In view of the number of people affected, it is important to develop an instrument that evaluates, in a global way, the spinal column in a standing position.

For that purpose, a completely mechanical and noninvasive system, designated Vertebral Metrics, has been built [3] which is able to identify the position in X, Y, and Z of each spine apophysis, from the first cervical vertebra to the first sacral vertebra, in biped vertical position.

The aim of the present study is to verify the validity of Vertebral Metrics by comparing the respective results with an optoelectronics system of Stereophogrammetry composed by 10 infrared cameras.

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II. Methods

The sample consists of 11 women, with no associated pathologies, aged between 14 and 39 years. An examiner using, in succession, the two different instruments, evaluated those women, starting with the Vertebral Metrics and then capturing the image in real time using a Davis digital pointer.

Each woman was asked to grant her informed consent to the experiment.

In order to compare the different measures in women, it was necessary for them to adopt exactly the same position on both occasions of the application of the instruments.

The data was collected at the Biomechanics Laboratory of the Faculty of Human Movement of the Technical University of Lisbon and was carried out through accidental sampling, i.e., our sample consisted of women who were available and easily accessed at the time of data collection.

The marking of the various points in the spinal column of each woman, from the 1st cervical vertebra to the 1st sacral vertebra, was previously made on the skin, using a washable pen.

We then first applied Vertebral Metrics, and afterwards the Stereophogrammetry setup. The data collection process with both instruments took about 20 minutes, followed by the comparison of the results between the two instruments.

A. *Vertebral Metrics*

Vertebral Metrics is a completely mechanical apparatus, which allows a noninvasive duplication of the position in X, Y, and Z of each vertebra, from the first cervical vertebra to the first sacral vertebra. The main components of the instrument are the body and the support (Fig.1).

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Fig. 1 Vertebral Metrics

The body has a vertical piece and 18 horizontal pieces called 2D Positioner. Each of these pieces is adjustable in three axes (X, Y, and Z) to allow tapering the end of the piece 1 (Fig.2) as to touch the marks previously made on the skin of each woman, identifying areas in each of the spine.

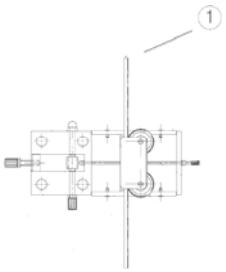

Fig. 2 Image of the 2D Positioner

After the application of the instrument, the collected values are entered into a database, where there are the factors of uncertainty associated with the correction.

B. Stereophogrammetry

Tridimensional location of the spine was captured with an optoelectronic system [4,5,6], constituted by 10 Qualysis (Ocqus 300) cameras, sensitive to the infrared band, with a frame rate of 200 Hz. Motion capture was made in real-time and analyzed with the biomechanical analysis software Visual-3D from C-Motion. The subject was asked to be standing in the anatomical position and each vertebra was located with a digital pointer (patented by Roy Davis). This structure in "T" shape has 4 reflective markers with well known distances between them. In the long axe extremity, there is a spring which when compressed, gives information about the displacement of the 4 markers. With that data, a virtual marker is generated at the opposite extremity of the pointer (the one that contacts with the subjects spine) and the tridimensional coordinated recorded.

This is an advantageous method because there is no need to fix a marker on the subjects' skin.

III. Results

In order to statistically validate Vertebral Metrics, a three-factor analysis of variance model was used to analyse the inter-vertebral distance. The considered factors where Instrument, Subject and Vertebra (between-vertebra gap).

In this model, the Instrument factor crosses with the Subject factor, which nests the Vertebra factor, because inter-vertebral distance is influenced by the individual characteristics of each individual. All factors have fixed effects.

In Table 1, the results of the data analysis are presented in an ANOVA table.

Table 1 Font sizes and styles

Factor	Sum of Squares	Degrees of Freedom	F Statistic	p-value
Instrument	7.557	1	0.764	0.383
Subject	8.736	10	25.3	< 0.001
Vertebra	451.924	253	0.004	> 0.999
Error	2612.5	264		

Since the p-value obtained for the hypothesis test of the absence of influence from the factor Instrument is high (0.383), the hypothesis of this factor not having influence on the measurement of the inter-vertebral distance is not rejected. One may then infer that the measures taken by both instruments do not have a statistically significant difference.

IV. Conclusions

Vertebral Metrics proved to be a reliable and valid instrument in comparison with the stereophogrammetry set-up, when performed by one examiner. The fact that Vertebral Metrics is an objective apparatus makes it usable by a larger number of examiners.

It is a device that is easy to carry and apply to identify the position X, Y, and Z of each vertebra in a standing position, and it can be used in any health institution.

This instrument was originally planned and built to be applied to pregnant women but, at a later stage, can be applied to any type of population.

Vertebral Metrics allows a reliable global assessment of the spine. Thus, identification of dysfunction and / or diseases of the spinal column in pregnant women will be shown on a full diagnosis and intervention programs, directly connected to the specific problems of each person, may then be structured and implemented.

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