The effect of height and BMI
on computer dynamic posturography parameters in women

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The human body's posture control is a complex system of organs and mechanisms which controls the body's centre of gravity (COG) over its base of support (BOS). Computerised Dynamic Posturography (CDP) allows for the quantitative and objective assessment of the sensory and motor components of the body's posture control system as well as of the integration and adaptation mechanisms in the central nervous system. The aim of this study was to assess the relationships between the body's height and BMI on CDP results in a group of young healthy women without any clinical symptoms of balance disorders. It was found that the MS depended significantly on the height and BMI of the subjects as well as on the SOT conditions. As the height and BMI increased the MS value decreased. The postural response latency (LC) in the MCT statistically significantly depended only on height and showed a positive correlation. The postural response latency increased with height. The postural response amplitude for both right and left lower limbs significantly depended on height and BMI, but only for the backward movement of the platform. The response amplitude for all platform translations under all MCT conditions increased with height and BMI. The body's resultant imbalance caused by the platform perturbations in the ADT was greater in shorter people and those with a lower BMI.

Key words: *computerised dynamic posturography, height, BMI, women*

1. Introduction

The human body's posture control is a complex system of organs and mechanisms which controls the body's centre of gravity (COG) over its base of support (BOS) (Yang et al. [29], [30]; Chaudhry et al. [5]; Iwańska and Urbanik [12]; Błażkiewicz [2]; Piecha et al. [22]).

Control of the body's posture is possible through the integration of sensory signals from the visual system, the vestibular system and the somatosensory system. It occurs in the central nervous system and activates the musculoskeletal system in such a way that the centre of gravity in the vertical plane does not extend beyond the boundaries of the base of support (Nashner [15]; Nashner [16]–[18]; Shepard et al. [24]; Wu et al. [28]; Gandelman-Marton et al. [18]; Chaudhry et al. [5]).

Computerised Dynamic Posturography (CDP) allows for the quantitative and objective assessment of the sensory and motor components of the body's posture control system as well as of the integration and adaptation mechanisms in the central nervous system. CDP consists of several test protocols which include: Sensory Organisation Test (SOT), Motor Control Test (MCT) and the AdaptationTest (ADT) (Nashner [17]; Chaudhry et al. [5]).

In the available literature works are devoted to assessing the impact of various factors such as: mental and physical fatigue, gender, neurological disorders, physical exercises on the effectiveness of the body's posture control using a variety of methods, including CDP (Faraldo-García et al. [7]; Liaw et al. [14]; Robillard et al. [23]; Oliveira et al. [21], Tsang and Hui-Chan. [25], [26]). In some of these studies, an impact assessment was carried out on the same study group before and after a specific test (Tsang and Hui-Chan, [25], [26]). Other studies compared the results of the body's posture control from two different groups, i.e., with and without a given factor (Oliveira et al. [21]). In the second case the comparison groups should be selected so as not to differ in other factors, which may affect CDP characteristics independently of the phenomenon studied.

Aim of the study

The aim of this study was to assess the relationships between the body's height and BMI on CDP results in a group of young healthy people without any clinical symptoms of balance disorders.

2. Materials and methods

Materials

The study was carried out on a group of 100 healthy women (20–26 years of age) without any clinical symptoms of balance disorders, with the approval of the Bioethical Committee for Research at the Medical University of Lublin. The 100 women were students selected on the basis of a health assessment questionnaire. The questionnaire related to cardiovascular, respiratory, metabolic, and neurological diseases as well as other chronic diseases that may affect the balance system. The questionnaire also took into account vision defects, faulty posture and dysfunctionality in the balance system as well as hearing disorders. In addition, questions related to previous injuries, operations, medication and alcohol consumption. Each participant had their height, weight and body mass index (BMI) recorded (Bray [3]) prior to the posturographic tests.

Posturographic tests

Using the Equitest posturograph manufactured by NeuroCom International Inc. in accordance with the manufacturer's instructions (NeuroCom Int. [19], [20]),

the following tests were performed: Sensory Organisation Test (SOT), Motor Control Test (MCT) and the Adaptation Test (ADT).

SOT is performed using six sensory stimulation conditions: (1) test is carried out on a stationary platform with eyes open and a stationary visual surround (SOT 1); (2) test is carried out on a stationary platform with eyes closed (SOT 2); (3) test is carried out on a stationary platform with eyes open and a sway-referenced visual surround (SOT 3); (4) test is carried out on a sway-referenced platform with eyes open and a stationary visual surround (SOT 4); (5) test is carried out on a sway-referenced platform with eyes closed (SOT 5); (6) test is carried out on a sway-referenced platform with eyes open and a sway-referenced visual surround (SOT 6) (Nashner [17]; NeuroCom Int. [19]). As part of the SOT the following analysis were performed: Equilibrium Score (ES), Sensory Analysis (SRS), Motor Strategies (MS), and Centre of Gravity Alignment Score (COG AS).

The MCT is performed using a platform with six degrees of freedom on which the patient stands: small forward (SFT) and backward (SBT) translation; medium forward (MFT) and backward (MBT) translation; large forward (LFT) and backward (LBT) translation. The screen displaying the visual surround is stationary (NeuroCom Int. [19]; Nashner [17]). The MCT analyses: weight symmetry (WS), latency (L), response amplitude (A), and amplitude symmetry (AS) (Nashner [17]; NeuroCom Int. [19]).

The ADT consists of two sequences, each consisting of five trials. In one sequence a change in platform tilt causes dorsal flexion (ATU), whilst in the other plantar flexion (ATD). In the ADT after each platform perturbation the sway energy is determined.

Statistical analysis

Statistical analysis was performed using the STATISTICA 10.0 (StatSoft) computer program. To verify that a quantitative variable came from a population with a normal distribution the Shapiro–Wilk test was used. Due to the fact that most of the CDP parameters did not have a normal distribution, and the parametric values occurred more than once, gamma – the correlation coefficient – was used to determine the relationships between the CDP parameters and height and BMI in the group. The significance of the correlation coefficient was determined based on the probability of p-values. Where $p < 0.05$ the correlation was considered to be statistically significant.

3. Results

The dependences of the computerised posturographic parameters on height and BMI of the women under test were characterised with the help of the correlation coefficient (γ), the significance coefficient (p) and the level of statistical significance (I): '#' $- p < 0.01$, '*' $- p \leq 0.01 \leq 0.05$, 'ns' $- p > 0.05$ as statistically insignificant (Figs. 1 to 5).
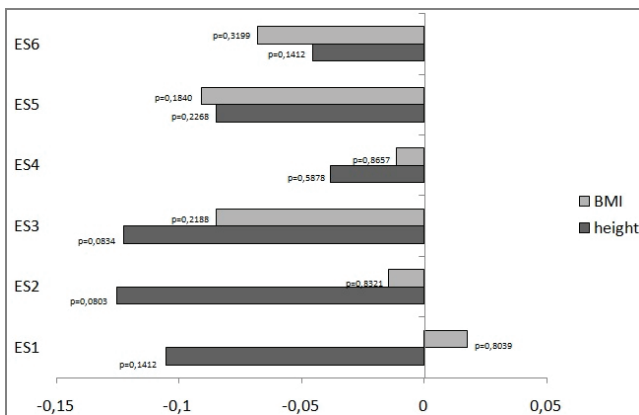

Fig. 1. The dependences of the Equilibrium Score (ES) on height and BMI under SOT 1 – SOT 6 test conditions [ns – no significant difference between groups ($p > 0.05$)]
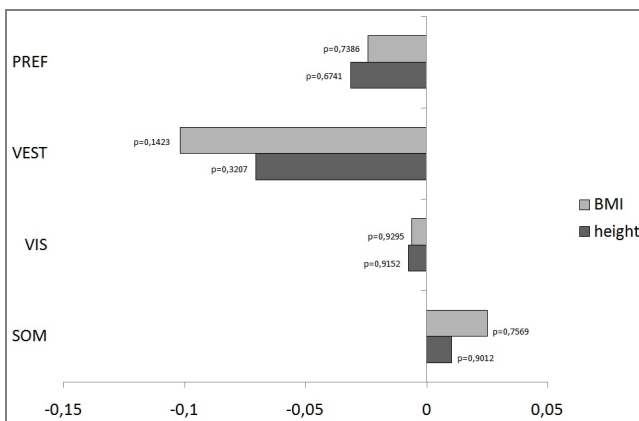

Fig. 2. The SOT dependences of Sensory Analysis (SRS) on height and BMI of the subjects for the: somatosensory (SOM) system, visual (VIS) system, vestibular (VEST) system, visual preferences (PREF) [ns – no significant difference between groups ($p > 0.05$)]

The dependences of the equilibrium score (ES) in the SOT on height and BMI are shown in Fig. 1. The study showed no significant correlation between the deviation of the body's centre of gravity in the forward-backward direction and height and BMI under all test conditions for the women (Fig. 1). Also, no significant dependences were found for the composite equilibrium score (CES) on height ($\gamma = -0.0994$, $p = 0.1690$) and BMI ($\gamma = -0.0789$, $p = 0.2620$). In addition, in the SOT, no significant dependences on height and BMI were found for the somatosensory system (SOM), visual system (VIS), vestibular system (VEST), and visual preference (PREF) (Fig. 2).

The SOT parametric values for the motor strategy (MS) are shown in Fig. 3. It was found that the MS depended significantly on the height and BMI of the subjects as well as on the SOT conditions. As the height and BMI increased the MS value decreased. Thus, in maintaining posture, the ankle muscles' activity decreased whilst the hip muscles' activity increased. There was no significant height dependency for SOT 4 (eyes open, moving platform, stationary surround). Also there was no significant BMI dependence for SOT 1 (eyes open, stationary platform and visual surround) and for SOT 2 (eyes closed, stationary platform and visual surround).
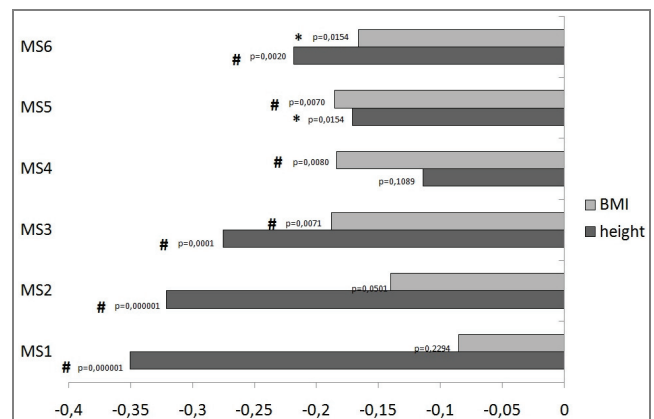

Fig. 3. The SOT dependences of motor strategies (MS) on height and BMI under SOT1–SOT6 test conditions [#$- p < 0.01$; *$- 0.01 \leq p \leq 0.05$; ns – no significant difference between groups ($p > 0.05$)]
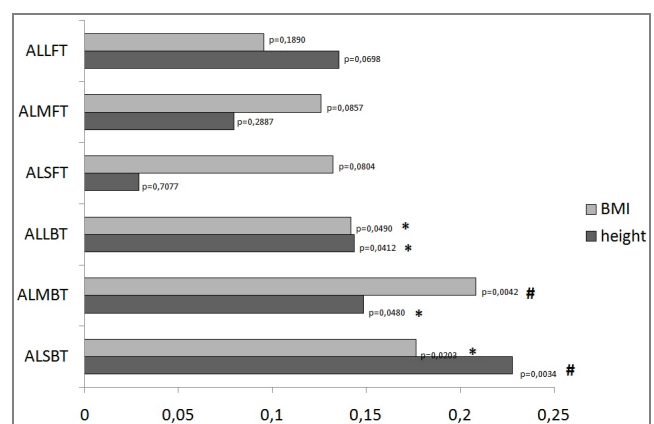

Fig. 4. The MCT dependencies of the response amplitude on height and BMI of the lower left limb (AR) for platform translations under all test conditions [#$- p < 0.01$; *$- 0.01 \leq p \leq 0.05$; ns – no significant difference between groups ($p > 0.05$)]
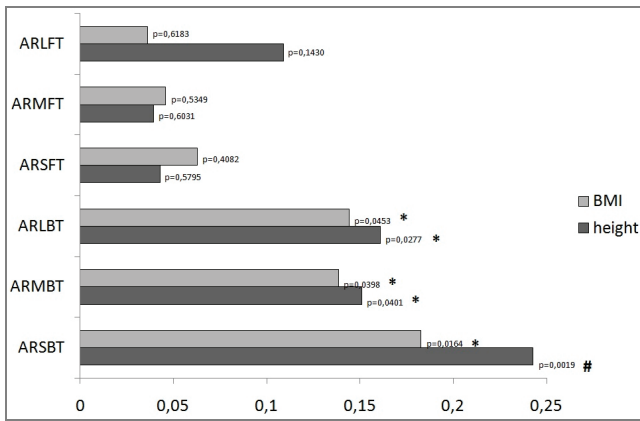
Fig. 5. The MCT dependences of the response amplitude on height
and BMI of the lower right limb (AR) for platform translations
under all test conditions [#– $p < 0.01$; *– $0.01 \le p \le 0.05$;
ns – no significant difference between group ($p > 0.05$)]

The postural response latency (LC) in the MCT
statistically significantly ($p = 0.0009$) depended only
on height and showed a positive correlation ($\gamma =$
0.2368). The postural response latency increased with
height. No significant relationship between the pos-
tural response latency and BMI ($\gamma = -0.0431$, $p =$
0.5365) was found.

The left (AL) and right (AR) response amplitudes
of the lower limbs in response to the platform transla-
tions under all MCT conditions for height and BMI
are shown in Figs. 4 and 5. The postural response
amplitude for both right and left lower limbs signifi-
cantly depended on height and BMI, but only for the
backward movement of the platform. The response
amplitude for all platform translations under all MCT
conditions increased with height and BMI. No signifi-
cant postural response amplitude dependency on
height or BMI under all test conditions was found
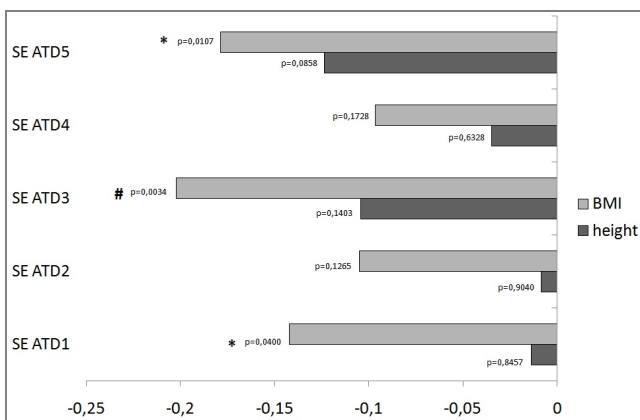during the platform's forward translation.

Fig. 6. The ADT dependences of the sway energy (SE) on height
and BMI for a series of five platform rotations causing dorsal
flexion(ATD1-ATD5) [#– $p < 0.05$; *– $0.01 \le p \le 0.05$;
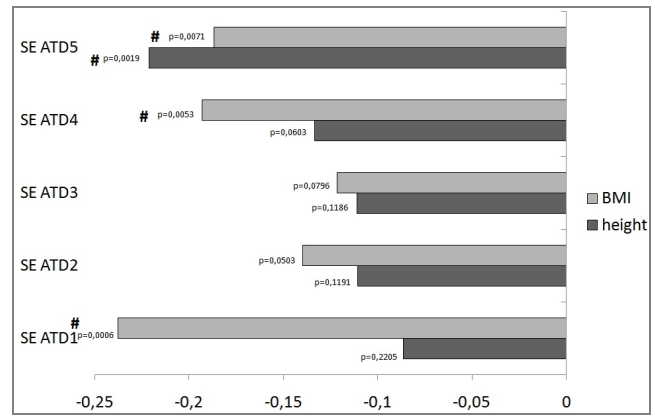ns – no significant difference between groups ($p > 0.05$)]

Fig. 7. The ADT dependences of the sway energy (SE) on height
and BMI for a series of five platform rotations causing plantar
flexion (ATD1-ATD5) [#– $p< 0.01$; *– $0.01 \le p \le 0.05$;
ns – no significant difference between groups ($p > 0.05$)]

Figures 6 and 7 show the sway energy (SE) de-
pendencies on height and BMI for both ADT trial
sequences. The study showed that the sway energy
significantly depended on height only in the fifth trial
of the rotating platform causing plantar flexion. How-
ever, as way energy dependency on BMI was ob-
served during platform rotation for both dorsal flexion
(in the first, third and fifth trial) and plantar flexion (in
the first, fourth and fifth trial). As the height and BMI
increased, the sway energy decreased.

4. Discussion

The study showed a significant correlation be-
tween the motor strategy (MS) results and height for
the women with the exception of SOT 4. Lower MS
values were observed for taller women. A significant
height dependency for the postural response latency
and the response amplitude was found only in the
backward translation for both lower limbs. For taller
women, higher postural response latency and higher
amplitudes were observed. Also, after the fifth de-
flection of the platform causing plantar flexion the
sway energy showed a correlation with height. For
taller women the sway energy decreased, and hence
less imbalance in response to this destabilising
stimulus.

The MS results showed a significant BMI depend-
ency for SOT3 to SOT6 conditions. For women with
a higher BMI the MS parametric values were smaller,
which indicated the hip-joint's leading role, i.e. a less
active role for the ankle-joint muscles with respect to
the hip-joint muscles. Furthermore, there was a posi-
tive correlation between BMI and the response am-

plitudes for both lower limbs for backward translation under all test conditions. The relationships of the sway energy in both ADT sequences indicate a smaller imbalance with increasing BMI.

Studies into the effects of height and BMI on the body's posture control using different diagnostic methods are available. According to Ku et al. [13] posture control deteriorates with increasing BMI. Silhouet testability in the forward-backward direction, assessed using the Biodex Balance System (BBS), is better in people who are underweight, of normal weight or overweight compared to those who are obese. In accordance with the findings of Hue et al. (Hue et al. [11]), stability decreases with increasing body mass, and a high body mass may be a risk factor in falls. Carneiro et al. (Carneiro et al. [4]) found that for obese women the stability boundaries are smaller whilst the risk of falling greater. Era et al. [6] found that in 75 year old women better posture control was associated with higher body weight and being shorter. However, in stability tests for 75 year old men shorter men achieved better results. Greve et al. [10] observed that with increasing BMI postural stability decreased on one, both dominant and non-dominant, lower limb when using BBS in healthy men aged 20 to 38 years. According to Balogun et al. [1] the duration of postural balance on one lower limb increased significantly with greater body height and weight.

However, in the available literature, there is little about the impact of height and BMI on CDP results. There are studies which highlight the differences in CDP values between women and men, explained by some authors to be due to differences in height and weight, amongst others, between these groups. In taller men, compared to women, the activity of the ankle-joint muscles with respect to the hip-joint muscles was less. Postural response, based mainly on ankle-joint muscular activity begins after a latency of 90–100 ms. It enables an effective posture control for a slight imbalance when the base of support has a large area (Nashner [18]). Postural response based mainly on hip-joint muscular activity enables are duct ion in the response time for an imbalance (Liaw et al. [14]). Muscular activity begins after a latency of 85–95 ms in the trunk and thigh muscles and progresses down into the lower limbs (Nashner, 1993). This response enables a faster return to the equilibrium position after a significant imbalance, or is an effective posture control when the base of support is a small area (Liaw et al. [14]).

An increase in height results in a longer path for the nerve impulses in long reflex arcs assessed in the MCT and therefore greater latency. Greater body weight associated with greater muscle mass allows postural responses with a higher amplitude to be generated. These observations are consistent with the findings of Wolfson et al. [27]. They observed shorter latency responses for large platform translations in forward and backward directions and smaller response amplitudes for large platform translations in the forward direction in lighter and shorter women compared to heavier and taller men.

The body's resultant imbalance caused by the platform perturbations in the ADT were greater in shorter people and those with a lower BMI. These observations are consistent with the results of Wolfson et al. [27]. The authors (Wolfson et al. [27]) claimed a higher incidence of falls in the ATU1-ATU4 and ATD1 trials among shorter and lighter women compared to taller and heavier men. According to the authors (Wolfson et al. [27]) the women's more frequent falls may be due to a lower ability to generate sufficient muscle power to cause movement in the ankle-joint in order to correct the silhouette's deviation.

The dependency of functional balance on body weight and BMI, assessed using the Bruininks–Oseretsky balance test, SOT, and the Limit of Stability (LOS) test was studied by Goulding et al. [9]. The study based on 93 men, aged 20–21 years, showed that for obese people, the parametric values deteriorate for both the SOT and motor function.

The complex dependencies between the sensory system and the motor system which controls the body's posture are determined by personal characteristics such as height and BMI. An assessment of their interrelationships can enable the differentiation between personal limitations and illness symptoms which can be diagnosed using computerised dynamic posturography.

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