Effects of anthropometric factors
on postural stability in individuals with hearing impairment

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Purpose: Identification of factors that affect postural stability may help to improve diagnostic accuracy and enhance the quality of treatment and rehabilitation. This study sought to assess the relationship between postural stability parameters and anthropometric factors of persons with hearing impairment (HI). *Methods*: The study included 128 individuals – 42 subjects with HI and 86 without HI (healthy controls). Research methodology included an interview and a medical examination, anthropometric measurements and stabilometric tests on platforms with stable and unstable surfaces. *Results*: In the group of female study participants with HI, significant correlations were only noted between body height and the Fall Risk Index (FRI). In the group of male subjects with HI, the study revealed significant correlations between FRI and body mass, BMI, % MM (muscle mass percentage) and % FAT (fat percentage). Moreover, moderate correlation was found between COP path with eyes open and body mass, while high correlation was observed between COP path with eyes open and BMI, % MM and % FAT. No significant correlation was noted between FRI and body height in men with HI. *Conclusions*: The examination of correlations between postural stability and body build of persons with HI did not confirm the effects of body height on postural stability in the examined group of individuals with HI, but revealed a greater influence of somatic parameters (body mass, BMI, % MM, % FAT) on postural stability in hearing-impaired men.

Key words: body composition, postural stability, balance, hearing impairment, anthropometry

1. Introduction

The influence of body composition on balance and, thereby, postural stability is still unclear. The identification of factors affecting balance may help to improve diagnostic accuracy and enhance the quality of treatment and rehabilitation. It is also crucial in terms of preventing falls [12], [14]. Anthropometric variables may affect stability limits and movement strategies connected with balance control [3], [9], [12].

According to Błaszczyk et al. [3] standing position under static conditions is more stable when body mass is greater, the centre of gravity is located lower and support area is larger. However, it ought to be stressed that the issue of stability looks different under dynamic conditions, since balance loss in individuals with large body mass means that to regain stability,

considerably greater effort of the muscular system is required. Studies on correlations between stability and body mass, body height, body composition parameters, BMI (in healthy adults) in changing conditions (support areas, eyes open, eyes closed) have been carried out by a lot of researchers [1], [2], [9], [11], [13], [21], [27]. However, their findings are different. The fact that there is no agreement as to which individual features (among anthropometric factors in particular) should be controlled to ensure balance assessment reliability makes it more difficult to perform analyses. It results in the fact that it is still necessary to conduct studies seeking normative data to control variables which may influence balance assessment [2], [9], [10], [12] in order to avoid errors in data analysis [6]. It makes particular significance in the context of examining stability of persons with hearing impairment (HI). In this case, reliable assessment of

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postural control requires taking into account a number of factors including.

Hearing impairment is a factor that may exert a negative influence on physical development and fitness levels [25]. The issue of physical and motor development of hearing-impaired children and youth has been investigated by other researchers, however, the groups they examined differed in terms of sample size, gender sex, hearing impairment degree, etio-pathogenesis, etc. Their findings were equivocal, yet they pointed to differences and sometimes irregularities in physical and motor development of deaf children and youth compared to their healthy peers. According to Zwierzchowska, when it comes to conditioning, motor development is similar to that of able-bodied individuals. On the contrary, there are some differences in coordination abilities, including balance [28], [29], which is the focus of the present study.

Hearing impairment or deafness results in receiving external information that is not always accurate. As a consequence, it may lead to psychomotor disorders. Hearing is a function that needs to be learnt, as it does not develop automatically also in persons without hearing impairment. The development of the central nervous system, together with the integration of senses (including a sense of hearing), is significant in terms of proper motor development. The fact that the body is capable of undergoing hyperadaptation and compensation of hearing impairment means that children with hearing dysfunctions can develop their motor abilities in a different manner to make up for some deficits [28], [29].

Unfavourable effects of deafness and of the factors that condition it (e.g., degree of hearing impairment, etiology, location of the dysfunction) on physical fitness levels (balance in particular) were described by Myklebust [after 28], Butterfield [4], Martens et al. [19] and others a long time ago, while these days this issue has been investigated by, e.g., Rine et al. [22] or Zwierzchowska [28], [29]. Butterfield [4] did not confirm the influence of the degree of hearing impairment on balance. He linked it with etiology, as he noted that children with idiopathic deafness demonstrated significantly lower levels of performance than children with genetically-based hearing dysfunctions. According to Martens et al. [19], individuals with HI should be divided into those with balance disorders resulting from vestibular dysfunction and those without such disorders. These conclusions are in line with the findings of other researchers [22].

The analysis of the literature regarding postural control in individuals with HI and factors contributing to this dysfunction revealed that research on this issue

in young persons in their early twenties is scarce. It is assumed that at the age of 20–24 fitness levels stabilise and there is very reason to try to reach one's peak in terms of motor activities.

In the context of the above-mentioned issues, it seems justified to attempt to verify a hypothesis related to an interaction between anthropometric factors and balance expressed in postural stability parameters and to determine the strength of this correlation in young adults with HI, which is significant in terms of practical applications. The identification of somatic parameters which affect balance may result in prophylactic activities or stimulation of these parameters, for instance, through a proper diet or training, and lead to the compensation of deficits resulting from hearing impairment.

The purpose of the study was to assess the relationship between postural stability parameters and anthropometric factors, i.e., body build of persons with HI.

2. Materials and methods

The group studied consisted of 128 individuals – 16 females and 26 males with HI as well as 38 females and 48 males without HI (healthy reference). HI group consisted of students from the Training and Education Centre for the Deaf in Warsaw.

The profiles of the study groups are presented in Table 1. According to the standards of the WHO Expert Committee, mean BMI values were normal in all the groups.

Table 1. Description of somatic parameters in the study groups

Group	n	Age [years]	Body height [cm]	Body mass [kg]	BMI
CF	38	20.32 ± 1.68	166.15 ± 4.74	58.25 ± 5.29	21.10 ± 1.73
EF	16	19.81 ± 1.52	163.69 ± 6.28	58.66 ± 9.63	21.88 ± 3.34
CM	48	19.56 ± 2.14	178.96 ± 4.86	74.71 ± 9.8	23.31 ± 2.86
EM	26	20.11 ± 1.60	176.76 ± 6.45	70.98 ± 9.74	22.69 ± 2.64

CF – females from the control group,
EF – females with HI,
CM – males from the control group,
EM – males with HI.

All the study participants (healthy reference and persons with HI) underwent medical examinations that excluded conditions affecting balance, such as dysfunctions of the central nervous system (CNS) and the vestibule. Selection process, supervised by a medical doctor, included an interview, medical chart analysis, clinical examinations, assessment of visual impair-

ment and nystagmus, ECG, evaluation of cranial nerves and possible meningeal symptoms, performing cerebellar trials as well as static and dynamic tests of posture and gait.

The study inclusion criteria for individuals with HI:
– profound or severe hearing impairment diagnosed before the age of three,
– hearing aid use,
– no other conditions or dysfunctions.

The analysis of hearing impairment etiology in the group of subjects with HI revealed that hearing impairment stemmed from congenital factors in 62.5% of the women and 65.4% of the men, acquired factors in 25% of the females and 30.8% of the males, and inherited factors in 12.5% of the women and 3.8% of the men. Factors causing hearing impairment in the postnatal period that were specified in the participants' medical charts and confirmed by interviews included rubella, meningitis, mechanical injuries, infections and pharmaceutical drugs.

All subjects underwent basic anthropometric measurements, i.e., body mass and body height (measured using electronic scales and an anthropometer). Based on the measurements, BMI was calculated.

Body composition measurements, e.g., total fat mass (FM), free fat mass (FFM) and muscle mass (MM) were also performed on the subjects with HI. The bioelectrical impedance method was employed to mark body composition using Tanita BC-420 MA body composition analyser.

The postural stability examination was carried out on:
1) the Biodex Balance System SD (BBS – USA) platform using:
   a) static surface for the bilateral stance test (20 s) with eyes open (EO) and feedback (COP observation on the screen) and with eyes closed (EC), the so-called Postural Stability Test (PST),
   b) unstable surface for the bilateral stance test (20 s) with EO and feedback with changing instability levels (in the range between 6 and 2), the so-called Fall Risk Test (FRT);
2) the AccuSway AMTI (Advanced Mechanical Technology INC – USA) platform with static surface for the bilateral stance test (30 s) with EO without feedback and with EC.

Statistical analysis included parameters obtained after conducting the above-mentioned stabilometric tests:
1) for trials on the Biodex Balance System SD platform:
   – OSI – overall stability index (OSI static EO and OSI static EC),
   – FRI – Fall Risk Index (FRI EO);
2) for trials on AccuSway platform:
   – COP path – the length of the path covered by COP (centre of pressure) during the examination (COP Path EO and COP Path EC).

STATISTICA (v.10) software was used to perform statistical analysis of data gathered. The Shapiro–Wilk test was applied to compare the distribution of the features under investigation with normal distribution. Due to significant deviations of the examined stabilometric features from normal distribution, the relationship between anthropometric and stabilometric parameters was tested using Spearman's rank correlation coefficient analysis (r_s).

3. Results

Mean values of basic somatic parameters (age, body height, body mass and BMI) of the study participants are collected in Table 1.

The analysis of variance (ANOVA) revealed that the same-gender groups were similar in terms of age

Table 2. Correlations between somatic and stabilometric parameters in female subjects with HI

EF	Body height		Body mass		BMI		%MM		%FAT	
Variables	r_S	p	r_S	p	r_S	p	r_S	P	r_S	p
OSI static EO	–0.06	0.82	0.03	0.90	0.01	0.96	–0.21	0.43	0.20	0.45
OSI static EC	0.25	0.35	–0.05	0.84	–0.26	0.33	0.12	0.64	–0.12	0.67
FRI EO	**0.57**	**0.02**[*]	0.11	0.69	–0.12	0.65	0.06	0.83	–0.04	0.87
COP path EO	–0.35	0.19	–0.07	0.77	0.03	0.89	0.06	0.83	–0.04	0.89
COP path EC	–0.11	0.69	–0.27	0.31	–0.31	0.26	0.21	0.44	–0.22	0.44

r_S – Spearman's rank correlation coefficient value, [*] $p < 0.05$,
EO – eyes open, EC – eyes closed,
OSI static – overall stability index, static platform,
FRI – fall risk index,
COP path – centre of pressure path length.

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(M; $p = 0.0715$, F; $p = 0.1967$), body height (M; $p = 0.0722$, F; $p = 0.1531$), body mass (M; $p = 0.1193$; F; $p = 0.9060$) and BMI (M; $p = 0.4446$; F; $p = 0.5555$) and no significant differences were found between the groups in any of the four features.

In the group of HI persons, fat percentage (% FAT) was 22.43 ($\pm$7.37) for females and 14.54 ($\pm$5.22) for males, muscle mass percentage (% MM) was 73.60 ($\pm$7.01) for women and 81.07 ($\pm$4.97) for men, and

free fat mass percentage (% FFM) was 77.57 ($\pm$7.38) for female and 85.34% ($\pm$5.22) for male study participants.

In order to assess the relationship between postural stability and body build of individuals with HI and healthy controls, Spearman's rank correlation coefficient analysis of selected stabilometric parameters with somatic parameters was performed (Tables 2–5).

Table 3. Correlations between somatic and stabilometric parameters in male subjects with HI

EM	Body height		Body mass		BMI		%MM		%FAT	
Variables	r_S	p	r_S	p	r_S	p	r_S	P	r_S	p
OSI static EO	0.11	0.62	0.18	0.41	0.05	0.82	−0.09	0.68	0.12	0.60
OSI static EC	0.23	0.27	0.07	0.74	−0.02	0.91	0.01	0.93	−0.04	0.87
FRI EO	0.37	0.09	**0.79**	**0.00002**[*]	**0.63**	**0.0020**[*]	**−0.67**	**0.0010**[*]	**0.69**	**0.0007**[*]
COP path EO	0.0003	0.99	**−0.44**	**0.0239**[*]	**−0.63**	**0.0006**[*]	**0.62**	**0.0009**[*]	**−0.63**	**0.0006**[*]
COP path EC	0.23	0.26	−0.12	0.54	−0.26	0.19	0.22	0.29	−0.22	0.29

r_S – Spearman's rank correlation coefficient value, [*] $p < 0.05$,
EO – eyes open, EC – eyes closed,
OSI static – overall stability index, static platform,
FRI – fall risk index,
COP path – centre of pressure path length.

Table 4. Correlations between somatic and stabilometric parameters in the female control group

CF	Body height		Body mass		BMI	
Variables	r_s	p	r_s	p	r_s	p
OSI static EO	0.17	0.29	−0.02	0.91	−0.11	0.52
OSI static EC	−0.24	0.14	0.01	0.94	0.19	0.24
FRI EO	0.04	0.81	0.22	0.17	0.27	0.09
COP path EO	−0.17	0.32	−0.29	0.08	−0.22	0.19
COP path EC	−0.16	0.53	−0.23	0.18	−0.09	0.61

r_S – Spearman's rank correlation coefficient value, [*] $p < 0.05$,
EO – eyes open, EC – eyes closed,
OSI static – overall stability index, static platform,
FRI – fall risk index,
COP path – centre of pressure path length.

Table 5. Correlations between somatic and stabilometric parameters in the male control group

CM	Body height		Body mass		BMI	
Variables	r_s	p	r_s	p	r_s	p
OSI static OO	−0.03	0.85	−0.10	0.48	−0.14	0.35
OSI static EC	−0.19	0.18	−0.01	0.97	0.11	0.47
FRI EO	**0.33**	**0.024**[*]	**0.46**	**0.001**[*]	**0.41**	**0.005**[*]
COP path EO	0.08	0.57	−0.11	0.49	−0.16	0.29
COP path EC	−0.08	0.59	−0.16	0.30	−0.15	0.32

r_S – Spearman's rank correlation coefficient value, [*] $p < 0.05$,
EO – eyes open, EC – eyes closed,
OSI static – overall stability index, static platform,
FRI – fall risk index,
COP path – centre of pressure path length.

In the group of women with HI, significant correlations were noted between body height and FRI (Table 2). Positive correlation was observed, so the greater height, the higher FRI and the worse the test results.

In the case of men with HI (Table 3), research revealed significant correlations between FRI and body mass, BMI, % MM and % FAT. High positive correlations between FRI and body mass, BMI and % FAT indicate that the greater the body mass, BMI and % FAT, the higher the FRI and the worse the test results. High negative correlation between FRI and % MM shows that when body mass is greater, FRI is lower and FRT results are better. Furthermore, moderate correlation was observed between COP path with EO and body mass, while high correlation was found between COP path with EO and BMI, % MM and % FAT. Negative correlation indicates that the greater the body mass, BMI and % FAT, the shorter the COP path. No significant correlation between FRI and body height was noted in men with HI.

In the female control group, no significant correlations between stabilometric parameters and somatic parameters were revealed (Table 4).

In the male control group, a significant correlation between FRI and body height, body mass and BMI occurred. It means that the greater the body mass, BMI and body height, the higher the FRI and the worse the FRT result (Table 5).

4. Discussion

The study revealed significant correlations between postural stability parameters and anthropometric parameters under static conditions only in the group of men with HI, in the test with EO, where moderate correlation was observed between COP path and body mass, while high correlation was noted between COP path and BMI, %MM and %FAT. Negative correlation indicates that the greater the body mass, BMI and %FAT, the shorter the COP path and the better the stability. This correlation is partly consistent with the biomechanical theory where all of the factors such as body mass, body height and support area are indicators of static stability [3].

The present study did not reveal significant correlations between stabilometric parameters with EC and body mass in any of the groups.

Alonso et al. [2] also revealed significant but low correlations between body mass, soft tissue mass, FFM and stabilometric parameters under static conditions in male subjects only. They concluded that it resulted

from the fact that men have larger body mass than women. This observation is in line with the findings of Ku et al. [13], Chiari et al. [5] and Majewska et al. [18], who noted that in individuals with proper BMI as well as slightly higher BMI (overweight) either there are no correlations with stabilometric parameters or they are low. When body mass increases, postural stability deteriorates in overweight and obese individuals. It was born out by the results of the studies conducted on prepubertal children [15], adults [11], [16], [20], [23] as well as elderly persons [8], [17].

It seems that examining the effects of anthropometric factors on stability taking into account body composition makes it possible to perform more thorough analyses [17], [26]. The correlation with higher FFM in males observed by Alonso et al. [2] as well as the correlation of %MM with stabilometric parameters revealed in the present study may point out to greater participation of muscles in maintaining balance in the group of male subjects. Alonso et al. [2] claimed that different results in the female group might stem from differences in body build. Women could develop other strategies (not so connected with body composition) to be able to maintain balance.

This study did not reveal the effects of body height on stabilometric results under static conditions. However, the majority of researchers believe that body height is the basic variable that correlates with stabilometric results the most. As noted by Alonso et al. [2], Fabunmi et al. [8], Hue et al. [11], Kejonen et al. [12], greater body height results in stability deterioration. In the present study, though, significant correlations between body height and stability index were only confirmed under dynamic conditions in female HI subjects and in male controls.

In their research on healthy adults, Strobel et al. [24] observed that body height did not affect balance, while a considerable decrease in postural stability was found in individuals with high BMI. Deforche et al. [7] also noted negative effects of high BMI and %FAT on healthy boys' balance both under static and dynamic conditions.

It seems that in the case of unstable conditions, body mass may play a more important role in maintaining balance [9]. Our study revealed the highest correlation between FRI (unstable platform) and body mass in the group of male participants with HI. However, high positive correlations were also found between FRI and BMI as well as between FRI and % FAT. It indicates that an increase in body mass, BMI and % FAT leads to a decrease in stability. Greve et al. [10] also observed high correlations between postural balance and BMI in a unipedal stance test in young

healthy men. In their further research, Greve et al. [9] revealed very high correlations with body mass and BMI under unstable conditions in male subjects, which is in line with the findings of the present study. Contrary to our results, they also noted correlations in the group of women; however, these correlations were considerably lower.

Due to high positive correlations between FRI and body mass under dynamic conditions in the group of HI males, it may be concluded that the greater the body mass, the more the muscular system is needed to maintain balance, which is in accordance with the principles of biomechanics [3]. Furthermore, negative correlation of %MM with FRI confirms that the muscular system exerts a considerable influence on stability under dynamic conditions in males with HI. It proves that when body mass is greater, FRI is lower and stability is better. Assessment on an unstable surface requires greater muscle control and may be more sensitive to changes in body composition than in static conditions [10]. The differences between genders in the effects of somatic parameters on stability also occurred in the control group, where only men demonstrated moderate correlations with body mass and BMI and low correlations with body height under unstable conditions. It seems that contrary findings regarding men and women result, in addition to body composition, from mass distribution and the COP location, as noted by Chiari et al. [5], Hue et al. [11] and Kejonen et al. [12]. In their opinion, there is no single anthropometric factor or variable that explains the variations in results. These researchers implied that body height and mass should be analysed using the inverted pendulum model taking into account the posture and that they should always be assessed as a set.

When it comes to identifying anthropometric factors that affect postural stability of persons with HI, additional difficulties in a univocal interpretation occur that stem (as described in the introduction section) from deafness determinants associated with etiopathogenesis of hearing impairment. In the present study, the authors did not analyse the effects of somatic factors on postural stability together with etiopathogenesis, which may be interpreted as a study limitation even though, as mentioned in the introduction section, there are empirically verified works in which researchers point out to a direct connection between the type, hearing impairment etiology and balance in individuals with HI [22], [28], [29]. In our study, a preliminary analysis of the findings regarding stability of persons with HI did not reveal significant differences in terms of hearing impairment etiology. Therefore, the results were presented without the divi-

sion into groups. The study included only patients with HI who were not diagnosed with vestibular dysfunctions that are directly associated with balance disorders. It also seems to be crucial when analysing the influence of the damage mechanisms. The authors presume that sample of large size would have shown differences in stability-related results with regard to etiology. Despite the limitations, the authors are convinced that the findings concerning young adults with HI constitute an interesting contribution to the identification of anthropometric factors affecting postural stability of persons with HI. However, further verification on a larger sample size is required in order to explore this issue.

To sum up, stronger correlations of such somatic parameters as body mass, BMI, %MM and %FAT with stability were noted in the group of male study participants with HI under both static and dynamic conditions. The results obtained from the control group confirmed greater effects of body mass and BMI on postural stability of males under dynamic conditions. Surprisingly, no correlations of somatic parameters with body height were observed in the group of male subjects with HI. Further research should be carried out on a larger sample size, taking into consideration factors of hearing impairment etiopathogenesis in order to be able to perform more thorough assessment of correlations between postural stability parameters and anthropometric factors in persons with HI.

5. Conclusions

The analysis of correlations between postural stability and body build of persons with HI did not confirm the effects of body height on postural stability in the examined group of individuals with HI but revealed a greater influence of somatic parameters on postural stability in HI males, where directions of changes indicate that greater body mass, BMI and %FAT result in better stability under static conditions and worse stability under dynamic conditions, and greater muscle mass results in better stability under dynamic conditions and worse stability under static conditions.

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