



## Postural Stability in Goalkeepers of the Polish National Junior Handball Team

by  
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*The aim of the study was to assess postural stability of goalkeepers from the Polish national junior handball team. Eleven juniors of the Polish national handball team (age  $16.82 \pm 1.6$  years, body height  $191.27 \pm 3.1$  cm, body mass  $88.41 \pm 12.26$  kg, BMI  $24.18 \pm 3.22$  kg/m<sup>2</sup>) were selected for the study. The Biodex Balance System and AccuGait AM-TI platform were used to evaluate postural stability. The obtained results indicated good postural stability of the subjects. During the Biodex Balance System platform tests, all subjects presented very good postural stability and maintained within Zone A. Postural sway was greater in the sagittal plane compared to the frontal one. Most of the participants demonstrated slight backward tilts, but maintained in Quadrant IV. During the AccuGait AMTI platform trial, Path Length and Average COP Speed significantly increased in the test performed with closed eyes. Furthermore, there were significant positive correlations between the number of variables obtained during the Biodex Balance System and AccuGait AMTI tests. Proper and stable posture are necessary conditions to be met to carry out most free movements and locomotion. They play a significant role in the game of a handball goalkeeper and for that reason, postural stability testing of handball goalkeepers is an important element of coordination training. Thus, the use of postural stability exercises implementing the biofeedback method on stabilo and dynamometric platforms is practical and justifiable.*

**Key words:** postural stability, Biodex Balance System, AccuGait AM-TI, goalkeepers.

### Introduction

Handball is a dynamic and intermittent sports discipline, in which the goalkeeper plays a very important role (Hermassi et al., 2017, 2018). Assuming this position, an athlete has restricted freedom of movement because s/he must be always ready to intervene whenever necessary (Schwesig et al., 2017). Goalkeeper's movements shall be coordinated, and as simple and economical as possible (Rousanoglou et al., 2014). The distance between the goalkeeper and the attacking players is small, therefore, the goalie must not only demonstrate quick reflexes, but also be able to predict the trajectory of the ball while engaging in cooperation with the defence (Asker et al., 2018). The goalkeeper is exposed not only to hits by the ball, injuries during various

interventions, bumps against the goal post construction, but also high-contact situations with opponents (Bělka et al., 2017). A goalkeeper defending 50-60% of all throws is a strong asset to the team (Maroto-Izquierdo et al., 2017), and the effectiveness of his/her game greatly impacts the attitude and efficiency of the whole team. It is often the case that when the goalkeeper's actions are successful, motivation of the team increases (Steffen et al. 2017). The number of goalkeeper's interventions during a game varies between 30 and 50 (Fieseler et al., 2017). That is why proper training of a goalkeeper is of great importance for performance and preparation of the entire team (Helm et al., 2016). The basic techniques of the goalkeeper's game are related to: posture and movement, catches, steals and passes, defence

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using hands, legs and/or a body. Characteristics of a good goalkeeper include proper movement, setting him/herself in an advantageous position within the goal, and having an intuition or sense of the game. Since the coaches' task is to constantly develop these skills, it is necessary to observe the goalkeeper's movements and balance (Schwesig et al., 2009). All types of the goalkeeper's catches, steals and passes should be controlled.

Therefore, the goalkeeper should follow specific training that includes coordination, flexibility, strength-speed and agility exercises (Hernández-Davó et al., 2018). Apart from fitness, technical and tactical preparation, playing at various positions can be practiced to understand the game from other players' perspective. Game observation should also constitute a part of the training process (Silva et al., 2017). Another aspect to be considered is coordination, notwithstanding balance and postural stability. The ability to maintain postural stability is an element of coordination affecting the quality of a handball goalkeeper's performance (Ashtiani and Mahmood-Reza, 2017). Maintaining balanced body posture is a specific motor task requiring precise cooperation of all body segments resulting from dynamic processes taking place outside one's consciousness (Ringhof and Stein, 2018). The central nervous system (CNS) acts as an intermediary in registering and processing afferent signals or generating decisions among efferent pathways (Powell and Williams, 2015). This requires permanent cooperation of the following sensory systems: proprioceptive, vestibular, visual, auditory, as well as extrinsic and mechanoreceptors recording the deviations of the center of body mass (COM) projection from the set values. This should be done in cooperation with the executive system which performs corrections aimed at minimizing these deviations (Mohamed et al., 2009). Body balance should also be understood as the ability to maintain the center of gravity (COG) projection inside the support plane defined by the foot contour. This is a strictly functional property, measured on the basis of registering a signal representing COG displacement (so-called postural sway) (Apthorp et al., 2014). Body posture stability is a much more complex concept associated with possibilities, dynamic properties and characteristics of all

systems involved in maintaining balance (Dello Iacono et al., 2017; Maszczyk et al., 2018). This applies to the efficiency of movement, reaction speed and decision-making, as well as the ability to properly analyse conflicting incoming information regarding the current state of the body, including the location of its segments, their speed and acceleration (Ingebrigtsen et al., 2013). And thus, the aim of this study was to assess postural stability in junior goalkeepers of the Polish national handball team.

## Methods

### *Participants*

Eleven players of the Polish junior national handball team (age  $16.82 \pm 1.6$  years, body height  $191.27 \pm 3.1$  cm, body mass  $88.41 \pm 12.26$  kg, BMI  $24.18 \pm 3.22$  kg/m<sup>2</sup>, training experience  $6.54 \pm 1.86$  year) took part in the study. At the time of the study they followed training with daily training sessions of 90 min. The research was carried out in February 2014 at the Kochanowski University Posturology Laboratory of the Faculty of Medicine and Health Sciences in Kielce. All the procedures during tests involving human participants were performed in accordance with the ethical standards imposed by institutional and/or national research committees while adhering to the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

### *Measures*

The Biodex Balance System and AccuGait AMTI platforms were used to assess postural stability. The Postural Stability Test was conducted on the Biodex Balance System platform, with double support in a stable position with open eyes. After entering participants' personal data and body height into the system, the position of the subject was determined by entering the angle of settings for the right and left foot. The Postural Stability Test consisted of three 20-s trials, separated by a 10-s rest interval. The subject's eyes were focused on a screen where a dot appeared. This was the symbolic representation of the COP (Centre of Foot Pressure). The task of the participant was to direct the dot towards the centre of the circle at the point of intersection of the coordinate axes. All variables registered by the platform were collected in a non-invasive manner. The following variables were

used to assess postural stability:

- Overall Stability Index (°) - reflected variability of the platform position from the horizontal plane for all movements performed in the test. This was expressed in degrees over time.
- Anterior-Posterior Index (°) - assessed variation of the platform's position for sagittal plane movements expressed in degrees.
- Medial-Lateral Index (°) - indicated variability of the platform position for frontal movements expressed in degrees.
- % Time in Zone provided information on the time a subject maintained in a given zone during the test. Zones A, B, C and D were equal to the degree of the platform inclination angle. They were marked out by concentric circles with the centre located in the middle of the platform.

The Zones were the following:

- Zone A - from 0 to 5 degrees of deviation in relation to the horizontal plane;
- Zone B - from 6 to 10 degrees of deviation in relation to the horizontal plane;
- Zone C - from 11 to 15 degrees of deviation from the horizontal plane;
- Zone D - from 16 to 20 degree deviation from the horizontal plane.

- % Time in Quadrant - indicated the time the subject maintained in a given quadrant.

Squares represent the four quadrants of the test graph between axes X and Y:

- Square 1 - left front;
- Square 2 - right front;
- Square 3 - left back;
- Square 4 - right back.

The results obtained in the Postural Stability Test were dependent on the number of platform position deviations from the horizontal plane. The lower the result, the better the postural stability.

Postural stability was also examined using the AccuGait AMTI platform via Balance Clinic software. The Romberg test, i.e. the standard free-standing stability test, was performed. It consisted of two successive 30-s trials. The first one was conducted with open eyes (OE), while the second with closed eyes (CE). Measurements on the platform required continuous observation of the COP. Recording the body's deflection allowed to obtain accurate information on postural stability. COP movements reflected those related to the Center of

Mass movements (COM) in the frontal and sagittal planes of the body. The Average Load Point X which determined lateral coordinates X (cm), Average Load Point Y, which determined the anterior-posterior coordinates Y (cm), Path Length (cm) of the COP during the test, Average COP Speed (cm/s) and Area Ellipse, which was the area determined by the COP at the time of the test (cm<sup>2</sup>), were analyzed. Participants with less stable postural values attained higher values for all of the above mentioned variables. Body Mass (kg) and Body Mass Index (BMI) were evaluated using the method of bioelectrical impedance analysis. This consisted of assessing resistance of electric currents flowing through the body. The Tanita MC 780 MA body composition analyser was used.

#### *Statistical Analysis*

Normality of data distribution was evaluated using the Shapiro-Wilk test. Differences in postural stability between the tests performed with open and closed eyes (OE-CE) were analysed using the Student's *t*-test for dependent variables. Relationships between all variables were evaluated using Pearson's linear correlation coefficients. The level of significance was set at  $p < 0.05$ .

## **Results**

The overall stability index was  $0.5 \pm 0.12^\circ$ , while the anterior-posterior index equalled  $0.36 \pm 0.1^\circ$ . The medial-lateral index was  $0.24 \pm 0.1^\circ$ . All subjects remained in Zone A during the test. With regard to distribution of time spent in particular squares, for 20.73% of the time, slight sways occurred in the direction of the left front (Square I), for 12.91% of the time, participants remained in Square II (right front), while 15.27% of the time in Square III (left back). The majority of participants slightly swayed towards the right rear. The participants remained in Square IV for 50.82% of the test duration (Table 1).

#### *Average Load Point X*

During the test carried out using the AccuGait AMTI platform, the Average Load Point X (cm) oscillated between 0.8 with eyes open (OE) and 0.55 with eyes closed (CE). The difference in the Romberg test totalled 0.24. This variable was not significantly different between the measurements obtained during the tests performed with open and closed eyes ( $t = 1.98$ ,

df=10,  $p = 0.0752$ ).

#### Average Load Point Y

The Average Load Point Y (cm) oscillated between 5.41 with eyes open (OE) and 4.81 with eyes closed (CE). The difference in the Romberg test was 0.6. This variable also did not reveal significant differences between the measurements performed with open and closed eyes ( $t = 3.04$ ,  $df = 10$ ,  $p = 0.0124$ ).

#### Path Length

Path Length (cm) value fluctuated from 52.64 with eyes open (OE) to 69.39 with eyes closed (CE). The difference in the Romberg test was -16.76. This variable was significantly different between the measurements conducted with open and closed eyes ( $t = 3.59$ ,  $df = 10$ ,  $p = 0.0049$ ).

**Table 1**  
Postural stability in the Biodex Balance System and variables in AccuGait AMTI postural stability

Variables in postural stability Biodex Balance System	Mean	Standard deviation	Minimum	Lower quartile	Median	Upper quartile	Maximum
Overall Stability Index (°)	0.50	0.12	0.30	0.40	0.50	0.60	0.70
Anterior-Posterior Stability Index (°)	0.36	0.10	0.20	0.30	0.30	0.50	0.50
Medial-Lateral Stability index (°)	0.24	0.10	0.10	0.20	0.20	0.30	0.40
Zone A (%)	100.00	0.00	100.00	100.00	100.00	100.00	100.00
Zone B (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Zone C (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Zone D (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quadrant 1 (%)	20.73	17.50	2.00	5.00	15.00	39.00	47.00
Quadrant 2 (%)	12.91	10.63	0.00	2.00	15.00	20.00	33.00
Quadrant 3 (%)	15.27	9.67	3.00	6.00	12.00	25.00	30.00
Quadrant 4 (%)	50.82	16.06	29.00	39.00	46.00	67.00	76.00
Variables in postural stability AccuGait AMTI	Mean	Standard deviation	Minimum	Lower quartile	Median	Upper quartile	Maximum
Average load point X (cm) (OE)	0.80	0.36	0.33	0.49	0.77	1.13	1.49
Average load point Y (cm) (OE)	5.41	1.70	2.87	4.41	5.04	6.14	9.30
Path length (OE)	52.64	8.74	42.07	47.43	50.24	59.25	72.19
Average speed COP (cm/s) (OE)	1.75	0.29	1.40	1.58	1.68	1.98	2.41
Area ellipse [cm] (OE)	6.28	2.43	1.61	4.45	6.10	7.94	10.86
Average load point X (cm) (CE)	0.55	0.61	0.01	0.22	0.29	0.58	2.03
Average load point Y (cm) (CE)	4.81	1.43	3.51	3.77	4.36	5.19	8.66
Path length [cm] (CE)	69.39	19.43	40.55	57.89	65.70	86.40	103.82
Average speed COP (cm/s) (CE)	2.31	0.65	1.35	1.93	2.19	2.88	3.46
Area ellipse [cm] (CE)	6.64	2.53	3.40	3.82	6.37	8.23	11.60
Average load point X (cm)(OE-CE)	0.24	0.41	-0.53	-0.12	0.41	0.63	0.64
Average load point Y (cm) (OE-CE)	0.60	0.65	-0.64	0.21	0.64	0.97	1.68
Path length (cm) (OE-CE)	-16.76	15.48	-44.57	-32.60	-15.46	-4.57	7.92
Average speed COP (cm/s) (OE-CE)	-0.56	0.52	-1.49	-1.09	-0.52	-0.15	0.26
Area ellipse (cm) (OE-CE)	-0.36	2.66	-6.63	-1.57	-0.65	1.05	4.12

**Table 2**  
Correlations between the Biodex Balance System and AccuGait AMTI variables

Variables in postural stability	Overall Stability Index (°)	Anterior-Posterior Stability Index (°)	Medial-Lateral Stability index (°)	Quadrant I (%)	Quadrant II (%)	Quadrant III (%)	Quadrant IV (%)
Average load point X (cm) (OE)	-0.0686 <i>p</i> = 0.841	0.0266 <i>p</i> = 0.938	-0.2233 <i>p</i> = 0.509	-0.2431 <i>p</i> = 0.471	0.4379 <i>p</i> = 0.178	0.0675 <i>p</i> = 0.844	-0.0644 <i>p</i> = 0.851
Average load point Y (cm) (OE)	0.0421 <i>p</i> = 0.902	-0.3708 <i>p</i> = 0.262	0.3680 <i>p</i> = 0.265	0.0431 <i>p</i> = 0.900	-0.0483 <i>p</i> = 0.888	0.0437 <i>p</i> = 0.899	-0.0471 <i>p</i> = 0.891
Path length (OE)	0.4443 <i>p</i> = 0.171	0.0706 <i>p</i> = 0.837	0.5429 <i>p</i> = 0.084	0.3426 <i>p</i> = 0.302	0.3538 <i>p</i> = 0.286	-0.1059 <i>p</i> = 0.757	-0.5386 <i>p</i> = 0.087
Average speed COP (cm/s) (OE)	0.4439 <i>p</i> = 0.171	0.0703 <i>p</i> = 0.837	0.5428 <i>p</i> = 0.084	0.3420 <i>p</i> = 0.303	0.3543 <i>p</i> = 0.285	-0.1056 <i>p</i> = 0.757	-0.5384 <i>p</i> = 0.087
Area ellipse (cm <sup>2</sup> ) (OE)	0.2792 <i>p</i> = 0.406	0.2258 <i>p</i> = 0.504	0.2132 <i>p</i> = 0.529	0.2103 <i>p</i> = 0.535	0.5580 <i>p</i> = 0.074	-0.2932 <i>p</i> = 0.382	-0.4147 <i>p</i> = 0.205
Average load point X (cm) (CE)	0.1406 <i>p</i> = 0.680	0.3395 <i>p</i> = 0.307	-0.1774 <i>p</i> = 0.602	-0.2333 <i>p</i> = 0.490	0.4578 <i>p</i> = 0.157	0.2652 <i>p</i> = 0.431	-0.2003 <i>p</i> = 0.555
Average load point Y (cm) (CE)	0.1639 <i>p</i> = 0.630	-0.2727 <i>p</i> = 0.417	0.4524 <i>p</i> = 0.162	0.2640 <i>p</i> = 0.433	-0.0339 <i>p</i> = 0.921	0.0300 <i>p</i> = 0.930	-0.2855 <i>p</i> = 0.395
Path length (cm) (CE)	<b>0.8277</b> <i>p</i> = <b>0.002</b>	<b>0.6214</b> <i>p</i> = <b>0.041</b>	0.5516 <i>p</i> = 0.079	0.1762 <i>p</i> = 0.604	0.1023 <i>p</i> = 0.765	0.1307 <i>p</i> = 0.702	-0.3295 <i>p</i> = 0.322
Average speed COP (cm/s) (CE)	<b>0.8277</b> <i>p</i> = <b>0.002</b>	<b>0.6214</b> <i>p</i> = <b>0.041</b>	0.5517 <i>p</i> = 0.078	0.1761 <i>p</i> = 0.605	0.1024 <i>p</i> = 0.764	0.1309 <i>p</i> = 0.701	-0.3295 <i>p</i> = 0.322
Area ellipse (cm) (OE)	<b>0.6196</b> <i>p</i> = <b>0.042</b>	<b>0.7352</b> <i>p</i> = <b>0.010</b>	0.0861 <i>p</i> = 0.801	0.2869 <i>p</i> = 0.392	0.0684 <i>p</i> = 0.842	-0.0424 <i>p</i> = 0.902	-0.3285 <i>p</i> = 0.324

**Table 3***Correlations between AccuGait AMTI postural stability variables in the Romberg test*

Variables in postural stability	Average load point X (cm) (OE)	Average load point Y (cm) (OE)	Path length (cm) (OE)	Average speed COP (cm/sec) (OE)	Area ellipse [cm] (OE)
AccuGait AMTI					
Average load point X (cm) (CE)	<b>0.7656</b> <i>p</i> = <b>0.006</b>	-0.0793 <i>p</i> = 0.817	-0.1506 <i>p</i> = 0.658	-0.1505 <i>p</i> = 0.659	-0.1944 <i>p</i> = 0.567
Average load point Y (cm) (CE)	-0.1787 <i>p</i> = 0.599	<b>0.9269</b> <i>p</i> = <b>0.001</b>	<b>0.6981</b> <i>p</i> = <b>0.017</b>	<b>0.6980</b> <i>p</i> = <b>0.017</b>	-0.1569 <i>p</i> = 0.645
Path length (cm) (CE)	-0.2642 <i>p</i> = 0.432	0.0050 <i>p</i> = 0.988	<b>0.6303</b> <i>p</i> = <b>0.038</b>	<b>0.6301</b> <i>p</i> = <b>0.038</b>	0.5154 <i>p</i> = 0.105
Average speed COP (cm/s) (CE)	-0.2641 <i>p</i> = 0.433	0.0050 <i>p</i> = 0.988	<b>0.6303</b> <i>p</i> = <b>0.038</b>	<b>0.6301</b> <i>p</i> = <b>0.038</b>	0.5154 <i>p</i> = 0.105
Area ellipse (cm) (CE)	-0.1107 <i>p</i> = 0.746	-0.1531 <i>p</i> = 0.653	0.4543 <i>p</i> = 0.160	0.4540 <i>p</i> = 0.161	0.4247 <i>p</i> = 0.193

*Average COP Speed*

Average COP Speed (cm/s) was between 1.75 with eyes open (OE) and 2.31 with eyes closed (CE). The difference in the Romberg test was -0.56. This variable also demonstrated significant differences between measurements performed with open and closed eyes ( $t = 3.59$ ,  $df = 10$ ,  $p = 0.0049$ ).

*Area Ellipse*

Area Ellipse (cm<sup>2</sup>) value oscillated

between 6.28 with eyes open (OE) and 6.64 with eyes closed (CE). The difference in the Romberg test equalled -0.36. This variable was not significantly different between open and closed eye measurements ( $t = 0.44$ ,  $df = 10$ ,  $p = 0.6658$ ) (Table 1).

*Biodex Balance System/AccuGait AMTI*

There were significant and directly proportional correlations between some of the variables obtained using the Biodex Balance

System and the AccuGait AMTI platform. The overall stability index ( $^{\circ}$ ) was significantly correlated with Path Length (cm) (CE) ( $R = 0.8277$ ,  $p = 0.002$ ), Average COP Speed (cm/s) (CE) ( $R = 0.8277$ ,  $p = 0.002$ ) and Area Ellipse (cm) (OE) ( $R = 0.6196$ ,  $p = 0.042$ ). The anterior-posterior stability index ( $^{\circ}$ ) correlated with path length (cm) (CE) ( $R = 0.6214$ ,  $p = 0.041$ ), Average COP Speed (cm/s) (CE) ( $R = 0.6214$ ,  $p = 0.041$ ) and Area Ellipse (cm) (OE) ( $R = 0.7352$ ,  $p = 0.010$ ) (Table 2).

#### *AccuGait AMTI/Romberg test*

There were also significant correlations between the variables of postural stability tested via the AccuGait AMTI platform in the Romberg test (OE-CE). The Average Load Point X (cm) (OE) was significantly correlated with the Average Load Point X (cm) (CE) ( $R = 0.7656$ ,  $p = 0.006$ ). The Average Load Point Y (cm) (OE) demonstrated significant and inverse correlations with the Average Load Point Y (cm) (CE) ( $R = 0.9269$ ,  $p < 0.001$ ), while Path Length (cm) (OE) was significantly correlated with the Average Load Point Y (cm) (CE) ( $R = 0.6981$ ,  $p = 0.017$ ), Path Length (cm) (CE) ( $R = 0.6303$ ,  $p = 0.038$ ) and Average COP Speed (cm/s) (CE), ( $R = 0.6303$ ,  $p = 0.038$ ). Average COP Speed (cm/s) (OE) was significantly and proportionally correlated with Average Load Point Y (cm) (CE) ( $R = 0.6980$ ,  $p = 0.017$ ), Path Length (cm) (CE) ( $R = 0.6301$ ,  $p = 0.038$ ) and Average COP Speed (cm/s) (CE), ( $R = 0.6303$ ,  $p = 0.038$ ) (Table 3).

## Discussion

Postural stability plays a very important role in coordination training of handball goalkeepers. The essence of stability is correct postural alignment in the sagittal, frontal and transverse planes. Another key element relates to the proper activation of adjustment reactions as well as balance that condition and ensure multifaceted linear arrangement of individual body parts. These reactions activate trunk muscles, including those being the basis for integrated stabilization of the lumbar-hip-pelvic complex. The correct course of these reactions always contains an element of elongation, through which myotatic reflexes activate muscles included in the so-called muscular cylinder. This applies to both global and local muscles of the trunk, the pelvic floor and the diaphragm. The basic goal of stability training is normalization of the

antigravity system, while an expression of postural alignment in the frontal plane is symmetry of individual segments of the right and left sides of the body. This is accompanied by axial positioning of the knees. In the transverse plane, the expression of postural alignment is tension balance during rotational movements of the trunk and intermediate lower limb positioning in the hip joint related to external and external rotation. In the development and maintenance of postural stability, anticipative adjustments and corrective reactions play an important role. Controlling balance, body stability and performance of movements require anticipatory adjustment. This is especially true at the initial stage. Maintaining body posture is primarily the effect of corrective adjustment mechanisms that require involvement of different CNS levels. In literature on the subject, postural stability of people practicing different sport disciplines was compared (Agostini et al., 2013; Notarnicola et al., 2016). The aim of another, similar study was to determine gender-specific influence of speed, power and balance on different agility tests performance. Most of the subjects were involved in different team sports (soccer, handball, basketball, and volleyball) or martial arts, gymnastics and dance. Different agility tests were used: a t-test, tests assessing jumping ability, balance tests to determine the overall stability index and the overall limit of the stability score (both tests used the Biodex Balance System), and maximum running speed tests (10- and 20-m straight-line sprints). Multiple regression and correlation analyses found speed, power (among women) and balance (among men) to be the most significant predictors of agility. The balance measures were significantly related to agility performance for men, but not women. In addition to demonstrating the well-known relationship between speed and agility in both genders, and a small, but statistically significant relationship between power and agility in women, these results indicate that balance should be considered as a potential predictor of agility in trained, adult men (Sekulic et al., 2013). In a different study (Bieniek and Wilczyński, 2014), the authors analysed the relationships between variables of body posture, postural stability and body composition among goalkeepers of the Polish national junior handball team. The authors

observed decreases in the thoracic kyphotic and lumbar lordotic angles. The majority of the examined adolescents had residual scoliosis and a positive correlation was observed between trunk length (from vertebra C7) and the midpoint between the sacral dimples (trunk length VP-DM). Another correlation was noted between trunk length VP-SP (from C7) and the beginning of the groove between the buttocks (mm) (trunk length VP-SP) (mm) and the percentage of time the athletes remained in Quadrant 1 (% Time in Quadrant I), i.e. sway in the right anterior direction. No significant correlations were found between body posture variables and body composition, nor between postural stability and body composition (Bieniek and Wilczyński, 2014).

When developing motor abilities among handball goalkeepers, it should be kept in mind that by mechanically perceiving the role of muscles, we are forced to concentrate on the development of general strength and strength related to the postural muscles (Zech et al., 2012). This element of the mentioned procedure is obviously important, but the approach to the functioning of these muscles should be completely different. There is enough evidence that despite the considerable strength and endurance of postural muscles, incorrect posture is often assumed and then, postural defects have a tendency to occur (Wilczyński et al., 2016). The development of postural stability is the effect of gradually integrating muscle tone during the creation of adjustment and balancing reactions (Grabara, 2017). The stability and condition of the body depend on many factors, primarily those including central regulation (Hassan et al., 2017) and related to the postural system, which gradually develops during the period of

ontogenesis. A well-functioning postural system consists of mutually dependent components, i.e. proper postural muscle tension, reciprocal innervation as well as correct postural and motor patterns (Lichota et al., 2011). Postural abnormalities are the result of self-compensation for postural dystonia. The development of postural stability is not only related to the reinforcement of individual muscle groups, but above all, to the integration of their function in postural and balancing reactions.

## Conclusions and practical implications

During the tests performed on the Biodex Balance System platform, all the subjects presented very good postural stability and maintained within Zone A. Greater postural sway was more frequently observed in the sagittal plane than in the frontal one. Most of the athletes demonstrated slight backward tilts, but maintained in Quadrant IV. During the trial on the AccuGait AMTI platform, a significant increase was noted for the tests performed with eyes closed regarding Path Length and Average COP Speed. There were significant positive correlations between some of the Biodex Balance System and AccuGait AMTI variables. Proper and stable posture are essential conditions that need to be met in order to perform most free and locomotive movements, and are of great importance for handball goalkeepers. Postural stability testing among handball goalkeepers is a key element in coordination training. For this reason, the use of postural stability exercises implementing the biofeedback method on stabilo and dynamometric platforms is practical and justifiable.

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