Spinal curvature: comparison of frontal measurements with the Spinal Mouse and radiographic assessment

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Aim. **The Spinal Mouse is an external non-invasive device which measures the spinal shape and mobility of the spine in several planes. The aim of the present study was to evaluate the reliability and the validity of the Spinal Mouse to assess frontal standing measurements of the spine in a sample of young healthy volunteers.**

Methods. **Twenty-six young volunteers of both sex took part in the study. Angle data of vertebral inclination of each subject in frontal view were measured by Spinal Mouse and standard radiography for vertebral segments from T1-T2 down to L5-S1.**

Results. **Repetition of the measurements by Spinal Mouse performed by two examiners in different days resulted in no significant difference for the parameter examined, as well as measurements performed by the two examiners in the same day (P<0.05). The ICC values showed no correlation between the two devices in the following pairs of vertebrae: T2-T3, T4-T5, T5-T6, T7-T8, T8-T9, T9-T10, T11-T12, T12-L1, L1-L2, L3-L4, L4-L5;.**

Conclusion. **The Spinal Mouse results, concerning the standing frontal curvature of the spine, even if reliable, were poor when compared with the standard radiography.**

Key words: Spine, structure - Spinal curvatures - Radiography.

A number of different devices, using several techniques of measurement, are currently employed for the non-invasive assessment of spinal movements in biomechanical studies concerning spinal loading or in clinical studies of low back disability and response to treatment.[1-4]

Some of these equipments simply show the range of motion measuring start and end posture, others, conversely, constantly monitor and record the changing of the spine curvature as it progresses through its range of motion or during the execution of given tasks.[3-6]

Even if this motion analysis devices have been shown to be reliable tools, several variables as the stable attachment, the exact placement of the measuring device on the individual back or the accuracy with which the device records the movements along a given plane, play a critical role in obtaining reliable and repeatable measurements.

In particular, the reliability of one of these newly computer-aided skin surfaces device, "The Spinal Mouse" has been recently assessed by Mannion *et al*.[7] with regard to measurements of the curvature together with global and segmental range of motion of the spine. Recently Guermazi *et al*.[8] evaluated the validity and reliability of the Spinal Mouse model to assess lumbar spine flexion in symptomatic patients correlating the mobility as assessed by lateral radiography in neutral and full trunk flexion position and Spinal Mouse; however, they did not compare any

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frontal measurements of the spine between the two methods.

Radiographic analysis, performed in multiple ways, have been applied for years to measure sagittal and frontal spine curvature or to quantify the *in vivo* motion, even if the high dose of radiation required is probably unjustifiable for a routine application in clinical practice.[6, 9-11]

The aim of the present study was to evaluate the reliability and the validity of the Spinal Mouse in assessing frontal standing measurements of the spine in a sample of young healthy volunteers.

Materials and methods

Study group

Thirty volunteers, agreed to participate in the study. Fourteen were males (24.3±2.5 years; 175±5 cm tall; 74.79±7.23 kg and 24.26±1.27 body mass index) and sixteen were females (21.5±10.8 years; 164.6±4.7 tall; 57.3±5.24 kg and 21.1±1.1 body mass index). They were students or workers of various branches. Twelve subjects used to practice sport habitually, whilst eighteen did not practice any regular sport. They had no history of serious low back pain and none had any low back pain at the time of testing or had experienced any low back pain in the previous four weeks. Four subjects were excluded from the study for the following radiological abnormalities: two suffered from a thoracic scoliosis with a rightward convexity, two suffered from a thoracic-lumbar scoliosis with a thoracic leftward primary curve. The final population was composed of 26 subjects who were radiographically normal. The study design was approved by the local institutional Committee of Medical Ethics as per the radiation exposure of healthy subjects. The volunteers gave signed informed consent to participate.

Equipment

Measures of spine mobility were performed with the Spinal Mouse system, a hand-held, computer-aided electromechanical device used to measure spinal curvature in various postures. The device is guided along the midline of the spine starting at the spinous process of C7 and finishing at the top of the anal crease, approximately S3. These landmarks are firstly determined by an operator and by palpation and finally marked with a cosmetic pencil. The device has two rolling wheels that follow the contour of the spine and the measurements, transmitted to a database, are elaborated by a standard personal computer with a dedicated software. Data are sampled every 1.3 mm as the mouse is rolled along the spine, giving a sampling frequency of approximately 150 Hz.

Figure 1.—Cobb's angle measurement for segmental thoracic and lumbar vertebral bodies inclination.

Measurement protocol

Radiographic analysis

Before the Spinal Mouse measurement, all the subjects had a standardized standing 36" (30x90 cm) frontal radiographic projection of the entire spine, including the pelvis and the acetabula. The subjects were asked to stand up straight, but relaxed, with their knees fully extended and their arms hanging by the side in a position of adduction and external rotation. Each radiograph

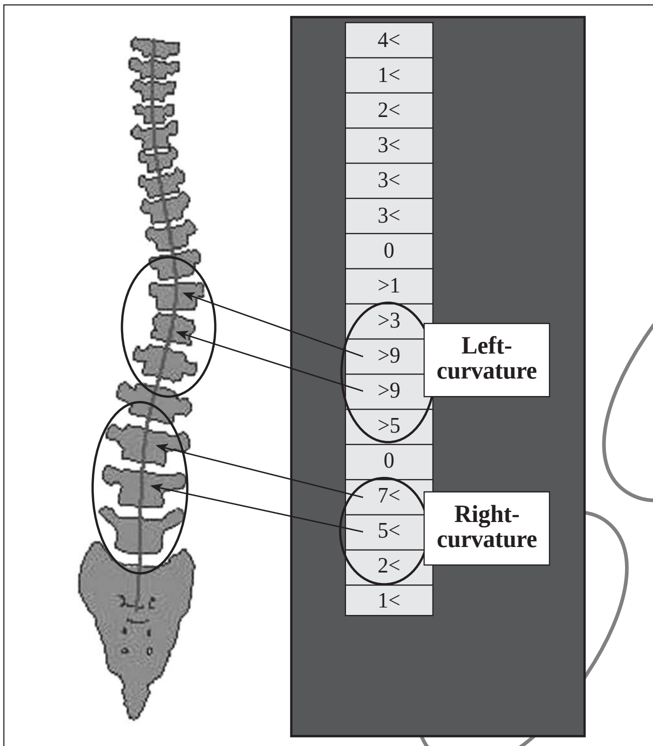

Figure 2.—Output derived by spinal mouse measurement in standing position.

was analyzed by two independent radiologists who obtained measurements as follow: total thoracic rightward or leftward convexity from T1 to T12 measured by Cobb method (a tangent line from the superior endplate of T1 to the inferior endplate of T12) and segmental thoracic vertebral body inclination (Cobb method for pairs of thoracic vertebrae: from the superior endplate of a vertebra to the inferior endplate to the adjacent vertebra) (Figure 1); total lumbar rightward or leftward convexity from L1 to L5 and segmental lumbar vertebral body inclination, for pairs of lumbar vertebrae, using the same method previously reported.

Skin device analysis

To assess intraexaminer reliability two experienced physicians used the Spinal Mouse device for measuring patients consecutively. The volunteers adopted the same position used during the radiographic analysis. The position were first described, demonstrated and practiced by the operator for each volunteer before the measurements. The examiner then touched the volunteer's back, marked the landmarks on the skin, and made the measurement in the posture previously described. At the end of each measurement, the skin marks were completely removed, the volunteers were marked anew and another measurement was per-

Table I.—*Intra-class correlation coefficient (ICC) and significance for inter-rater reliability, intrarater reliability, and Spinal Mouse-radiography reliability.*

Pair of vertebrae	Inter-rater				Intrarater					
	OP11 *vs* OP12		OP21 *vs* OP22		OP11 vs OP21		OP12 *vs* OP22		SM *vs* RX	
	ICC	sig.	ICC	sig.	ICC	sig.	ICC	sig.	ICC	sig.
T1-T2	0.991	0.000	0.973	0.000	0.991	0.000	0.983	0.000	0.467	0.006
T2-T3	0.884	0.000	0.666	0.000	0.934	0.000	0.865	0.000	0.313	0.052
T3-T4	0.985	0.000	0.902	0.000	0.908	0.000	0.950	0.000	0.385	0.022
T4-T5	0.884	0.000	0.839	0.000	0.935	0.000	0.930	0.000	-0.298	0.938
T5-T6	0.902	0.000	0.792	0.000	0.954	0.000	0.887	0.000	0.141	0.237
T6-T7	0.980	0.000	0.929	0.000	0.979	0.000	0.967	0.000	0.434	0.011
T7-T8	0.879	0.000	0.788	0.000	0.800	0.000	0.940	0.000	0.081	0.342
T8-T9	0.971	0.000	0.778	0.000	0.828	0.000	0.945	0.000	-0.106	0.705
T9-T10	0.960	0.000	0.858	0.000	0.945	0.000	0.949	0.000	0.429	0.011
T10-T11	0.971	0.000	0.878	0.000	0.887	0.000	0.980	0.000	0.644	0.000
T11-T12	0.965	0.000	0.807	0.000	0.853	0.000	0.914	0.000	-0.026	0.552
T12-L1	0.896	0.000	0.722	0.000	0.839	0.000	0.917	0.000	-0.030	0.561
L1-L2	0.993	0.000	0.905	0.000	0.915	0.000	0.986	0.000	-0.079	0.656
L2-L3	0.964	0.000	0.900	0.000	0.902	0.000	0.972	0.000	0.462	0.007
L3-L4	0.973	0.000	0.945	0.000	0.961	0.000	0.975	0.000	0.216	0.315
L4-L5	0.973	0.000	0.793	0.000	0.765	0.000	0.972	0.000	-0.008	0.517
L5-S1	0.995	0.000	0.910	0.000	0.931	0.000	0.989	0.000	0.490	0.004

OP11:-measure examiner one first day; OP12: measure examiner one second day; OP21: measure examiner two first day; OP22: measure examiner two second day; SM: spinal mouse; RX: radiography.

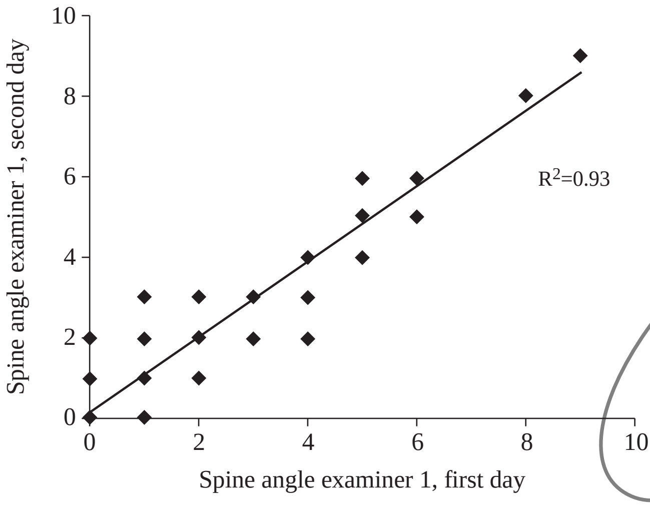

Figure 3.—Spine angle by observer one in the first day plotted against that in the second day.

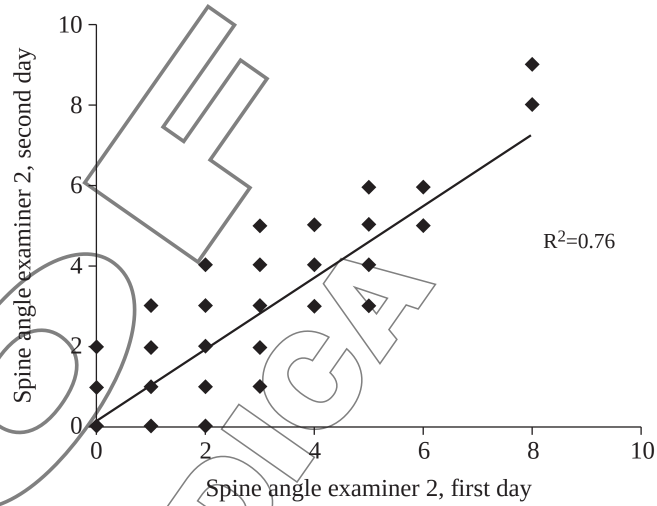

Figure 4.—Spine angle by observer two in the first day plotted against that in the second day.

formed. Each measurement was repeated twice by both the examiners in two consecutive days. Each measurement was repeated three times and only the third value of the three sets of measures was used for further analysis.

The relevant parameters recorded by the Spinal Mouse in the position mentioned above were: individual inclination angle (from T1/2 through to L5/S1); thoracic rightward or leftward convexity (T1/2 to T11/12); lumbar rightward or leftward convexity (T12/L1 to the Sacrum) (Figure 2).

Statistical analysis

Angle data of vertebral inclination were calculated for each individual vertebral spine segments from T1-T2 down to L5-S1. Initially, paired t-tests were used to examine mean differences between the measurements performed by the two examiners. Reliability was studied applying the intra-class correlation coefficient (ICC), to evaluate intrarater between-days reliability (the same examiner on two different days), inter-rater reliability (different examiners in the same day), and the correlation between measurements as assessed by Spinal Mouse and the radiography in the frontal view. Two different levels of significance were considered $P<0.01$ and $P<0.05$. ICC value was considered of good/high reliability when higher than 0.8.[12, 13] SPSS version 12 was used to calculate the statistical analysis (SPSS Chicago, IL, USA).

Results

There was no significant difference between the measurements performed by the two examiners on different days. In the same way, measurements performed by the two examiners in the same day using the Spinal Mouse showed no statistical difference ($P<0.05$).

The intrarater ICC ranged between 0.879 and 0.995 (good/high reliability) for the first examiner ($P<0.01$), while for the second examiner values ranged between 0.666 and 0.973 ($P<0.01$; 11 out of 17 with good/high reliability), with a level of significance <0.01 (Table I). The relationship between the whole spine measures (from T1-T2 down to L5-S1) as measured by observer 1 in two days and observer 2 in two days is shown in Figures 3, 4, respectively.

The inter-rater (Table I) ICC ranged between 0.865 and 0.989 (good/high reliability) in the first day ($P<0.01$) and between 0.765 and 0.991 (one measure without good/high reliability) in the second day ($P<0.01$). The relationship between the whole spine measures (from T1-T2 down to L5-S1) as measured by observer 1 *vs* observer 2 is shown in Figures 5, 6, respectively.

The intrarater test and the inter-rater test suggest high consistency and confirm that the tests could be repeated by the same operator (on different days) and by two different operators in the same day.

The test reliability for each pair of vertebrae measured with Spinal Mouse and radiography (Table I)

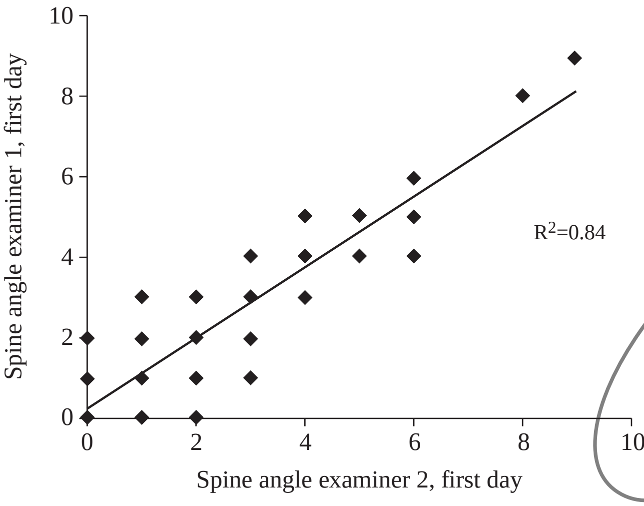

Figure 5.—Spine angle by observer one plotted against that by observer two, first day.

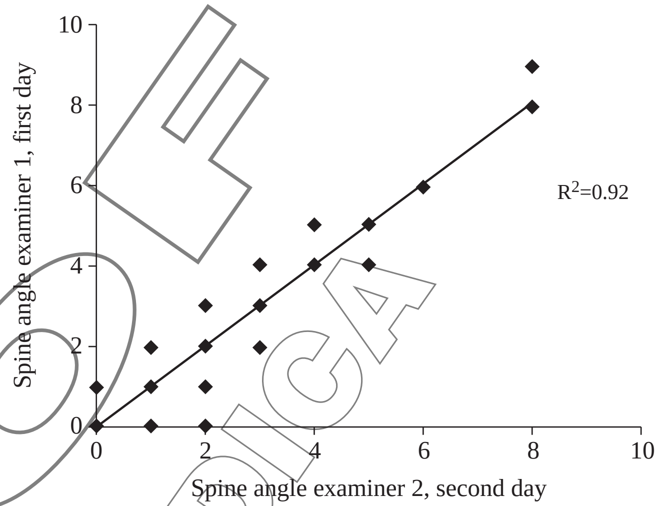

Figure 6.—Spine angle by observer one plotted against that by observer two, second day.

showed a more complex situation. The analysis was conducted on measures obtained with Spinal Mouse by the first examiner in the first day, considering that results showed higher consistence (however ICC between Spinal Mouse and radiography are consistent for operators and days). The ICC values (Figure 7) showed no correlation in the following pairs of vertebrae: T2-T3, T4-T5, T5-T6, T7-T8, T8-T9, T9-T10, T11-T12, T12-L1, L1-L2, L3-L4, L4-L5; and correlation in T1-T2, T3-T4, T6-T7, T10-T11, L2-L3, L5-S1. The ICC level, for significative pairs, was respectively 0.467, 0.385, 0.434, 0.429, 0.644, 0.462, and 0.490, which, with the exception of the pair T10-T11, can be defined as a poor reliability level.

Discussion

In the last years many attempts have been made to develop non-invasive equipments, especially skin surface devices for the assessment of spinal shape and related movements.[7, 14] This necessity arose in order to limit the risk of exposure to radiations commonly required during a routine radiographic measurement of the spine.[15-17]

In general, most of these motion analysis devices have shown to be reliable.[18-22] In particular, the Spinal Mouse, a new computerized external device, was primarily tested by Mannion *et al.*[7] for intra and inter-rater reliability with regard to measures of standing sagittal curvature, global range of motion of the hips and lumbar and thoracic regions of the spine and the range of flexion of individual motion segments of the whole spine. For the majority of parameters investigated, the ICCs were higher than 0.8, thus indicating a good reliability. Post *et al.*,[23] conversely, assessed Spinal Mouse for inter-rater reliability in a sample of 111 subjects where 2/3 of patients were affected by spinal fractures. Even in this study the ICCs for most of the measures were 0.92.

However, both the studies lack a comparison between the Spinal Mouse's data and the values of a gold standard technique to confirm the true accuracy of the equipment. Guermazi *et al.,* in their French paper, were the first to investigate the validity of Spinal Mouse to assess lumbar flexion with standard radiography, and they concluded that Spinal Mouse has acceptable metrological properties to assess segmental and global lumbar mobility during trunk flexion, except for the segmental mobility of L5-S1.[8] The present study was designed to compare, preliminarily, a spinal measurement performed in the frontal plane with the Spinal Mouse with that obtained with a routine (antero-posterior) radiographic assessment. However, whether radiographs should be chosen as the "gold standard" is questionable, since no previous studies in the Literature make the same comparison, but it is well-known that the radiographic method is one of the most frequently used to monitor the spine during a clinical set-up. The results of this study confirmed a good/high Spinal Mouse frontal measure-

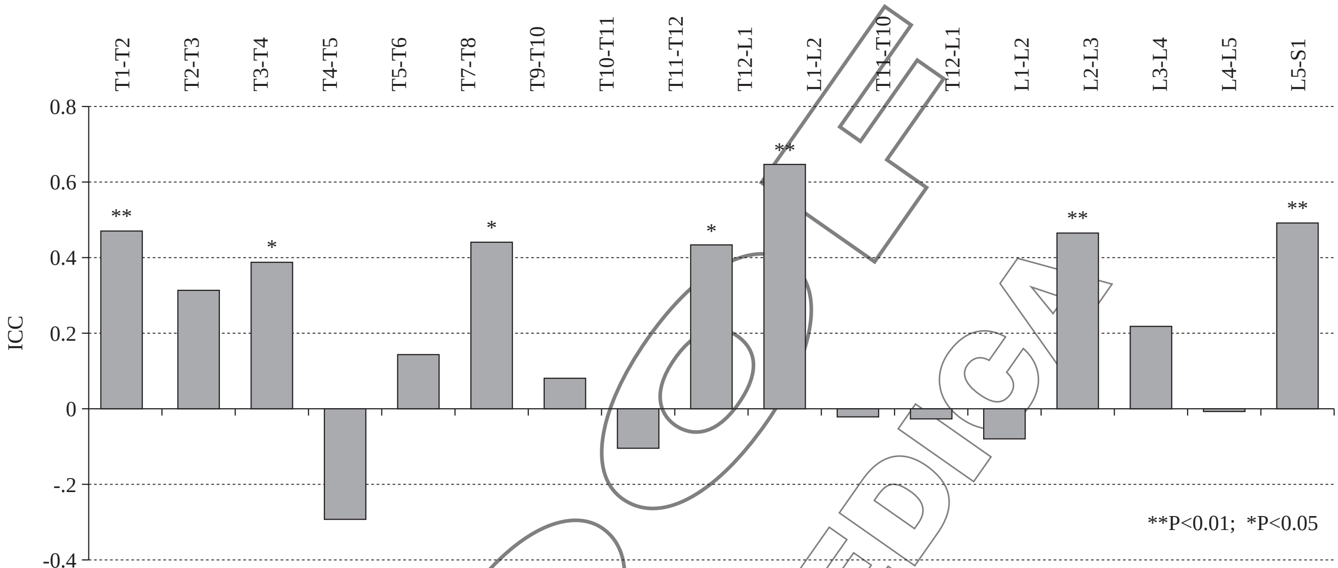

Figure 7.—Spinal mouse-radiography intra-class correlation coefficient for pairs of vertebrae and significance.

ments intrarater and inter-rater reliability, as demonstrated by the previous authors.[7, 23] Unfortunately, the comparison between Spinal Mouse values and radiography values showed no correlation for the following pairs of vertebrae: T2-T3, T4-T5, T5-T6, T7-T8, T8-T9, T9-T10, T11-T12, T12-L1, L1-L2, L3-L4, L4-L5. In order to gain some insight into the measurement differences among these pairs of vertebrae, it is possible to hypothesize some feasible reasons. As regard as to the radiographic assessment, each radiograph was analyzed by two independent radiologists and even if no differences were found in the values, it is likely that vertebral body endplate architecture may have a substantial effect, especially if some of the films were damaged, and the line drawn by the operators thus results in the measurement of different angle values.[24-26] Another explanation for the difference in the values recorded could concern some factors involved in the measurement with the skin device, for example the exact path followed during the rolling of the mouse (perfectly down to the midline of the spine) or the pressure exerted by the examiner in rolling the mouse along the back, that could contribute to slight errors in the angles detected by the Spinal Mouse. On the other hand, to explain the significant differences detected in the analysis per vertebral segments, for the thoracic pairs of vertebrae the accuracy in the X-ray measurements could be distorted for the presence of large muscles and soft tissues which increase the opacity of the film, making some possible errors per measurement. For what concerns the lumbar segments, some anatomical features of the L3-L4 segment must be taken into consideration. According to the spine anatomy, in fact, L3 is located at the apex of the lumbar lordosis with a more developed posterior arch; it acts as "a muscle relais" between the lumbar fibers of *longissimus dorsi*, which inserts on the L3 transverse apophysis and the insertion of epispinosus muscle on the L3 spinosus apophysis and, consequently, is largely influenced by the tension state of the muscles inserted at the sacrum level, which can modify its position. This is the reason why it is considered by some authors the most mobile vertebra of the lumbar tract.[27] It seems reasonable that the anatomic peculiarity of L3 and the variety of muscular condition of each subject could affect the correct measurements of the lumbar tract.

Limitations of the study

However, comparison of the present results with the Literature is difficult because only three studies, previously mentioned, have been published on the Spinal Mouse.

The restricted number of the sample, even if homogeneous in the anthropometric measures, could be another limitation of this study, as finding many volunteers who agree in participating in a study in which they must undergo a relatively high dose of radiations (especially when, as in this study, the whole spine needs to be assessed) is a quite difficult task.

The Spinal Mouse is an external wheeled device provided with accelometers which measure the spinal shape and the trunk mobility in the sagittal and lateral plane and is able to provide with separate information about thoracic, lumbar and sacral/hip segment mobility. In this preliminary study, it was decided to compare only the values concerning the standing frontal curvature of the column collected with the Spinal Mouse and the X-rays, to better validate the device.

Conclusions

Radiographic analysis of the spine is probably one of the most used method of evaluation and measurement in every day clinical practice, allowing to obtain qualitative information especially in detecting pathologies like fractures, spondylisthesis, osteophorosis, etc, but with all the risks related to the exposure to radiations. This study confirmed a good/high intrarater and inter-rater reliability as regards as the Spinal Mouse frontal measurement of the spine. However, the metrological properties of Spinal Mouse did not show validity to assess frontal segments of spinal curvature when compared with standard radiography

Considering the short time available for an evaluation, together with the low cost and safety, this device could be a good tool for a physician to gain quick and objective data, *i.e.* during a personalized rehabilitation program. Further studies have to be designed with a greater numberof patients, especially group of individuals affected by a spinal pathology or structural deformity, like kyphosis and scoliosis, to assess its validity.

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