



The Importance of Posture And Body Composition for the Stability and Selected Motor Abilities of Professional Handball Players

by

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The aim of the research was to analyze body composition, body posture and postural stability of professional male handball players and to determine the differences between players with correct and incorrect body posture, considering power of the lower limbs and agility, speed, and change of direction deficit. The study comprised 16 professional handball players. Body composition analysis was performed using the method of electrical bioimpedance. Body posture was examined using the Diers formetric III 4D optoelectronic method. Postural stability was tested via the Biodex Balance System. Players performed the following fitness tests assessing lower limb muscle power (LP, HS, CMJ), linear speed (SLS 20 m), and COD speed (Zig-Zag test, COD deficit). Only 31.25% of players demonstrated body posture with correct physiological curvatures, while 68.75% showed changes in body asymmetry. The group with correct body posture performed better in SLS 20m than the group with incorrect posture, yet in the Zig-Zag agility test, the difference in the results was not significant and this affected the COD deficit, which was higher. The vast majority of participants demonstrated postural defects and incorrect physiological curvatures of the spine. The occurrence of scoliotic posture was also observed. The body deflection angles indicated that athletes' postural stability was good. However, it is worth noting that the majority demonstrated a tendency towards asymmetrical body deflections to the right or to the left, backwards direction. One-sided sports specialization leads to disturbances in the statics of the body, therefore, it becomes necessary to include postural re-education exercises in training.

Key words: body composition, body posture, postural stability, handball players.

Introduction

Body posture is a characteristic feature of every human being. It is an external reflection of the structure and functional state of the musculoskeletal system, as well as temperament, character and mood (Asker et al., 2018; Rühlemann et al., 2020; Rousanoglou et al., 2014). Posture is an indicator of proper development as well as static and dynamic fitness of the body (Wilczyński, 2018; Zwierzchowska et al., 2014, 2020). It determines the free position of the body in a standing position, which a person can freely alter into posture (Hassan et al., 2017; Salzer et al., 2020; Steffen et al., 2017). It should be defined as the resultant of morphological,

neurophysiological and environmental factors (Caballero et al., 2020). Physical activity manifests itself in motor actions, which also include postural stability (Ashtiani and Mahmood-Reza, 2017). It is the starting point for locomotor activities and determines the mobility of an athlete (Maroto-Izquierdo et al., 2017).

Correct and stable posture is a necessary condition for the implementation of most free movements and locomotion, therefore it plays an important role in the game of handball (Dello Iacono et al., 2017; Ohlendorf et al., 2019; Zwierzchowska et al., 2022). In this game, a very important role is also played by motor coordination, especially postural balance and

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stability (Powell and Williams, 2015). The ability to maintain postural stability is an element of coordination and affects the quality of handball players' motor activities (Wagner et al., 2014, 2018; Zech et al., 2012). All types of physical activity, due to the performance of the most important movements, are divided into asymmetric, symmetric and mixed (Gorostiaga et al., 2006; Maszczyk et al., 2018). Handball is an intense game of offensive and defensive actions, which includes single-legged jumps, throws and one-handed passes, therefore, it should be classified as an asymmetric sport (Michalsik and Aagaard, 2015; Gorostiaga et al., 2006).

Exercises unevenly loading the locomotor system in long-term asymmetric positions may adversely affect body posture and lead to permanent changes over time (Gaweł and Zwierzchowska, 2021; Kuhn et al., 2019). Unilateral sports specialisation can lead to disturbances in the statics of the body. Therefore, systematic research is needed to monitor the body composition, body posture and postural stability of handball players (Mascarin et al., 2017; Massuca et al., 2014).

Measurements of change of direction (COD) performance and agility take into account the total time to complete various agility tests or the mean speed achieved over a specific distance used in the test. Unfortunately, most tests involve running in a straight line, thus, it is difficult to assess whether a player is agile or just fast. To evaluate the ability to slow down and accelerate in a new direction, a method of change of direction deficit (COD-D) was proposed, with the sprint time with a change of direction subtracted from the straight-line sprint time at the same distance (Nimphius et al., 2016; Pereira et al., 2018) or the assessment of differences in velocity between a linear sprint test and an agility test of equal distance.

Several researchers have assessed the COD-D in terms of body and spine asymmetry. Correct posture due to the lack of changes in the structure of the spine and muscle strength is related to the speed of running in a straight line, acceleration and the ability to change direction, although the question about the effect of the COD-D remains open (Nimphius et al., 2016).

Therefore, the aim of the present study was to analyze body composition, body posture

and postural stability of professional male handball players, and to determine the differences between players with correct and incorrect body posture, considering power of the lower limbs, agility, speed, and the COD deficit.

Methods

The study comprised 16 professional handball players from PGE VIVE Kielce. This team is a 17-time Polish champion, a 16-time winner of the Polish Cup and the winner of the Champions League during the 2015/2016 season. Research was carried out in August 2019 at the Posturology Laboratory of the Jan Kochanowski University in Kielce. The age of participants was 22 to 38 years and their professional experience was 5 to 13 years.

The study was conducted with the consent of the team's head coach and the players themselves. Prior to testing, participants were informed about the procedures and objectives of the study. All procedures were performed in accordance with the 1964 Declaration of Helsinki and approved by the Bioethics Committee of the Academy of Physical Education in Katowice, Poland (3/2019).

Body composition

The method of electrical bioimpedance was used to evaluate body composition. The test was performed via the TANITA MC-780 device. The total measurement duration was approximately 20 s. The following variables were determined: Body Mass (BM) (kg), Body Mass Index (BMI) (kg/m²), Adipose Tissue Mass (ATM) (kg), ATM (%), Muscle Mass (MM) (kg), Total Body Water (TBW) (in kg and %), and Basal Metabolic Rate (BMR) (in kJ and kcal) (Jaremków et al., 2020).

Posture

The posture was assessed via the Diers formetric III 4D optoelectronic method with the use of raster stereography. This 3-dimensional analysis is a combination of optical imaging techniques and digital data processing. It is a non-contact and fast 4D photogrammetric measurement of the surface of the back and spine. The results of the measurements are precise as well as detailed, and thanks to the immediate transfer of the image to the computer, the data analysis is carried out immediately after their execution. The posture analysis was performed in

DiCAM with the "Average measurement option". This consisted in making a sequence of 12 film frames, which, due to the creation of average values, reduced the postural variance and thus, improved the clinical quality of measurements.

A computer program was used to analyse the data and establish a photogrammetric digital image of the body posture. The following variables describing body posture were determined: thoracic kyphosis angle ($^{\circ}$), lumbar lordosis angle ($^{\circ}$), trunk length (mm), lateral deviation (mm), pelvic torsion ($^{\circ}$), pelvic skewness (mm), surface rotation ($^{\circ}$), lumbar dimple spacing (mm), apex of thoracic kyphosis (mm) and apex of lumbar lordosis (mm). The following classification was adopted for the evaluation of scoliotic posture: pelvic skewness 1-4-mm, lateral deviation 1-4-mm and surface rotation 1-4 $^{\circ}$.

To define scoliosis, pelvic skewness had to be equal to or greater than 5-mm, lateral deviation equal to or greater than 5-mm, surface rotation equal to or greater than 5 $^{\circ}$ and all three conditions had to be met. The norm for the thoracic kyphosis angle was 42-57 $^{\circ}$, while for lumbar lordosis 37-47 $^{\circ}$. The norm for pelvic skewness was up to 4-mm, pelvic torsion up to 2 $^{\circ}$, deviation from vertical position up to 7-mm, surface rotation up to 5 $^{\circ}$ and a lateral deviation up to 5-mm (Degenhardt et al., 2020).

Postural stability

The Biodex Balance System platform was used to assess postural stability. The Postural Stability Test was performed in a position with both legs on a stable surface with eyes open. The test consisted of 3 and 20s trials, separated by a 10s rest interval. During the examination, the participant's eyes focused on the monitor screen. There was a dot demonstrating a symbolic representation of the Centre of Pressure (COP) of the feet. The task of the participant was to place the dot in the centre of the circle visible on the monitor, at the point where the coordinate axes intersected. The following variables were used to assess postural stability: Overall Stability Index ($^{\circ}$), Anterior-Posterior Index ($^{\circ}$), Medial-Lateral Index ($^{\circ}$), Time in Zone (%): A, B, C and Dm and Time in Quadrant %: Quadrant 1 - right front, Quadrant 2 - left front, Quadrant 3 - left rear, Quadrant 4 - right rear (Sekulic et al., 2013).

Study design

Testing of jumping ability as well as strength and power of the lower limbs was conducted until noon following two days of rest. On the first day, after a 15-min warm-up, 16 players started a speed test. After a 5-min rest interval, the agility test was carried out. Then athletes performed power tests on the Leg Press and Kaiser Squat devices and jumping tests using the Force Deck. A 5-min rest interval was administered between each jumping test so that each subsequent test was performed after full recovery. At that time, players exercised to maintain proper body temperature (Freitas et al., 2019; Nimphius et al., 2016).

20 m speed test

Players sprinted 20-m and their performance was assessed using photocells. They ran the sprint twice, starting from a crouched start, with the dominant leg at the front, 0.3-m behind the starting line. The test was conducted in an indoor gym. A 5-min rest interval was allowed between the two tests. The best time of both tests was taken into account for further analyses.

Zig-Zag agility test

The Zig-Zag test consisted of four 5-m sections marked with cones at an angle of 100 $^{\circ}$. The procedure was the same as in the straight-line speed test. Players performed the test twice and the best results were recorded for further analyses.

CMJ

The CMJ test was carried out on a dual force plate using FD4000 Dual Force Platform, where participants performed four maximum vertical jumps while holding their hands on the hips (CMJ). The purpose of the test was to assess the power of the lower limbs during a counter-movement jump (CMJ) based on the measurement of ground reaction force. The mean of all jumps was used for further analysis. During the jump, hands were held on the hips.

Strength

After the warm-up, 1RM was measured for each athlete, using the Beachle 2008 procedure. After a 5-min rest interval, maximum force during the concentric phase was evaluated, using the Kaiser A300 Squat. The movement consisted of a half squat position (90 $^{\circ}$ knee flexion) as fast as possible with a load of 60% 1RM. The best result of three tests was registered for further analysis.

Next, participants performed the seated leg press using the Keiser Air300 Leg Press. The adjustable sitting position protected the lower back by keeping it stable, allowing the gluteal muscles to be stretched and more active during the exercise. Firstly, 1RM was evaluated and, after a 5-min rest interval, a test was performed with the athlete performing the leg press exercise at a load of 60%1RM (four repetitions). This test was used to evaluate maximum concentric strength of the lower limbs.

Statistical analysis

All variables were expressed as mean or median \pm standard deviation (SD). Before using a parametric test, the assumption of normality was verified using the Kolmogorov-Smirnov test. The distribution of all variables was normal or close to normal. The numbers of quality data for analyzing groups were obtained using analysis of the contingency table.

Correlation analysis with Pearson's coefficients was used to determine significant correlations between body composition and posture variables.

One-way ANOVA was used with the level of significance set at $p < 0.05$, to determine differences between groups. When appropriate, a Tukey post hoc test was used to compare selected data, and the effect of each test was calculated to determine the significance of the results.

To interpret effect sizes (ES) for statistical differences we used eta square classified as small ($0.01 < \eta^2 \leq 0.06$), medium ($0.06 < \eta^2 \leq 0.14$) and large ($\eta^2 > 0.14$) (Cohen, 1988). The level of significance was set at $\alpha = 0.05$.

The remaining analyses were performed using STATISTICA (Stat Soft, Inc. (2018) version 12).

Results

The posture characteristics in the sagittal and frontal planes

When assessing posture in the sagittal plane, kyphosis and reduced lordosis were observed in 38.75% of players. Reduced kyphosis and reduced lordosis, the so-called flat back, were noted in two of the participants. In one of players, reduced kyphosis and enlarged lordosis were exhibited, while one player was characterized by increased kyphosis and normal lordosis, the so-called round back. Furthermore, one of players

demonstrated enlarged kyphosis and increased lordosis, the so-called round-concave back. Concluding, only 31.25% of players had body posture with the correct course of physiological curvatures. The angle of thoracic kyphosis in 68.75% of athletes was normal, in 18.75% reduced and in 12.50% excessive. The reduced lumbar lordosis angle was noticed in 50% of athletes, normal in 37.50% and enlarged in 12.50%. The pelvic torsion in 50% of handball players was too severe. The pelvic skewness in 68.75% of handball players was outside the norm. Surface rotation exceeded the norm in 43.75% of players. Deviation from the vertical position was beyond the norm in 37.50% of players. As for lateral deflection, 75% of handball players were outside the norm.

In the frontal plane, the direction of traces of the spinal curvature was left-sided in 62.50%, and right-sided in 37.50% of players. The pelvic skewness direction was right-sided in 50% of handball players, left-sided in 37.50%, while in 12.50%, pelvic skewness was correct. The left-sided direction of pelvic skewness was noted in 50%, right-sided in 31.25%, while in 18.75% of handball players, it was correct. In 50% of athletes, left-sided surface rotation was noted, right-sided rotation was observed in 37.50% of athletes and in 12.50%, there were no defective rotations. The direction of deflection from the vertical position was left-sided in 50% of handball players, right-sided in 37.50%, and in 12.50% of players, no defective deflections from the vertical position were noted. The direction of lateral deflections was left-sided in 56.25%, and right-sided in 43.75% of athletes.

The assessment of body posture in the frontal plane was slightly better, as only 19.00% of handball players presented scoliotic posture, but none had scoliosis.

Intergroup differences between posture and body composition, agility, speed, and COD deficit

Analysis revealed significant correlations between some of the body composition and body posture variables. The same analysis showed that the thoracic kyphosis angle ($^{\circ}$) positively correlated with the BMI ($r=0.63$, $p=0.036$). Moreover, surface rotation ($^{\circ}$) was positively correlated with the BMI ($r=0.68$, $p=0.02$) and with TBW (kg) ($r=0.65$, $p=0.03$).

The mean of the Overall Stability Index

was 0.67 (°), the mean of the Anterior-Posterior Index was 0.45 (°) and the mean of the Medial-Lateral Index was 0.38 (°). During the test, all participants maintained in Zone A (100%). The mean duration of maintaining within the quadrants during the test was: Quadrant 1 (right

front) - 20.37 (%), Quadrant 2 (left front) - 14.75 (%), Quadrant 3 (left back) - 24.31 (%) and Quadrant 4 (right back) - 40.56 (%).

Table 1*Characteristics of professional handball players.*

Characteristics	⊙	S	V
BH [cm]	195.50	6.79	3.47
BM [kg]	99.49	10.36	10.41
BMI	25.98	2.21	8.52
ATM [%]	42.83	40.60	94.79
ATM [kg]	44.44	42.38	95.38
FFM [kg]	89.78	10.45	11.63
MM [kg]	86.94	11.81	13.58
TBW [kg]	73.29	19.98	27.26
TBW [%]	72.78	19.82	27.23
BMR [kJ]	7334.63	5127.67	69.91
BMR [kcal]	1777.00	1189.40	66.93

Note: Body Mass (BM) (kg), Body Mass Index (BMI) (kg/m²), Adipose Tissue Mass (ATM) (kg), ATM (%), Muscle Mass (MM) (kg), Total Body Water (TBW) (kg), and TBW (%), BMR (kJ and kcal)

Table 2*Differences between groups using one-way ANOVA.*

	Correct body posture group	Incorrect body posture group	<i>p</i>	ES (η^2)
	Mean \pm SD	Mean \pm SD		
Mass [kg]	101.12 \pm 5.28	98.11 \pm 6.79	0.001	0.25
Height [cm]	194.94 \pm 6.09	191.29 \pm 5.87	0.004	0.18
Skeletal muscle mass [kg]	81.34 \pm 2.02	79.22 \pm 3.05	0.004	0.17
VEL 20m [m/s]	6.08 \pm 0.14	5.94 \pm 0.24	0.001	0.23
Zigzag [m/s]	3.63 \pm 0.14	3.69 \pm 0.12	0.181	0.04
COD-D [m/s]	2.45 \pm 0.18	2.25 \pm 0.22	0.024	0.13
Leg Press [W/kg] [60% 1RM]	3179,52	2559.22	0.001	0.23
HS [W/kg]	3110,75	2627,75	0.001	0.24
CMJ [W/kg]	3179,26	2967,32	0.001	0.26

Note: CMJ: countermovement jump; W/kg: watt per kilogram; HS: half-squat; VEL: velocity; COD-D: change of direction deficit; *p*: level of significance, ES: effect size

The results of the analysis of motor abilities including a division into correct and incorrect body posture groups are presented in Table 2. Handball players with correct body posture presented statistically better effect size (ES) results in LP, HS and CMJ (1.33, 1.24 and 1.76, respectively), and were much heavier (ES:1.25) and taller (ES:1.08), than the group with incorrect body posture. The skeletal muscle mass in the correct body posture group was much higher than in the incorrect one (ES:1.73). Handball players with correct body posture achieved higher straight-line speed (ES:1.23) and had a higher COD-D (ES:0.65). No significant differences were found between the groups in the Zig-Zag agility test (ES:0.48).

Discussion

Our tests allowed to demonstrate the correct body composition of professional male handball players. However, most of athletes developed body posture defects in the sagittal and/or the frontal plane. Only five (31%) handball players demonstrated body posture with the correct course of the physiological curvature, while three (19.00%) participants showed signs of scoliotic posture. Postural defects may be caused by the asymmetry of loads on the musculoskeletal system and result from the nature of the game. This thesis has been confirmed by studies of both young and older professional athletes. Biomechanical adaptation, often functionally unfavorable, is an often observed phenomenon in professional sport (Gaweł and Zwierzchowska, 2021; Tuz et al., 2021; Zwierzchowska and Tuz, 2018; Zwierzchowska et al., 2020). The negative influence of sports specialisation on the quality of players' posture was also observed by other researchers, who drew attention to the increased incidence of posture defects in those training team sports, compared to runners and judokas (Maszczyk et al., 2018). The authors of those studies claim that competitive training should begin only after bone growth is completed (Maszczyk et al., 2018). Until then, only lighter forms of exercise should be carried out, which load the developing spine to a lesser extent (Grabara, 2018).

The training program should also include elements influencing the improvement of body statics. Other researchers have shown that the

majority of handball players have incorrect posture, regardless of the duration of their playing experience (Caballero et al., 2020). This is probably due to the asymmetric technique of the game, e.g., throwing a ball or dribbling it. During a goal shot, the player jumps up and performs a vigorous arm movement, which rotates the body inwards. This movement also causes a temporary curvature and rotation of the spine, which becomes permanent over time. It also causes lateral deflection and a tilt of the body from the vertical position. When landing after a throw, one hip plate is always higher, which, in turn, causes the pelvis to rotate and tilt.

In our research, the direction of the pelvic torsion turned out to be right-sided, while trunk rotation was directed to the left. The fact that intense sports training can cause various negative effects on the locomotor system has also been confirmed by other researchers (Helm et al., 2016). They argue that extensive sports training does not have to be the main factor affecting body posture. This is mainly caused by the negative influence of asymmetric playing technique on pelvic statics. The pelvis is a complex and important structure of the human body, which supports the entire spine. Misalignment of the pelvis causes changes in the overall posture. In one study, as many as 70% of handball players demonstrated pelvic torsion (Zech et al., 2012). Similarly, in our study, half of participants had an abnormally rotated and tilted pelvis.

On the other hand, in other studies it has been shown that handball players have deepened thoracic kyphosis, similarly as volleyball players, track-and-field and taekwondo athletes (Gaweł and Zwierzchowska, 2021; Zwierzchowska et al., 2022). In our research, in 19% of participants, the angle of thoracic kyphosis was reduced, while in 12.00%, it was enlarged. On the other hand, we observed a reduction in the angle of lumbar lordosis, excessive lateral deflection, surface rotation and deflection from the vertical position in the majority of handball players.

The second step of this research was focused on determining the differences between players' correct and incorrect body posture, in power of the lower limbs and agility, speed, and COD deficit.

In our study, the magnitude of the COD deficit resulted from the fact that the correct body

posture group outperformed the incorrect body posture group in the straight-line sprint test over a distance of 20-m ($p < 0.05$; ES: 1.23; 0.83; 0.93), but in the Zig-Zag test there were no statistically significant differences. The differences in power (LegPress, half-squat and counter-movement jump peak power), between the incorrect body posture group and the correct body posture group were statistically significant ($p > 0.05$).

Studies of other authors confirm the influence of strength training (half squat, jump squat) on the improvement of linear sprint performance (Loturco et al., 2018; Styles et al., 2016). Similar devices were used to evaluate lower limb strength in the drive phase (Plyo Press, Agaton Max Series Leg Press) (Massuça et al., 2014), but the difference in the body position (a sitting position on Keiser Air300 and a lying position on Plyo Press) and foot press which is moved during the push phase (in the Keiser Air 300, the pressure of the legs on the sliding element of the machine, while in the Plyo Press the pressure is exerted by the arms) can significantly affect the assessment of lower limb power. The Keiser Air 300 Leg Press is a modern device in which the athlete presses down while sitting with a 90° bend in the knees and a maximally stabilized pelvis. In our study, properly built players outperformed the other athletes in all tests. This may indicate the influence of posture and body symmetry on the players' motor potential.

Considering peak power CMJ [W/kg], the statistically significant result may indicate that power generated by the correct body posture group of players was the result of a more symmetrical work, with the simultaneous use of both limbs. Studies of other authors confirm that jump height is influenced by the symmetry of the jump (McFarland et al., 2016).

For the group of players with correct body posture, the COD deficit was higher. In general, the improvement in the agility test reduces the COD deficit, while the improvement in the 20 m speed test increases the deficit. This study shows the direct effect of power generated by both groups on speed, but not on agility (COD deficit).

Other studies confirm the lack of consistency between strength and agility (Spiteri et al., 2015), but there are also conflicting results

indicating that strength correlates with agility (Sheppard and Young, 2006). It is very important to choose strength training or exercise that improves COD ability and COD deficit.

Conclusions

1. The vast majority of participants demonstrated posture defects and the incorrect course of physiological curvatures of the spine. The occurrence of scoliotic posture was also observed. The body deflection angles indicate that players had good postural stability. However, it is worth noting that the majority showed tendencies towards asymmetrical body deflections in the right or left back directions.
2. There were significant correlations between some of the examined posture and body composition variables. Vigorous exercise and a correct body mass, with a high content of muscle mass and an appropriate BMI is not a guarantee of correct posture. Handball is a discipline in which asymmetrical positions are often assumed, which further adversely affects body posture and its stability. One-sided sports specialization leads to many disorders of body statics, therefore, it is necessary to include postural re-education exercises in training.
3. The results presented in this study, show the importance of correct posture in terms of power, speed and agility in men's handball. By dividing players into those who show correct and incorrect body structure, differences in muscle power generated by the lower limbs and in running speed and other motor abilities can be observed, in favor of athletes with correct posture (despite their minority in the study). However, further research is needed to confirm or rule out whether only the correct posture has a direct impact on the variables analyzed in this study.

Acknowledgments

The authors would like to thank all the handball players who participated in this study.

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