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Published in:
Turkiye Fiziksel Tip ve Rehabilitasyon Dergisi

DOI:
10.5606/tftrd.2016.56688

Publication date:
2016

Document Version
Publisher's PDF, also known as Version of record

Citation for published version (Harvard):
Abaraogu, UO & Ugwa, WO 2016, 'Ergen ve genç erikin erkeklerde static dengenin ilikili faktörleri olarak baz antropometrik özellikler, spinal postür ve gövde kas dayankll', *Turkiye Fiziksel Tip ve Rehabilitasyon Dergisi*, vol. 62, no. 1, pp. 9-15. https://doi.org/10.5606/tftrd.2016.56688

Turk J Phys Med Rehab 2016;1(62):9-15
DOI: 10.5606/tftrd.2016.56688

Original Article / Özgün Araştırma

Selected anthropometrics, spinal posture, and trunk muscle endurance as correlated factors of static balance among adolescent and young adult males

Ergen ve genç erişkin erkeklerde static dengenin ilişkili faktörleri olarak bazı antropometrik özellikler, spinal postür ve gövde kas dayanıklılığı

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Received / *Geliş tarihi*: September 2014 Accepted / *Kabul tarihi*: March 2015

ABSTRACT

Objectives: This study aims to investigate the possible relationship of selected anthropometric variables, spinal posture, and trunk muscle endurance with static balance among adolescent and young adult males.

Patients and methods: Between April 2014 and June 2014, a total of 153 males (mean age 20 years; range 13 to 25 years) were included in this study. The anthropometric measures of height, weight, body mass index, waist circumference, waist-hip ratio, waist-height ratio, trunk-cephalic height, conicity index, fat mass index, and fat-free mass index were recorded. Thoracic and lumbar curvatures were assessed with flexicurve and the angles calculated in degrees using the formula, 4 actan (2h/L). Trunk flexor and extensor endurance levels were measured with flexor endurance test and Sorenson's test, respectively. Static balance was assessed using the single-limb stance test.

Results: Among all anthropometric variables measured, a significant correlation was only found between the fat-free mass index and trunk extensor endurance (r=0.175, p=0.033). The trunk flexor and extensor endurance were each significantly correlated with static balance (r=0.359, p=0.000 and r=0.276, p=0.001, respectively). A negative correlation was equally found between thoracic kyphotic angle and trunk flexors endurance (r= -0.233, p=0.004).

Conclusion: Our study results suggest a significant relationship between static balance and each of trunk flexor and extensor endurance, between thoracic kyphotic angle and trunk flexor endurance, and between fat-free mass index and trunk extensor endurance.

Keywords: Anthropometry; male; spinal posture; static balance; trunk muscle endurance.

ÖZ

Amaç: Bu çalışmada ergen ve genç erişkin erkeklerde bazı antropometrik değişkenler, spinal postür ve gövde kas dayanıklılığının statik denge ile olan muhtemel ilişkisi araştırıldı.

Hastalar ve yöntemler: Nisan 2014 - Haziran 2014 tarihleri arasında, çalışmaya toplam 153 erkek (ort. yaş 20 yıl; dağılım 13-25 yıl) alındı. Boy, kilo, vücut kütle indeksi, bel çevresi, bel-kalça oranı, bel-boy oranı, gövde-sefalik boy, koni indeksi, yağ kütle indeksi ve yağsız kütle indeksinin antropometrik ölçümleri kaydedildi. Esnek eğri ve 4 aktan (2 s./L) formülü ile derecesi hesaplanan açılar ile torasik ve lomber kürvatürler değerlendirildi. Gövde fleksör ve ekstansör dayanıklılık düzeyleri, sırasıyla fleksör dayanıklılık testi ve Sorenson testi ile hesaplandı. Statik denge, tek ekstremite duruş testi kullanılarak değerlendirildi.

Bulgular: Ölçülen tüm antropometrik değişkenler arasında, yalnızca yağsız kütle indeksi ve gövde ekstansör dayanıklılığı arasında anlamlı bir ilişki bulundu (r=0.175, p=0.033). Gövde fleksör ve ekstansör dayanıklılığı, tek başına statik denge ile anlamlı düzeyde ilişkili idi (sırasıyla r=0.359, p=0.000 ve r=0.276, p=0.001). Torasik kifoz açısı ve gövde fleksör dayanıklılığı arasında eş değer negatif bir ilişki saptandı (r= -0.233, p=0.004).

Sonuç: Çalışma bulgularımız, statik denge ve gövde fleksör ve ekstansör dayanıklılığı, torasik kifoz açısı ve gövde fleksör dayanıklılığı ve yağsız kütle indeksi ve gövde ekstansör dayanıklılığı arasında anlamlı bir ilişki olduğunu göstermektedir.

Anahtar sözcükler: Antropometri; erkek; spinal postür; statik denge; gövde kas dayanıklılığı.

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Cite this article as:
Abaraogu UO, Ugwa WO. Selected anthropometrics, spinal posture, and trunk muscle endurance as correlated factor of static balance among adolescent and young adult males. Turk J Phys Med Rehab 2016;62:9-15.

The trunk consists of different muscles which stabilize the spine and provide the basis for movements in the extremities. Their contributions in posture maintenance are critical such that interventions to postural abnormalities which are not focused on them often prove ineffective.[1] These muscles help control movement, transfers energy, shift body weight, and distribute the stresses of weight bearing,[2] and lack of the development of the muscles can result in predisposition to injury.[3] It is suggested that although the trunk muscles strength is necessary for activity and sports, endurance plays an important role in the spinal stability during prolonged physical activity, protecting them from injury.[4-6]

The postural alignment is important in the functioning of the neuro-musculoskeletal system as a deviation from the ideal posture, which can produce excessive stress on the musculoskeletal system. A forward head posture or an increased lumbar lordosis may cause an altered strength of the lumbar flexors compared to the extensors.[7] The evaluation of sagittal spinal posture, defined as the orientation and alignment of bones of the vertebral column from the lateral side view,[8] is taken as the most effective way of assessing spinal posture, as greater degree of spinal movement occur in the sagittal plane around the mediolateral axis.[8] Recently, studies into the human spinal alignment have generated a great interest as medical conditions, which pose threat to the postural alignment, and spinal integrity, in particular, have becoming more prevalent.[8]

Reports on the influence of anthropometric variables on the postural stability and balance have largely been contradictory. A number of studies have shown that postural stability is affected by body mass in prepubescent children, adolescents, adults, and even the elderly.[9-14] However, evaluations which were performed on stable surfaces with individuals who are overweight or with normal body indices have shown that posture does not appear to be affected by weight status.[15] Similarly, Ferreira et al.[16] failed to identify whether variations in the postural alignment among adults were attributed to the variations in the individuals' anthropometric measures. Also, Kuo et al.[7] were unable to establish whether differences in the postural alignment in their sample were sequel to the age-related changes or mere differences in the anthropometric variables. Therefore it is not clear if anthropometry is related to the postural alignment and stability of individuals independent of age or sex.[17] It is believed that activity of muscles, as dynamic stabilizers, around a joint influences the integrity of such joints.[19] Similarly, it is assumed that trunk muscles located adjacently to the spine should hypothetically exert their influence on it with subsequent influence on balance maintenance;[17] however, the extent of this influence has not well studied yet.

Establishing a relationship between anthropometric variables, spinal posture, trunk muscle endurance, and static balance may be essential for manipulating any one of the variables for therapeutic purpose or to enhance fitness. Also, this information is relevant in clinical decision regarding how to restore or regain postural stability by targeting anthropometrics and particularly muscles around in and around the trunk. Therefore, in this study, we aimed to investigate the possible relationship of selected anthropometric variables, spinal posture, and trunk muscle endurance with static balance among adolescent and young adult males. If there is a relationship, we also aimed to investigate how much of the static balance is explained by changes in the variables.

PATIENTS AND METHODS

This correlational study included a total of 153 adolescent and young adult males (mean age 20.1±3.6 years, height 1.7±0.1 meters, and weight 64.7±10.3 kilograms) who were recruited from the University of Nigeria, Enugu Campus, and Uwani Boys' Secondary School, Enugu. Each participant voluntarily signed an informed consent form, after the overview of the research was thoroughly explained to them. The inclusion criteria were as follows: age within 13 to 25 years, no active involvement in any form of sporting or fitness activities, and no form of visual, neuromuscular, and vestibular impairment. The ethical approval for the study was obtained from the University of Nigeria Teaching Hospital, Health Research Ethics Committee. A written informed consent was obtained from each patient. The study was conducted in accordance with the principles of the Declaration of Helsinki.

The anthropometric measures assessed included height, weight, body mass index (BMI), waist circumference, waist-hip ratio, waist-height ratio, trunk-cephalic height, conicity index, fat mass index (FMI) and fat-free mass index (FFMI). Height was measured to the nearest 0.1 cm with a stadiometer. Weight was measured to the nearest 0.1 kg with the subject in minimal clothing, barefoot, and standing in an erect posture looking straight ahead. The trunk-cephalic height was measured by taking the distance from the anterior superior iliac spine to the vertex of the head. Waist and hip circumferences were measured using a tape rule to the nearest 0.1 cm. Waist circumference was measured in an erect standing position by placing the tape immediately below the lowest rib, at the narrowest part of the waist.[18] The hip circumference was equally measured in the standing position by placing the tape at the widest part of the buttocks.[18] Waist-hip ratio was calculated as the ratio of waist circumference to hip circumference (both in cm). Waist-height ratio was calculated as the ratio of waist circumference to height in cm. Conicity index was calculated using the following formula: waist circumference/[0.109* (W/H) 0.5] where W is weight in kg and H is height in meters. Fat mass index was calculated by dividing the fat mass with the square of height (in meters) with the fat mass determined by multiplying the body weight with body fat percent.[19] Body fat percent was measured using body fat/hydration monitor scale to the nearest 0.01%. Fat-free mass index was calculated using this formula: FFMI= [body weight-(%body fat * body weight)]/height squared.[19]

In addition, spinal posture was assessed in the sagittal view in the categories of thoracic and lumbar curvatures. The curvatures were obtained with an inelastic flexible ruler placed from the spinous processes of T_1 to that of T_{12} and from T_{12} to S2 for thoracic kyphotic and lumbar lordotic curvatures respectively in line with earlier procedures.[20,21] With the curvatures copied, the flexible ruler was placed on a plane sheet and the curvatures traced with a pencil. A straight line, L was drawn from the highest point of the curve to the lowest (ie. from T_1 to T_{12} and from T_{12} to S2 for thoracic and lumbar curvatures respectively). Another line, H was drawn to intersect the L-line from the deepest part of the curve. The lengths of these lines were measured using a meter rule and with the conversion formula, $\theta = 4 \text{ actan } (2h/L)$, the thoracic kyphotic and lumbar lordotic angles were calculated in degrees. The reliability and validity of this procedure have been extensively reported in the literature.[20,21]

Trunk muscle endurance was assessed in the categories of trunk flexor and extensor endurance.

Trunk flexor endurance: It was assessed using the trunk flexor endurance test.[1] The participant lied on a cushioned and flat surface with the hip and knee joints flexed at 60° and the palms placed at the back of head (i.e. on the occipital region). Then, he was asked to gently raise the trunk and hold it as much as possible. As this was done, the length of time he was able to hold the movement was recorded with a stop watch as trunk flexor endurance.

Trunk extensor endurance: The Sorenson's test was performed to assess the trunk extensor endurance.[1] The participant lied prone on a table with the upper edge of the iliac crests positioned on the edge of the table. The pelvis, ankles, and knees were fixed on the table with three straps and the arms folded against the chest. Then, he was asked to isometrically maintain the upper body as much as possible in a horizontal position. The length of time the subject was able to hold the upper body in a horizontal position was recorded with a stop watch as the trunk extensor endurance. The reliability and validity of these measurements have been reported in the literature.[22]

Static balance was measured with a quantifiable clinical test termed the single-limb stance test.[1] Participants were asked to stand on a dominant foot by placing their hands on the iliac crests with the contra-lateral foot, in slight hip, and knee flexion, placed over the dorsum of the stance foot. The participants were, then, told to lift the stance foot heel and keep the stance position motionless, while time was recorded. The amount of time the individual was able to hold the movement was recorded as the static balance level.

Statistical analysis

The baseline characteristics of the participants were analyzed using descriptive statistics of means and standard deviation. We aimed to detect a simple correlation of at least r=0.25 using a two sided test, 5% significance level test (α=0.05) (the probability of type I error) with power 80% power (the probability of type II error β=0.2). By this calculation, required sample size is 123 (n=123). Relationships of the variables of anthropometry, spinal posture and trunk muscles endurance with static posture were tested using Pearson product-moment correlation coefficient. Relationships of anthropometric measures, thoracic kyphotic angle, and lumbar lordotic angle with variables of trunk muscles endurance were equally tested using the Pearson's correlation coefficient along with variables of trunk muscles endurance set as the outcome variables. Furthermore, we build regression model of the independent variables prediction on the static balance. First data was checked to see violations in the regression modeling assumptions and probability plot of the residuals were normal. Error variance was observed to be constant. Also, multicollinearity of the independent variables was not observed, neither were outliers influential. Then, anthropometry, spinal posture, and trunk muscles endurance as dependents variables were entered in a stepwise multiple regression model to examine their

Table 1. Physical characteristics of participants (n=153)

Variables	Mean±SD	Minimum value	Maximum value
Age (years)	20.1±3.6	13	25
Height (m)	1.7±0.1	1.42	1.93
Weight (kg)	64.7±10.3	38.70	90.00
Body mass index (kg/m^2)	22.3±2.6	16.14	29.18
Waist circumference (cm)	72.8±5.5	52.00	88.00
Waist hip ratio	0.8±0.0	0.72	0.93
Waist height ratio	0.4±0.0	0.37	0.52
Trunk cephalic length (cm)	70.3±4.4	60.00	81.00
Conicity index	731.8±50.5	537.46	864.92
Fat mass index	3.4±1.1	0.76	8.22
Fat-free mass index	18.9±1.8	15.29	25.35
Kyphotic angle (^{0})	40.6±10.6	17.00	67.00
Lordotic angle (^{0})	45.4±12.1	16.00	69.00
Trunk flexor muscle endurance (sec)	97.7±77.1	9.00	474.00
Trunk extensor muscle endurance (sec)	102.3±38.1	12.00	199.00
Static balance (sec)	66.9±52.3	4.00	368.00

SD: Standard deviation.

predictive value for static balance. All analysis was performed using IBM SPSS version 20.0 software (IBM Corporation, Armonk, NY, USA) with an alpha level of 0.05.

RESULTS

The mean angle of lordosis is greater than that of kyphosis indicating that, on average, an individual has more curvature of the lumbar spine than the thoracic (Table 1). It was also observed that the extensor muscles of the trunk have higher endurance level than the flexors. Of all the anthropometric variables, a positive significant correlation was only found between the FFMI and trunk extensor endurance (r=0.175, p=0.033), as presented in Table 2. A negative significant correlation was found between the thoracic kyphotic angle and trunk flexor endurance with r= -0.233 and p=0.004 (Table 2). Trunk flexor and extensor endurance were each significantly correlated with the static balance (r=0.359, p=0.000 and r=0.276, p=0.001, respectively). In a regression model, only the trunk flexion endurance [p<0.001, t=4.2, confidence interval (CI) 0.319-0.113] and trunk extension endurance (p=0.004, t=2.9, CI 0.097-0.512 predicted static balance posture. In the model, all the independent variables accounted for about 30% of the static balance (R^2=0.310). The trunk flexion endurance alone accounted for about 13% of the value (adjusted R^2=0.129), while the trunk extension endurance accounted for the 17% (adjusted R^2=0.170).

Table 2. Correlations of selected anthropometric variables, spinal posture, and trunk muscles endurance with static balance

Variables	Trunk flexor endurance		Trunk extensor endurance		Static balance	
	r	*p*	r	*p*	r	*p*
Age (years)	−0.113	0.171	0.074	0.372	0.077	0.349
Height (m)	0.001	0.987	0.048	0.559	−0.062	0.455
Weight (kg)	−0.043	0.606	0.116	0.160	−0.008	0.919
Body mass index (kg/m^2)	−0.050	0.549	0.152	0.064	0.064	0.441
Waist circumference (cm)	−0.036	0.663	0.055	0.503	−0.052	0.532
Waist hip ratio	−0.128	0.120	0.056	0.494	0.010	0.903
Waist height ratio	−0.041	0.623	0.036	0.666	−0.002	0.978
Trunk cephalic length (cm)	0.053	0.521	0.072	0.383	−0.001	0.990
Conicity index	0.003	0.972	0.062	0.451	−0.051	0.540
Fat mass index	−0.049	0.554	0.069	0.406	−0.014	0.865
Fat free mass index	−0.024	0.770	0.175*	0.033	0.098	0.236
Trunk flexor endurance (sec)	–	–	–	–	0.359**	0.000
Trunk extensor endurance (sec)	–	–	–	–	0.276**	0.001
Kyphotic angle (^{0})	−0.233*	0.004	−0.103	0.212	−0.111	0.176
Lordotic angle (^{0})	−0.025	0.762	−0.005	0.952	0.105	0.189

* Significant at p≤0.05; * Significant at p≤0.001.

DISCUSSION

The result of the present study shows no correlation of static balance with each of height, weight, BMI, waist circumference, waist-hip ratio, waist-height ratio, trunk-cephalic height, conicity index, FMI, and FFMI. Similarly, Okafor et al.[23] found no correlation between balance (assessed using the functional reach test) and anthropometrics of weight, height, arm length, leg length, bi-acromial breadth, foot length, and trunk length. In contrast, study by Alonso et al.[15] which assessed the postural balance in two conditions (i.e. eyes closed and eyes open) found a correlation of postural balance with anthropometric variables of height and trunk-cephalic height only in the eyes closed condition. Studies have shown that the visual system plays a part in balance maintenance.[2,24,25] Hence, since all the participants in the present study were assessed only in the eyes open condition, it is possible that the visual system may be having overriding influence on the postural balance than the anthropometrics variables, as Alonso et al.[15] also did not find any correlation in the eyes open condition.

The present study did not find a correlation between the trunk flexor endurance level and each of height, weight, BMI, waist circumference, waist-hip ratio, waist-height ratio, trunk-cephalic height, conicity index, FMI and FFMI. This finding is in consistent with the results of Koley and Vashisth[26] in 2014; however, it contradicts with the findings of Dejanovic et al.,[27] which found a correlation between height, weight, and waist circumference. However, among all the anthropometric measures assessed significant correlation was only found between FFMI and trunk extensor endurance. This does not support the findings of Koley and Vashisth,[26] which found a correlation between body weight and trunk extensor endurance. Body weight is made up of both fat and non-fat components. Therefore, the study of Koley and Vashisth[26] found a correlation between the body weight and extensor endurance compared to the present study which found a correlation only between the FFMI and trunk extensor endurance and it is reasonable, hence, to report that the high athletic nature of their subjects due to their training status might altered their body composition and the influence of their body fat component became insignificant. As a result, these findings may be interpreted that the FFMI assessed in this study might have the same influence as the body weight assessed in their study. Also, inconsistent with the present study, Dejanovic et al.[27] in 2012 equally showed a significant but weak correlation of the trunk flexor and extensor endurance profile with height, weight, and waist circumference. This difference can be explained by the fact that they studied pre-pubertal children of 7 to 14 years. Since the present study focused on adolescent and young adults, the hormonal effect of puberty on musculoskeletal system amongst the study population may not be ruled out as having an influence. One unique feature of this study is that a correlation was found between the FFMI and trunk extensor endurance, but not with the trunk flexor endurance. Could it be that the abdominal muscles which constitute majorly the trunk flexors have a different biophysical profile or could it be that the readily deposition of fats around the abdominal regions have an implication on their strength and endurance? A randomized control trial which will take into consideration the biophysical attribute of trunk flexors compared to that of extensors is, therefore, needed to answer these questions.

One of the major findings of the present study was that there was no correlation between the spinal posture and static balance. This finding contradicts with that of Fernanda et al.[28] in 2010 and Pallavi and Nandakumar[29] in 2013, each concluding that postural balance was influenced by thoracic hyperkyphosis. Since their study was a comparison study between young and elderly women, it can possibly be explained that the influence might been resulted due to age-associated biomechanical and neuromuscular changes.

This study shows that there is a significant correlation of static balance with trunk extensor and flexor endurance levels. This result is in consistent with the findings of Barati et al.[1] in 2012, but disagrees with that of Brooke[30] in 2012 which concluded that core muscle endurance does not have any relationship with functional balance and motor play skills in kindergartners. The Brooke's study included kindergarten children of five and six years and assessed balance with the use of functional reach test. Since his study assessed the functional balance against this study which assessed the static balance at which the musculature of the trunk are in lengthened/shortened position resulting from the dynamic posture of the spine, it is, then, reasonable to attribute this difference to the differences in the balance assessed, as well as to the age difference of the study populations. Notwithstanding, the major implication of this finding is that the trunk muscle endurance precipitates the static balance level of an individual in that for an improvement balance, interventions for trunk muscle strength, and endurance should be advocated.

This study classified the spinal posture into thoracic kyphotic and lumbar lordotic curvatures and trunk muscle endurance into the trunk flexor and trunk extensor endurance levels with results showing no significant relationship except between trunk flexor endurance level and thoracic kyphotic angle, where there was a negative correlation. To the best of our knowledge, no published work has been done to investigate this relationship. Nonetheless, the negative correlation between thoracic kyphotic angle and trunk flexor endurance implies that more anterior displacement of the thoracic vertebrae in frontal plane is inimical to the endurance of the spinal flexors.

Finally, with trunk muscles endurance correlating positively with static balance as observed from this study, it may, therefore, be inferred that from the skill-related perspective, specific training designed for improving trunk muscle endurance should also incorporate balance training design and vice versa. In particular, about 30% of static balance improvement is able to be gained by targeting the trunk muscle flexor and extensors alone. Although both contribute significantly to the static balance mechanism of the spine, it does appear that that extensor muscles contribute a little (4%) higher than the flexor. Also, about 70% of the trunk static balance is not explain by the variables studied in this research and, therefore, warrant further inquiry. However, as the present study did not establish a cause and effect relationship, further randomized controlled trials are required to increase the level of evidence. Further studies on the female category are also needed to analyze whether there would be sex-based differences in the relationship of the trunk muscle endurance with static balance.

On the other hand, the major limitations to the present study may have come from the psychological status of the participants, as adequate concentration is always needed for all endurance tests. However, verbal cues and incentive measures were used as encouragement to reduce this effect.

In conclusion, we investigated the possible relationship between anthropometrics, trunk muscle endurance, and static spinal stability in our study and found a significant relationship between the trunk muscle endurance and static balance. The finding is important, as the trunk endurance training through tailored exercise programs could be explored as adjunct to the athletic training specifically aimed at improving the balance. Although we studied healthy males, our findings highlight the potential effects of trunk muscle fatigue on the postural system. From this point of view, the trunk muscle fatigue can significantly raise risks for postural instability and hypothetically increase the risk for pathomechanics and consequent injury. Succinctly put, the postural and locomotive segments of males adolescent or adult whose trunk muscle is fatigue may be at increased risk for musculoskeletal disorder. However, this assumption should be further studied.

Declaration of conflicting interests

The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding

The authors received no financial support for the research and/or authorship of this article.

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