# DEVELOPMENT OF A MECHANICAL INSTRUMENT TO EVALUATE BIOMECHANICALLY THE SPINAL COLUMN IN PREGNANT WOMEN

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Abstract: The incidence of problems related to rachialgiae is so frequent and usual that it must be studied as if it were an epidemic and social disease (Knoplich, 2003). Instruments that evaluate the spinal column in a standing position, in a global way, are needed to attain a better insight into this problem. This work presents a completely safe instrument to assess the evolution of all the vertebra locations throughout time, in order to study the biomechanical changes in women during pregnancy. A mechanical system, registered as Vertebral Metrics, with the objective of evaluating the curvatures and lateral deviations of the spinal column in the standing position was built. A measuring part, which is the body of the instrument, and a supporting part, where the previous part is mounted, constitute the new non-invasive instrument. The measuring part consists of 17 identical adjustable mechanical blocks that allow us to reproduce the position of each vertebra of the spinal column, from the first cervical vertebra to the first sacral vertebra. Vertebral Metrics was originally planned and built to be applied to pregnant women. However, after redefining dimensions of the different parts it can be applied to any type of population, in the future.

## 1 INTRODUCTION

Rachialgiae constitute a relevant problem in modern society (Alexandre & Moraes, 2001). In many women this problem appears for the first time during pregnancy and remains for the rest of their lives, causing serious problems of absenteeism and consequently a great loss under the point of view of the economy of the country. It is necessary to have instruments that evaluate, in a global way, the spinal column in standing position, in order to understand better the behaviour of the spinal column during the gestational period.

There are many instruments to evaluate the spinal column. However, most use ionizing radiation and very few allow us to analyse the spinal column in a standing position.

The instrument that is most used to evaluate the spinal column in the standing position is the radiograph. However, since it uses ionizing radiation, it should not be used on pregnant women (Harlick e al, 2007; Pinel-Giroux e tal, 2006) and, besides, it would only give a collapsed two-dimensional view.

The study presented here is part of a broader analysis where we intend to identify and describe the biomechanical alterations of the spinal column that occur throughout pregnancy. We found it was necessary to build a non-invasive instrument that would allow the reproduction of the position of each of the vertebrae, through the identification of each of the vertebral apophyses of the spinal column, from



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the first cervical vertebra to the first sacral vertebra. In a global way Vertebral Metrics evaluates the curvatures and lateral deviations of the spinal column in the standing position.

After an exhaustive search of existing instruments we found the inexistence of an apparatus with the required characteristics, which led us to prepare and elaborate an equipment to measure the lateral deviations and curvatures of the spinal column.

The elaboration started with the conceptual design of the apparatus, based on some existing instruments. Measurements on 134 women were carried out in order to define its dimensions, including the height of the body, the support, the size of horizontal pieces and the stand of Vertebral Metric. The experimental procedure of the previously mentioned study was performed as follows:

1- The length between various points of reference was measured in each woman.
2 - The Normality test for each of the variables was applied.
3 - Significance> 0.05 was found.
4 - The confidence intervals for 99% were calculated

The details of the mechanisms of each of the pieces and the choice of the convenient materials to use (polycarbonate, brass, steel and duralumin) to build the instrument were defined afterwards.

Finally, Vertebral Metrics was built (Figure 1) and the necessary adjustments were performed.

## 2 VERTEBRAL METRICS: DESCRIPTION AND FUNCTIONING

The objective of Vertebral Metrics, a non-invasive mechanical instrument, is to identify the x, y and z positions of each vertebra, from the first cervical vertebra to the first sacral vertebra. After entering these data into a mathematical model of the spine, the curvatures and lateral deviations of that segment in the standing position can be calculated.

The components of the apparatus (Figure 2) are the *"body"* (1) and the *"support"* (2).

The *"body"* has a vertical piece (5), mounted in the support (2), with 18 horizontal pieces (4) called *"2D Positioner*". Two pieces, one vertical, where the body of the instrument fits, and a stand where the person to be evaluated stands up, constitute the *"support"*.

Figure 1: Image of Vertebral Metrics.

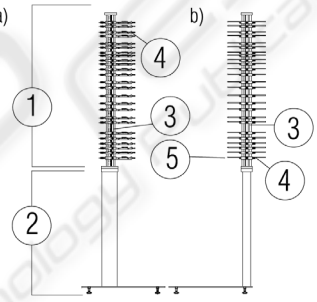


Figure 2: Diagram of Vertebral Metrics.

Figure 2 presents two views of the whole instrument, with (a) and (b) showing the frontal view and the left lateral view, respectively.

The Vertical piece of the body (Figure 3) consists of a rectangular profile with two plates at the ends, which provide rigidity and the fixation to the system.

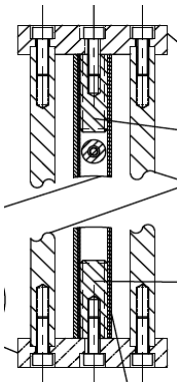

Figure 3: Vertical piece of the body of Vertebral Metrics.

A detail of the instrument, is presented in Figure 4. The *"2D Positioner"* (4) slides along the scaled ruler attached on the vertical piece (3).

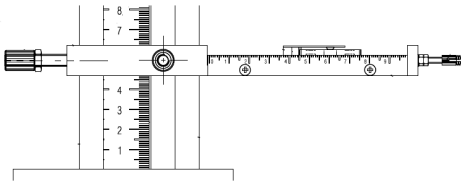

Figure 4: One of the *"2D Positioner"* and the vertical piece of the body of the instrument.

Figure 5 shows components, 6, 7, 8, 9 and 10 of the *"2D Positioner*. The component 7 is a square sectioned rod, with a cone shaped tip, which is where it makes contact with each vertebra apophysis contact point. This rod is manoeuvred by two pinions, (6), placed horizontally and touching the rod *via* a neoprene O-ring surrounding the pinions. It fixes the y position of the vertebral apophysis. This coordinate is calculated through the distance from the conical end, (5), to each *"2D Positioner"*, (4), of the body of the instrument.

The pieces 6 and 7, moved by the horizontal threaded rod (8), are fixed at the top by a plate and two bolts. These bolts are inserted in two vertical threaded holes, passing through the rotational axis of the pinions 6.

At the fixed end of the rod 8 there is a small handle which rotation enabling rotational movement of the rod, which, in turn, allows movement of piece 7. Measurements of the x position (see Figure 4) of the vertebral apophysis of each of the vertebrae are then possible.

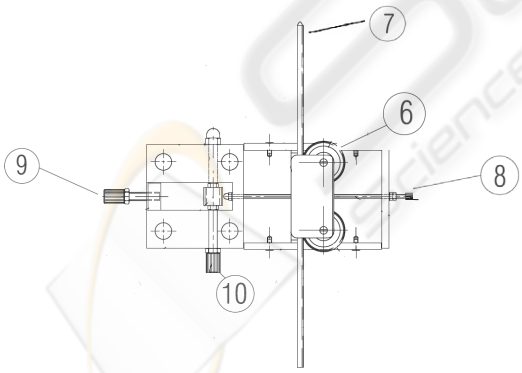


Figure 5: Top view of *"2D Positioner"*.

The component 9 is a piece that fixes the *"2D Positioner"* which moves upwards/downwards on the vertical piece (3), as component 10 rotates. Finally, coordinate z is obtained from the measurement of the position of the horizontal part in piece 4 (see Figure 1).

The support of Vertebral Metrics has two pieces: one horizontal plate supported on four feet, where the person to be evaluated stands, and one vertical piece, shown in Figure 6, where the vertical part of the body of the instrument (see Figure 2) fits.

Figure 6: The support of Vertebral Metrics.

After marking the vertebral apophyses (Figure 7), with a washable pen, each pregnant woman stands up on the stand of the support of the instrument with the posterior face of the trunk facing the body of Vertebral Metrics.

Figure 7: Marking the vertebral apophyses with a washable pen.

All the 18 *"2D Positioners"* of the body of Vertebral Metrics are identical and adjustable, allowing the identification of the x, y and z positions of the vertebral apophyses, from the first cervical vertebra to the first sacral vertebra.

Three of the *"2D Positioner"* pieces are used distinctively. The first is placed in the occipital region and is used, during the data collection, as a reference point. The second piece collects the data of the cervical vertebra and the piece number fifteen collects the data from the first, second and third

lumbar vertebra. The remaining horizontal pieces will identify the position of all other vertebral apophyses of the spinal column (Fig 8).
The x, y and z positions of each *"2D Positioner*" are then obtained.

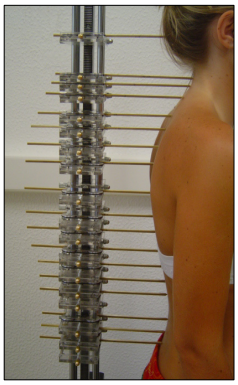

Figure 8: Example of application of Vertebral Metrics.

Each data collection lasts seven minutes. Figure 9 shows the position of the *"2D Positioner*" after application of Vertebral Metrics.

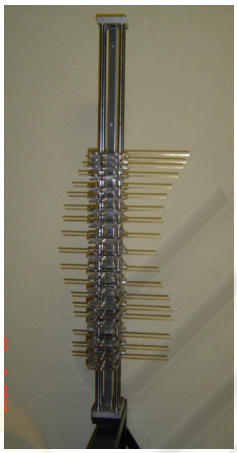

Figure 9: After the application of Vertebral Metrics.

The collected data are then recorded and transferred to a specific data basis with correction factors associated with the instrument included. The final data will then be inserted into the previously mentioned mathematical model.

## 3 CONCLUSIONS

*Vertebral Metrics* is a non-invasive mechanical instrument, which assesses the curvatures and lateral deviations of the spine in a standing position. The patent was registered and the study with pregnant women was accepted by the Ethics Committees of the Maternidade Dr Alfredo da Costa and Regional Health Administration of Lisbon and Vale do Tejo.

The validation process for the instrument, including the calculation of the correction factors and uncertainties associated with it was accomplished.

This instrument allows a global assessment of the spine. Thus, identification of dysfunctions and / or diseases of the spinal column in pregnant women, will be shown on a thorough diagnosis. Intervention programs, directly connected to specific problems of each person, may then be elaborated and implemented.

Vertebral Metrics was originally planned and built to be applied to pregnant women. However, it can be applied to any type of population after redefining the dimensions of the different parts.

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