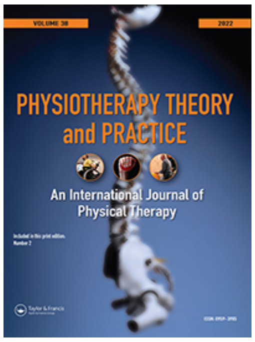

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The relationship between thoracic posture and ultrasound echo intensity of muscles spanning this region in healthy men and women

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ABSTRACT

Purpose: Skeletal muscle echogenicity intensity (EI) is considered a measure of muscle quality, being associated with old age and pathologies. Whether EI variations can be identified in healthy adults, due to habitual shortened or elongated muscle position is unknown. Thus, this study aimed to assess the relationship between thoracic kyphosis angulation and EI scores of muscles spanning this region ((Lower Trapezius (LT), Rhomboid Major (RM), Erector Spine (ES)) in healthy young people and in addition to examine the relationship between the change in thoracic kyphosis angle from relaxed to upright position (Δ°) and the EI of these muscles.
Methods: Thoracic kyphosis in relaxed and erect standing was measured using a digital inclinometer in 29 healthy adults (16 women, 13 men), aged 25–35 years. The thoracic kyphosis angles including the difference between relaxed and erect postures (Δ°) were correlated to the EI scores of right and left LT, RM and ES.
Results: No significant differences in EI were found between the 3 muscles EI or between sides, hence they were pooled together to a total thoracic EI score (TTEI). Although the TTEI did not correlate with relaxed or erect thoracic kyphosis, it was significantly but negatively correlated with Δ° in the entire group: Pearson's correlation coefficient of $r = -0.544$; $p = .01$ and in men; $r = -0.732$; $p = .01$, failing to reach significance in women; $r = -0.457$.
Conclusion: The negative association between the EI of the explored muscles and Δ° could imply a possible relationship between these muscles range of movement excursions and their composition.

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Ultrasound imaging; muscle echogenicity; thoracic kyphosis; posture

Introduction

The use of musculoskeletal ultrasound imaging has expanded in recent years to include the evaluation of soft tissues in the movement system (muscle, tendon, cartilage) (Özçakar et al., 2015). It is most effective for measuring muscle's architectural characteristics such as thickness, cross sectional area, fiber length, pennation angle (Özçakar et al., 2018; Scanlon et al., 2014), and echo intensity (EI) (Stock and Thompson, 2021) which relates to the level of sound wave return from muscle tissue on a scale of 0–255 grayscale with 0 = black and 255 = white. Its value depends on the extent of connective tissue interwoven in that muscle. The lesser the intra-muscular connective or adipose tissue infiltration is, the lower is the EI index and vice versa.

Preliminary studies have associated low EI values with stronger, healthier, and higher-quality muscles (Fukumoto et al., 2018; Ticinesi et al., 2018). On the other hand, skeletal muscles afflicted with functional and metabolic impairments (Paris, Bell, Avrutin, and Mourtzakis, 2020) as well as pathological or aging states (Yoshiko et al., 2018) have been associated with high EI. Pereira et al. (2020) referred to muscle echogenicity as a practical low-cost measure to assess muscle functionality (i.e. quality of muscle). They found that EI was positively associated with age, being higher in elderly people, positively associated with body mass index (BMI) and negatively associated with total lean body mass. Frank-Wilson et al. (2018) correlated older age with smaller quadriceps muscle mass and greater intramuscular adipose tissue area as can be assessed by EI, with slower rates of force development and lower peak isometric torques. Paris, Bell, Avrutin, and Mourtzakis (2020) referred to EI as a means for evaluating muscle tissue composition and quality.

However, whether variations in muscle composition, expressed by EI, can be identified in healthy, young adults due to habitual normal variation of muscle length or ability to change its length, remains unexplored. One venue for testing this question may be presented by the

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muscles that lie along the thoracic spine in healthy individuals, the multi-articular muscles: erector spinae (ES), lower trapezius (LT) and rhomboid major (RM), which may be influenced by the angular curvature of the thoracic kyphosis (TK). The normative range of the thoracic kyphosis angles is wide: 20°-50° (Prushansky et al., 2013) hence normal variations (i.e. not of pathological origin) of habitual relaxed TK posture as well as the range of change between a relaxed and upright posture may be manifested in those muscles' EI.

To the best of our knowledge, the relationship between TK angle and muscle EI in this area has not been investigated. Furthermore, the difference (Δ°, in degrees) between a relaxed and upright posture, which may be an indication of soft tissues flexibility as well as inter-vertebral joints/muscles mobility, may shed additional light on muscle condition in this area (Prushansky et al., 2013).

In order to eliminate the possibility that differences in the EI scores of the thoracic muscles were due to interpersonal EI variability, not related to posture, the EI of the anterior arm elbow flexors, biceps brachii (BB) and brachialis (BR) were also recorded bilaterally, in order to compare their EI to those of the thoracic region. The hypothesis of the current study was that there is a relationship between thoracic kyphosis and change of posture between relaxed and upright position and the morphology of muscles spanning this region, as expressed by their EI. In order to examine this hypothesis, the main objectives of the current study were therefore as follows: 1) assess the relationship between the angulation of the TK and EI scores of muscles spanning this region (LT, RM and ES) in healthy young people; and 2) examine the relationship between the change in TK angle from relaxed to an upright position (Δ°) and the EI of these muscles. Additional goals were to examine the effect of sex on the 2 main objectives and bilaterally compare the EI scores of the right and left thoracic area muscles.

Methods

Study design

The current study is a cross-sectional study.

Participants

A convenience sample of 29 healthy adults,16 women and 13 men, aged 25–35 years, were recruited from Tel Aviv University campus community. Sample size was calculated according to: Correlation sample size calculator (http://sample-size.net/correlation-sample-size/) with Threshold probability for rejecting the null hypothesis. Type I error rate α(two-tailed) = 0.05, Probability of failing to reject the null hypothesis under the alternative hypothesis. Type II error rate β = 0.2 and the minimum expected correlation coefficient r = 0.5. Total sample size = $N = [(Z_\alpha+Z_\beta)/C]^2 + 3 = 29$

Table 1. Demographic data (mean ± SD) of all subjects participating in the study.

	Group (n = 29)	Men (n = 13)	Women (n = 16)
Age (years)	30.5 ± 3.4	32.3 ± 2.5	28.9 ± 3.3
Height (cm)	170.8 ± 9.4	179.3 ± 4.9	164.0 ± 5.8
Weight (kg)	70.6 ± 14.2	81.8 ± 7.6	61.5 ± 11.7
BMI (kg/m^2)	24.0 ± 3.6	25.4 ± 2.5	22.8 ± 4.0

SD = standard deviation, cm = centimeter, kg = kilogram, m = meter, BMI = body mass index.

Inclusion criteria consisted of absence of musculoskeletal or neurological disorders, pain or discomfort in the shoulders or spine during the week prior to the testing session, participation in competitive sports or pregnancy. The demographic data of the participants is outlined in Table 1. The study was approved by the Institutional Review Board of Tel Aviv University on 15.8.19, approval number 0000114–1. All participants signed an informed consent form before starting the experiment.

Instruments

B-mode Ultrasound imaging device (SonoScape S2 portable digital color Doppler ultrasound system, Guangdong, China), was used to obtain and record ultrasound images. A 5.0 cm linear transducer (Model L741, 6–9 MHz) was used for the calculation of the EI.

Measurement of the TK angle was performed using a digital inclinometer (DI, Fennel, Germany) with a resolution of ±0.1°, to which a plastic ruler with two protruding 40 mm long pegs set 55 mm apart was attached to its underside (Figure 1). The DI was equipped with a 'hold' button that allowed 'freezing' of the displayed score in the measurement position, thus reducing the error due to further movement of the device (Prushansky et al., 2008).

Protocol

After signing the informed consent, subjects were given explanations regarding the procedure. The spinous processes of C7, T5 and T12 were then uniformly palpated in standing position, and marked with small color stickers to serve as anatomical landmarks for the measurements. Additional stickers were placed on the right and left anterior arm, 2/3 of the distance between the axillary fold and the medial epicondyle of the humerus.

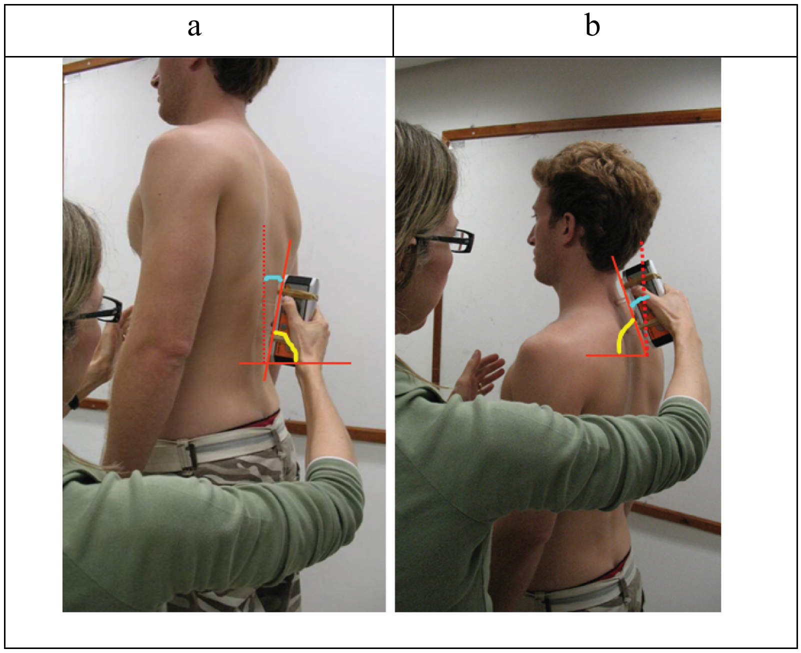

Figure 1. Measurements of thoracic kyphosis angle, using digital inclinometer. A) The lower peg of the inclinometer is positioned over T12 spinous process. B) The upper peg of the inclinometer is positioned over C7 spinous process.

Ultrasound images were obtained in the relaxed sitting position. The transducer was generously coated with water soluble transmission gel and was located with minimal compression 2 cm lateral to T5 spinous process (Figure 2(a)) so that a transverse image of thoracic ES, RM and LT, could be captured in one image (Figure 2(b)). Two images were obtained on the right and two on the left. Thereafter, two transverse ultrasound images were obtained on the right and left anterior arm to capture the BR and BB muscles. The same examiner obtained all images.

Reliability indices of Ultrasound imaging for evaluating muscle morphology are considered to be fair to excellent: Intra-rater of r = 0.72–0.999, 0.81–0.99, 0.73–0.99 for quadriceps, elbow flexors and trunk muscles, respectively (Nijolt et al, 2017). Intra-rater of ICC = 0.83–0.99 and inter-rater of 0.93–0.99 for thoracic paraspinal muscles (Zapata, Wang-Price, Sucato, and Dempsey-Robertson, 2015).

For measuring the TK angle, subjects were instructed to assume a relaxed barefoot standing position. The DI was first placed with the upper peg on C7 SP so that the lower peg was touching the skin below and the DI aligned with the sagittal plane and the related angle captured (Figure 1(a)). Next, the DI was placed parallel to the sagittal plane, with the lower peg on the spinous process of T12 with the upper peg touching the skin above. The related angle was captured (Figure 1(b)) and recorded. The participant was then requested to stand as erect as possible, with the

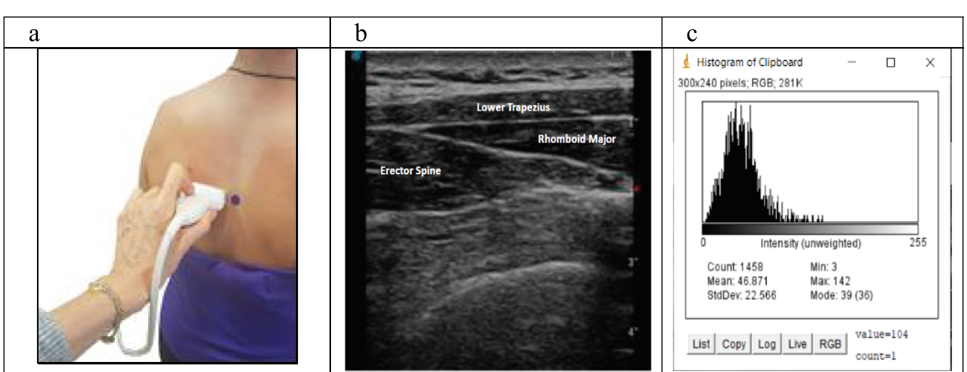

Figure 2. Location of the ultrasound transducer 2 cm lateral to T5 spinous process **(A)** for capturing a transvers image of lower trapezius, rhomboid major and thoracic erector spine **(B)** and ImageJ histogram analysis of Lower Trapezius region of interest (**C**).

feet flat on the floor and the eyes pointing forward. The same DI measurement procedure was repeated and then additional measurements of both postures took place in an identical manner. The same examiner performed and recorded all measurements. The angular value of the thoracic curve was calculated by adding the two complementary angles to those measured at T7 and T12 (Figure 1(a-b)).

The intra-tester reliability of the measurements using this device was found to be excellent with ICC = 0.92 and SEM = 2°, for measurements of sagittal pelvic posture, in young subjects (Prushansky et al., 2008). The intra-tester reliability of digital and analog inclinometer for measuring TK angle was found to be highly reliable with Cronbach's alpha of $0.9 > \alpha \geq 0.8$ and ICC = 0.95 and SEM = 1°, respectively (Barrett, McCreesh, and Lewis, 2014).

Muscle echogenicity analysis

All ultrasound images were processed using ImageJ image analysis software (National Institutes of Health, Bethesda, MD, USA, version 1.46) based on 0–255 grayscale level, expressed in arbitrary units (AU). Once an ultrasound image was uploaded, as large as possible region of interest (ROI) was carefully drawn with the polygon tracking tool, on each of the muscles, so that the ROI would not include bone or surrounding fascia (Caresio, Molinari, Emanuel, and Minetto, 2015). Means and standard deviations of each ROI's EI were calculated and depicted (Figure 2(c)). The mean value of EI relating to each of the muscles was calculated from the two images that were obtained. A total thoracic echo intensity (TTEI) score was calculated by averaging the EI of all the 3 muscles on both right and left sides, for each subject.

Data analysis

Analysis of the results was performed using SPSS version 25 (IBM Corp., Armonk, NY). The differences between men and women (age, height, weight, BMI) were compared using independent samples t-tests. Mixed design ANOVA was used for detecting differences between relaxed and erect thoracic kyphosis angle within subjects and between sexes as well as for analyzing differences between EI levels between sex and within muscles and sides. Paired samples t-tests were used to detect EI differences between muscles in the thoracic region and arm muscles. Pearson's r was used for correlating BMI, EI of thoracic angular values, EI of arm muscles and thoracic curve angular values in relaxed, erect and Δ° (Relaxed – Erect).

Results

Table 1 presents the demographic data of the participants. Men were significantly older ($t = 3.084$, $df = 27$, $p = .005$), taller ($t = 7.428$, $df = 27$, $p = .0001$), heavier ($t = 5.388$, $df = 27$, $p = .0001$) and had higher BMI ($t = 2.058$, $df = 27$, $p = .049$) compared to women in the respective groups.

Table 2 outlines the participants' TK angles in relaxed and erect postures, including the Δ° (i.e. relaxed to erect kyphosis). In the relaxed posture, men exhibited larger kyphosis curve in comparison to women, but this difference, did not reach significance ($t = 1.933$, $df = 27$, $p = .064$). In all participants thoracic curve angulation was reduced significantly upon changing from relaxed to erect posture by a mean of 9.3°±3.8 ($F_{(1,27)} = 164.912$, $p < .0005$), with no significant gender Δ° variation ($F_{(1, 26)} = 3.861$, $p = .06$).

Table 3 depicts the EI scores of the 3 muscles tested in the thoracic region and the two arm muscles, on the right and left sides, in both sexes and for the whole group. Each subject's representative score is the mean of two EI scores obtained from two ultrasound images.

No significant differences were found between the 3 muscles EI ($F_{(2, 54)} = 1.316$ $p = .277$) or between right and left sides ($F_{(1, 27)} = 1.316$, $p = .09$). Men had significantly lower EI scores compared to women ($F_{(1, 27)} = 4.855$, $p = .036$).

Since no significant differences were found between muscles and sides of the thoracic region they were all pooled together to yield a mean total thoracic echogenicity intensity score (TTEI).

The EI score of the Biceps was significantly lower in comparison to that of the Brachialis ($F_{(1, 27)} = 57.514$, $p = .0001$) in both sexes, i.e. there was no main effect of sex ($F_{(2, 27)} = 3.805$, $p = .062$). Right side muscles had significantly lower EI score in comparison to the left side ($F_{(1, 27)} = 12.581$, $p = .001$) without sex effect. Men had higher EI scores than women with respect to BR ($t = 2.618$, $df = 27$, $p = .014$) but not BB ($t = 0.405$,

Table 2. Thoracic kyphosis angles (mean ± SD), in relaxed and erect postures, including Δ° (difference, in degrees between thoracic curve in relaxed and in erect postures) for men, women, and group.

	Group (n = 29)	Men (n = 13)	Women (n = 16)
Thoracic Relaxed kyphosis (degrees)	35.8 ± 7.6	38.7 ± 7.4	33.4 ± 7.2
Thoracic Erect kyphosis (degrees)	26.5 ± 6.8	28.9 ± 7.0	24.4 ± 6.0
Δ° (Relaxed -Erect kyphosis)	9.3 ± 3.8	9.7 ± 3.2	8.9 ± 4.3

SD = standard deviation

Table 3. Subject's muscles echogenicity intensity (mean ± SD) in arbitrary units, for men, women and entire group, partitions to right and left sides, for the 3 thoracic and 2 arm muscles, as well as total thoracic echogenicity intensity score (TTEI) of all 3 thoracic muscles.

	Group (n = 29)			Men (n = 13)			Women (n = 16)		
	Right EI (AU)	Left EI (AU)	Total EI (AU)	Right EI (AU)	Left EI (AU)	Total EI (AU)	Right EI (AU)	Left EI (AU)	Total EI (AU)
Lower Trapezius	45.1 ± 14.5	44.1 ± 14.0	44.6 ± 13.0	39.9 ± 10.4	39.3 ± 9.0	39.6 ± 9.2	49.3 ± 16.2	47.9 ± 16.4	48.6 ± 14.5
Rhomboid Major	40.8 ± 14.5	39.8 ± 15.2	40.5 ± 13.5	35.5 ± 13.5	34.8 ± 10.9	35.1 ± 11.5	45.4 ± 14.2	43.9 ± 17.2	44.9 ± 13.8
Erector Spine	40.1 ± 13.4	43.0 ± 12.4	41.5 ± 12.0	37.8 ± 10.3	40.0 ± 12.4	38.9 ± 10.9	42.0 ± 15.5	45.4 ± 12.2	43.7 ± 12.8
Total Thoracic EI (TTEI)		42.2 ± 10.1			37.9 ± 8.5			45.7 ± 10.2	
Biceps Brachii	47.3 ± 12.3	53.5 ± 14.2	50.4 ± 12.5	47.8 ± 12.1	55.1 ± 12.9	51.5 ± 12.0	46.9 ± 12.8	52.2 ± 15.4	49.5 ± 13.2
Brachialis	68.5 ± 22.5	75.8 ± 23.4	72.1 ± 21.3	78.8 ± 23.9	86.4 ± 21.6	82.6 ± 20.1	60.1 ± 17.8	67.2 ± 21.7	63.6 ± 18.7

SD = standard deviation, EI = echogenicity intensity, TTEI = total thoracic echogenicity intensity (echogenicity intensity mean score of the 3 thoracic muscles on both sides), AU = Arbitrary Units.

df = 27, p = .689). This finding remained unchanged when the 4 men with left side dominance were omitted from the analysis (t = −3.408, df = 24, p = .002).

Comparing the TTEI to BB and BR revealed that the TTEI was significantly lower in comparison to either BB (t = −3.843, df = 28, p = .001) or BR (t = −7.079, df = 28, p = .0001) (both sides pooled together). In men, the TTEI was also significantly lower than the BB (t = −4.793, df = 12, p = .0001) or BR (t = −8.417, df = 12, p = .0001) while in women, this was valid only with respect to the BRs (t = −3.943, df = 15, p = .001), but not the BB (t = −1.412, df = 15, p = .178).

Tables 4a, 4b, 4c, depict the Pearson's r correlations coefficients between BMI, TTEI, and the corresponding EIs of the BB and BR and the angular values of thoracic relaxed, erect and Δ° kyphosis curves in men, women and the entire groups. The BMI was significantly associated with relaxed and erect thoracic curves in the whole group and when split by sex.

The relaxed and erect thoracic curves were significantly correlated in the entire group and in both sexes. The TTEI was significantly correlated with Δ° in the entire and men groups, but did not reach significance in women's group. The BB's EI was significantly associated with TTEI in the gender- as well as in the pooled groups while the BR's EI and the TTEI was not. However, the BR's EI was significantly associated with that of the BB in the entire and in both genders.

Discussion

The main objective of the current study was to find out whether long term habitual anatomical configuration of muscles may be correlated to their composition, as expressed by their EI scores. The muscles spanning the TK were chosen as candidates for this enquiry, since the normative range of the thoracic kyphosis values, in healthy individuals, is extremely wide: 20–50° (Prushansky et al., 2013). This inter-subject variability may cause these muscles to be in various habitual but normal lengths, which might be related to morphological changes. The TK values were measured using a DI, in relaxed and erect positions, and the obtained scores, including the Δ° between the two values, were correlated with the EI scores of the LT, RM and the thoracic ES.

Focusing first on the TK, the kyphosis angle was 38.7° ±7.4 and 33.4°±7.2 for men and women respectively, with no significant difference between the sexes. Those values are in accord with a recent study (Yukawa et al., 2018) that measured sagittal spinal curves in free standing spine radiograph, and found a non-significant difference between men 34.9° ± 8.1 and women 33.9° ± 9.1, in the 3rd decade. They did find though a significant difference between men 37.3°±9.1 and women 33.4° ±9.0 in the 4th decade, and indicated that between the 3rd and 8th decade, the men's TK was larger than the women's, but this difference did not always reach significance.

When asked to assume a maximal erect posture, both sexes straightened their thoracic curve significantly, (Δ°) by an average of 9.3°± 3.8, albeit with no significant difference between men 9.7°±3.2 and women 8.9°±4.3. The ability to actively straighten the thoracic curve depends on soft tissues flexibility as well as on the inter-vertebral joints mobility (Prushansky et al., 2013) and on normally acting muscular pull forces. Age-related differences in TK and postural stiffness were documented between younger and older women by means of repeated flexicurve measurements performed in both a relaxed and a maximally erect position (Hinman, 2004). In addition, Roghani et al. (2019) found that age-related hyperkyphosis (i.e. Thoracic Kyphosis angle ≥ 50°) was associated with decreased static maximal force and endurance of the back extensor muscles and that during a dynamic flexion-extension task, there was prolonged silence of the erector spinae muscles in the hyperkyphosis group compared with the group without hyperkyphosis. This may suggest a relation between muscle function and postural stiffness (i.e. thoracic hyperkyphosis and inability to change the thoracic posture).

Table 4. Pearson's correlation coefficients between BMI, total thoracic echogenicity intensity (TTEI), echogenicity intensities (EI) of biceps brachii and brachialis and the angular values of thoracic relaxed, erect and Δ° kyphosis curves for the entire group 4a (n = 29) for men 4b (n = 13) and women 4c (n = 16) groups.

4a Entire group						
Variables	BMI	Relaxed Kyphosis°	Erect Kyphosis°	Δ°	TTEI	R + L Biceps EI
BMI	1					
Relaxed Kyphosis°	0.637**	1				
Erect Kyphosis°	0.658**	0.865**	1			
Δ° Relaxed-Erect	0.104	0.459*	−0.049	1		
TTEI	−0.096	−0.383*	−0.124	−0.544**	1	
R + L Biceps EI	0.213	0.022	0.214	0.335	0.506**	1
R + L Brachialis EI	0.427*	0.063	0.212	−0.250	0.093	0.546**
4b Men group						
Variables	BMI	Relaxed Kyphosis°	Erect Kyphosis°	Δ°	TTEI	R + L Biceps EI
BMI	1					
Relaxed Kyphosis°	0.771**	1				
Erect Kyphosis°	0.812**	0.898**	1			
Δ° Relaxed-Erect	−0.001	0.332	−0.116	1		
TTEI	0.226	−0.238	0.091	−0.732**	1	
R + L Biceps EI	0.251	−0.148	0.070	−0.485	0.555*	1
R + L Brachialis EI	0.033	−0.309	−0.174	−0.325	0.325	0.494
4c Women group						
Variables	BMI	Relaxed Kyphosis°	Erect Kyphosis°	Δ°	TTEI	R + L Biceps EI
BMI	1					
Relaxed Kyphosis°	0.510*	1				
Erect Kyphosis°	0.534*	0.801**	1			
Δ° Relaxed-Erect	0.1	0.539*	−0.073	1		
TTEI	−0.016	−0.323	−0.058	−0.457	1	
R + L Biceps EI	0.18	0.102	0.314	−0.271	0.603*	1
R + L Brachialis EI	0.483	0.063	0.321	−0.347	0.332	0.640**

*correlation is significant at the 0.05 level (2-tailed); **correlation is significant at the 0.01 level (2-tailed); BMI = body mass Index, EI = echogenicity intensity, TTEI = total thoracic echogenicity intensity (echogenicity intensity mean score of the 3 thoracic muscles on both sides), Δ° = The difference (in degrees) between thoracic curve in relaxed and in erect postures, R = right, L = left.

A higher BMI was significantly related to increased thoracic curve angular values as measured by DI. This association was more pronounced in men who had significantly higher BMI compared to women and higher but not significantly larger thoracic curves. This may be due to thicker superficial soft tissue which is located over the spine. In another study, Hoseinifar, Ghiasi, and Akbari (2007) TK measured by flexible ruler was not correlated with BMI in healthy men and women, ages 18–25 years. The kyphosis angle in this study was 23.7° ±7.8, which could be due to the younger age group. In the current study the BMI was not associated with EI, nor with age. BMI was found previously to be positively correlated with EI and age (Pereira et al., 2020) probably due to the older age of the subjects in that study.

As for the EI reliability, results from previous studies reveals that it is reasonable with intra-rater ICCs > 0.78, SEMs < 4.18 AU, ICCs > 0.902, SEMs < 5.01% AU, ICCs > 0.715, SEMs < 10.17% AU, ICCs = 0.72, SEMs < 3.68% AU, ICCs > 0.851, SEMs < 9.7% AU for elbow flexors, quadriceps, hamstrings, plantar-flexors and abdominal muscles, respectively (Stock and Thompson, 2021), Intra-rater ICC of 0.73 and SEM of 11.03% for the superficial lumbar multifidus (Resende, de Oliveira, Pereira and de Oliveira 2021) and intra-rater reliability of deep neck muscles EI: ICC of 0.51 and 0.49 for longus colli and rectus capitis posterior minor (Ahmadipoor et al., 2021). To inject a clinical flavor into the above values, we have calculated MDC scores which set the threshold for clinically meaningful change as follows: 11.57AU, for the elbow flexors, 13.8%AU for the quadriceps, 29.8%AU for the hamstrings, 10.1%AU for the plantar flexors and 26.8%AU for the abdominal muscles (Stock and Thompson, 2021) while for the superficial lumbar multifidus the MDC score was 31.3%AU (Resende, de Oliveira, Pereira, and de Oliveira, 2021).

Due to the fact that various ultrasound devices and image settings are used, the ability to compare EI values across studies is limited. In addition, variables such as image depth, participants position or probe tilt should be standardized (Stock and Thompson, 2021). Relating to EI ratios between muscles rather than AU may be one way to bypass this variability.

We were not able to locate previous studies that reported the EIs of LT, RM, and ES in order to compare our findings with other data. Most muscular EI studies assesses muscles of the limbs or lumbar region. The EIs of the lumbar multifidus in elderly subjects were 47.45 ± 6.97AU in men, and significantly higher in women, 60.65 ± 9.61AU (Yoshiko et al., 2018) in comparison to 99.62 ± 20.23AU and 76.25 ± 22.61 for the

Superficial and deep lumbar multifidus, respectively, in young participants (Resende, de Oliveira, Pereira, and de Oliveira, 2021).

In view of the similarity in the EI scores, muscles and sides, we arrived at the Total Thoracic Echogenicity Intensity (TTEI) score. Men had significantly lower TTEI score compared to women. Between sex differences in EI are not conclusive, and no solid conclusions can be drawn (Akima et al., 2017; Caresio, Molinari, Emanuel, and Minetto, 2015; Stock and Thompson, 2021). However, in elderly subjects, significant lower EI scores in men were reported with respect to the lumbar multifidus but not in limbs muscles (Yoshiko et al., 2018) whereas in young as well as in older women, Plantar Flexors' EI were significantly higher compared to men's (Akagi et al., 2018).

In order to eliminate the possibility that differences in the EI scores of the thoracic multi-articulated muscles were due to inter-personal variability which were not related to posture, the EI of the anterior arm elbow flexors, the one joint BR and the three-joint BB were also recorded, bilaterally. The biceps' EI was significantly lower than that of the BR's, the muscles on the right side had significantly lower EI than their counterparts on the left, while no significant sex differences were noted, supporting previous findings by Careio et al. (2015). The EI of the TTEI score was significantly lower than the BB or BR. It should also be mentioned that in a reliability study of EI scores of the BB in women in their 3rd decade (Vieira et al., 2016) the measurements proved to be highly reliable with a mean EI of 44.6 AU, matching that of the current study.

The EI values of the BB and BR were significantly correlated with each other while the TTEI was significantly correlated with the EI score of the former but not the latter muscle. The positive correlation between TTIE and the biceps' EI values may support the validity of the results. We speculate that the lack of correlation between TTEI and BR's EI values may point out to a possible link between lower EI scores in multi-articulated muscles as opposed to one joint muscles, but this hypothesis requires further research.

In both sexes, the TTIE did not correlate with either relaxed or erect posture. It did however correlate significantly and negatively with Δ°, which is related to thoracic flexibility and the ability to change the position of the spine. Higher mobility, over higher ranges of movement (ROM), may therefore be associated with lower EI of the muscles involved. This may be related to an increased functionality of the muscles which may lead to preservation of their composition or quality, as measured by the EI (Paris, Bell, Avrutin, and Mourtzakis, 2020). Movement along larger ROM may also explain the significantly lower EI in the multi articulated BB vs. the uni-articulated BR.

The main question of the present study was whether normative prolonged postures of muscles spanning over the TK may lead to changes in their composition as assessed by EI, and by correlating the kyphotic angles to the EI values. In a longitudinal study (Lorbergs et al., 2019), the association between TK and trunk muscles size and density was evaluated via computerized tomography, in elderly women and men. Their findings suggest that the severity of the kyphosis was related to smaller and lower density trunk muscles at the thoracic spine. Lower muscle density observed in CT is correlated with higher EI values in ultrasound imaging (Watanabe et al., 2018) and is a marker of increased muscle fat infiltration or myoestatosis, which may serve as a predictor of negative health outcomes and is known to increase with age (Correa-de-araujo et al., 2020).

In the current study, no correlation was found between TK and the EI of the muscles spanning over that region, which may imply that muscular changes due to habitual posture develop in a more advanced age. On the other hand, an interesting negative correlation was found between those muscles' EI and the Δ°. This negative association could indicate a possible relation between muscles ROM excursions, and their composition but this contention requires further research. This would entail the testing of various uni or multi-articulated muscles among subjects with varying ranges of motions. In addition, it would be of much interest to find out whether preserving ROM, apart from being a functional necessity contributes also to muscle quality. Future studies should also employ comparisons of EI derived from healthy TK musculature vs. conditions such as diagnosed hyper kyphosis.

The limitations of the current study are: 1) small sample size; 2) lack of a reliability study regarding UI scanning and derived EI scores of the muscles explored. It should however be mentioned that reliability studies regarding EI of various other muscles and acquisition methods have suggested acceptable reproducibility (Caresio, Molinari, Emanuel, and Minetto, 2015; Ruas et al., 2017; Vieira et al., 2016). In addition, the consistency of the consecutive samples of each scanning was high; 3) the ability of the TK to change, as expressed by the Δ°, is not exclusively a function of the ability of the related muscles to perform. The compliance of other structures such as fasciae or joints are also involved, and their impact on the results could not be isolated; and 4) there was no accounting for confounding variables such as work-related factors or smoking which could also have affected the results.

Conclusion

This study did not reveal a correlation between the EI of muscles spanning over the TK and the angular extent of the TK in young healthy subjects. However, a negative association was found between those muscles' EI and the angular difference between relaxed and erect TK postures. This finding suggests a possible relationship between muscle ROM excursions and their composition in young (age range 25–35) healthy people.

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