Video Analysis of Sagittal Spinal Posture in Healthy Young and Older Adults

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Abstract

Objective: Changes in posture are of concern because of their association with pain or impaired physical function. Previous studies that have used computer-aided video motion analysis systems to measure posture have been compromised by the use of problematic models of skin marker placement. This study aimed to quantify and compare sagittal spinal posture in standing and sitting between young and older adults using a two-dimensional PEAK Motus system and a revised skin marker model.

Methods: Twenty-four healthy young adults and 22 healthy older adults volunteered for this study. The angles of the upper and lower cervical spine, thoracic spine, lumbar spine as well as the orientations of the head, neck, and pelvic plane with respect to an external reference were measured in the standing and sitting positions.

Results: Compared to young adults, healthy older adults demonstrated a forward head posture, with increased lower cervical spine flexion and increased upper cervical extension in both positions. Older adults also sat with significantly increased thoracic kyphosis and decreased lumbar spine flexion.

Conclusion: The angular relationship between adjacent spinal regions in the sagittal plane can be objectively quantified using image-based analysis. The concept that the anteroposterior tilt of the pelvis in standing dictates the lumbar and thoracic curves was supported by the correlations between these adjacent regions in both age groups. The model of skin marker placement used in this study can have a broader application as a clinical tool for image-based postural assessment. (J Manipulative Physiol Ther 2009;32:210-215)

Key Indexing Terms: *Posture; Aging; Spine*

Changes in posture are of concern to clinicians because postural deviation can produce excessive stress on the musculoskeletal system. As a result, a "forward head" posture[1,2] or an increased lumbar lordosis[3] may be associated with spinal pain. Increased thoracic kyphosis in older adults can also lead to altered gait pattern,[4] reduced physical function,[5] increased body sway, and risk of falls.[6,7]

Sagittal standing posture is frequently assessed by referencing body landmarks to an imaginary plumb line passing through the mastoid process[8]; however, the visual observation of spinal posture has not proven valid or reliable.[9,10] Changes in older adults in standing posture have been reported in radiographic studies[11-14]; however, little is known about sitting posture in older adults. Although radiographic methods are considered the "gold standard" for measurement of skeletal alignment,[15,16] the risk of radiation exposure limits its use for postural assessment. In contrast, computer-aided video motion analysis systems track reference markers attached to the skin of relevant body segments and provide noninvasive measurement of human movement during functional tasks. These motion analysis systems have been extensively used to investigate walking[17,18]; however, only a small number of studies have used these systems to measure posture, and results have frequently been compromised by the use of problematic models of skin marker placement. For example, in two recent studies,[19,20] pairs of markers were mounted on large fin-shaped devices and attached to the body surface. It has been noted in our laboratory that although remaining attached to the skin at the base, even lightweight devices of this type tend to droop under their own weight. As the validity of the data obtained from these markers depends on the device remaining parallel to the upper/lower surface of specific vertebral bodies, any loosening and/or tilting of the device will result in measurement error. A pair of markers was also attached to a headband, where the questionable consistency of positioning the headband among participants also provided a likely source of measurement error.

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A 2-dimensional (2D) model that uses small spherical 2.5-cm-diameter markers attached directly to the skin has been developed in our movement laboratory for measurement of sagittal plane posture and movement. The aim of this study was to quantify and compare sagittal spinal posture in standing and sitting between healthy young and older adults using a 2D video motion analysis system (PEAK Motus) and our revised skin marker model.

Methods

Participants

Twenty-four healthy young adults (15 women, 9 men; age, 17-27 years; weight, 62.6 ± 8.9 kg; height, 170.2 ± 9.1 cm; body mass index, 21.5 ± 1.9 kg/m^2) and 22 healthy older adults (14 women, 8 men; age, 60-83 years; weight, 69.3 ± 12.1 kg; height, 163.9 ± 8.4 cm; body mass index, 25.8 ± 4.0 kg/m^2) volunteered for this study by responding to advertisements. Volunteers were screened to exclude those with identifiable movement dysfunction, pain, and/or pathology in the spine or lower extremities requiring treatment during the preceding 6 months. The project had ethics approval from the Human Research Ethics Committee of the university, and informed consent was obtained from each participant.

Model of Skin Marker Placement

Nine spherical reflective markers (B&L Engineering, Tustin, CA) were attached to specific anatomic landmarks of participants in standing position (Fig 1). For ease of application, one face marker was attached to the center of the flexible ear hook of a headphone piece (SHS3201/97, Philips), whereas the other face marker was attached to the midpoint between the right corner of the mouth and the right nasal ala. Details for locating the other skin reference markers have been reported previously.[21,22] Good intrarater reliability of skin marker placement was established in standing (intraclass correlation coefficient 1,1 = 0.83-0.92).

Experimental Procedure

Participants wore dark-colored underwear during video recording, with equipment setup and lighting as previously described.[21] The right side of the participants was videotaped as they stood with bare feet in a quiet erect position for 5 seconds. To ensure a consistent standing posture, participants maintained their gaze straight ahead at a target adjusted for body height and placed both hands lightly on a stable anterior support at approximately waist level (shoulder flexion, 30°-45°) as visually estimated by the investigator. For sitting posture, participants sat on a backless and armless chair with the seat level adjusted to the height of the midlateral knee joint line. A standardized gaze and arm position was also used in sitting, with participants resting their hands on their thighs, fingertips touching knees.

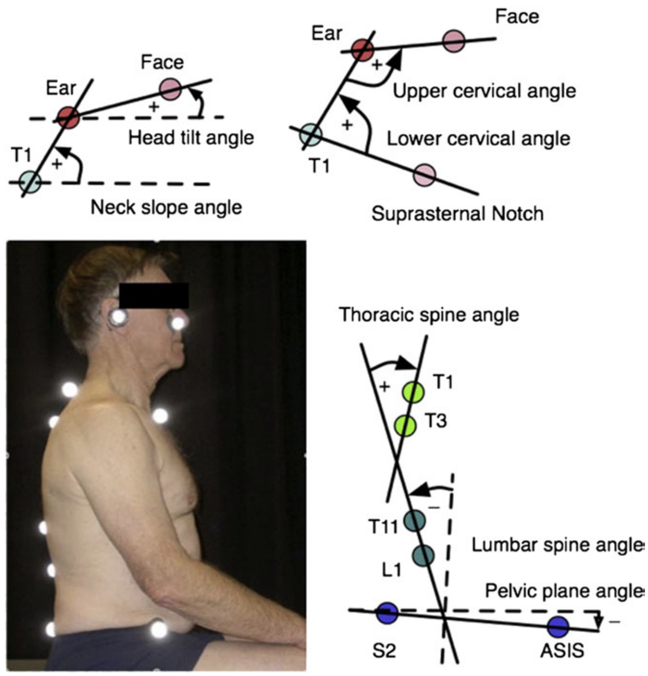

Fig 1. *Marker placement and angle definition. Increasing head tilt and neck slope angles indicate that the face is tilted upward and the neck is inclined less forward. Increasing upper and lower cervical spine angles indicate extension. A positive thoracic angle indicates flexion, and a negative lumbar angle indicated extension. A negative pelvic plane angle (S2-ASIS) indicated that the anterior superior iliac spine (ASIS) moved below the horizontal plane.*

Data Analysis

Figure 1 illustrates the angle definitions and calculation. The location of each skin reference marker on the 5-second videotaped images was automatically digitized at a frequency of 50 samples per second using the 2D PEAK software program. The x and y coordinates were converted to angular data that were smoothed using a fourth-order Butterworth (high cutoff) filter[23] at an optimum cutoff frequency determined by the software.[24]

All data were analyzed using SPSS version 13.0 (SPSS, Inc, Chicago, IL). Mean values and standard deviations (SD) were calculated for all angles. To determine the group difference in sagittal spinal angles, unpaired *t* tests were used. Pearson product moment correlation coefficients were calculated to examine the correlation between sagittal spinal angles in standing and sitting. The statistical significance level was set at $P < .05$.

Results

Significant differences were found in sagittal standing and sitting postures between young and older participants (Table 1). The pelvic plane and lumbar spine angles were similar in both groups in standing position (P = .7). Older participants had less lumbar flexion than young participants

Table 1. *Summary for sagittal angles of the spine and hip joint for the young (n = 24) and older (n = 22) groups in standing and sitting*

Angles	Young	Old	Difference	t	95% CI
Standing					
Head tilt	−21.6 ± 7.4	−16.2 ± 8.9	−5.4	−2.26 *	−10.3 to −0.6
Neck slope	47.7 ± 5.1	40.7 ± 7.6	7.0	3.68 **	3.1 to 10.8
Upper cervical	110.7 ± 7.1	123.1 ± 10.4	−12.4	−4.76 ***	−17.6 to −7.1
Lower cervical	75.5 ± 6.4	69.0 ± 6.3	6.5	3.48 **	2.8 to 10.3
Thoracic	38.3 ± 8.2	42.8 ± 11.3	−4.5	−1.57	−10.3 to 1.3
Lumbar	−16.0 ± 5.6	−15.2 ± 9.3	−0.8	−0.34	−5.3 to 3.8
Pelvic plane	−5.0 ± 3.7	−5.5 ± 6.1	0.5	0.34	−2.5 to 3.5
Sitting					
Head tilt	−18.5 ± 5.7	−13.5 ± 5.9	−5.0	−2.93 **	−8.5 to −1.6
Neck slope	47.1 ± 5.8	39.9 ± 6.0	7.2	4.14 ***	3.7 to 10.7
Upper cervical	114.4 ± 8.3	126.6 ± 7.9	−12.2	−5.10 ***	−17.0 to −7.4
Lower cervical	79.6 ± 6.8	70.4 ± 5.6	9.2	4.98 ***	5.5 to 12.9
Thoracic	33.3 ± 8.1	40.2 ± 11.2	−6.9	−2.41 *	−12.6 to −1.1
Lumbar	15.3 ± 8.3	6.0 ± 9.6	9.3	3.52 **	4.0 to 14.6
Pelvic plane	13.1 ± 7.5	9.8 ± 7.4	3.3	1.50	−1.2 to 7.8

Values are mean ± SD. *CI*, Confidence interval.
* $P < .05$.
** $P < .01$.
*** $P < .001$.

in sitting position ($P = .001$), and although the younger group had greater posterior pelvic tilt in sitting position, the mean difference of 3.3° was not significant ($P = .14$). Similarly, older participants presented with increased thoracic kyphosis in both standing and sitting positions; however, these between-group differences were only statistically significant in sitting ($P = .02$) but not in standing position ($P = .13$).

In both standing and sitting positions, older participants inclined their neck more forward with respect to the horizontal than the young (standing, $P = .001$; sitting, $P < .001$) and tilted their head more upward (standing, $P = .03$; sitting, $P = .005$). Corresponding to the findings for neck slope and head tilt, older participants had more flexion of their lower cervical spine in both positions (standing, $P = .001$; sitting, $P < .001$) and more extension of their upper cervical spine (standing, $P < .001$; sitting, $P < .001$).

The sagittal spinal angles demonstrated a significant chain of correlations during standing and sitting (Fig 2). Increased anterior tilting of the pelvic plane was associated with increased lumbar extension in both standing ($r = 0.60$, $P < .001$) and sitting positions ($r = 0.67$, $P < .001$). In standing, increased extension in the lumbar spine was associated with increased thoracic flexion ($r = −0.48$, $P = .001$), increased extension in the upper cervical spine ($r = 0.32$, $P = .033$), and increased forward neck slope ($r = −0.41$, $P = .004$). Similar to the correlations in standing, increased thoracic flexion in sitting was also associated with increased forward lean in the neck ($r = −0.44$, $P = .002$) and extension in the upper cervical spine ($r = 0.41$, $P = .004$). However, the thoracic curve did not directly correlate to that of the lumbar spine in sitting ($r = −0.15$, $P = .3$).

In both standing and sitting positions (Fig 2), decreased forward lean of the neck was associated with decreased flexion in the lower cervical spine and increased flexion in the upper cervical spine with downward tilt of the head. However, the neck slope angle was not correlated with the head tilt angle in either position (standing, $r = 0.08$, $P = .6$; sitting, $r = −0.18$, $P = .2$).

Discussion

The pelvis is considered to be the base for the spine, and its anteroposterior orientation affects the sagittal curves of the spine. The "neutral" position of the pelvis in standing has been defined as the posterior superior iliac spine (PSIS) and anterior superior iliac spine being approximately in the horizontal plane, a posture that produces the optimal degree of lumbar lordosis.[8] Increased anterior pelvic tilt is said to result in a larger lumbar lordosis and compensatory increases in the thoracic and cervical curves above so that the head is maintained above the feet. This interaction of adjacent segments, based on pelvic orientation, is sometimes referred to as a "bottom-up" postural adjustment. In this study, the significant correlation observed between pelvic plane and lumbar lordosis supports this concept, as does the correlation between the sagittal lumbar and thoracic angles. However, there was no direct correlation between the thoracic and lower cervical spine angles. The thoracic spine and lower cervical spine were correlated with each other through the upper cervical spine. It is possible that this interruption of the bottom-up correlation occurred because the head is responsible for important senses such as vision and hearing and induced a "top-down" adjustment. In other words, the bottom-up and top-down interactions within the kinematic chain of the spine may co-exist in static postures.

Similar correlations between the spinal regions have been reported in radiographic studies; however, previous studies did not include the cervical spine[14,25] or simply analyzed the

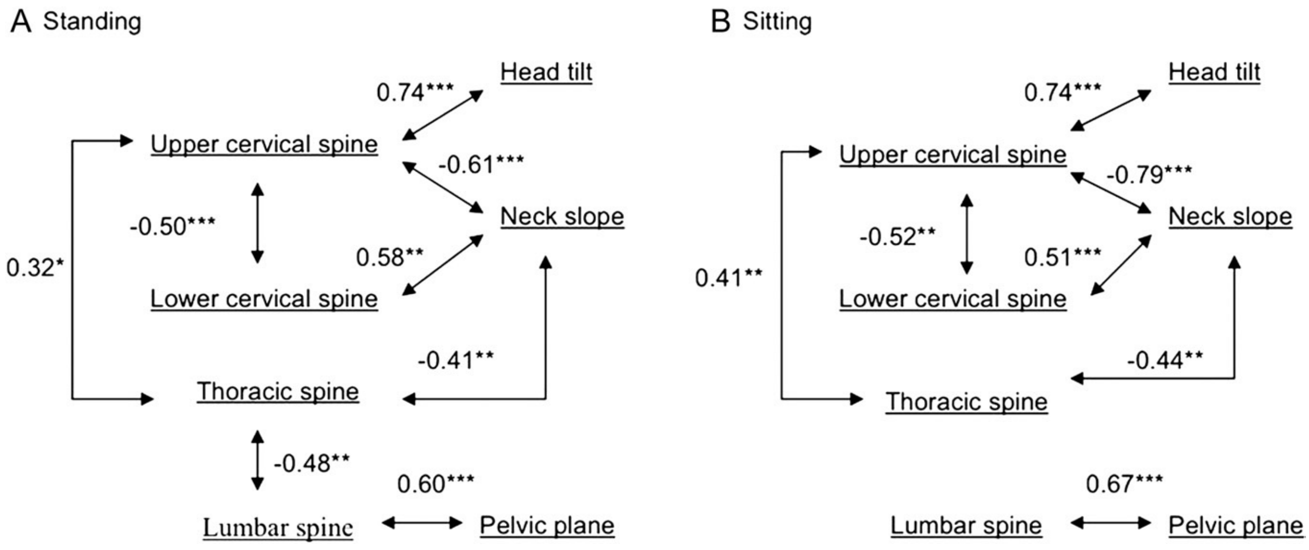

Fig 2. *The significant chain of correlations between the sagittal angles of spine and hip joint in standing (A) and sitting (B). Values are Pearson product moment coefficients. * P <.05, ** P <.01, *** P <.001.*

cervical spine as a whole.[15] This study provides a more complete picture of the angular interaction within the spine in both standing and sitting postures.

Effect of Aging

Although increased thoracic kyphosis is the most noticeable and commonly acknowledged postural change in older adults, this study did not find any statistically significant difference between the age groups in standing. This may be explained by the similarity in the pelvic plane and lumbar lordosis between groups in this position. It can be argued that there was no requirement for the thoracic spine of the older group to adjust in compensation to alteration in the orientation of the pelvic base and lumbar posture. Another explanation for this result is the sampling method used in this study. Older adults with significantly increased thoracic kyphosis may have had other health conditions,[5,26] which prevented them volunteering for a study that targeted healthy older adults, or significant musculoskeletal problems that caused them to be excluded during the recruitment process.

Lack of a back support appears to have allowed participants to adopt their natural slump posture when seated, with older participants adopting a significantly increased thoracic curvature and decreased lumbar flexion posture. The difference in sitting lumbar spine posture may be due to age-related stiffness in lumbar flexion found in previous studies.[27,28] The protruding abdomen in the elderly may have also limited the available lumbar flexion in sitting.

The finding of decreased posterior pelvic tilt and lumbar flexion in older adults may explain the difference in thoracic kyphosis in sitting that was not found in the standing position. On sitting down, as the lumbar spine flexed, the thoracic spine assumed a more extended posture than in standing in both groups. In the young, the flexed lumbar spine was accompanied by more thoracic extension than in the elderly. The lack of lumbar flexion in older adults may have necessitated increased thoracic flexion to bring the center of mass of the upper body sufficiently forward over the seated base of support, that is, buttocks and thighs.

The relationship between aging and increased forward incline of the neck relative to the horizontal as reported in the literature[29] is supported by this study. However, measurement of neck slope only indicates the position of the neck segment in space, with the angle being influenced by the position of the more caudal body segments. For example, neck slope may be altered by bending the knees or leaning the trunk forward from the hips. In this study, the results for the lower cervical spine (neck-trunk angle) demonstrated that the older participants truly had a forward head posture, with an age-related change occurring in the lower cervical spine. That the neck slope angle was similar to the lower cervical angle in this study indicates that the participants must have been sitting with a relatively erect/vertical trunk.

The finding of a relatively weak correlation (r = 0.4) between the sagittal thoracic curve and neck slope in both standing and sitting was at first surprising, as it had been envisaged that an increase in thoracic kyphosis would be accompanied by an increase in the forward lean of the neck However, there was only a poor correlation between thoracic kyphosis and lower cervical angle indicating that participants with increased kyphosis increased their lower cervical extension. The finding that the older group significantly tilted their head upward more than the young group is contrary to the conclusion of Raine and Twomey.[29] However, as with neck slope, the tilt of the head against an external (vertical or horizontal) reference is affected by the position of the more distal body segments. For this reason, comparison of results for head tilt across studies is difficult.

The head tilt angle is also affected by the reproducibility of the head position. Although measurement of cervicothoracic kyphosis has been found to be reliable,[30] it appears more difficult to achieve a reproducible head tilt despite the use of a visual target to standardize gaze level.

In this study, the model of skin marker placement permitted the separate measurement of upper and lower cervical spine angles and provided supporting evidence for the anecdotal relationship between these regions described in the literature,[8,29,31] that is, of forward head posture being accompanied by a relatively more flexed lower cervical spine and an extended upper cervical spine. It also showed that measurement of the slope of a body segment with reference to an external reference can only provide an accurate measure of the true angle between segments if one of those segments is either vertical or horizontal.

Clinical Implications

Clinicians need to be aware of the difference in sitting posture between young and older adults. The use of a lumbar support to increase lumbar lordosis in sitting has been recommended to prevent or alleviate low back pain[32;] however, a lumbar support may not be appropriate for older adults who already sit with a relatively extended lumbar spine. Similarly, in a rehabilitation or elderly care setting, a specific contour of chair may be ordered for older adults. Failure to appreciate the age-related difference in sitting posture may lead to faulty decision making in these instances.

The tendency for young adults to sit with a more flexed lumbar spine, particularly for an extended period, may have implications for potential damage to spinal structures.[33,34] Two recent studies of slump sitting[35,36] found decreased activity of deep trunk muscles that stabilize the intervertebral joints. The authors hypothesized that habitually adopting a slump sitting posture may decondition these deep trunk muscles and possibly affect stability of the lumbopelvic region, thereby increasing risk of injury and low back pain. However, young adults are likely have more range of motion, and although their lumbar sitting posture was substantially more flexed than the elderly, the lumbar spine may not have been at the limit of range. Therefore, the effect of the flexed lumbar sitting posture seen in young adults is unclear.

The finding that the use of a video motion analysis system with skin reference markers reflects the positional correlation between the sagittal spinal angles, which were previously shown in radiographic studies, supports this noninvasive measurement. Although some studies found that measurement of surface curvature with skin reference markers did not accurately reflect radiographic measurement of cervical spine alignment,[37,38] this method allows noninvasive and reliable measurement of sagittal spinal curves, particularly in the thoracic region where there are fewer soft tissues overlying the spinous processes.[39]

In addition, the model of skin marker placement used in this study has a broader application in clinical practice. Skin reference markers can be quickly attached to the patient, and the sagittal images of standing and sitting postures photographed with a digital camera. A similar model of angle calculation can be used with freely downloadable image analysis software, for example, ImageJ,[40] to obtain the curve values from the digital images. This approach offers an easy and noninvasive method to objectively document the relative position of body segments.

Conclusion

The study showed that the angular relationship between adjacent spinal regions in the sagittal plane can be objectively measured using image-based analysis. Age-related changes in the sagittal spinal posture in standing and sitting were quantified. The concept that the anteroposterior tilt of the pelvis in standing dictates the lumbar and thoracic curves was supported by the correlations between these adjacent regions in both age groups. The model of skin marker placement used in this study can have a broader application as a clinical tool for postural assessment.

Practical Applications

- The angular relationship between adjacent spinal regions in the sagittal plane can be objectively quantified using image-based analysis.
- The concept that the anteroposterior tilt of the pelvis in standing dictates the lumbar and thoracic curves was supported by the correlations between these adjacent regions in both age groups.
- Older adults demonstrated a more forward head posture, with increased lower cervical flexion and upper cervical extension in both standing and sitting.
- The posture of the elderly in sitting was different, with decreased lumbar flexion and increased thoracic flexion.
- Despite the potential effects of aging, older adults in this study maintained lumbar and thoracic postures similar to the young in standing.

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