



RELATIONSHIP BETWEEN ANTHROPOMETRIC MEASURES AND SAGITTAL SPINAL CURVATURES IN ADULT MALE HANDBALL PLAYERS

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ABSTRACT

Purpose. Increasing anthropometric measures bring considerable spinal loads during sports practice, which inversely affects the adaptation abilities of the spinal structures; this in turn influences the spinal curvatures. The study was conducted to explore the relationship between anthropometric measures and sagittal spinal curvatures in handball players.

Method. The total of 83 male handball players were divided into 2 groups, depending on their body height: group 1 (age, 23.62 ± 2.07 years) consisted of 40 handball players with height above average, group 2 (age, 24.63 ± 2.58 years) consisted of 43 handball players with height below average. The thoracic and lumbar curvatures and trunk height were measured with the Formetric III 4D spine and posture analysis system.

Results. The thoracic kyphosis of group 1 was significantly higher than that of group 2 ($p = 0.038$), without a significant difference in lumbar lordosis ($p = 0.312$), and significant difference in the coefficient of compensation between thoracic kyphosis and lumbar lordosis ($p = 0.026$). Group 1 showed strong positive correlation between body height and kyphotic angle ($r = 0.897$), and moderate positive correlation with lordosis angle ($r = 0.496$). In group 2, there was weak positive correlation with kyphotic angle ($r = 0.381$), and weak negative correlation with lumbar lordosis angle ($r = -0.355$).

Conclusions. Increasing body height of handball players is associated with bigger kyphotic and lordotic angles. Owing to frequent sagittal asymmetric overloading of the spine during handball training, exercises that help maintain good posture and correct the thoracic kyphosis are required, especially for taller players.

Key words: body height, spinal curvatures, sagittal angles

Introduction

Physical activity has an impact on the posture and physical development of young players. Sports training as a specific form of directional physical activity can exert a significant effect on the process of posture development of young men owing to high training loads and repeated unilateral exercises [1, 2]. The sagittal spinal curvatures have been evaluated in several studies among gymnasts [3], ballet dancers [4], soccer players [5], paddlers [6], wrestlers [7], and heterogeneous groups of athletes [8]. Other studies have compared the effects of different sports on the sagittal spinal curvature [1, 9]. Certain sports are related with sagittal spinal deformities (excessive kyphosis or lordosis), especially in adolescent population [10].

Indeed, there are lower thoracic kyphosis and a more pronounced pelvic tilt and lumbar lordosis in young soccer players [5]. In contrast, López-Miñarro et al. [6] found a reduction of the lumbar lordosis in standing

posture, and greater thoracic and lumbar flexion in paddlers. Also, Rajabi et al. [7] observed higher thoracic kyphosis in freestyle wrestlers than in Greco-Roman wrestlers. These differences are related to the specific positions typical of each discipline. The free style routinely puts the spine in a more flexed position while the Greco-Roman style is associated with an almost erect position of the spine. Moreover, the thoracic and lumbar curves of gymnasts and ballet dancers are significantly flatter than in the previously mentioned sports athletes [3, 4].

Sports activities, often asymmetric or performed under high loads and aimed at shaping specific skills, may lead to postural disorders, especially when practised by very young subjects [11]. In many sports, including team games, disproportional body mass and muscle strength, spine statics disorders and/or trunk asymmetries are often noted; these might be due to non-uniform loads applied to the spine and/or sport-specific unilateral muscle work [2, 12].

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Forte et al. [13] proved that athletes with segmental asymmetry might be more susceptible to low range of motion and injuries. Moreover, the body alignments should be monitored to prevent injuries and performance impairment in young soccer players. Krzykała [14] defined the morphological asymmetry in sportsmen as the difference between the right and left part of the body. However, very few researchers have focused on sagittal spine asymmetry. So, it needs further investigation, especially for adult athletes, in whom sagittal spine deformities are apparent, though not permanent.

The specificity of movements performed during the training applied in a particular sport, such as handball, may influence the spinal anterior-posterior curvatures and the type of body posture [15]. Handball is considered as one of the sports of predominant forward flexion and extension posture, which tend to change the sagittal spinal curvatures and predispose to spinal injury [16]. Pieper [17] reported that handball was a unilateral loading sport. So, during handball practice, there is a definite need for regular posture observation and assessment [18].

It is obvious that previous studies have reported the effect of asymmetrical spinal loading in such athletes as soccer players, paddlers, wrestlers, gymnasts, and ballet dancers. However, to the authors' knowledge, the literature lacks discussion on the relationship between handball playing and sagittal spinal curvatures, which are especially characterized by asymmetrical spinal loading. Moreover, no study has established the relationship between anthropometric variables and sagittal spinal curvatures in handball players, which may be essential for therapeutic purposes or to enhance the physical fitness and protect the players from spinal injuries. Accordingly, this study was conducted to investigate the relationships between anthropometric measures and sagittal spinal curvatures in handball players.

Material and methods

Participants

A sample of 83 collegiate male handball players with identical training levels were divided into 2 groups, according to their body height. Group 1 consisted of 40 handball players with body height above average (172.75 cm) [19], and group 2 consisted of 43 handball players with body height below average. Their demographic data are presented in Table 1.

One of the inclusion criteria of the study was that all the participants had attended 90 minutes training 5 times a week in addition to 45 minutes of mandatory physical education classes held 4 times a week. Their minimum duration of training was 3 years without any pauses and maximum 6 years, with no participation in any other sport. Their age ranged from 20 to 27 years

and all of them were right-handed. The information related to duration and frequency of training was obtained through an interview with the participants before starting the assessment procedures.

Subjects with history of traumatic back injury, musculoskeletal disorders, diagnosed scoliosis, a documented congenital spine abnormality, postural asymmetry (e.g. scoliosis, leg length discrepancy), foot deformities and balance disturbance were excluded from participation. A written consent form was signed by each participant. The study was performed in accordance with the Declaration of Helsinki and approved by the local institutional review board.

Procedures

All participants were assessed at the same time of the day (9:00–11:00 a.m.). They were barefoot and were wearing only underwear. The participants were instructed not to eat for at least 2 hours prior to measurements to avoid fluctuation of body weight immediately after meals.

The body height and weight were determined with a tap measurement and weight scales, respectively, while the body mass index (BMI; $\text{weight}/\text{height}^2$) was calculated from the body height and mass. Trunk length (from C₇ to the centre of the sacrum) and shoulder width (distance between two acromion processes of both shoulders) were detected for each subject with the use of the Formetric III 4D device. The Formetric III 4D spine and posture analysis system (DIERS, model No. 1010112157, Italy) was employed for optical measurements of sagittal curvatures of the spine (kyphosis angle and lordosis angle) and trunk length. The device is used for photogrammetric recording of the back with a video rasterstereography process with DiCAM v2.2.0. The resulting data provide an accurate 3-dimensional model of the back surface. The reliability of the results obtained with the Formetric III 4D back shape analysis system has been corroborated by an extensive comparison with ca. 500 digitized and objective-numerically analysed X-ray images. The Formetric III 4D device has a good validity compared with XR with an overall excellent intra- and inter-rater reliability [20]. The validity of rasterstereography compared with X-ray measurements was confirmed by Mohokum et al. [21], who indicated that rasterstereography facilitates the analysis of spinal column with less amount of radiation and helps in detecting various spinal deformities like thoracic kyphosis [21].

The stereographic camera/projector was calibrated by mounting a vertical flat white board in the position of the participant; the image of the white board was taken daily for calibration of volume origin. The height of the stereographic camera/projector was adjustable according to the participant's height. The cameras and their corresponding strobes were positioned to yield the best

fields of view and photographic resolution. The frames were taken after instructing the subject to stand in a relaxed, upright position on the foot stop. Parallel horizontal white light lines were projected on the patient's back in a dark room; the lines covered the whole back of the player, from ears to buttocks (Figure 1). This was followed by mathematical modelling. On the basis of the sagittal profile, photographs of the backs of each subject were obtained to measure the degree of thoracic and lumbar curvatures with the reported accuracy of lateral error (x/y axis) < 0.20 mm and depth error (z-axis) < 0.25 mm [22].

Brightness and contrast were adjusted to enhance image quality. The images were scanned as black and white positives and then cropped to reduce data storage. A 3-dimensional shape was produced automatically by an analysis of the distortion of parallel horizontal white light lines projected on the participant's back to quantify the angles of thoracic kyphosis and lumbar lordosis of each subject. For the accuracy of the anatomical landmarks, vertebra prominence (C₇), sacrum point, and the two lumbar dimples (left and right) were verified. For the 4-dimensional average measurement type, the displayed image is the average for all captured images. Therefore, the available result is not a video, but one image (Figure 2).

Statistical analysis

The statistical analysis included the calculation of the means and standard deviations (mean \pm SD) of the measured variables. The normality of distributions was verified by the Kolmogorov-Smirnov test. The independent t-test was used to detect differences in anthropometric parameters and sagittal spinal curvatures between both groups. Pearson's correlation coefficient (r) was applied to determine the potential effect of the different anthropometric data on the sagittal spinal curvatures in both groups. These correlations were calculated among the mean of the body height, trunk length, body weight, BMI, shoulder width, kyphotic angle, and lordotic angle in both groups. The sample size of 83 participants yielded the analysis power of 95%, with the alpha level of 0.05. The level of significance was set at $p < 0.05$. All statistical analyses were performed with the IBM Statistical Package for the Social Sciences (SPSS), version 20.

Ethical approval

The research related to human use has been complied with all the relevant national regulations, institutional policies and in accordance the tenets of the Helsinki Declaration, and has been approved by the authors' institutional review board or equivalent committee.

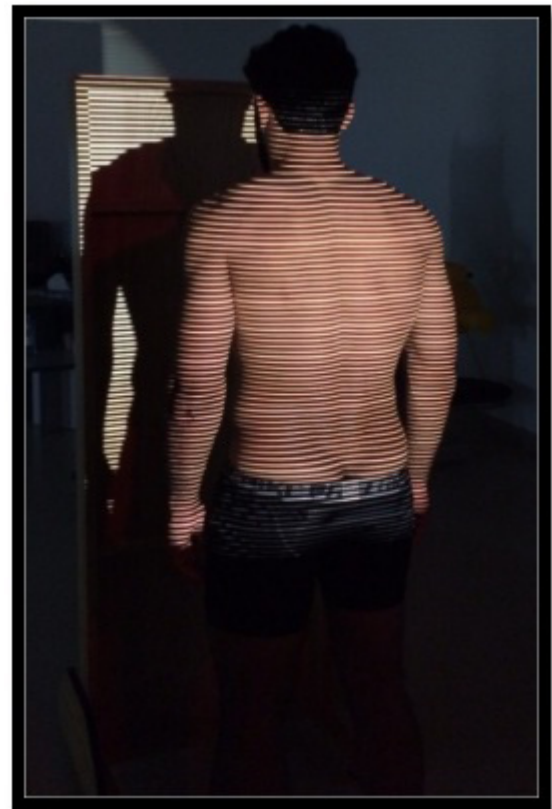


Figure 1. Parallel horizontal white light lines were projected with stereography

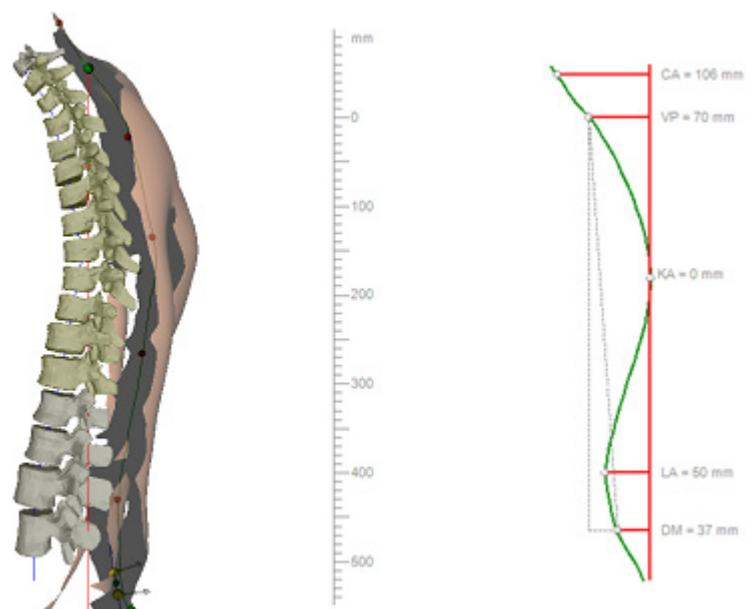


Figure 2. The 4-dimensional average detects the kyphotic and lordotic angles

Results

There was no significant difference between the groups in relation to age, BMI, or shoulder width ($p = 0.054$, 0.200 , 0.139 , respectively). However, group 1 was significantly taller, with longer trunk length and heavier body weight than group 2 ($p = 0.001$).

The thoracic kyphosis angle of group 1 was significantly bigger than that in group 2 ($p = 0.038$). There was no significant difference in the lumbar lordosis angle between the groups ($p = 0.312$). The coefficient of compensation (CC, an evidence of increasing thoracic kyphosis and decreasing lumbar lordosis) of group 1 was significantly higher than that in group 2 ($p = 0.026$), as shown in Table 1.

The Pearson product-moment correlation showed a strong positive correlation between the body height and the kyphotic angle in group 1 ($r = 0.897$, $p = 0.001$), and a weak positive correlation between the body height and the kyphotic angle in group 2 ($r = 0.381$, $p = 0.012$). Moreover, there was a moderate positive correlation between the body height and the lumbar lordotic angle in group 1 ($r = 0.496$, $p = 0.001$), and a weak negative correlation between the body height and the lumbar lordotic angle in group 2 ($r = -0.355$, $p = 0.019$).

The trunk length showed moderate to strong positive correlations with the thoracic kyphotic angle in both groups ($r = 0.660$, $p = 0.001$; $r = 0.827$, $p = 0.001$). Furthermore, the trunk length demonstrated a moderate

positive correlation with lumbar lordosis in group 1 ($r = 0.697$, $p = 0.001$) and a strong negative correlation with the lumbar lordotic angle in group 2 ($r = -0.751$, $p = 0.001$).

The body weight showed a strong positive correlation with the thoracic kyphotic angle in group 1 ($r = 0.792$, $p = 0.001$), and a weak correlation with the thoracic kyphotic angle in group 2 ($r = 0.413$, $p = 0.008$). In addition, the body weight demonstrated weak positive correlations with the lumbar lordotic angle in group 1 ($r = 0.455$, $p = 0.003$) and weak negative correlations with the lumbar lordotic angle in group 2 ($r = -0.381$, $p = 0.015$).

The BMI showed no correlations with the kyphotic or lordotic angles in group 1 ($r = 0.226$, $p = 0.161$; $r = 0.139$, $p = 0.391$, respectively). However, the BMI demonstrated weak positive correlations with the kyphotic angle ($r = 0.324$, $p = 0.034$) and no correlation with lordotic angles ($r = -0.214$, $p = 0.165$) in group 2. Finally, there were moderate to strong negative correlations between shoulder width and the kyphotic angle in group 2 ($r = -0.642$, $p = 0.001$; $r = -0.836$, $p = 0.001$), as shown in Table 2.

Discussion

The study was conducted to examine the relationship between anthropometric measures and the sagittal spinal curvatures in handball players. The results proved that the anthropometric parameters differenti-

Table 1. Demographic characteristics of participants

Variable	Group 1 ($n = 40$)	Group 2 ($n = 43$)	p value
Age (years)	23.62 ± 2.07	24.63 ± 2.58	0.054
Weight (kg)	81.00 ± 5.74	75.06 ± 4.59	0.001*
Height (cm)	178.39 ± 4.47	170.67 ± 1.62	0.001*
Body mass index (kg/m ²)	25.47 ± 1.28	25.85 ± 1.42	0.200
Shoulder width (cm)	46.25 ± 3.76	45.06 ± 3.47	0.139
Trunk length (cm)	47.93 ± 2.38	46.26 ± 1.43	0.001*
Kyphotic angle (°)	49.35 ± 5.73	46.98 ± 4.49	0.038*
Lordotic angle (°)	29.07 ± 6.08	30.37 ± 5.62	0.312
Coefficient of compensation (°)	20.29 ± 1.58	16.70 ± 9.99	0.026*

* statistically significant results ($p < 0.05$)

Data are presented as mean ± standard deviation.

Table 2. Correlations between anthropometric parameters and sagittal spinal curvatures in both groups

Anthropometric parameter	Group 1 ($n = 40$)		Group 2 ($n = 43$)	
	Kyphotic angle	Lordotic angle	Kyphotic angle	Lordotic angle
Body height (cm)	$r = 0.897$, $p = 0.001$	$r = 0.496$, $p = 0.001$	$r = 0.381$, $p = 0.012$	$r = -0.355$, $p = 0.019$
Trunk length (cm)	$r = 0.660$, $p = 0.001$	$r = 0.697$, $p = 0.001$	$r = 0.827$, $p = 0.001$	$r = -0.751$, $p = 0.001$
Body weight (kg)	$r = 0.792$, $p = 0.001$	$r = 0.455$, $p = 0.003$	$r = 0.413$, $p = 0.008$	$r = -0.381$, $p = 0.015$
Body mass index (kg/m ²)	$r = 0.226$, $p = 0.161$	$r = 0.139$, $p = 0.391$	$r = 0.324$, $p = 0.034$	$r = -0.214$, $p = 0.165$
Shoulder width (cm)	$r = -0.642$, $p = 0.001$	–	$r = -0.836$, $p = 0.001$	–

r – Pearson's correlation coefficient

ated the 2 study groups of handball players according to height, trunk length, and body weight. Despite significant differences in body height and weight, the lack of significant difference in BMI was a surprise as handball players should be not only tall but also slim. This result agrees with the findings of Grabara [23], who found no significant difference in BMI between volleyball players and non-athletes. Moreover, the body height of the participants in the current study was lower (from 185.01 to 192.62 cm) than that of the participants of the Men's Handball World Championship 2013 [24].

There was no significant difference in the shoulder width between both groups, which might contribute to the increase of the thoracic kyphosis according to the body height in both groups (as with an increase of thoracic kyphosis, the rounded shoulder appeared and the distance between the acromions of both shoulders started to decrease). Although there was a significant difference in thoracic kyphosis between the groups, the lordotic angle showed no difference. This result disagreed with the findings of Grabara [25], who reported smaller lordotic angles for female handball players than for their non-training peers; moreover, the tall subjects had small lordotic angles compared with the other participants [23].

The present study revealed significant differences in the sagittal spinal curvatures, especially in the thoracic kyphosis. Handball players of group 1 showed a higher degree of thoracic kyphosis than those in group 2, with an increase of the body height and trunk length; this is consistent with the findings of Rajabi et al. [7], who reported that sports with a predominance of forward bending postures were associated with a greater thoracic kyphotic angle in standing. Despite the similarity between handball and tennis, Muyor et al. [16] observed that tennis did not alter sagittal spinal morphology in the relaxed standing posture in highly trained adolescent tennis players. The thoracic hyperkyphotic posture during relaxed standing in male tennis players might be more related to other factors than the specific training in tennis, such as lack of postural scheme.

However, the degree of lumbar lordosis in both groups appeared to be below the normal values reported in previous studies (40–45°) [1, 26]; with an increase in the body height, group 1 demonstrated a higher degree of lumbar lordosis than group 2, which indicated that the degree of compensation between the thoracic kyphosis and lumbar lordosis in the handball players of group 1 was higher than in group 2. This compensation tends to maintain sagittal balance of the spine and may prevent the incidence of injury [27]. Van Royen et al. [28] detected this positive correlation between the lumbar lordosis and thoracic kyphosis, which maintains the sagittal spinal balance. Many studies [9, 10, 29] proved that there was a relationship between different sports trainings and the shape of sagittal spinal curvatures. Moreover, Lichota et al. [15] found that handball and volleyball players demonstrated more thoracic kyphosis than lumbar lordosis,

while players in other types of sports showed balanced sagittal spinal curvatures.

The sagittal spinal posture plays an important role in maintaining balance; Drzał-Grabiec et al. [30] observed that the change of the centre of pressure position and the balance sensitivity depended on the development of sagittal spinal curvatures and shoulder girdle rotation. A compensatory mechanism for thoracic hyperkyphosis would be an increase in the lumbar lordosis with an increase of the body height to maintain the spine in a neutral position and to preserve the line of gravity within the centre of the base of support; this was more obvious in the handball players of group 1 than group 2, in which the CC (the ratio between the two curvatures) increased in comparison with non-athletic subjects [31]. On the other hand, Bruno et al. [32] revealed that hyperkyphosis might not be associated with posture adjustment; such uncompensated posture was observed with the non-athlete participants in the present study. In some cases, thoracic kyphosis might be related with an increase in the lumbar lordosis or pelvic tilt to maintain a stable centre of mass and horizontal eye sight [33].

The trunk length is one of the components forming the human stature. The sitting height consists of trunk length and head length [34]. So, the similarity between the results of trunk length and body height can be explained by the findings of Fredricks et al. [35], who stated that body height and sitting height were very closely related as the sitting height can be used to estimate the total body height and development.

Although there was no significant difference in the shoulder width between the study groups, the results showed a strong negative correlation between the kyphotic angle and shoulder width in group 2, which indicated that with an increase of body height, there would be an increase in the kyphotic angle and the rounded shoulder (decrease in the shoulder width) by the effect of gravity and sustained muscles contraction in the anterior aspect of the shoulder during the performed activities. This is supported by the findings of Cheshomi [36], who confirmed that with increasing thoracic kyphosis, the subacromion space would be decreased by the scapular protraction. This scapular protraction, as a compensatory mechanism of thoracic hyperkyphosis, would be the cause for the reduction of shoulder width. In addition, the continuous scapular protraction is increasingly associated with shortening of pectoralis major and minor muscles. Grabara [31] showed that young football players had more protruded shoulder blades than their untrained counterparts.

BMI is widely applied in adult population for an internationally recognized definition of overweight and obesity [37]. The current study has proved no relationship between BMI, and kyphotic and lordotic angles in handball players, except the kyphotic angle in group 2. This is consistent with the results obtained by Hoseinifar et al. [38]. However, some other studies have reported correla-

tion of BMI with thoracic kyphosis [33] and lumbar lordosis [39, 40]. This discrepancy may be attributed to differences in population, age, tools of measurement, and study design.

Moreover, the load of the spine is greatly affected by the body weight and height. Han et al. [41] used a computer model to estimate the amount of load on the spine during daily activities. They found that the resultant moment was greatly affected by increasing the body weight and height. The rise in the resultant moment was contributed by the greater effect of gravity. With an increase in the body weight and height, the resultant moment tends to rise with the activities of daily living. This may explain the association between body weight and kyphotic and lordotic angles, especially in group 1, which was heavier than group 2.

Most of the previous studies confirmed the influence of sports training on the shape of vertebral curvatures [7, 8, 25]. Uetake et al. [8] reported that the shape of anteroposterior curvatures of the spine depended on the specificities of sports disciplines. They found that sprinters, runners, jumpers, kendo participants, and throwers had deep spinal curvatures, whereas swimmers, bodybuilders, sailors, soccer players, rugby players, and non-athletes had a shallow curvature. Lichota et al. [15] observed that the thoracic kyphosis was greater than the lumbar lordosis (kyphotic type of posture) in both volleyball and handball players, which supports the findings of the present study; in turn, sprinters and taekwondo competitors exhibited a compensated posture type.

On the basis of the findings of the current study and previous research, it can be hypothesized that the severity and magnitude of sagittal postural asymmetry is related to the specificities of each sports discipline. The development of posture asymmetries should not be underestimated. It is important to achieve symmetry in the training process and regularly assess the degree of asymmetry in order to reduce the risk of injuries and maximize the athletic efficiency [14]. It is also advisable to design individual compensatory and stretching exercises for all athletes, especially for the muscles in the front and back of the body [42].

A limitation of this study consists in the fact that it involved males only. So, the appropriateness of generalizing the results is confined to this specific population. Moreover, the effect of player position in the team (i.e. wings, pivots, goal, and backwards centre) was not examined. It has been proved that each specific position in handball requires unique physiological and physical characteristics. Future studies shall consider the effect of training duration on the sagittal spinal curvatures, which is important for athletic rehabilitation and training programs design. It would also be interesting to compare the sagittal spinal curvature between handball players and the non-athlete population and to evaluate the spinal curvatures in the frontal plane to identify pos-

sible scoliosis in handball players. Furthermore, extended studies are needed on the relationship between anthropometric variables, spinal posture, and trunk muscle electromyography with static balance among handball players with different body anthropometry.

Conclusions

The anthropometric measures have an effect on the changes in the sagittal spinal curvatures among tall handball players. Increasing body height tends to enlarge the kyphotic angle, which is associated with rounded shoulder, small shoulder width, and a rise in the lordotic angle in handball players. So, it is important to consider the anthropometric measurements of the body which affect the spinal curvatures and load distribution, especially in athletes. Although we studied healthy males, our findings highlight the potential effects of anthropometric measurements on the posture in general. From this point of view, somatic parameters can significantly raise the risk of postural instability and, hypothetically, of pathomechanics and consequent injury. Therefore, handball coaches should consider frequent posture assessment among handball players because of asymmetric spine overloads during training, as well as include exercise that helps maintain good posture in training sessions.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

Authors state no conflict of interest.

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