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Gender Differences in Spinal Morphological Attributes among Young Adults: A Preliminary Study

(Perbezaan Jantina dalam Ciri-ciri Morfologi Tulang Belakang dalam Kalangan Orang Dewasa Muda: Kajian Awal)

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ABSTRACT

There is limited information regarding gender differences in spinal morphological attributes among healthy young adults although alterations have been reported to influence postural changes, mainly with forward-bending and extension postures. The aim of this preliminary study was to examine gender differences in spinal morphological attributes of lumbar extensor muscles that includes its muscle fibre angles, thickness, endurance and thoracolumbar curvature among young adults. Nineteen male and 26 female healthy young adults (aged 21-24 years) matched for age, body mass index and physical activity levels participated in this preliminary study. Fibre angles and thickness of lumbar extensor muscles were examined using ultrasonography. Lumbar extensor muscle endurance and thoracolumbar curvatures were assessed using Sorenson's test and a flexible ruler respectively. Paired t-test showed a significant mean difference ($p < 0.01$) between the right and left fibre angles. However, no significant mean difference ($p = 0.50$) was found between the right and left muscle thickness. Results of independent t-test showed a significant difference ($p < 0.01$) in muscle thickness between males and females. No significant differences were shown in right fibre angle ($p = 0.12$), left fibre angle ($p = 0.89$), muscle endurance ($p = 0.46$), thoracic curvature ($p = 0.76$) and lumbar curvature ($p = 0.06$) between genders. There were no gender differences in spinal morphological attributes except for lumbar extensor muscle thickness in young adults age between 21 to 24. This study data may be useful as an initial reference norm of spinal morphological attributes among young adults. Further studies may be required to examine the factors that may influence changes in spinal morphological attributes among healthy adults.

Keywords: Lumbar extensor muscles; muscle geometry; physical activity; thoracolumbar curvatures; fibre angles

ABSTRAK

Terdapat maklumat yang terhad mengenai perbezaan jantina dalam ciri morfologi tulang belakang di kalangan orang dewasa muda sihat walaupun perubahan dilaporkan akan mempengaruhi perubahan postur, terutamanya postur bongkok ke depan dan postur ektensi. Tujuan kajian awal ini adalah untuk mengkaji perbezaan jantina dalam ciri-ciri morfologi tulang belakang otot ekstensor lumbar termasuk sudut gentian otot, ketebalan, ketahanan dan kelengkungan torakolumbar di kalangan orang dewasa muda. Sembilan belas orang lelaki dan 26 orang wanita dewasa muda sihat (berumur 21-24 tahun) yang dipadankan umur, indeks jisim badan dan tahap aktiviti fizikal mengambil bahagian dalam kajian awal ini. Sudut gentian dan ketebalan otot ekstensor lumbar diperiksa menggunakan ultrasonografi. Ketahanan otot ekstensor lumbar dan kelengkungan torakolumbar diukur menggunakan ujian Sorenson dan pembaris fleksibel, masing-masing. Hasil ujian T berpasangan menunjukkan perbezaan min yang signifikan ($p <0.01$) di antara sudut gentian kanan dan kiri. Walau bagaimanapun, tiada perbezaan yang signifikan ($p = 0.50$) di antara ketebalan otot kanan dan kiri. Ujian t tidak bersandar menunjukkan perbezaan yang signifikan ($p < 0.01$) bagi ketebalan otot antara lelaki dan perempuan. Tiada perbezaan yang signifikan dalam sudut gentian kanan ($p = 0.12$), sudut gentian kiri ($p = 0.89$), ketahanan otot ($p = 0.46$), kelengkungan torasik ($p = 0.76$) dan kelengkungan lumbar ($p = 0.06$) di antara jantina. Tidak ada perbezaan jantina dalam ciri morfologi tulang belakang kecuali pada ketebalan otot ekstensor lumbar di usia muda antara umur 21 hingga 24 tahun. Data kajian ini berguna sebagai nilai rujukan awal ciri morfologi tulang belakang di kalangan orang dewasa muda. Kajian lanjutan mungkin diperlukan untuk mengkaji faktor-faktor yang mungkin mempengaruhi perubahan dalam ciri morfologi tulang belakang di kalangan orang dewasa sihat.

Kata kunci: Otot ekstensor lumbar; geometri otot; aktiviti fizikal; lengkungan torakolumbar; sudut gentian

INTRODUCTION

Movements and force generation is the basic function of skeletal muscle (Frontera & Ochala 2015; Oatis 2004). The amount of force produced by a muscle is affected by its morphological attributes that includes its musculoskeletal system. For example, deterioration in lumbar extensor muscle strength is linked to its altered fibre angles and thoracolumbar curvature (Singh et al. 2010; Singh et al. 2011a; Singh et al. 2011b; Singh et al. 2013). Lumbar extensor muscles are primarily postural muscles that maintain spinal posture and functional performance (Palastanga et al. 2006).

A relationship was found between lumbar extensor muscle strength and its fibre angles, but its muscle fibre angles did not appear to be a predictor of its strength (Singh et al. 2013). Furthermore, poor lumbar extensor muscle endurance over a period of time led to decline load transference and increased mechanical stress on other supporting musculoskeletal structures (Kisner & Colby 2012). This may result in low back pain (Nourbakhsh & Arab 2002).

Muscle strength and geometrical differences in the human spine across the lifespan between genders affect function (Peters et al. 2014; Singh et al. 2013; Marras et al. 2001; Marras et al. 2002). The mean width and height of vertebral bodies in males were found to be significantly larger compared to in females (Bonivtch et al. 2006). Moreover, lumbar extensor muscle strength was found to be greater in males but it had a proportional greater loss in strength compared to women with increased age (Sinaki et al. 2001). This reduction in back extensor muscle strength in women coincided with increased body mass index and decreased level of physical activity with age (Sinaki et al. 2001). The rate of decline in older women in lumbar extensor muscle strength was approximately two times higher than older men (Singh et al. 2013).

Thoracolumbar curvatures are designed to absorb shock, increase spinal range of motions and enhance muscle performance (Damascenes et al. 2006; Solberg 2008). Thoracolumbar curvature changes have been reported to be influenced by age and gender (Lariviere et al. 2003). In the study by Singh et al. (2013), it was found that age was negatively correlated with lumbar extensor muscle fibre angles ($r = .40, p < 0.01$). Although strongly associated with lumbar extensor muscle strength, gender accounted for 53% and 21% of the variation in lumbar muscle strength among older and younger adults respectively, indicating that trunk muscle strength did not occur in a linear pattern with age (Singh et al. 2013).

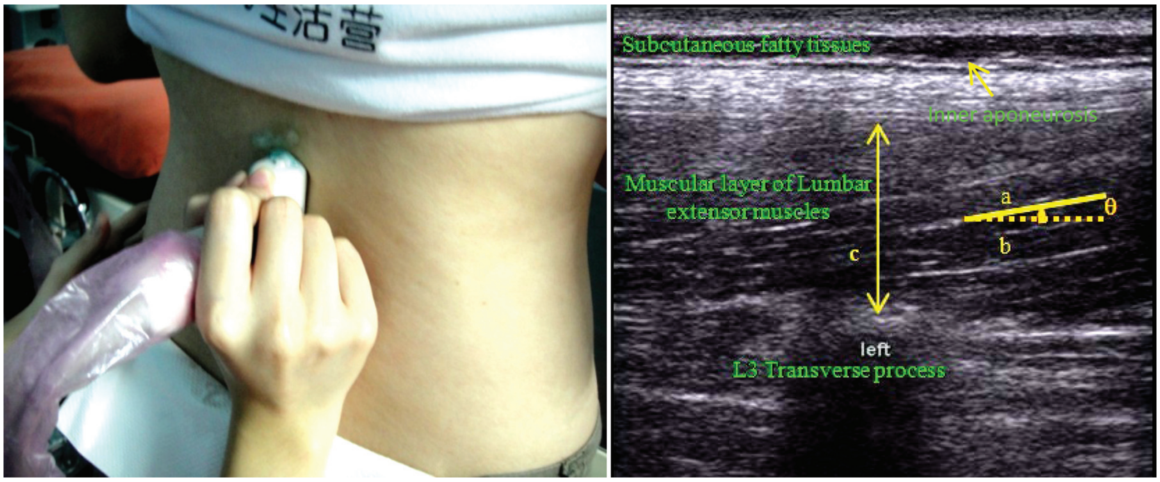
There is limited understanding of gender differences in spinal morphological attributes among young adults. A study on plantar and dorsiflexors in younger participants demonstrated that tibilias anterior, medial gastrocnemius and soleus pennation angles were significantly larger in males in comparison to females (Manal et al. 2006). The implications of these differences with impairments are not fully understood. Knowledge about gender differences in spinal morphological attributes among healthy adults is important for further understanding and comparative purposes when examining groups with impairments. The aim of this preliminary study was to examine gender differences in spinal morphological attributes that includes lumbar extensor muscle geometry (fibre angles, thickness), endurance and thoracolumbar curvatures among young adults.

EXPERIMENTAL METHODS

A total sample size of 52 participants (26 in each group) was deemed sufficient to demonstrate a significant difference ($p < 0.05$) between 2 groups based on previous data of fibre angles with an effect size of 0.80. Participants were recruited using study information flyers. Participants with known history of spinal disease, back surgery, pregnancy or with body mass index (BMI) more than 25 kgm^{-2} were excluded. We excluded those with BMI more than 25 kgm^{2} due to the difficulty in obtaining clear images of the muscle in these participants. Ethical approval was obtained from the Secretariat for Research and Ethics Committee, Universiti Kebangsaan Malaysia (UKM1.5.3.5/244/SPP/NN-173-2010). Written informed consent was obtained from all participants prior to data collection.

To capture lumbar extensor muscle images for fibre angles and muscle thickness measurements, we used an ultrasound machine (Siemens Acuson x300, Siemens Medical Solutions USA, Inc). Ultrasound imaging was performed by a radiographer trained to do ultrasound imaging. Ultrasound imaging was performed with a 7.5 linear array ultrasound probe, at the level of the 3rd lumbar spinal vertebra (Figure 1(a)) while standing with both feet at shoulder-width apart. The 3rd lumbar spinous process was palpated by a final year physiotherapy undergraduate and transducer was rotated on the 3rd lumbar spinous process, moving laterally 3 to 4 cm to locate the echogenic transverse processes (Watanabe et al. 2004). The reason for imaging at the 3rd lumbar process was because it lies in the midpoint of the lumbar curve. Images of both the left and right lumbar extensor muscles were captured and saved for further analysis (Figure 1(b)). The fibre angles and muscle thickness were analyzed using MATLAB® (The mathworksInc.MA, US) image processing software. Fibre angles was measured as described in a previous study by Singh et al. (2011a) and muscle thickness was the distance between the inner layers the muscle aponeuroses.

Sorenson's test (Biering-Sorensen 1984) was used to assess lumbar extensor muscles endurance. Participant lied on their tummy with the upper body out of the bed and iliac crest aligned to the plinth edge (Tekin et al. 2009) (as shown in Figure 2). The lower body was strapped to the plinth at three positions: at the ankles as close to the malleoli as possible, at knee crest, and at the level of greater trochanter of femur. The straps were tightened as



(a) (b)

FIGURE 1. Ultrasound imaging of lumbar extensor muscle at the 3rd lumbar spinal vertebral level (a) and an ultrasound image of lumbar extensor muscle (a = fibre nearest to midpoint of lumbar extensor muscles; b = line parallel to inner skin layer; c = thickness of lumbar extensor muscles; θ = fibre angle of lumbar extensor muscles) (b)

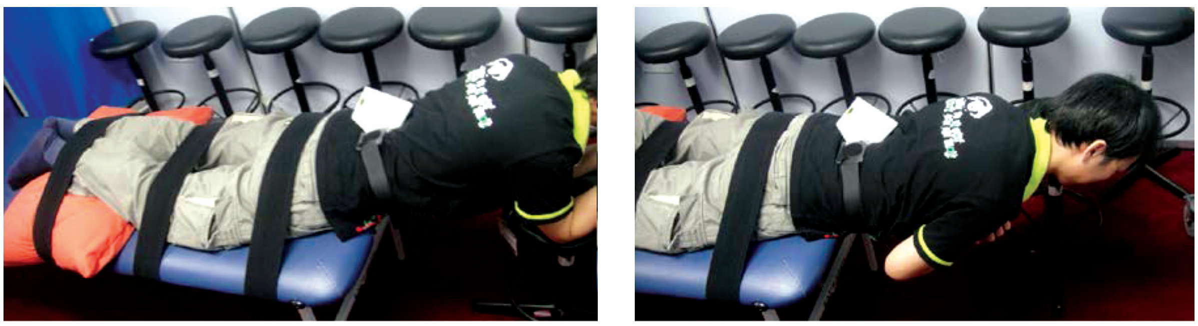


FIGURE 2. Measurements of lumbar extensor muscle endurance using Sorenson's test

firm as possible while considering participant's comfort. The duration participants were able to hold in horizontal trunk position was recorded in seconds. An inclinometer was placed in the first sacral (S1) to ensure that there was no deviation of more than 10 degrees from horizontal.

A flexible ruler (Figure 3(a)) was used to measure thoracolumbar curvature, in terms of degree of the thoracic and lumbar curvature (Seidi et al. 2009). Participants were requested to stand in a relaxed posture while their backs were exposed. Seventh cervical (C7), twelve thoracic (T12), first lumbar (L1) and second sacral (S2) spinous process were palpated. The flexible ruler was molded on the mid-line contour of the spine (Figure 3(a)). It was carefully removed and traced onto a piece of paper. A vertical line was drawn to connect the T12 and S2 (represented by L2) landmarks as the total length of curvature of lumbar curvature and C7 to T12 (represented by L1) landmarks as the total length of thoracic curvature. The maximum width of the curvature was measured in centimeters and used to calculate the degree of lumbar curvature (represented by H2) and thoracic curvature (represented by H1) (Figure 3(b)) using Eqn. (1).

$$\theta = 4(\arctan(2H/L)). \tag{1}$$

In Eqn. (1), θ = the angle of the measured curvature; H = the maximum width of the curvature; L = the total length of the curvature. Results were analyzed using SPSS (Statistical Package for the Social Sciences) version 17.0. Paired t test was used to analyze the left and right lumbar extensor muscle fibre angles and thickness. Independent t test was used to examine lumbar extensor muscle fibre angle, thickness, endurance and thoracolumbar curvature between genders.

RESULTS

Forty-five participants aged between 21-24 years (19 males and 26 females) matched for age, body mass index and physical activity levels from a local university participated in this study. The mean age of the participants was 22.44 years with mean body mass index of 19.39 kgm^{-2}. Total physical activity score of 8.25 (indicating moderate level) was measured using Baecke Physical activity questionnaire (Baecke et al. 1982) among both groups.

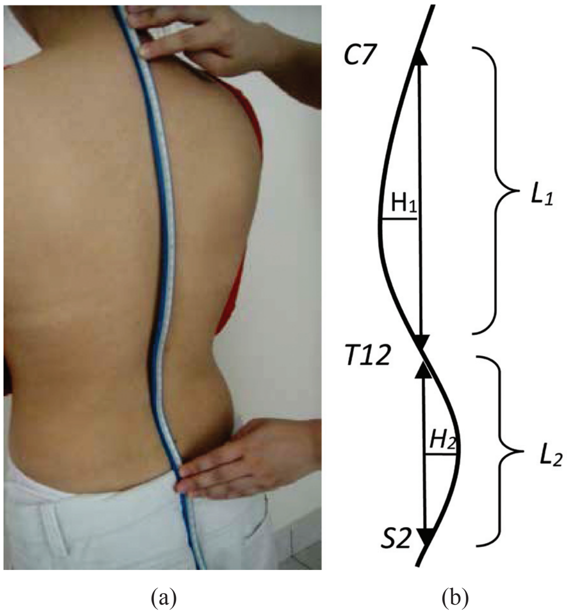


FIGURE 3. Measurements of the degree of thoracic and lumbar lordosis using a flexible ruler (a) and an illustration of thoracolumbar curvature measurement performed in the study (L_1 = total length of thoracic curvature; L_2 = total length of lumbar curvature; H_1 = maximum width of thoracic curvature; H_2 = maximum width of lumbar curvature (b).

A significant difference with $t(44) = 3.22$, $p = < 0.01$ was demonstrated between the right and left lumbar extensor muscle fibre angles. Hence, the left and right lumbar extensor muscle fibre angles were analyzed separately. However, no significant difference with $t(44) = 0.68$, $p = 0.50$ was found between the right and left lumbar extensor muscle thickness. The left and right lumbar extensor muscle thickness were combined as mean lumbar extensor muscle thickness for further analysis.

Mean, standard deviation (*SD*) values, range and *p*-values of each variable measured are as presented in Table 1. Independent *t*-test results showed a significant ($p < 0.05$) difference in lumbar extensor muscle thickness between genders. However, no significant differences were found in right and left fibre angles, muscle endurance, thoracic kyphosis and lumbar lordosis curvatures between genders.

DISCUSSION

The main aim of this preliminary study was to examine if there was gender differences in spinal morphological attributes of lumbar extensor muscle that included its muscle fibre angles, thickness, endurance and thoracolumbar curvature among young adults. The results of this preliminary study demonstrated that there is a significant gender difference in lumbar extensor muscle thickness but not in its muscle fibre angles, endurance and thoracolumbar curvatures in young adults age between 20-24 years.

Lumbar extensor muscle in males was significantly thicker compared to females, ranging from 0.5 mm to 2.8 mm. This result is consistent with other study reports. Males were noted to have thicker abdominal muscles (Kanehisa et al. 2006; Rho et al. 2013; Tahan et al. 2016). Muscle thickness and its cross sectional area is related to muscle strength (Muraki et al. 2013). Our study results suggest that males have stronger lumbar extensor muscle. It is known that men have larger muscles and muscle mass compared to women, which explains its greater strength.

A significant difference between left and right lumbar extensor muscle fibre angles was demonstrated in our study results. The left lumbar extensor muscle fibre angle was smaller than the right in both males and females. Our teams' previous study (Singh et al. 2011a) showed otherwise. Although males had larger muscle thickness in our study, no significant difference was demonstrated in fibre angles between genders. This result is contradictory to previous findings, showing larger fibre (pennation)

TABLE 1. Mean (*SD*), range and *p*-values of spinal morphological attributes in young adults

Variables	Gender	Mean (SD)	Range	*t*(43)	*p*-value
Right lumbar extensors muscle fibre angle (degrees)	Males Females	11.76 (4.99) 9.62 (4.08)	3.00-20.26 0.30-18.85	1.58	0.12
Left lumbar extensors muscle fibre angle (degrees)	Males Females	7.96 (5.11) 7.77 (3.93)	0.70-18.01 1.79-16.84	0.14	0.89
Lumbar extensors muscle thickness (cm)	Males Females	2.44 (0.28) 1.97 (0.30)	1.74-2.98 1.22-2.55	5.30	0.01
Lumbar extensors muscle endurance (cm)	Males Females	138.37 (54.59) 126.50 (50.31)	66.00-240.00 44.00-240.00	0.75	0.46
Thoracic curvature (degrees)	Males Females	32.51 (9.19) 31.60 (10.12)	13.98-46.85 8.81-51.34	0.31	0.76
Lumbar curvature (degrees)	Males Females	40.84 (11.94) 46.66 (8.31)	21.51-64.18 26.68-59.56	1.93	0.06

angles in ankle muscles (Manal et al. 2006). We deduce that besides gender, age, body mass index, position, muscle contraction state (in rest or during contraction), muscle specific, other unidentified conditions such as muscle adaptation and loading pattern could have influenced fibre angle measurements.

Similarly, no gender differences existed in lumbar extensor muscle endurance and thoracolumbar curvatures in our study results that involved young adults. These results are in agreement with the results of an earlier study reporting lumbar extensor muscle endurance among young males and females (Bayraktar et al. 2015). To the best of the authors' knowledge, there are no previous studies reporting thoracolumbar curvatures among healthy young adults. Concerning gender differences in thoracolumbar curvatures among adults, the results have been inconsistent (Lundsgaard & Kiens 2014).

Participants in our study were between age 20-24, an age span at the end of growth. Moreover, lumbar extensor muscle architecture is specific in the sense that its fibres have an oblique orientation but are not categorized as pennate muscles. Hence, the results may not be applicable to other age groups and across all muscles. Another limitation in our study was that the images of lumbar extensor muscle were taken at third lumbar vertebra level to ensure consistency of the results and cannot be generalized to other lumbar levels. We suggest comparison of spinal morphological attributes among young adults with and without impairments in future studies for further understanding.

Our study results should be treated cautiously as it is a preliminary study with limited sample size. However, information about gender differences in spinal morphological attributes have important scientific relevance. The findings of our study suggest that gender differences have to be taken into consideration in young adults when using lumbar muscle thickness parameter for modelling spinal force predictions. Clinically, this study data may be useful as an initial reference norm of spinal morphological attributes for comparative purposes when investigating young adults with impairments in the lumbar spine.

CONCLUSION

Our study results indicate that lumbar extensor muscle thickness is different by gender in young adults. However, there were no differences in the other spinal morphological attributes of lumbar extensor muscle (fibre angle, endurance and thoracolumbar curvatures). Further studies are required to understand gender ambiguity in spinal morphological attributes among young adults.

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