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Could kyphotic posture disturb body balance in young healthy population?☆,☆☆,☆☆☆,☆☆☆☆

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ABSTRACT

Background: Kyphosis is roughly a slight forward curvature of the spine. A slight kyphosis or posterior curvature is normal throughout the human body and is present in every individual. Hyperkyphotic is a kyphotic angle greater than 40° commonly measured on a lateral X-ray measured by the Cobb method between C7 and T12. Postural instability and loss of balance can result from shifting the center of mass beyond the support base's limits. Studies are showing that kyphotic posture affects the center of gravity and affects falls in the elderly, but there are limited studies on the effect of balance in young individuals.

Objectives: the correlation between the balance and thoracic kyphosis angle has been investigated.

Methods: Forty-three healthy individuals over the age of 18 participated in the study. Participants who met the criteria were split into two groups based on their kyphosis angle. For measuring thoracic kyphosis, Flexi Curve is used. Objective evaluation of static balance was made with NeuroCom Balance Manager® static posturography device.

Results: In terms of mean difference, there was no significant difference between the kyphotic and control groups in the balance measures, and there was no correlation between the kyphosis angle and balance measures, according to statistical analysis.

Conclusion: According to our study, no significant relationship was found between body balance and thoracic kyphosis in the young population.

1. Introduction

The natural posteriorly convex curves in the thoracic and sacral portions of the vertebral column are known as kyphosis (Levangie and Norkin, 2011). An aberrant elevation in the normal thoracic posterior convexity can happen occasionally, and this is known as kyphosis (Venes, 2017). Kyphosis as a term is a normal spine curvature, but can occur excessively as a result of bad postural habits or osteoporosis, or it can occur as a result of an increase in the normal lumbar curve (Yaman and Dalbayrak, 2014). Kyphosis has a variety of causes, which is the majority of them are unknown. The degree of kyphosis is split into two categories: low degree such as rounded back and high degree such as angular gibbus deformity (Ghandi et al., 2015), congenital kyphosis (Yaman and Dalbayrak, 2014), and Scheuermann (Sardar et al., 2019). In the standing position, kyphotic posture can promote anterior displacement of the center of mass, encouraging the center of mass to be positioned outside the limits of stability, diminishing postural balance, and raising the risk of falling. (Sinaki et al., 2005). The biomechanical and structural outcome associated with the gravity line will pass anteriorly at a greater distance from the thoracic spine, leading to an increase in the gravitational moment arm, increasing tensile stresses in the posterior direction (Convexity of the curve) (Pamela and Cynthia, 2006). In healthy school students, the prevalence of hyper-kyphosis as spinal deformity was found to be 21.4% in boys and 15% in girls

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(Ghorbani et al., 2010). The severity of kyphosis increases with age, and women have a larger incidence rate than males. (Roghani et al., 2017). Hyper-kyphosis is particularly associated with aging in women (Akkawi and Zmerly, 2018). According to Greig and colleagues, balance problems in an osteoporotic population have a consistent link with vertebral fracture, but not with the degree of thoracic kyphosis (Greig et al., 2007), and this results are compatible with Ishikawa and colleagues, there were no significant associations between postural balance and thoracic kyphosis (Ishikawa et al., 2009). Another study by Eum and others showed that there was no association between larger kyphosis index and balance or auto-reporting disability results (Eum et al., 2013).

It is difficult to determine if balance impairments are a result of the postural alterations associated with kyphosis or if balance performance is influenced by factors related to underlying age (Greig et al., 2007) or neurological reasons (Schenkman et al., 2000) among those factors. Studies on postural kyphosis and balance involvement are very few in the literature, especially in the healthy population. Most of the studies that have looked at kyphosis and balance have been restricted by the small sample size and the exclusion of men as gender (Arnold et al., 2005). Many have concentrated their efforts primarily on the senior population (Ishikawa et al., 2009; Eum et al., 2013). Besides, subjective measures have been addressed to assess body balance (Cook, 2003). The determination that the detrimental effect of abnormal thoracic kyphosis posture on trunk biomechanical alignment may be related to balance disorders could contribute to future modifications regarding how physicians and therapists consider hyper-kyphosis as a crucial issue to prioritize during balance rehabilitation programs. This study aims to investigate whether the static balance is affected by the abnormal thoracic kyphotic posture.

2. Methods

2.1. Study design

This is a case control study, Institutional ethical approval was granted by the ethics committee in Faculty of Medicine, Marmara University, Reference number (Protocol code): 09.2020.897, approved in 24.07.2020. Registered in the clinical trial gov. ID is NCT04834141. Subjects were enrolled in the study if their age was above 18 years. The exclusion criteria were spine trauma, surgery, bone pathology, arthritis, etc. Also, those with spinal deformity, bone abnormality, and disc herniation with/without peripheral symptoms, body mass index (BMI), which is an indicator of obesity, more than >30 kg/m^2. Also participants, who complaining of balance problems, coordination problems, other neurological or vestibular diseases, using of any medication that can cause dizziness or drowsiness in the last months that affect body balance and posture have been excluded.

2.2. Sample size calculation

In the literature, the number of participants in similar studies is approximately 38 (Anbarian et al., 2010). The sample size of this study was calculated using a Sample Size Calculators software. The estimated minimum total sample size is determined, 29 participants. Since Alpha (α) is equal to 5%, the correlation coefficient ($r = 0.5$; P-value = 0.05) and Beta (β) is equal to 20%.

2.3. Recruitment procedures

The study took place in Marmara University, Başıbüyük campus, between the period September to December 2020. Participants were recruited through an online poster announcement, they directly contacted the primary investigator for booking an appointment. During the assessment, all of the precautions procedures has taken druing the COVID-19 pandemic. Each participant filled out a questionnaire and subjected to a detailed examination by the main investigator, to check whether there is any factor that would cause the participant to be excluded from the study. Participants who fulfill the criteria are divided into two groups according to their kyphotic angle degrees; for those who joined the thoracic kyphosis group, individuals with a kyphosis angle $\geq 40^\circ$. Individuals with a kyphosis angle $<40^\circ$ for the control group. A written informed consent form was signed by each participant.

2.4. Data acquisition

Kyphosis angle measurement; the current gold standard for measuring thoracic kyphosis is lateral radiography, a method that provides a Cobb angle (Briggs et al., 2007; Harrison et al., 2001). Radiography in the therapeutic environment is often cumbersome, involves expensive expenditures, and makes the patient exposed to large doses of possibly hazardous radiation (Kellis et al., 2008; Korovessis et al., 2001; Teixeira and Carvalho, 2007). In this study, the FlexiCurve ruler method was used, which is a reliable tool for measuring kyphosis height and kyphosis index. It is also non-invasive, cheap, and straightforward to utilize in a clinical environment (Hinman, 2004; Yanagawa et al., 2000).

Spinal kyphosis measured for each subject using the FlexiCurve ruler, a malleable metal band about 60 cm long and covered with plastic. Before measuring spinal kyphosis angle, participants were asked to stand with their feet on either side of a spot marked on the floor (to ensure standardization of subject position) and adopt a comfortable standing position that felt natural to them. A trained therapist palpates and identified the spinous process of the seventh cervical vertebra (C-7) and the superior aspect of the thoracic vertebrae (T-12) and marked with a 6-mm diameter non-allergenic adhesive stickers. The therapist instructs the participant to stand as straight as possible, by fully extend their both knees and bring their feet together. Meanwhile, the flexible curve ruler aligns to the posterior curve of the spine from C7 to T12.

The ruler has been fixed by stripes over the A3 paper and its outline be followed, to avoid slight shifting of the ruler causing measurement error. A straight line then is drawn from the ruler position of C7 to T12, corresponding to the length (l) of thoracic kyphosis, measured in cm. The height (width) of the thoracic kyphosis (h) in cm be determined by drawing a perpendicular line to the point where it intersects the straight line drawn from the highest point on the thoracic curve from C7 to T12.

The kyphosis index is calculated by applying the formula (Yanagawa et al., 2000). A Kyphosis Index (KI) was calculated from measures of the width and length of the thoracic section of the spine using the following formula: **KI= Thoracic Width (H)/Thoracic Length (I) × 100**.

It was possible to obtain an angular value for kyphosis (AngKI) (Greendale et al., 2011), from KI, in other words using the following formula: **AngKI= (314,61×KI) + 5,11**.

Objective evaluation of the static balance done by the NeuroCom Balance Manager System ® static posturography device (45 × 45 cm NeuroCom® System Version 8.1 Balance Manager International, Clackamas, Oregon, USA). The subject asked to place their feet on the right alignment shown on the platform.

Three different tests have been applied, which is; Modified Clinical Test of Sensory Interaction on Balance (CTSIB), refer to sensory balance control assessment (Melillo et al., 2017). Limits of Stability, refer to the maximum distance a person can voluntarily travel and control of their body's center of gravity (COG) and center of mass (COM) to reflect their body's directional control (Enix et al., 2014). Rhythmic Weight Shift, refer to voluntary directional motor control to four directions right/left and forward/backward.

2.5. Statistical analysis

The statistical value was determined at $p < 0.05$. The demographic data of the two groups, including age, height, and weight, were computed for the mean and standard deviations. The analysis of the data was done using the SPSS program (26.0 version, SPSS Inc, Chicago, IL). Significant differences between the groups were explored with

independent sample *t*-test for normally distributed data and Mann–Whitney U tests for not normally distributed. Correlation analysis has been performed using Pearson for normally distributed variables, and Spearman for not normally distributed variables to examine the correlation between balance parameters and kyphosis angle.

3. Results

3.1. Descriptive statistics

Forty-six healthy individuals over the age of 18, included in our study. Three participants were excluded from the study because of incomplete data of balance analysis, one participant has a history of vertigo, and the third one was excluded because of recent ankle injury. Participants who fulfill the criteria were divided into two groups according to their kyphotic angle degrees: thoracic hyper-kyphosis group (n = 18) and normal thoracic kyphosis group (n = 25) (Fig. 1). A total of forty-three subjects were tested for this study. Descriptive statistics according to the normality tests for the two groups are presented in (Table 1).

3.2. Comparing independent means of different groups

According to the data normality, the independent sample *t*-test for normally distributed balance parameters, represented in Table 2, and Mann–Whitney U tests for not normally distributed balance parameters represented in Table 3.

3.3. Correlation between balance parameters and kyphosis angle of all groups

Through running the Pearson (correlation coefficient) for normally distributed variables to examine the correlation of movement velocity (MVL), reaction time (RT), endpoint (EPE), and forward/backward velocity comparison, and Spearman test for not normally distributed variables to examine the correlation of CTSIB, max excursions (MXE), directional control (DCL), left/right velocity, left/right directional control (DCL), and forward/backward directional control (DCL) comparison with kyphosis angle for all groups and for each group respectively as represented in (Table 4). The following classification (Hinkle et al., 2003) was used to cateogrize the correlations between each balance parameters and the kyphosis angle, for the correlation coefficient "r" values, 0.00–0.30 "negligible correlation", 0.30–0.50 "low correlation", 0.50–0.70 "moderate correlation", 0.70–0.90 "high correlation", and 0.90–1.00 "very high correlation".

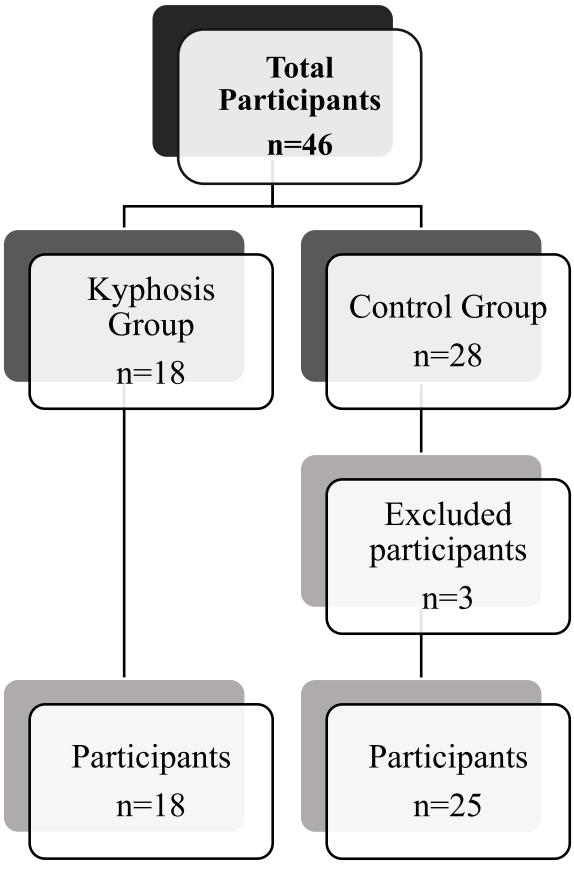

Fig. 1. Flowchart of participants recruitment.

Table 1
Descriptive statistics of study population.

		Kyphosis Group	Control Group	Sig. (2-tailed) P-Value
Sample Size		18	25	
Age Mean (Years) (SD)[a]		33 (12.13)	31.68 (9.28)	0.931
Age Median (Years) (Interquartile)		28 (23.75–45.5)	31 (24.5–35.5)	
Gender	Male n (%)	10 (55.6%)	17 (68%)	0.471
	Female n (%)	8 (44.4%)	8 (32%)	
Weight (Kg)		73.33 (13)	73.02 (11.24)	0.932
Height (Cm)		168.56 (9.199)	170.88 (9.55)	0.429
BMI** (Kg/Cm2)		25.67 (3.25)	24.92 (2.77)	0.419
Kyphosis Angle (Degrees)		46.48 (4.88)	28 (6.67)	<0.001

[a] Data expressed as the mean [standard deviation (SD)], and P-value. **BMI: Body Mass Index.

3.4. Clinical significance of the results

According to Cohen's calculation of the effect values based on group mean differences divided by the pooled standard deviation. CTSIB = 0.43 which is implies small effect, RT = 0.0.52 which is implies moderate effect, MVL = 1.70 which is implies large effect, EPE = 1.68 which is implies large effect, MXE = -.171 which is implies trivial effect, DCL = -1.08 which is implies large effect, LR Velocity = 0.21 which is implies small effect, LR DCL = 0.66 which is implies moderate effect, FB Velocity = -.93 which is implies large effect, and FB DCL = -.2 which is implies small effect.

4. Discussion

The current study showed no correlation between the different tested balance parameters and kyphosis for all groups as a whole, and each group individually. This correlation might indicate no direct effect of kyphosis itself and disturbance on body balance in the young population. Most of the previous work done by many researchers has reported that the relation between balance impairment and kyphosis within the different population, healthy (Anbarian et al., 2010), osteoporotic population (Sinaki et al., 2005; Cook, 2003), and most of those studies has a representation of woman other than men (Greig et al., 2007; Cook, 2003). Our study has representation of both men (n = 27, 62.7% and women (n = 18, 41.8%). Also, all of the participants who joined the study were healthy, weren't complaining of any physical, neurological disease, or vestibular disorder which might affect their balance. In the current study, there were no reported significant differences or any evidence between the kyphotic group and healthy control group regarding all of the balance parameters, and also a very low and probably meaningless correlation between the kyphosis angle and balance parameters. These findings corroborate those of Greig and colleagues, who found no variations in balance measures in osteoporosis patients with low vs high thoracic kyphosis and linked balance impairments in an

Table 2
Independent sample test for balance variable (Normally distributed).

	t-test for Equality of Means			95% Confidence Interval		Effect Size
	P-Value	Mean Difference	Std. Error Difference	Lower	Upper	
RT Comparison	0.535	0.0495	0.0792	−0.110	0.209	0.52
MVL Comparison	0.022	0.792	0.332	0.120	1.465	1.70
EPE Comparison	0.272	3.038	2.729	−2.474	8.550	1.68
FB Velocity Comparison	0.096	0.291	0.171	−0.053	0.637	−0.93

RT: reaction time, MVL: Movement Velocity, EPE: Endpoint, and FB: Forward/Backward.

Table 3
Mann-Whitney test for balance variable (Not-normally distributed).

	P-Value	Mean Rank		Effect Size
		Control	Kyphosis	
CTSIB Comparison*	0.910	21.82	22.25	0.43
MXE Comparison	0.970	22.06	21.91	−.171
DCL Comparison	0.912	21.82	22.25	−1.08
L/R Velocity Comparison	0.739	22.54	21.25	0.21
L/R DCL Comparison	0.892	21.78	22.31	0.66
F/B DCL Comparison	0.621	22.80	20.89	−0.2

CTSIB: Modified Clinical Test of Sensory Interaction on Balance, MXE: Max Excursions, DCL: Directional Control, LR: Left/Right, and FB: Forward/Backward.

osteoporotic population to vertebral fractures other than the amount of thoracic kyphosis (Palumbo et al., 2001). According to a study on osteoporotic population reported by Lynn et al., women with kyphosis exhibited higher postural sway than women with normal posture and healthy people without kyphosis (Lynn et al., 1997). It is hard to conclude if balance deficits are the result of osteoporosis-related kyphosis, or postural alterations or whether the performance of balance is linked to aging related in the elderly. For example, research by Sinaki et al. the osteoporotic women have a lesser back muscle extender strength than normal women of a similar age and the same for lower limb muscles (Sinaki et al., 1993). Most of the previous studies which studied the relationship between balance, kyphosis, and other variables such as osteoporosis and vertebral fracture assessed those variables in groups aging more than fifty years old (Greig et al., 2007; Cook, 2003; Lynn et al., 1997), Wolfson et al. have found that the decline in the stability of the posture and balance in response to aging in the elderly population is likely connected to a lower extremity strength loss and poor sensorimotor processing performance (Wolfson et al., 1992), muscle strength decreases with aging (Sinaki et al., 2001).

G. Lynn et al. also discovered that osteoporotic groups may have shown a greater dependence on hip methods due to a scare of falling or a lack of ankle power and strength (Lynn et al., 1997). Those with kyphosis, in particular, have distinct balancing characteristics, relying heavily on hip techniques, which might destabilize them throughout regular tasks (Sinaki et al., 2005).

Cook reported that the individuals diagnosed with osteoporosis who have a higher degree of thoracic kyphosis had considerably worse balance outcomes than those with osteoporosis who have a smaller degree of thoracic kyphosis, even using the functional reach and timed get up and go tests were used to detect balance dysfunction in 52 women diagnosed with osteoporosis, with an average age of 69.4 years (Cook, 2003), which is a subjective assessment, compared to the current study assessed balance parameters using objective assessment. Other factors such as drugs, activities, co-morbidities, and the strength of the lower extremities and trunk were not taken into account in the previous research. The computerized dynamic posturography objectively examined balance in the osteoporosis and kyphosis O–K participants and found that they had inferior balance. It's impossible to say whether this imbalance is caused only by osteoporosis or by a combination of osteoporosis and hyperkyphosis (Sinaki et al., 2005). Sedative usage, decreased cognition, and diminished proprioception were all linked to these falls (Position sense disorders of the legs) (Lord et al., 1991), decreased muscle strength, balance, gait, and foot issues (Tinetti et al., 1988). With age, peripheral neuropathy, inner ear diseases, vision problems, and impaired cognition become more frequent, increasing the risk of falling (Tinetti and Speechley, 1989). Within people with osteoporotic vertebrae caused fractures, Tsai et al. discovered balance impairment (Greater swinging and sway area) in those subjects with whole kyphosis (Thoracic kyphosis associated with marked lumbar lordosis, which maintains the center of mass COM centrally) compared to lower kyphosis only (Thoracic kyphosis with joint lumbar lordosis, which is maintaining the COM centrally) (Tsai et al., 2004).

It is also possible that the variance in the range and magnitude of thoracic kyphosis within the specimen population in results between the current and previous literature that reported a relationship between thoracic kyphosis and balance impairment is related as some studies have reported hyper-kyphosis among those with a kyphotic angle greater than fifty degrees (Sinaki et al., 2005; Cook, 2003; Lynn et al., 1997) and others consider the kyphosis angle above forty degrees (Greig et al., 2007).

Since substantial differences in techniques and instruments for

Table 4
Correlations between balance parameters and kyphosis angle.

Balance Parameter	According to each group				For all groups	
	Correlation Coefficient "r"		P-value		"r"	P-value
	Control	Kyphosis	Control	Kyphosis		
RT Comparison	0.423[a]	−0.011	0.031[a]	0.967	0.064	0.684
MVL Comparison	−0.378	−0.329	0.057	0.183	−0.141	0.367
EPE Comparison	−0.172	0.223	0.401	0.374	−0.153	0.327
FB Velocity Comparison	0.016	0.325	0.936	0.189	−0.445[a]	0.003[a]
CTSIB	0.271	−0.080	0.180	0.751	0.111	0.482
Max Excursions (MXE)	−0.127	0.313	0.535	0.206	0.026	0.867
Directional Control (DCL)	0.139	0.248	0.498	0.321	0.084	0.592
Left/Right Velocity	0.120	0.423	0.561	0.080	0.065	0.679
Left/Right DCL	−0.284	0.400	0.160	0.100	−0.017	0.915
F/B DCL Comparison	0.165	0.347	0.420	0.158	0.051	0.747

[a] Correlation is significant at the .005 level (2-tailed).

measuring thoracic kyphosis exist, there is a limited comparison of kyphotic measurements. Future recommendation to consider higher kyphosis angle measures in the healthy group for balance correlation. Also, a larger sample size should be considered in future studies like the current number of participants is small. Muscle weakness and associated poor strength and power performance in the geriatric population will reflect on balance strategies for motor control as they tend to depend on the hip strategy instead of ankle strategy to keep the body balance (Greig et al., 2007). Gender difference regarding body balance has been studied to find out if there is a relationship between men and women regarding the balance parameters, but a study that included young, healthy people using computerized dynamic posturography showed that there are no significant differences were found between men and women in the displacement of the center of gravity in the forward-backward direction for the sensory organization test (Olchowik et al., 2015). More studies should be done to understand better the influence of hyperkyphotic on equilibrium, and risk of falls. Meanwhile, the balancing system for those at risk of harmful falls seems to be evaluated objectively as a method to deliver the best possible rehabilitation programs based on age, muscle power, drugs in use at present.

5. Conclusion

To summarize, our study results indicate that there is no notable association between kyphosis angle and body balance, suggesting that other factors may contribute to balance impairments in individuals with a moderate to high risk of falls. Future research should focus on exploring the relationship between other postural malalignment and balance.

CRediT authorship contribution statement

Hussein Youssef: Conceptualization, Methodology, Software, Formal analysis, Visualization, Writing – original draft, Writing – review & editing. **Aysel Yildiz:** Supervision, Investigation, Resources, Writing – review & editing.

Declaration of competing interest

The authors whose names are mentioned confirm that they do not have any connections or involvement with any organization or group that has a financial interest (such as receiving payments, grants, being part of a speaker's bureau, holding stocks, giving expert testimony, or licensing patents) or a non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) related to the subject matter or materials discussed in this article.

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