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Analysis of lumbar flexion in sitting posture: Location of lumbar vertebrae with relation to easily identifiable skin marks

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Abstract

Lumbar flexion analysis is a widely used technique for surveying the sitting posture and evaluating the ergonomics of chair designs. Non-invasive measurement devices require the correct identification of the position of the vertebral bodies and spinous processes by palpation, and the effect of the skin displacement associated with the trunk flexion must also be taken into account. Procedures for this location are developed for the clinical examination of the ranges of lumbar motion and are usually carried out in standing posture by specialists. Pelvis rotation and skin displacement that occur when sitting make these procedures difficult to apply for ergonomic purposes. This paper presents the results of a radiological study aimed at selecting easily identifiable reference marks on the back, which can be used to analyse the lumbar flexion that occurs in sitting posture. The relationships between internal and external angles in the lumbar area of the back and the effect of skin displacement in the determination of the position of the spinous processes are also considered in a proposal for a simple and reliable procedure for the identification of anatomical marks of the spine that can be used for ergonomic purposes.

Relevance to industry

Sitting posture is commonly used at workplaces. Lumbar flexion measurement in sitting posture is important to evaluate the ergonomics of workplaces. Proper location of lumbar vertebrae is necessary for this purpose.

Keywords: Sitting posture; Lumbar flexion; Location of lumbar vertebrae; Anatomical marks

1. Introduction

The analysis of spine curvature in a sagittal plane is a widespread technique for the evaluation of sitting posture. Maintaining the kyphotic posture while seated for long periods has been related to low-back pain, due to an increase in intervertebral disc pressure (Anderson et al., 1979). The discomfort of the lumbar back contributes greatly to the general discomfort in sitting posture, and this discomfort is related to the level of trunk flexion and mobility of the lumbar spine (Bishu et al., 1991; Vergara and Page, 2002).

The most accurate techniques for measuring the spinal curvature are biplanar X-rays or sagittal X-rays (Stokes et al., 1987). Despite their accuracy, methods based on X-rays are not suitable for ergonomics analysis because of the risks of radiation, and several non-invasive techniques have been developed. These techniques consist in identifying two markers on the skin and measuring the spine flexion of the region between both markers by different methods: from the skin distension between markers (Miller et al., 1992; Snijders and Van Riel, 1987), from the inclination of the two markers (Bridger et al., 1989), or directly from the angle between the two markers (Öhlen et al., 1989; Boocock et al., 1994; Mandal, 1986). Other techniques record the complete shape of the spine between both markers (Burton, 1986; Eklund and Liew, 1991; Wielki,

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1983; Tichauer et al., 1973; Vergara and Page, 2000). Several attempts have been made to predict internal spine geometry from external measurements (Campbell-Kyureghyan et al., 2005).

Nevertheless, all non-invasive measurement device errors depend on two factors: (a) the identification of the position of vertebral bodies and spinous processes generally made by palpation, and (b) the effect of the skin displacement associated with the trunk flexion. Important errors in measurements on the skin are associated with the identification of anatomical landmarks (Lee et al., 1995). Furthermore, the procedures used for the location of vertebral bodies have been developed to be carried out in standing posture, because they are used basically for the clinical examination of the ranges of lumbar motion in this posture. Moreover, when sitting, the pelvis rotation is considerable, and the consequent displacement of the skin at the lumbar level has not been studied with an appropriate degree of detail and accuracy.

Finally, these procedures need a high degree of anatomical knowledge and expertise. In short, clinical procedures provide no suitable references for ergonomic applications in the analysis of the sitting posture. Therefore, in this study an experiment was conducted to facilitate measurement of the lumbar flexion in sitting posture for ergonomic purposes. The first objective of the experiment was to obtain a reliable location of the lumbar spine from skin markers in sitting posture (L1, L5 and T1 levels), avoiding palpation of the spinous processes that requires a good knowledge of the spine anatomy. Secondly, the effect of skin displacement on the identification of these markers was analysed in order to propose suitable procedures to alleviate this effect. Finally, an analysis of the relationship between the angles of the vertebral bodies and the external angles measured over the skin was performed.

2. Material and methods

Ten normal subjects (5 males, 5 females, with statures varying from 157 to 188 cm) participated in the study. They were free from scoliosis and other problems involving the axial skeleton. The selection was made on a voluntary basis after they had received information about the risks of radiation. The study was conducted under the authority of the Ethics Committee of The Institute of Biomechanics of Valencia.

The whole experiment was carried out in sitting posture in order to avoid the effects of skin movement in the lumbar region. The seat pan was arranged horizontally and the subjects were provided with appropriate support for their feet, in order to maintain a 90° angle for both knees and ankles.

The three most easily identifiable anatomical landmarks on the spine (according to the recommendations made by expert anatomists) were then located: C7 (as the vertebra with the most prominent spinous process at neck level), the iliac crests and the "dimples of Venus" (Miller et al., 1992).

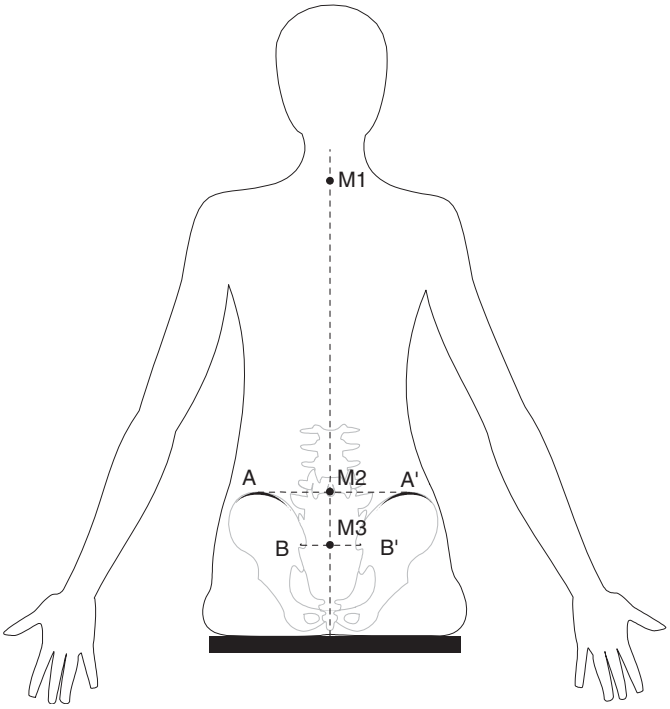

Fig. 1. Chosen anatomical landmarks. AA′: highest point of the iliac crests and BB′: dimples of Venus.

Other landmarks in the lower back, such as the spinous process of L5 or the lumbosacral junction, were rejected because their identification required a high degree of expertise in exploration techniques.

The identification of these points was made by a non-expert person, with no special knowledge of anatomy, after a short training session. In the training session this person was told to place the following three markers on the ten subjects (Fig. 1) and to report any problems or difficulties arising in the marking procedure:

Marker M1: With the subject bending the head forward, palpate the most prominent point (spinous process) at the neck level; maintain the palpation while the subject raises the head; and then place the mark with the subject's head erect.[1]

Marker M2: With the subject sitting in an erect posture, palpate at the sides the highest point of the iliac crests and, placing the hands horizontally, follow this height across to the midline of the spine and place the marker there.

Marker M3: With the subject sitting in an erect posture, visually locate the "dimples of Venus" and place the marker at this height on the midline of the spine.

These three points were marked with steel balls (2.5 mm in diameter), which were attached to the skin in the reference posture (erect seated posture) and remained fixed throughout the whole experiment. A set of additional balls were attached on the central line along the back,

[1]This process was selected to facilitate the procedure of palpation while avoiding the great displacement of the skin when the marker is placed with the head bent. The spinous process of C7 is less prominent in retroflection of the cervical spine.