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Differences on Spinal Curvature in Standing Position by Gender, Age and Weight Status Using a Noninvasive Method

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This aim was to examine differences on lumbar lordosis and thoracic kyphosis in standing position by gender, age and weight status in healthy subjects using a noninvasive method. A total of 297 women (36.6 ± 7.3 years) and 362 men (39.8 ± 7.5 years) participated in this study. Participants were categorized according to the international BMI (kg/m^2) cut-off points. Age was stratified by ten years increments starting from 20 y. Men showed smaller lumbar lordosis (17.3 ± 9.3) and larger thoracic kyphosis (42.8 ± 8.8°) than women (29.6 ± 11.3 and 40.4 ± 9.5° respectively; both $p < .001$). Older groups presented smaller lumbar lordosis and larger thoracic kyphosis values compared with the 20–29 y group (20.9 ± 10.4, 20.8 ± 11.2 and 23.6 ± 12.6° for ≥50, 40–49 and 30–39 y, respectively vs. 26.7 ± 12.2° for 20–29 y in lumbar lordosis and 42.6 ± 9.8, 42.61 ± 8.7 and 41.8 ± 8.9° for ≥50, 40–49 and 30–39 y, respectively vs. 37.5 ± 10.9° for 20–29 y in thoracic kyphosis; both $p < .05$). Finally, overweight and obese groups showed smaller lumbar lordosis (19.4 ± 11.1 and 20.9 ± 11.8° respectively) and larger thoracic kyphosis values (42.7 ± 8.9 and 42.8 ± 9.4° respectively) compared with nonoverweight participants (25.1 ± 12.4 and 40.6 ± 9.2° for lumbar lordosis and thoracic kyphosis respectively; all $p < .05$). However, when gender, age and weight status were take into account all together only gender seems to influence the lumbar lordosis curvature. The results of this study suggest that gender could be the only determinant factor of lumbar lordosis in healthy people.

Keywords: lumbar lordosis, thoracic kyphosis, SpinalMouse, healthy participants

The sagittal plane contour of the spine plays an important role in the normal function of the spine and the development of many spinal disorders (Jackson & Hales, 2000; Jackson & McManus, 1994; Korovessis et al., 1998). Alterations in the sagittal shape of the spine are associated with low back pain, so that postural changes may cause stress on the joint and weaken tissues as muscles and ligaments (Christie et al., 1995; Jackson & McManus, 1994; Tsuji et al., 2001). The assessments of sagittal spinal curvature in standing position can be of help for early detection of alterations and institution of adequate preventive measures.

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The relationship of gender, age and weight status with spinal curvatures has been previously studied (Murrie et al., 2003; Nourbakhsh et al., 2001; Tuzun et al., 1999; Youdas et al., 2000, 1996, 2006). Regarding gender, most of the studies showed that women have greater curvatures in both lumbar lordosis and thoracic kyphosis than men (Bergenudd et al., 1989; Fon et al., 1980; Milne & Lauder, 1974; Milne & Williamson, 1983; Norton et al., 2004; Youdas et al., 1996, 2006), whereas other studies report that thoracic kyphosis is not influenced by gender (Boyle et al., 2002; Gelb et al., 1995; Jackson & McManus, 1994; Korovessis et al., 1998).

Aging is characterized by loss of lumbar lordosis (Amonoo-Kuofi, 1992; Gelb et al., 1995; Kobayashi et al., 2004; Milne & Lauder, 1974; Nourbakhsh et al., 2001), an increment of the thoracic kyphosis which is associated to forward shifts of sagittal spinal balance (Amonoo-Kuofi, 1992; Kobayashi et al., 2004; Milne & Lauder, 1974; Schwab et al., 2006). Regarding the influence of weight status on spinal curvatures, inconsistent results have been reported with either positive or negative correlations between body mass index (BMI) and degree of lumbar lordosis (Hoseinifar, 2007; Murrie et al., 2003; Nourbakhsh et al., 2001; Tuzun et al., 1999). These contradictory results may be influenced by the method used and the number of participants included (Youdas et al., 1996, 2006).

Radiological analysis is the reference method for assessing lumbar lordosis and thoracic kyphosis (Amonoo-Kuofi, 1992; Bartynski et al., 2005; Boyle et al., 2002; Fon et al., 1980; Gelb et al., 1995; Jackson & McManus, 1994; Kobayashi et al., 2004; Korovessis et al., 1998; Manns et al., 1996; Schwab et al., 2006; Voutsinas & MacEwen, 1986) but an important limitation of this method is the high dose of radiation required (Morin Doody et al., 2000). Therefore, several noninvasive, external methods have been developed and used such as goniometry, kyphometers, inclinometers, flexicurve instruments coupled or not with electronic computer aid (Bergenudd et al., 1989; Hoseinifar, 2007; Mannion et al., 2004; Mellin, 1986; Murrie et al., 2003; Ng et al., 2001; Norton et al., 2004; Nourbakhsh et al., 2001; Youdas et al., 2000, 1996, 2006). The SpinalMouse (Idiag, Voletswil, Switzerland) is a noninvasive electronic computer-aided device that measures distance and changes of inclination between spinal segments. The values of each vertebral inclination are recorded considering spinous process as reference points with regard to the vertical line as it is rolled along the length of the spine. SpinalMouse has been shown to be valid and reliable to assess the sagittal spinal curvatures and sagittal range of motion with an ICCs higher 0.80 (Mannion et al., 2004; Post & Leferink, 2004). Studies examining the spinal curvature using SpinalMouse are scarce and reference values have not been established (Mannion et al., 2004). The aim of this study was to examine the differences on lumbar lordosis and thoracic kyphosis in standing position by gender, age and weight status in healthy participants using a noninvasive method such as SpinalMouse.

Methods

Participants

A total of 297 women (36.6 ± 7.3 years) and 362 men (39.8 ± 7.5 years) participated in this study. Mean body mass and height were 62.6 ± 10.5 kg and 163.5 ± 6.1 cm in women, and 83.9 ± 12.2 kg and 176.9 ± 6.4 cm in men. All participants were white collar workers and, after being fully informed, they all voluntarily participated in a hotel based health promotion program where physical activity and healthy nutrition were basic characteristics (Sotogrande Health Experience, Cádiz, Spain). All participants were free of disease (after self-report and clinical assessment by a consultant physician) and were normal on musculoskeletal examination. The study protocol was performed in accordance with the ethical standards established in the 1961 Declaration of Helsinki (as revised in Hong Kong in 1989 and in Edinburgh, Scotland, in 2000).

Weight Status

Body mass was measured by using a Seca scale (SECA, Vogel & Halke GmbH & CO. KG, Hamburg, Germany; precision of 0.1 kg) with participants in underwear and barefoot. Height was measured with a stadiometer incorporated in the balance (SECA, Vogel & Halke GmbH & CO. KG, Hamburg, Germany, precision of 0.1 cm). The participant was instructed to take and hold a full breath. Stretched height with the head at the Frankfort plane was recorded.

Participants were categorized according to the international BMI (kg/m^2) cut-off points (WHO, 2000). Overweight is determined by a BMI of 25.0–29.9 kg/m^2, and obesity is defined by a BMI ≥ 30.0 kg/m^2. Non-overweight is considered to occur with a BMI of ≤ 24.9 kg/m^2. Underweight group (BMI < 18.5 kg/m^2) was not considered due to the low number of participants in this category (n = 13).

Age

Age was stratified by ten years increments starting from 20 y, except the last group which included all those aged ≥ 50 years: 20–29, 30–39, 40–49, ≥50 years.

Measurement of Spinal Curvature

Measurements of global and segmental spinal curvature were performed with the SpinalMouse system, which measures intersegmental distance and angle changes between segments by spinous process as referent points in sagittal and frontal projections (See Figure 1).

The value of each vertebral inclination was recorded as positive or negative when kyphotic or lordotic angles existed, respectively. The device consists of a mobile unit of 2 rolling wheels interfaced to a based station through telemetry. Data were sampled every 1.3 mm as the mouse was rolled along the spine, giving a sampling frequency of approximately 150 Hz. The average total length of the spine was 550 mm, so the time required to measure the whole length was 2–4 s. Therefore, approximately 423 measurements were made over about 3 s. The local angle or inclination relative to a perpendicular line is given at any position by an internal pendulum connected to a potentiometer. An intelligent recursive algorithm computes information concerning the vertebral inclinations by outline of the skin over the relative position of spinous process in the sagittal plane, based on geometrical and trigonometric methods (See Figure 2).

Specifically, lumbar lordosis and thoracic kyphosis in standing position were measured following the protocol described by Mannion et al. (Mannion et al., 2004). Participants were asked to take the test position on standing. Participants were in a relaxed position, focusing on a marker in the wall at eye level, feet to the width of the shoulders, straight knees and hanging arms on the side. The device is made to roll paravertebrally along the spinal column passing on the top of spinous processes. By detecting the notch caused by these spinous processes, the sagittal spinal alignment and vertebra angles were calculated and displayed on the computer monitor. The assessment started at the spinous process of C7 and finished at the top of S3. These landmarks were previously determined by palpation and marked on the skin surface.

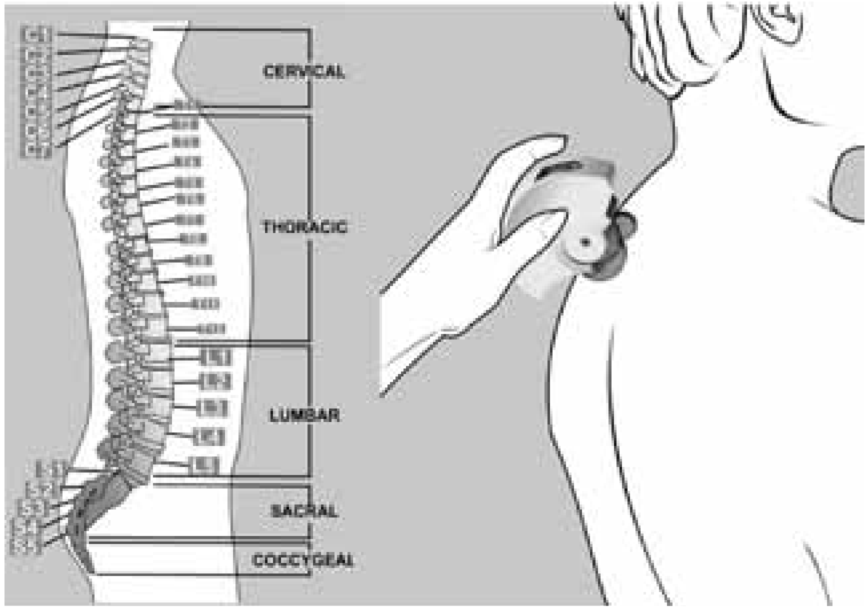

Figure 1 — The SpinalMouse is run paravertebrally from C7 to S3.

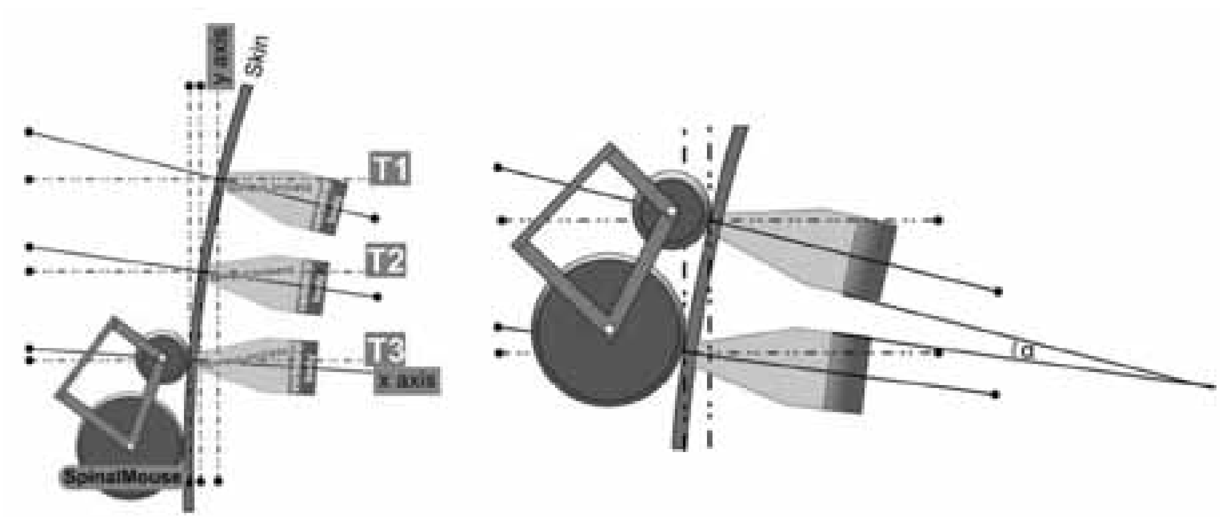

Figure 2 — Schematic drawing of α angle calculated.

Statistical Analysis

All variables were checked for normality using the Kolmogorov–Smirnov test, showing a satisfactory pattern. Gender, age and weight status differences on lumbar lordosis and thoracic kyphosis were analyzed by one-way ANOVA. Moreover, three-way ANOVA was used to examine the main effects of gender, age and weight status on lumbar lordosis and thoracic kyphosis. Interaction effects were not found for gender × age × weight status in relation to lumbar lordosis neither thoracic kyphosis (all p values >0.2). Package for Social Sciences software (SPSS, v. 16. 0 for WINDOWS; SPSS Inc, Chicago) was used, and p values <0.05 were considered statistically significant.

Results

Descriptive characteristics of the participants according to gender are presented in Table 1. Spinal curvatures according to gender, age and weight status without adjustment (one-way ANOVA), and with adjustment (three-way ANOVA) for each other, are shown in Tables 2 and 3 respectively. Without adjustment for age and weight status, gender was significantly associated with

Table 1 Characteristics (means ± *SD* and range) of the participants in the study

	Women (*n* = 297)		Men (*n* = 362)	
	Means ± *SD*	Range	Means ± *SD*	Range
Age (years)	36.6 ± 7.3	20.0–67.0	39.8 ± 7.5	22.0–68.0
Weight (kg)	62.6 ± 10.5	42.7–124.5	83.9 ± 12.2	49.7–124.0
Height (cm)	163.5 ± 6.1	148–180	176.9 ± 6.4	155–196
BMI (kg/m²)	23.4 ± 3.8	17.4–45.7	26.8 ± 3.5	16.8–39.6

Note. BMI: body mass index.

Table 2 Means and standard error (*SE*) of lumbar lordosis (degrees) in healthy adults by gender, age and weight status

			Lumbar Lordosis (°)	
			No Adjustment (1-way ANOVA)	Adjustment (3-way ANOVA)
	n	Range	Means ± *SE*	Means ± *SE*
Gender				
Women	297	-4 to 56	29.6 ± 0.7	30.7 ± 11.6
Men	362	-6 to 38	17.3 ± 0.5	16.5 ± 9.3
	p		≤0.001	≤0.001
Age (years)				
20–29	63 (43♀; 20♂)	-4 to 48	26.7 ± 1.5*	23.7 ± 1.9
30–39	345 (169♀;176♂)	-5 to 53	23.6 ± 0.7†	23.2 ± 0.8
40–49	193 (67♀;126♂)	-6 to 56	20.8 ± 0.6	22.9 ± 1.4
≥50	58 (18♀;40♂)	4 to 56	20.9 ± 1.4	24.7 ± 1.8
	p		0.001	0.873
Weight status				
Nonoverweight	328 (212♀;116♂)	-6 to 56	25.1 ± 0.7⁺	23.4 ± 0.8
Overweight	255 (67♀;188♂)	-5 to 53	20.9 ± 0.7	23.5 ± 1.0
Obese	76 (18♀;58♂)	-4 to 56	19.4 ± 1.4	23.5 ± 1.9
	p		≤0.001	0.902

Note. ♀, women; ♂, men; *$p < 0.05$ for 20–29 years vs. 40–49 and ≥50 years; †$p < 0.01$ for 30–39 years vs. 40–49 years; ⁺$p < 0.05$ for non-overweight vs. overweight and obese.

lumbar lordosis and thoracic kyphosis. Men showed smaller lumbar lordosis and larger thoracic kyphosis than women (both $p < .001$). Overall, adjusting for the rest of the variables strengthened the association between lumbar lordosis and gender but not weaken the association with thoracic kyphosis.

Age showed a significant association with lumbar lordosis and thoracic kyphosis curvatures when not adjusted for gender and weight status (Tables 2 and 3). Older groups presented smaller lumbar lordosis and larger thoracic kyphosis values compared with the 20–29 y group ($p < .01$). However, these associations became nonsignificant when the adjustment analysis were performed (Tables 2 and 3).

Weight status was significantly associated with lumbar lordosis and thoracic kyphosis in the nonadjusted analysis (Tables 2 and 3). Overweight and obese groups showed smaller lumbar lordosis and larger thoracic kyphosis values compared with nonoverweight participants (all p values <0.05). Significant differences were not observed between weight status and spinal curvature when the adjustment analyses were performed.

Table 3 Means and standard error (*SE*) of thoracic kyphosis (degrees) in healthy adults by gender, age and weight status

			Thoracic Kyphosis (°)	
			No Adjustment (1-way ANOVA)	Adjustment (3-way ANOVA)
	n	Range	Means ± *SE*	Means ± *SE*
Gender				
Women	297	15 to 65	40.4 ± 0.6	40.8 ± 1.1
Men	362	19 to 64	42.8 ± 0.5	42.1 ± 0.8
	p		0.001	0.340
Age (years)				
20–29	63 (43♀;20♂)	15 to 62	37.5 ± 1.3*	38.4 ± 1.7
30–39	345 (169♀;176♂)	17 to 65	41.8 ± 0.5	42.3 ± 0.7
40–49	193 (67♀;126♂)	24 to 64	42.6 ± 0.6	41.4 ± 1.3
≥50	58 (18♀;40♂)	22 to 60	42.6 ± 1.3	43.7 ± 1.5
	p		0.001	0.098
Weight status				
Nonoverweight	328 (212♀;116♂)	17 to 65	40.6 ± 0.5⁺	40.8 ± 0.7
Overweight	255 (67♀;188♂)	15 to 64	42.7 ± 0.6	41.5 ± 0.9
Obese	76 (18♀;58♂)	18 to 62	42.8 ± 1.1	42.0 ± 1.7
	p		0.014	0.734

Note. ♀, women;♂, men *$p < 0.05$ for 20–29 years vs. 40–49 and ≥50 years; ⁺$p < 0.05$ for nonoverweight vs. overweight.

Discussion

We examined the differences on lumbar lordosis and thoracic kyphosis by gender, age and weight status in healthy adults using the SpinalMouse. The results suggested that women have larger lumbar lordosis and smaller thoracic kyphosis values than men. Moreover, older groups presented smaller lumbar lordosis and larger thoracic kyphosis values compared with the youngest group. Regarding to weight status, overweight and obese groups showed smaller lumbar lordosis and larger thoracic kyphosis values compared with nonoverweight participants. However, when gender, age and weight status were take into account all together only gender seems to influence the lumbar lordosis curvature.

Lumbar Lordosis and Thoracic Kyphosis by Gender

Our results concur with previous studies in relation to the influence of gender on lumbar lordosis (Amonoo-Kuofi, 1992; Norton et al., 2004; Nourbakhsh et al., 2001; Youdas et al., 1996, 2006), that is, larger lumbar lordosis values in women compared with men. This was true even using different methods to measure spinal curvatures such as radiographic methods (Amonoo-Kuofi, 1992) or noninvasive surface methods of contact as Metrecom Skeletal Analysis System (Norton et al., 2004) and flexicurve instrument (Youdas et al., 1996, 2006). It has been suggested that the greater angles on lumbar lordosis observed in women could be due to differences in the vertebral shape variation. In addition, the anatomical differences and functional capacity influences biomechanical factors in standing position (Amonoo-Kuofi, 1992; Cheng et al., 1998; Nourbakhsh et al., 2001). Others suggested that these differences could be related with the pregnancy process, which alters the biomechanical factors of lumbar column (Nourbakhsh et al., 2001). In addition, our study did not find any relationships between gender and thoracic kyphosis when age and weight status when taken into account, which is in accordance with previous studies performed using radiographic methods (Boyle et al., 2002; Gelb et al., 1995; Jackson & McManus, 1994; Korovessis et al., 1998).

Lumbar Lordosis and Thoracic Kyphosis by Age

Significant differences were not found on lumbar lordosis in standing position between the younger and older groups when adjusted for gender and weight status. Our results concur with previous studies which developed invasive technique such as radiography (Korovessis et al., 1998) and noninvasive techniques such as flexicurve device (Youdas et al., 2006). These studies did not find any association between age and lumbar lordosis. Korovesis et al., (Korovessis et al., 1998) showed that total lumbar lordosis was not related with age in 61 women and 38 men aged 20–79 years using radiographic methods. This is in disagreement with other studies where lumbar lordosis decreased with age independently of the method used (Amonoo-Kuofi, 1992; Gelb et al., 1995; Kobayashi et al., 2004; Milne & Lauder, 1974; Nourbakhsh et al., 2001). Nourbakhsh et al. (Nourbakhsh et al., 2001) found a smaller values on lumbar lordosis in the 50–65 years group compared with 20–34 and 35–40 years groups, in both women and men, with and without low back pain, using flexicurve instrument. Similar results were found by Amoono-Kuofi et al. (Amonoo-Kuofi, 1992) using radiographic methods. Moreover, Gelb et al. (Gelb et al., 1995) observed that a loss of lumbar lordosis at L5-S1 was correlated with age. Allowing for the contradictories results warrants further studies.

Regarding thoracic kyphosis, significant differences were not found between the different age groups when the influence of gender and weight status was considered. The results concur with previous studies which did not find any relation between thoracic kyphosis and age, these studies were conducted by the radiographic method (Gelb et al., 1995) and video analysis noninvasive measurement (Kuo et al., 2009). Some studies observed larger values in older groups compared with youngest group (Bartynski et al., 2005; Fon et al., 1980; Hinman, 2004; Korovessis et al., 1998; Milne & Lauder, 1974; Ostrowska et al., 2003; Sidhu & Singal, 1983). It could be due to the fact that authors did not take into account any other variable such as gender or weight status. Nevertheless, the effect of age on spinal curvatures may be more accurately analyzed in longitudinal studies.

Lumbar Lordosis and Thoracic Kyphosis by Weight Status

In agreement with previous studies, we did not find any relation for lumbar lordosis and weight status in standing position in the adjusted analysis (Youdas et al., 1996, 2006). Youdas et al. (Youdas et al., 2006) analyzed, using a flexicurve instrument, the relationships between weight status and lumbar lordosis in 116 women and 119 men healthy participants aged 20–79. They did not find any influence of weight status on lumbar lordosis. Contradictory results have been also found (Hoseinifar, 2007; Murrie et al., 2003; Nourbakhsh et al., 2001; Tuzun et al., 1999; Youdas et al., 1996, 2006). Nourbakhsh et al., (Nourbakhsh et al., 2001) observed in 840 participants (420 women) aged 20–65 that the degree of lumbar lordosis was negatively related to the weight of the participants. Other studies found positive correlations between BMI and lumbar lordosis (Hoseinifar, 2007; Murrie et al., 2003; Tuzun et al., 1999). Further studies focused on the effects between lumbar lordosis and weight status are needed.

Regarding to thoracic kyphosis we did not find any association with weigh status such as that observed in previous studies (Findikcioglu et al., 2007; Hoseinifar, 2007). Findikcioglu et al. (Findikcioglu et al., 2007) studied the association between breast size, spinal curvatures and weight status in a radiological study. They did not find any differences on thoracic kyphosis and lumbar lordosis by weight status (Findikcioglu et al., 2007). In contrast, Bergenudd et al., (Bergenudd et al., 1989) observed in a longitudinal study (45 years between measures) in 575 adults (252 women and 323 men), positive correlations between the degree of thoracic kyphosis and body mass in women. Contradictories results in these studies could be attributed to the methodology used as well as the differences in weight status classification.

To our knowledge, only one study examined lumbar lordosis and thoracic kyphosis using SpinalMouse in healthy adults, obtaining values similar to our study (Mannion et al., 2004). The values obtained in this study for lumbar lordosis were similar to those recorded with other skin-surfaces devices in healthy adults (Mellin, 1986; Ng et al., 2001; Ng et al., 2002; Norton et al., 2002; Troke et al., 2007; Waddell et al., 1992). Nevertheless, our values were smaller compared with those obtained by radiographic techniques which varying between 44° and 62.5° (Bernhardt & Bridwell, 1989; Gangnet et al., 2006; Gelb et al., 1995; Glassman et al., 2005; Harrison et al., 2001; Jackson & Hales, 2000; Jackson & McManus, 1994; Korovessis et al., 1998). The thoracic kyphosis values using SpinalMouse and radiographic techniques were similar, 45° for SpinalMouse and from 42° to 48° for radiography, respectively (Gelb et al., 1995; Harrison et al., 2002; Jackson & McManus, 1994).

Some limitations should be recognized. The participants were recruited from those participating in a hotel based health promotion program; therefore the sample could be biased by ability to pay, and by interested in personal health. They were assessed once so data about reliability and responsiveness were not reported in this study. However, the relatively large sample of participants and the use of an objective and noninvasive skin-surfaces device such as SpinalMouse are notable strengths.

In conclusion, the results of this study suggest that when analyzing the influence of gender, age and weight status on spinal curvatures in standing position in healthy middle-aged participants, gender could be the only determinant factor of lumbar lordosis. Our findings may help physicians and health care professionals to better understanding the relationships of gender, age and weight status with spine curvatures on sagittal plane.

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