Original paper

Canonical correlations between somatic features and postural stability in children aged 10–12 years

Korelacje kanoniczne między cechami somatycznymi a stabilnością posturalną u dzieci w wieku 10–12 lat

Jacek Wilczyński[1], Katarzyna B. Bieniek[2]

[1]Posturology Department, Hearing and Balance Rehabilitation, Faculty of Medicine and Health Sciences, Jan Kochanowski University, Kielce, Poland
Head of the Department: Prof. JKU Jacek Wilczyński MD, PhD
[2]Jan Kochanowski University Graduate in Physiotherapy, Faculty of Health Sciences, Jan Kochanowski University, Kielce, Poland
Head of the Faculty: Prof. Marianna Janion MD, PhD

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Key words: postural stability, somatic features, canonical correlations.

Słowa kluczowe: stabilność posturalna, korelacje kanoniczne, cechy somatyczne.

Abstract

Introduction: The analysis of somatic features is an important part of health assessment. Body mass, height, and the size of the support surface are determinants of static mechanical stability
Aim of the research: To analyse canonical correlations between somatic features and postural stability in children aged 10–12 years.
Material and methods: The study included 301 children aged 10–12 years. Body composition was assessed using the method of bioelectrical impedance analysis, which consists of the evaluation of resistance to the flow of an electric current. Postural stability was evaluated using the Biodex Balance System platform. Postural stability testing was performed with both feet positioned on a stable surface, with open eyes.
Results and conclusions: Measurements of somatic traits and body composition, which were compared to norms, showed that the majority of subjects had normal somatic features and body composition. All children during the postural stability test were in research Zone A, and most of them tended to lean to the right and left back (Quadrant III, IV). There were significant correlations between somatic variables and postural stability. On the somatic variables side, the largest share was in body height and muscle mass (%), and the highest shares in the postural stability variables were the total stability index, the percentage of time spent in Quadrant III, and the percentage of time spent in Quadrant IV. Body height and muscle mass (%) were most strongly correlated with variable postural stability.

Streszczenie

Wprowadzenie: Analiza cech somatycznych jest ważnym elementem oceny stanu zdrowia dzieci. Masa ciała, wysokość i wielkość powierzchni podparcia są wyznacznikami statycznej stabilności mechanicznej.
Cel pracy: Analiza korelacji kanonicznych między cechami somatycznymi a stabilnością posturalną u dzieci w wieku 10–12 lat.
Materiał i metody: Badaniami objęto 301 dzieci w wieku 10–12 lat. Skład ciała oceniono metodą impedancji bioelektrycznej, która polega na ocenie oporności przepływu prądu elektrycznego. Stabilność postawy badano za pomocą platformy Biodex Balance System. Wykonano test stabilności postawy z obiema stopami ustawionymi na stabilnym tle z otwartymi oczami.
Wyniki i wnioski: Pomiary cech somatycznych i składu ciała, które porównywano z normami, wykazały, że większość badanych miała prawidłowe cechy somatyczne i skład ciała. Wszystkie dzieci w czasie testu stabilności posturalnej znajdowały się w strefie badawczej A i większość z nich miała tendencję do wychylania ciała w prawy i lewy tył (kwadrat III, IV). Stwierdzono istotne korelacje między zmiennymi somatycznymi a stabilnością posturalną. Po stronie zmiennych somatycznych największy udział miały wysokość ciała i masa mięśni (%), a po stronie zmiennych stabilności posturalnej – całkowity indeks stabilności, procent czasu przebywania w III kwadracie i procent czasu przebywania w IV kwadracie. Wysokość ciała i masa mięśni (%) były najsilniej skorelowane ze zmiennymi stabilności posturalnej.

Introduction

Somatic development consists of transformations leading to the formation of a complex, precise, and perfect creation from a simple cell structure, i.e. the body of an adult human [1, 2]. These changes involve the growth as well as differentiation of cells and tissues, the improvement of the structure and function of individual organs, and the progression of greater individual autonomy and maturity [3, 4]. Also, body composition and its somatic structure are subject to multiple changes that are genetically determined and modified by environmental factors [5]. The analysis of somatic features is an important part of health assessment. The human body can maintain its vertical position in space as long as the projection of the centre of gravity remains within the base field [6]. The mechanical stability of the body, i.e. the sensitivity to external forces, primarily depends on its mass and shape, and in particular, on the relation of height to the radius of the posture [7]. Body mass, height, and the size of the support surface are determinants of static mechanical stability [8]. The greater the mass, the lower the centre of gravity, and the greater the support area, the more stable the standing position [9, 10]. The issue of dynamic stability is different. In obese individuals, regaining balance requires much more muscle function efficiency than for those of normal weight [11]. In this case, the increase in inertia associated with excessive body fat deteriorates stability [12]. Stability is maintained by constant or phase tension of postural muscles, whose activity is controlled by both central and peripheral signals [13]. The resultant of this control is the determined location of the body's centre of gravity [14, 15]. It is generally assumed that posture control is based on the control of the centre of gravity of the body. Correct, stable posture is a prerequisite for carrying out most free movements and locomotion [16]. It also allows for the proper psychophysical development of a child. When the postural system functions well, the child can freely focus on cognitive functions rather than the meticulous mechanics of movement [17]. Therefore, postural stability testing is included in most clinical trials evaluating motor activity to determine optimal therapeutic procedures [18].

Aim of the research

The aim of the study was to analyse canonical correlations between somatic features and postural stability in children aged 10–12 years.

Material and methods

The research was conducted at the beginning of 2016 in the Laboratory of Posturology at the Faculty of Medicine and Health Sciences in Kielce (Poland). The selection of subjects was conducted according to the randomisation principle, after prior criteria were set for each group. Before the test, children and their parents were informed about the purpose of the study, its course, and duration. All parents gave written consent for their child to participate in the study. All research procedures were carried out in accordance with the 1964 Declaration of Helsinki and with the consent of the University Bioethics Board for Scientific Research at Jan Kochanowski University in Kielce (Poland) (Resolution No. 5/2015). The study involved 301 children aged 10–12 years from three primary schools. The total number of studied girls was 142 (47.18%), and boys 159 (52.82%). Body composition was assessed using the method of bioelectrical impedance analysis (BIA), which consists of the evaluation of resistance to the flow of an electric current. For BIA analysis, knowledge is used concerning the prevalence of electrolytes and better electrical conductivity of muscle tissue, which contains a considerable amount of water; in turn, adipose tissue is less conductive. BIA is a reliable, non-invasive, and easily available means of estimation of body composition parameters. As a research instrument, a Tanita MC 780 MA body composition analyser was used. From the measurement, the following variables were obtained: body height (cm), body mass (kg), body mass index (BMI), fat mass (kg), fat mass (%), fat-free mass (kg), fat-free mass (%), muscle mass (kg), muscle mass (%), total body water (kg), and total body water (%). Postural stability was evaluated using the Biodex Balance System platform. The Postural Stability Test was performed with both feet positioned on a stable background, with open eyes. The platform was blocked, which means that it was rigid and fully stable. After introducing personal data and body height into the system, the patient's position was determined. For this purpose, the centre line of the foot and platform axes were used as reference points. The position was determined by entering the angles of feet position on the screen of the device using the centre line separately for the right and left foot. The Postural Stability Test consisted of three 20-second trials, divided by a 10-second break. During the examination, the patient's sight was focused on the monitor screen, on which a characteristic dot appeared (centre of pressure – COP). The task of the patient was to balance the body in such a way that the dot (COP) was in the centre of a circle displayed on the monitor, at the point of intersection of the coordinate axes. During the examination, verbal correction of the patient was permitted. All the parameters registered by the posturological platform were collected in a totally non-invasive way; the device was safe for the whole group. The Overall Stability Index (°) reflects the variability of the positioning of the platform with respect to the horizontal plane, expressed in degrees, during all movements performed in the test. Its high value shows a large amount of movements performed during the test. The Anterior-Posterior Stability Index (°) reflects the variability of the platform displacement for movements in the sagittal plane, expressed in degrees. The Medial-Lateral Stability Index (°) reflects the variability of the platform displacement for movements in the frontal plane, expressed in degrees. The patient's scoring in the Postural Stability Test depended on the number of sways from the centre, which means that the lower the result, the better the postural stability. The percentage of time in a zone (%) is the index of the time spent by a patient in a given zone. Target zones A, B, C, and D are equal with respect to the degree of platform tilt. They are determined by concentric circles with the middle in the centre of the platform: Zone A: from zero- to five-degree deviation with respect to the horizontal plane; Zone B: from six- to 10-degree deviation with respect to the horizontal plane; Zone C: from 11- to 15-degree deviation with respect to the horizontal plane; and Zone D: from 16- to 20-degree deviation with respect to the horizontal plane. Time in a quadrant (%) – this index is the time that the patient spent in a given quadrant. Quadrants represent four areas of the test graph between axis X and Y: Quadrant 1: right anterior, Quadrant 2: left anterior, Quadrant 3: left posterior, and Quadrant 4: right posterior. The patient's scoring in the Postural Stability Test depended on the number of sways from the centre, which means that the lower the result, the better the postural stability. Individuals with postural disturbances generally present higher values of all the mentioned parameters.

Statistical analysis

The variables were verified regarding normality of distribution using the Shapiro-Wilk Test. Factor analysis was used to identify non-dependent variables. The relationship between somatic and postural stability variables was determined by canonical correlations. Significant levels were assumed at $p < 0.05$.

Results

Measurements of somatic features and body composition were compared with somatic development norms and indices of children and youths from the Kielce region [19]. Comparison showed that the majority of subjects were characterised by normal somatic features and body composition (Table 1). During the measurement of postural stability, all of the children remained in study Zone A (0–5°), and most of them showed a tendency towards postural sway in the right and left backwards direction (Quadrant III, IV) (Table 1). A fraction of the somatic variables were strongly correlated with one another. The correlations between each other were also shown in the case of postural stability variables. However, analysis of canonical correlations demands that each canonical variable (left and right sets) be created from independent variables. That is why factorial analysis was used in order to determine variables' non-indicating dependencies. As a result of explorative factorial analysis using Varimax rotation, among the 11 normalised somatic variables, two orthogonal factors not indicating correlations with each other were extracted. The share of these two factors in the total variance was slightly higher than in the case of the others. The following variables had the highest absolute values of factorial loads: Factor 1: body height (LC = 0.994) and Factor 2: muscle mass (%) (LP = 0.960). The extracted orthogonal factors of somatic features equalled 81.6% of the total variance. The selected variables did not correlate with each other despite the range: ($R = -0.102$, $R = -0.102$) (Table 2). In the explorative factorial analysis with Varimax rotation, among 11 of the normalised variables characterising postural stability, three orthogonal factors were determined, which equalled 87.0% of the total variance. The selected variables did not correlate with each other despite the range: ($R = -0.400$, $R = 0.259$). The highest absolute values of the factorial loads were attributed to the following variables: Factor 1 – Overall Stability Index (°) (LC = –0.975); Factor 2 – the percentage of time in Quadrant 4 (LC = 0.851); and Factor 3 – the percentage of time in Quadrant 3 (LC = –0.919) (Table 2). Subsequently, canonical correlations were conducted for the somatic variables, in which the greatest share (absolute value of canonical weight) was related to body height (–0.997) and muscle mass (%) (–0.227). In the case of postural stability variables, the greatest share regarded: Overall Stability Index (0.487), the percentage of time in Quadrant III (%) (–0.226), and the percentage of time in Quadrant IV (%) (–0.156) (Table 2). Among the three significant elements (solutions), the first was chosen due to the greatest merit value (the validity of canonical variables determined by the weight of the individual component variables. The canonical analysis of selected somatic variables (left set) and postural stability variables (right set) allowed the creation of significant and correlated variables at the level of ($R = 0.19557$) ($p < 0.05$) (Table 2).

Discussion

The development of postural stability is primarily determined by the quality of the antigravity system [20]. The main component of this system is individually differentiated postural tension, and the magnitude of postural tension influences the type of antigravity activity. Along with reduced postural tension, a compensatory antigravitational system develops [21]. In the case of postural tension disorders, there is no possibility to stabilise body segments [22]. The postural system compensates for these deficiencies by triggering spontaneous substitution. So-called passive stabilisation takes place, which is obtained by manipulation of the support plane and projection of the centre of gravity or by utilising periarticular elements for the

Table 1. Characteristics of somatic features and postural stability variables

Characteristics of somatic features								
Variables of somatic features	***N***	**Mean**	**SD**	**Confidence –95%**	**Confidence 95%**	**Med.**	**Min.**	**Max.**
Body height [cm]	301	150.372	10.059	149.231	151.513	150.00	126.00	173.0
Body mass [kg]	301	41.842	10.580	40.641	43.042	40.10	23.70	72.60
Body mass index [BMI]	301	18.313	3.100	17.961	18.664	17.80	12.30	27.00
Fat mass [kg]	301	9.663	4.482	9.155	10.172	8.50	2.90	32.30
Fat mass (%)	301	22.286	5.496	21.663	22.910	21.50	9.80	45.60
Fat-free mass [kg]	301	32.181	6.926	31.396	32.967	31.30	19.40	52.50
Fat-free mass (%)	301	77.717	5.494	77.094	78.340	78.514	54.378	90.235
Muscle mass [kg]	301	30.495	6.596	29.747	31.243	29.70	18.40	49.80
Muscle mass (%)	301	73.626	5.160	73.040	74.211	74.456	51.553	85.185
Total body water [kg]	301	23.560	5.066	22.986	24.135	22.90	14.20	38.40
Total body water (%)	301	56.921	4.065	56.460	57.382	57.5	39.80	67.10
Characteristics of postural stability variables								
Variables of postural stability	***N***	**Mean**	**SD**	**Confidence –95%**	**Confidence 95%**	**Med.**	**Min.**	**Max.**
Overall Stability Index [°]	301	0.535	0.340	0.496	0.573	0.50	0.10	2.40
Anterior-Posterior Stability Index [°]	301	0.384	0.243	0.356	0.411	0.30	0	1.70
Medial-Lateral Stability Index [°]	301	0.267	0.218	0.242	0.292	0.20	0	1.80
Percentage of time in Zone A (%)	301	99.834	0.938	99.728	99.940	100.00	89.00	100.00
Percentage of time in Zone B (%)	301	0.153	0.866	0.055	0.251	0	0	11.00
Percentage of time in Zone C (%)	301	0.010	0.100	–0.001	0.021	0	0	1.00
Percentage of time in Zone D (%)	301	0.003	0.058	–0.003	0.010	0	0	1.00
Percentage of time in Quadrant I	301	27.963	13.809	26.397	29.530	26.00	0	82.00
Percentage of time in Quadrant II	301	10.548	10.125	9.400	11.697	7.00	0	59.00
Percentage of time in Quadrant III	301	12.874	9.493	11.797	13.951	11.00	0	51.00
Percentage of time in Quadrant IV	301	48.578	18.069	46.529	50.628	49.00	1.00	99.00

purpose of passive stabilisation [23]. The second way is excessive proximal or distal stabilisation, so-called fixation based on reflexive tonic activity. Both the first and second methods impose non-physiological, compulsive positioning of particular body segments. The postural consequences of passive substitutional stabilisation are primarily non-axial positions of the individual body segments: head, trunk, shoulder, and hip girdle [24]. The absence of normal proximal postural tension leads to insufficient stabilisation of the trunk and the shoulder as well as hip girdle in an upright position, excluding axial alignment with each other in the anterior and posterior planes. As a result, excessive forward and backward body tilting or lateral displacement of the trunk with respect to the hip girdle occur. The presented results are confirmed by the research of

Table 2. Canonical weights and summary of canonical analysis

Canonical weights						
Left set			Right set			
Variables of somatic features	Elem 1	Elem 2	Variables of postural stability	Elem 1	Elem 2	Elem 3
Muscle mass	–0.997	–0.126	Overall Stability Index [°]	0.487	0.916	0.146
Body height	–0.227	0.979	Percentage of time in Quadrant III	–0.226	0.189	1.026
			Percentage of time in Quadrant IV	–0.156	–1.044	–0.783

Summary of canonical analysis		
	Left set	Right set
Number of variables	2	3
Isolated variation	100.00%	64.58%
Total redundancy	2.05%	1.64%
Variables	Variables of somatic	Variables of postural stability
1	Muscle mass	Overall Stability Index (°)
2	Body height	The percentage of time in Quadrant III
		Percentage of time in Quadrant IV

$R = 0.19557$; χ^2 $(6) = 12.76198$; $p = 0.04700$.

Boucher *et al.* [25], the purpose of which was to examine the effects of obesity on the execution of aiming tasks performed in standing and seated conditions in children. Twelve healthy-weight and 11 obese children between the ages of eight and 11 years pointed to a target in a standing and seated position. The mean speed of the centre of pressure displacement (COP speed) was calculated to assess postural stability during the movement. Obese children had significantly higher MTs compared to healthy-weight children in seated and standing conditions, which was explained by greater durations of the deceleration phase when aiming. Concerning COP speed during the movement, obese children showed significantly higher values when standing compared to healthy-weight children. This was also observed in the seated position. In conclusion, obesity adds a postural constraint during an aiming task in both seated and standing conditions and requires obese children to take more time to correct their movements due to greater postural instability of the body when pointing to a target with the upper-limb [25]. In another study by Steinberg *et al.* [26], a group of 59 obese children age 6–12 years were interviewed for current medical diagnoses and were later examined posturographically for balance and stability. The overall stability of all the obese children significantly deviated from norms. 32.2% of the obese children had a pattern of balance that could indicate orthopaedic problems. Obese children with ADHD or perceived clumsiness had significantly worse balance and postural performance compared to other obese children. Balance and posture among obese children without suspicion of problems were similar to non-obese controls. In conclusion, obese children with associated disorders (such as ADHD or perceived clumsiness) manifested disturbances in balance control. Thus, physical activity interventions for these children should include safety measures to decrease the chances of falling and subsequent injury [26]. Cruz-Gómez *et al.* assessed the influence of BMI and gender on postural sway of adults and adolescents during quiet standing. During recordings on a hard surface, closing the eyes produced a greater increase of sway in obese subjects than in the case of lean or overweight subjects, with a larger increase on the length and the area of sway. Although gender differences were found in the four sensory conditions, no interaction was observed between the BMI groups and gender. These results were not related to the age of the subjects. Compared to non-obese subjects, the postural stability of obese subjects may be more vulnerable when vision is not available, with no influence of gender [27]. In other studies [28] the aim of the research was to analyse the correlation between anthropometric features and postural reactions in children with scoliosis and scoliotic posture. In Romberg's test with opened eyes (OE), there were no significant correlations between the anthropometric variables and postural reactions.

However, in the study with eyes closed (CE), there were significant, inversely proportional correlations between body height and FBSD, and between body height and AFBS. Inversely proportional correlations are understandable, because taller children are generally slightly older, and along with age in children the reduction of postural reactions (better balance) has been observed. Analysis of the relationships between BMI and postural reactions with eyes closed (CE) showed a significant directly proportional correlation only with Average COP Y. Higher values of BMI correspond to the higher values of Average COPY [28]. The purpose of another study [29] was to investigate postural balance control under normal and experimentally altered sensory conditions in normal-weight versus overweight children. Removal of vision resulted in systematically greater occurrences of postural sway, but no significant BMI group differences were demonstrated across sensory conditions. However, under normal conditions, lower plantar cutaneous sensation was associated with higher COP velocities and maximal excursion of the COP in the medial-lateral direction for the overweight group. Regardless of condition, higher variability was shown in the overweight children within the 7–9-year-old subgroup for postural sway velocity, and, more specifically, medial-lateral velocity. In spite of these subtle differences, the results did not establish any clear underlying sensory organisation impairments that may affect standing balance performance in overweight children compared to normal-weight peers. Consequently, it is believed that other factors account for overweight children's functional balance deficiencies [29]. Early diagnosis of somatic and postural stability development disturbances allows for quick rehabilitation, which can have positive effects on the psychomotor development of a child [30].

Conclusions

Measurements of somatic features and body composition, which were compared to the norms, showed that the majority of subjects were characterised by normal somatic features and body composition (Table 1). During the measurement of postural stability, all of the children remained in study Zone A (0–5°), and most of them showed a tendency towards postural sway in the right and left backwards direction (Quadrant III, IV). Measurements of somatic features and body composition, which were compared to the norms, showed that the majority of subjects were characterised by normal somatic features and body composition. During the measurement of postural stability, all of the children remained in study Zone A (0–5°), and most of them showed a tendency towards postural sway in the right and left backwards direction (Quadrant III, IV). In the canonical correlations regarding somatic variables, the largest share concerned: body height and muscle mass (%). While in the case of postural stability variables, the largest share regarded: Overall Stability Index, percentage of time in Quadrant III, and the percentage of time in Quadrant IV.

Conflict of interest

The authors declare no conflict of interest.

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Address for correspondence:

Prof. JKU **Jacek Wilczyński** MD, PhD
Posturology Department,
Hearing and Balance Rehabilitation
Faculty of Medicine and Health Sciences
Jan Kochanowski University
ul. Żeromskiego 5, 25-369 Kielce, Poland
Phone: +48 603 703 926
E-mail: jwilczynski@onet.pl