Research Report

Lumbar Curvature in Standing and Sitting in Two Types of Chairs: Relationship of Hamstring and Hip Flexor Muscle Length

Key Words: Equipment, general; Lumbar vertebrae; Muscles; Neck and trunk, back; Spine.

A purpose of this study was to determine the difference in the lumbar curves of subjects while they stood compared with while they sat in two chairs with different seat angles—the Balans® Multi-Chair (BMC) and a standard conventional chair (SCC). An additional purpose was to determine the relationship between lumbar curvature and 1) anthropometric factors and hamstring and hip flexor muscle length during standing and during sitting in the two chairs and 2) amount of time spent sitting. Sixty-one men between 20 and 30 years of age served as subjects. Lumbar curve measurements were taken with a flexible ruler with the subjects first standing and then sitting in the two chairs. Hamstring and hip flexor muscle lengths were indicated by range-of-motion measurements taken with a gravity goniometer. Age, number of hours spent sitting per day, upper body length, and right leg length also were recorded. Subjects had significantly more lumbar extension when they sat in the BMC than when they sat in the SCC. Hip flexor length was the only factor that appeared to relate significantly to the difference between the standing lumbar curve and the lumbar curves in the BMC and the SCC. [Link CS, Nicholson GG, Shaddeau SA, et al. Lumbar curvature in standing and sitting in two types of chairs: relationship of hamstring and hip flexor muscle length. Phys Ther. 1990;70:611–618.]

Key Words: Equipment, general; Lumbar vertebrae; Muscles; Neck and trunk, back; Spine.

Disorders of the low back are among the most common musculoskeletal problems in the United States.¹ Kelsey et al,² in 1979, reported that, of approximately 18.9 million people who suffered some type of musculoskeletal impairment, 8.0 million had a disorder of the back and spine.

Because work environments have become increasingly automated and computerized, many workers may be living more sedentary life styles and spending a greater proportion of their lives sitting. This position is often uncomfortable for individuals with back pain. Frymoyer et al³ included

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Carol S Link
Garvice G Nicholson
Shirley A Shaddeau
Robert Birch
Marilyn R Gossman

C Link, MS, PT, is Physical Therapist, Physical Therapy Department, The Institute of Rehabilitation and Research, 1333 Moursund, Houston, TX 77030. She was a student in the Division of Physical Therapy, School of Health Related Professions, The University of Alabama at Birmingham, Birmingham, AL 35294, when the study was completed in partial fulfillment of the requirements of her master's degree.

G Nicholson, MS, PT, is Associate Professor, Division of Physical Therapy, School of Health Related Professions, The University of Alabama at Birmingham, and Supervisor of Orthopaedic Physical Therapy, Department of Physical Therapy, University of Alabama Hospital, 619 S 19th St, Birmingham, AL 35233. Address all correspondence to Mr Nicholson at Division of Physical Therapy, School of Health Related Professions, The University of Alabama at Birmingham, UAB Station, Birmingham, AL 35294 (USA).

S Shaddeau, MMSc, PT, is Associate Professor, Division of Physical Therapy, School of Health Related Professions, The University of Alabama at Birmingham.

R Birch, PhD, is a bio-statistician, National Biotherapy Study Group, Biological Therapy Institute, Franklin, TN 37064. He was Assistant Professor, Department of Bio-statistics and Biomathematics, The University of Alabama at Birmingham, when the study was completed.

M Gossman, PhD, PT, is Professor and Director, Division of Physical Therapy, School of Health Related Professions, The University of Alabama at Birmingham.

This study was approved by the Institutional Review Board for Human Use at The University of Alabama at Birmingham.

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prolonged sitting as one of the risk factors associated with low back pain (LBP).

Patients with back pain are often instructed to maintain "optimal" postural alignment. Reports on intradiskal pressure and the myoelectric activity of the back muscles indicate that certain positions, particularly excessive lumbar flexion, may predispose individuals to back pain.4-10

Mandall11 observed a reduction in lumbar flexion when subjects sat on a 15-degree forward-tilting seat and worked at a desk that sloped 10 degrees. Mandall11 stated that each degree of seat tilt had a direct effect on increasing the amount of lumbar extension.

Patients with LBP frequently find that pain makes sitting difficult or intolerable. Increased loads on the spine (eg, increased intradiskal pressure and excessive myoelectric activity of the back muscles) may cause the symptoms that patients with LBP experience while sitting. Studies of activities performed during sitting indicate that the type of chair may be important in influencing loads on the spine. Bendix et al12 reported that subjects preferred a freely tilting seat and varied the angle of tilt while sitting for an extended period of time. Bendix13 and Bendix and Biering-Sørensen14 observed subjects sitting in chairs with different seat angles and found that the subjects achieved the most vertical positioning of the trunk when they sat on a forward-tilting seat.

Various devices and special furniture are available to help people maintain good posture while sitting. Ergonomically designed chairs that are intended to preserve the neutral anterior lumbar curve are often suggested. The Westnofa Balans® Multi-Chair® (BMC) is one chair designed for this purpose. The BMC features a forward-tilting seat and cushions for the knees, which support a person in a semi-kneeling position (Fig. 1). Keegan15 described an optimal posture similar to that provided by the BMC. The hips are flexed, creating a thigh-to-trunk angle of about 135 degrees, and the knees are flexed to 90 degrees. The manufacturers of the BMC state that a trunk-to-thigh angle of 110 to 120 degrees is provided when sitting upright in this chair.

Frey and Tecklin16 found that when subjects sat in the BMC and began writing at a desk, their lumbar curve more closely approximated their standing lumbar curve than when they sat in a standard conventional chair (SCC). They attributed the change in lumbar curvature to the differences in chair design. Frey and Tecklin,16 however, did not study anatomical variables that also might account for this change. Several authors17-19 have suggested that muscle length affects posture. In theory, the length of the hamstring and hip flexor muscles influences the pelvic tilt and the lumbar curve.

A relatively simple and noninvasive method of measuring the lumbar curve consists of using a flexible ruler and measuring the curve between the spinous processes L-1 and S-2,20,21 Hart and Rose21 used intraclass correlation coefficients (ICCs) to determine that measurements obtained with the flexible ruler method were reliable (ICC = 97, N = 89) and valid when compared with measurements obtained from radiographs of the lumbar curves.

One purpose of this study was to determine the difference in the subjects' lumbar curves while they stood compared with while they sat in the BMC and the SCC. Another purpose was to determine the relationship between lumbar curvature and 1) anthropometric factors and hamstring and hip flexor muscle length during standing and during sitting in the two chairs and 2) amount of time spent sitting. We hypothesized that a significant difference in the degree of lumbar curvature would exist among subjects while they sat in each of the two chairs.

**Method**

**Subjects**

Healthy men with no current knee or back pain were recruited from The University of Alabama at Birmingham. Individuals with gross pelvic obliquity or scoliosis were excluded from the study. Sixty-one men between the ages of 20 and 30 years were selected as subjects. Each subject read and signed an informed consent document prior to participation in the study.

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*Westnofa USA Inc, 7040 N Austin Ave, Niles, IL 60648.*
**Instrumentation**

A gravity level was used as a goniometer to measure knee and hip joint range of motion (ROM). These ROM measurements were used as indications of hamstring and hip flexor muscle length, respectively. The angle of lumbar curvature was determined by a flexible ruler, using the method described by Hart and Rose. The dimensions of the BMC, the SCC, and the desk used in this study are presented in Table 1. The slope of each chair's seat was determined with the gravity goniometer. The seat height of the BMC was adjusted to the middle notch in accordance with the procedure followed by Frey and Tecklin and in accordance with the manufacturer's guidelines for standard desk use. The BMC seat height was approximately equal to that of the SCC. The seat of the BMC was kept at this height because the seat of the SCC was not adjustable.

**Procedure**

A pilot study was performed on 10 subjects to determine the reliability of the lumbar curve measurements and the ROM measurements indicating muscle length. Intrarater reliability (ICC[2,1]) was determined for lumbar curve, hamstring muscle length, and hip flexor muscle length measurements (ICC = .89, .99, and .96, respectively). Intrarater reliability also was determined for lumbar curve, hamstring muscle length, and hip flexor muscle length measurements (r = .84, .89, and .90, respectively).

Data collection took place in a private room, and each subject received an identification number for confidentiality. Subjects answered a question regarding the amount of time spent sitting each day. The subjects' age was recorded, and they were asked whether they had any current knee or back pain. With the subjects wearing gym shorts and no shoes, the spinous processes of L-1 and S-2 were palpated and marked with removable stickers. The spinal process S-2 was located by palpating the posterior superior iliac spines and moving the thumbs medially to the midline of the sacrum. The spinous process L-1 was located by palpating and moving the thumbs superiorly six levels above the S-2. Each subject was asked to stand relaxed with weight distributed evenly, arms hanging relaxed, and feet even and slightly apart. Each foot was approximately in line with the respective acetabulum.

The flexible ruler was placed against the subject's bare back, spanning the length between L-1 and S-2. Two twist-tie markers were attached to the flexible ruler at the same level of each skin marker, and the ruler was pressed firmly to the spine. The curve of the ruler, representing the lumbar curve, then was traced onto paper for further analysis, noting where the two reference points for L-1 and S-2 were located. The method for determining the degree of lumbar curvature ($\Theta$), as described by Shoun (CA Shoun, personal communication, 1980) and validated by Hart and Rose, was used. Two points on the curve, representing L-1 and S-2, were connected by a line (I). A perpendicular line (h), representing the height of the lumbar curve, bisected line I. The length of each line was determined in millimeters, and the values were inserted into the formula

$$\Theta = 4 \times \arctan(2h/I)$$

to calculate the degree of curvature (Fig. 2). Angles that were positive numbers were considered lumbar extension, and angles that were negative numbers were referred to as lumbar flexion.

The next sequence of measurements was randomized so that the subject sat first on either the SCC or the BMC. These measurements were randomized to control for a potential effect of order. The subject was asked to sit comfortably, as if he were going to be writing for some time. Paper and a pen were provided, and the subject was instructed to write. Each subject was given brief instructions, if necessary, on how to sit in the BMC and was allowed to adjust the distance from the chair to the desk for comfort. As soon as the subject stated he was comfortable and had begun to write, the appropriate spinous processes were palpated and marked and the lumbar curve was measured in the same manner as in standing. The subject was instructed to continue writing while these measurements were obtained. The procedure was

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*Pickett 12-Inch Flexible Curve Model No FC12, Pickett Industries, 1 River Rd, Leeds, MA 01053.*
then repeated while the subject sat in the other chair.

The spinous processes were palpated and marked after the subject assumed each new position because the skin often shifted over the bony landmarks. Subjects were asked to walk a short distance and reposition themselves between measurements. Two measurements were made in each position, the average of which was used in the statistical analysis. The same verbal cues were given to all subjects for assuming their typical standing and sitting postures.

While the subject sat in the SCC, right leg length and upper body length were measured. \textit{Leg length} was defined as the distance from the superior margin of the greater trochanter to the fibular head and from the fibular head to the inferior margin of the lateral malleolus with the knee at approximately a right angle. Because there was no evidence of gross pelvic obliquity in the subjects, only the right leg length was measured to categorize long-legged versus short-legged subjects. Upper body length was measured from the chair seat to the apex of the head while the subject sat up straight. We considered upper body length to be important because the subjects leaned over the desk in a writing position, which may have affected the lumbar curve measurements.

Measurements of knee and hip joint ROM were obtained bilaterally to indicate hamstring and hip flexor muscle length, respectively. We believe that passive ROM measurements at the point of initial resistance are a useful indicator of muscle length. Stopping at that point in the joint ROM should eliminate the involvement of joint structures, tendons, and other sources of variability.\textsuperscript{17,19,25,24} Hamstring muscle length was indicated using the passive knee-extension method described by Delitto et al.\textsuperscript{24} Subjects were positioned supine with the lower extremity opposite the one measured positioned in hip and knee flexion so that the foot rested flat on the table. The thigh of the limb to be measured was held in 90 degrees of flexion relative to the trunk. The knee was extended passively to the point of initial resistance perceived by the examiner (CSL). The gravity goniometer then was placed along the midshaft of the tibia to measure the angle of knee extension. The two-joint hip flexor muscle length was indicated using the method described by Kendall and McCleary.\textsuperscript{17} Two measurements of each muscle length were averaged and referred to as the mean ROM reflecting the hamstring and hip flexor muscle lengths.

**Data Analysis**

Descriptions of the central tendency and variability of the data were included in the statistical analysis. The variables observed included the degree of lumbar curvature in the three different positions (ie, sitting in the BMC, sitting in the SCC, and standing), knee and hip joint ROM as an indication of hamstring and hip flexor muscle length, age, number of hours estimated by the subjects spent sitting each day, right leg length, and upper body length. Pearson product-moment correlation coefficients ($r$) were used to show the associations between these variables. The difference (in degrees) between the lumbar curve in standing and the lumbar curve in
Table 2. Descriptive Values for Measured Variables (N = 61)

<table>
<thead>
<tr>
<th>Variable*</th>
<th>X</th>
<th>SD</th>
<th>Range</th>
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</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>25.15</td>
<td>2.54</td>
<td>(20.00–30.00)</td>
</tr>
<tr>
<td>HRS-SIT</td>
<td>7.80</td>
<td>2.40</td>
<td>(4.00–14.00)</td>
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<tr>
<td>LL (cm)</td>
<td>84.00</td>
<td>3.44</td>
<td>(77.00–91.00)</td>
</tr>
<tr>
<td>UBL (cm)</td>
<td>92.84</td>
<td>3.71</td>
<td>(85.00–101.00)</td>
</tr>
<tr>
<td>HFL (°)</td>
<td>15.90</td>
<td>7.71</td>
<td>(1.75–44.75)</td>
</tr>
<tr>
<td>HSL (°)</td>
<td>43.40</td>
<td>5.70</td>
<td>(32.25–54.00)</td>
</tr>
<tr>
<td>STD-LC (°)</td>
<td>34.41</td>
<td>9.85</td>
<td>(18.29–62.96)</td>
</tr>
<tr>
<td>SCC-LC (°)</td>
<td>-6.54</td>
<td>11.70</td>
<td>(-31.76–22.14)</td>
</tr>
<tr>
<td>BMC-LC (°)</td>
<td>2.40</td>
<td>11.50</td>
<td>(-27.85–23.60)</td>
</tr>
<tr>
<td>STD-BMC (°)</td>
<td>32.01</td>
<td>12.20</td>
<td>(-0.23–56.95)</td>
</tr>
<tr>
<td>STD-SCC (°)</td>
<td>40.96</td>
<td>12.56</td>
<td>(5.23–65.60)</td>
</tr>
<tr>
<td>DIF-CHR (°)</td>
<td>8.95</td>
<td>8.71</td>
<td>(-13.83–34.62)</td>
</tr>
</tbody>
</table>

*HRS-SIT = number of hours sitting per day; LL = leg length; UBL = upper body length; HFL = average hip flexor muscle length; HSL = average hamstring muscle length; STD-LC = average lumbar curve during standing; SCC-LC = average lumbar curve during sitting in standard conventional chair; BMC-LC = average lumbar curve during sitting in Balans Multi-Chair; STD-SCC = average difference in lumbar curvature between standing and sitting in standard conventional chair; STD-BMC = average difference in lumbar curvature between standing and sitting in Balans Multi-Chair; DIF-CHR = average difference in lumbar curvature between sitting in standard conventional chair and sitting in Balans Multi-Chair.

The two chairs was related to each independent variable using a stepwise linear multiple-regression analysis. A Student's paired t test was used to determine the mean difference between lumbar curves in the two sitting positions. The .05 level of probability was accepted as the criterion for statistical significance.

**Results**

Thirty-three subjects were between the ages of 20 and 25 years, and 28 subjects were between the ages of 26 and 30 years. Table 2 provides descriptive statistics for central tendency and characteristics of the subjects. The sample studied was a group of relatively young adults who estimated that they spent 7.8 hours (SD = 2.4) per day sitting. Subjects varied little in upper body height, leg length, and hamstring muscle length. The mean lumbar curve in the standing position was 34.4 degrees (SD = 9.8). The mean lumbar curve in the SCC was negative, indicating lumbar flexion, whereas the mean lumbar curve in the BMC was positive, indicating lumbar extension when compared with the mean lumbar curve for standing. A majority of subjects had short hip flexor muscles, according to Kendall and McCreary's test for this muscle's length. A larger mean difference in curvature was found between standing and sitting in the SCC (X = 41.0°, SD = 12.6°) than between standing and sitting in the BMC (X = 32.0°, SD = 12.2°).

Comparison of the subjects' lumbar curvature in each chair revealed that the lumbar curves were in approximately 9 degrees more extension in the BMC than in the SCC (P < .05). A linear regression analysis revealed a significant relationship between sitting order and the degree of lumbar curvature (F = 4.35, P = .04, R² = .08).

Table 3 documents the correlation coefficients between all variables. A significant relationship was found between hip flexor muscle length and the difference between lumbar curves in standing and in sitting on the SCC (r = .25, P = .048). The other significant correlation occurred between leg length and the degree of lumbar curvature in the BMC. As leg length increased, the amount of lumbar extension decreased (r = -.28, P < .05).

The stepwise linear multiple-regression analysis confirmed that hip flexor muscle length was a significant predictor of the difference in lumbar curvature between standing and sitting in the BMC (F = 10.43, P = .03, R² = .20). A regression analysis also confirmed the significant relationship between hip flexor muscle length and the difference in lumbar curvature found between standing and sitting in the SCC (F = 5.20, P = .03, R² = .20). Table 2 identifies the variables used in the stepwise linear multiple-regression analysis.

**Discussion**

One purpose of this study was to determine the relationship between the
Table 3. Summary of Product-Moment Correlation Coefficients (r) for All Variablesa (N = 61)

<table>
<thead>
<tr>
<th>Variable</th>
<th>STD-BMC</th>
<th>STD-SCC</th>
<th>DIF-CHR</th>
<th>STD-LC</th>
<th>BMC-LC</th>
<th>SCC-LC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>-.08</td>
<td>-.17</td>
<td>-.14</td>
<td>-.19</td>
<td>-.08</td>
<td>.03</td>
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<td>.02</td>
<td>.02</td>
<td>-.004</td>
<td>.13</td>
<td>.09</td>
<td>.09</td>
</tr>
<tr>
<td>LL</td>
<td>.10</td>
<td>.01</td>
<td>.12</td>
<td>-.20</td>
<td>-.28b</td>
<td>-.19</td>
</tr>
<tr>
<td>UBL</td>
<td>.06</td>
<td>.02</td>
<td>-.06</td>
<td>.01</td>
<td>-.06</td>
<td>-.02</td>
</tr>
<tr>
<td>HSL</td>
<td>.16</td>
<td>.13</td>
<td>-.02</td>
<td>.25</td>
<td>.04</td>
<td>.06</td>
</tr>
<tr>
<td>HFL</td>
<td>.34b</td>
<td>.25b</td>
<td>-.11</td>
<td>.25</td>
<td>-.15</td>
<td>-.06</td>
</tr>
</tbody>
</table>

*aSee Tab. 2 for definitions of variables.

bP < .05.

For all variables, the results of the study indicate that when subjects sit in the two chairs, there is a difference in their lumbar curves. The reason for this difference, however, remains unknown. Frey and Tecklin16 based their findings on the relationship between pelvic tilt and the degree of curvature in the lumbar spine. Walker et al25 found no relationship between pelvic tilt and lumbar lordosis in the standing position. Walker et al25 used a similar measure of lumbar curvature as in this study except that the flexible ruler was placed from the L-3 to the S-2 spinous processes. Toppenberg and Bullock19 examined the relationship of spinal curvature to muscle length in healthy adolescent female subjects. They also found no relationship between pelvic tilt and lumbar curvature. Longer abdominal muscle length and shorter erector spinae muscle length were associated significantly with a greater degree of lumbar curvature. Of the lower extremity muscle groups studied, only hamstring muscle length was related significantly to the lumbar curve, and, interestingly, negatively related (ie, shorter hamstring muscles were associated with a greater lumbar anterior curvature).19 Differences in the methods of measuring the spinal curve and muscle length and in the gender of the subjects make comparison of findings between these studies difficult.

Few studies have measured the relationship between hamstring and hip flexor muscle lengths and the degree of lumbar curvature in sitting subjects. In contrast to the research findings of Toppenberg and Bullock,19 Kendall and McCreary's17 personal observations suggest that individuals with a "flat" back or reduced lumbar curvature in standing tend to have short, or "tight," hamstring muscles. In Kapandji's18 opinion, the hamstring muscles are responsible for actively restoring the anteriorly tilted pelvis to a neutral position during standing and the degree to which the hamstring muscles act on the pelvis depends on the knee and hip angles and on the inherent muscle length. The hamstring muscles may be stretched when sitting with the knees extended, but they may be placed in a neutral position, or "on slack," when sitting in a chair with the knee flexed. When sitting in the SCC or the BMC, the knee is flexed greater than 90 degrees, putting the hamstring muscles in a slackened position. The lack of a significant correlation between the lumbar curve in a sitting position and hamstring muscle length may be due to the inefficiency of muscle action in these relatively slackened positions. Alternatively, these results may be attributable to the small knee and hip joint ROMs used as an indicator of hamstring muscle length in this study (X = 43.4°, SD = 5.7°, range = 32.2°–54.0°).

A significant relationship existed between the indicator of hip flexor muscle length and the difference in lumbar curvature between standing and sitting in either chair. The positive relationship suggests that as hip flexor muscle length decreased, the differences in lumbar curvature between standing and sitting in either chair increased. These larger differences in lumbar curvature suggest that as lumbar flexion increased, hip flexor muscle length decreased. According to the opinion of Kendall and McCreary,17 shortness of the hip flexor muscles produces different effects on the lumbar curve in the standing and sitting positions. In standing, hip flexor muscle shortness increases the degree of lumbar extension because of the anteriorly tilting forces exerted on the pelvis by the iliacus, tensor fasciae latae, and rectus femoris muscles.17 In theory, psoas muscle tightness would pull the lumbar vertebrae directly into more extension during standing.17 During sitting, the hips are flexed; this flexion puts the psoas muscles on slack, thus diminishing their influence on the lumbar curve.
These differing effects on the spine in sitting and standing may explain why the subjects with hip flexor muscle shortness in our study showed increased spinal flexion when sitting in either chair. Subjects with short hip flexor muscles demonstrated more extension in standing than subjects with longer hip flexor muscles; therefore, we believe they had a greater capacity for change.

Age correlated positively with hamstring muscle length \((r = 0.27, P = 0.03)\) and negatively with hip flexor muscle length \((r = -0.31, P = 0.01)\). These results indicate that, with age (in the 20- to 30-year-old range), the hamstring muscles increased in length, whereas the hip flexor muscles decreased in length. These relationships may reflect the relatively large number of hours these subjects sat per day, as many were medical students who spent a considerable amount of time in the classroom.

Leg length and the lumbar curves of subjects sitting in the BMC showed a negative correlation \((r = -0.30, P = 0.03)\). Subjects with long legs had less-pronounced lumbar curves when sitting in the BMC compared with subjects with shorter legs. This finding may be a result of the investigators not adjusting the height of the BMC to accommodate different leg lengths. Subjects with long legs may have had to sit further back on the seat than those with shorter legs, thus having a greater distance to reach the desk. If the BMC seat height had been adjusted according to leg length, the correlation might not have been significant.

Over 50% of the subjects in Frey and Tecklin’s study were in lumbar flexion during sitting in the BMC. In contrast, only 36% of the subjects in our study demonstrated some degree of lumbar flexion while sitting in the BMC. When the two curves were compared directly, the subjects had more extension in the BMC than in the SCC. When muscle length and the lumbar curvature in the standing position were taken into account, however, more lumbar flexion occurred in both chairs as hip flexor muscle length decreased.

The BMC is designed to maintain a neutral lumbar curve when sitting and is sometimes recommended for use by patients with LBP. When prescribing a chair for patients with back problems, the clinician should determine the effects of various positions on the patient’s symptoms. A careful analysis of posture and flexibility should be performed to determine the potential influence of these factors on the patient’s ability to assume the desired position. The results of this study suggest that hip flexor muscle length affects the lumbar curve and is an important factor to consider before selecting the BMC as a means of maintaining optimal positioning for an individual.

Suggestions for future studies are 1) investigating the long-term effects of sitting in the BMC; 2) correlating muscle length, pelvic tilt, and lumbar curve measurements; 3) measuring the three hip flexor muscles separately to determine their individual effects; and 4) studying subject groups of different age groups and gender.

Conclusions

A significant difference was demonstrated between the lumbar curves of subjects sitting in the two types of chairs. Subjects generally had more extension in the BMC than in the SCC when comparing the two curves directly. When taking muscle length into account, however, the shorter the hip flexor muscles, the greater the difference between the lumbar curves of the subjects in the standing and sitting positions. Subjects had more relative lumbar flexion while sitting in either chair as hip flexor muscle shortness increased.

References


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