Estimation of selected parameters in stabilographic image depending on physical activity level in children and adolescents

Ocena wybranych parametrów równowagi w obrazie stabilograficznym w zależności od poziomu aktywności fizycznej u dzieci i młodzieży

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Key words
balance, stabilometric platform, physical activity

Summary
Introduction: Balance is an extremely important component of everyday human functioning. Assessment of body balance in children can be not only a diagnostic tool, but also information about the maturation of the balance system, diversity in terms of age and sex, as well as factors affecting balance and its development. In practice, maintaining body balance is a dynamic process, consisting in “continuous loss and regaining balance”. According to scientific reports, in addition to age, psychosomatic status, the development of specific sensory-motor capabilities and strategies is also influenced by the type of sport.

Objective: The aim of the study was to assess balance in a group of children and adolescents with different levels of sports activity.

Material and methods: The study comprised 64 children and adolescents aged 10 to 13. The group was divided into: Group 1 (15 girls and 17 boys) regularly physically active, and Group 2 (17 girls and 15 boys) not undertaking any physical activity. All participants were assessed regarding postural stability using a CQStab2P stabilometric platform. Four tests were carried out for each participant: standing on both feet, on the left and right limb, and free standing with an additional task. The following parameters were analysed: SP (Sway Path) MA (Mean Amplitude) and MF (Mean Frequency).

Results: In the majority of cases, the variables indicated statistically significant differences from normal distribution – except for MA-R (on the right lower limb) and MF-T (standing on both feet with additional task). In the case of the SP-L indicators (on the left lower limb), SP-B (standing on both feet), SPT, MA-B and MA-T, the advantage of low results was observed in the examined sample (distribution accuracy) and clear concentration near the average (leptocurticity of distribution). In the case of the trial to stand on the right lower limb, training subjects obtained statistically significantly higher SP results than those non-training. During the standing test, the length of MA was recorded as statistically significantly lower than in other conditions. In addition, the SA index, when trying to stand on the right lower limb, was statistically significantly higher in relation to the length of the radius when standing on the left limb. Training participants had a higher average radius compared to those not training.

Conclusions: Physical training positively affects the results of posturographic examination. Non-training girls have a statistically significantly lower level of SP compared to boys not training and training girls.

Słowa kluczowe
równowaga, platforma stabilometryczna, aktywność fizyczna, posturografia

Streszczenie
Wprowadzenie: Równowaga jest niezwykle istotną komponentą codziennego funkcjonowania człowieka. Ocena balansu ciała u dzieci może być nie tylko narzędziem diagnostycznym, ale również źródłem informacji o dojrzewaniu układu równowagi,
zróżnicowaniu pod względem wieku i płci, a także o czynnikach wpływających na równowagę i jej rozwój. W praktyce, utrzy- mywanie balansu ciała jest procesem dynamicznym, polegającym na „ciągłej utracie i odzyskiwaniu równowagi”. Według do- niesień naukowych oprócz wieku oraz stanu psychosomatycznego na rozwój określonych możliwości i strategii sensomoto- rycznych ma wpływ również rodzaj uprawianej dyscypliny sportowej.

Cel: Celem badań była ocena wybranych zmiennych równowagi w grupie dzieci i młodzieży o zróżnicowanym poziomie ak- tywności sportowej.

Material i Metody: W badaniu uczestniczyły 64 dzieci i młodzieży w wieku od 10 do 13 lat. Grupę podzielono na: Grupę I (15 dzieci i 17 chłopców) regularnie aktywnych fizycznie, oraz Grupę II (17 dzieci i 15 chłopców) nie podejmujących żadnej aktywności fizycznej. U wszystkich uczestników wykonano ocenę stabilności posturalnej za pomocą platformy stabilome- trycznej typu CQPabst2P. Przeprowadzone zostały 4 próby dla każdego uczestnika: w staniu obuńczym na lewej, a w prawej kończy- nie oraz w staniu swobodnym z zadaniem dodatkowym. Analizowano następujące parametry: SP (ang. Sway Path – całkowita długość ścieżki statokinezjogramu), MA (ang. Mean Amplitude – średnia długość promieni) oraz MF (ang. Mean Frequency – średnia częstotliwość zmian położenia punktu CoP – wartość środka ciężkości ciała (ang. center of pressure)).

 Wyniki: U większości badanych analizowane zmienne wykazywały statystycznie istotne rozbieżności od rozkładu normalnego – wyjątkiem stanowiły MA-P (na prawej kończynie dolnej) oraz MF-Z (w czasie stania obuńczego z zadaniem dodatkowym). Analizu- jąc SP-L (na lewej kończynie dolnej), SP-O (w czasie stania obuńczego), SP-Z, MA-O, MA-Z, zaobserwowano przewagę wyników niskich w badanej próbie (prawoskokość rozkładu) oraz wyraźne skoncentrowanie w okolicy średniej (leptokurtyczność roz-kładów). W próbie stania na prawej kończynie dolnej, osoby zakwalifikowane do Grupy I (treningująca) uzyskiwały istotnie sta- tystycznie wyższe wyniki SP niż osoby z Grupy II (nie treningująca). Podczas prób stania obuńczego odnotowano długość MA jako istotnie statystycznie niższą, niż w pozostałych warunkach. Ponadto wskaźnik SA podczas prób stania na prawej kończynie dolnej był istotnie statystycznie wyższy w odniesieniu do długości promieni podczas stania na kończynie lewej. Osoby trenu- jące cechowały się wyższą średnią promieni w porównaniu do nietrenujących.

Wnioski: Trening fizyczny wpływa pozytywnie na wyniki badania posturograficznego. Nietrenujące dziecięca cechują się istotnie statystycznie niższym poziomem wskaźnika SP w porównaniu do chłopców nietrenujących i trenujących dziecięca.

INTRODUCTION

Body balance is an extremely important component of everyday human functioning. Maintaining stable, upright body posture, e.g. when walking, sitting down, standing up or changing body position, requires the body to simultaneously synchronise the activities of several systems. In order for this complex process to proceed properly, its correct development is also essential. The assessment of body balance in children can be not only a diagnostic tool, but also a source of information concerning the maturation of the balance system, differentiation in terms of age and gender, as well as factors influencing balance and its development. In an upright position, body balance is constantly disturbed by external forces acting on it. To maintain stable posture, the motor effect of the counter-acting balance system must be equal to the destabilising forces. From the point of view of biomechanics, this consists in maintaining projection of the centre of pressure (CoP) within the area of support, which is defined by the feet. In practice, maintaining balance of the body is a dynamic process consisting in “continuous loss and regaining of balance”. The organ of sight, the vestibular and proprioceptive systems are responsible for maintaining balance, which controls spatial positioning of the body by receiving information about shifts in CoP and movement (its direction and speed) of individual parts of the body, and in response, mobilises the motor apparatus to perform a quick, adequate response to deflection. When working properly, the balance system perceives stimuli that reach the vestibular system symmetrical- ly. The motor response of the movement apparatus is controlled by the cerebellum, which collects information from somatoreceptors, thanks to which it supervises the range and adequacy of this response, and also coordinates the movements performed.

According to scientific reports, in addition to age and psychosomatic state, the development of certain sensorimotor abilities and strategies is also influenced by type of performed sports discipline. There are activities which disturb dynamic stability but, at the same time, have a positive effect on static stability. Posturography is an examination that is used to register and analyse displacements regarding projection of the body’s centre of gravity towards the surface. It allows for the assessment of the balance system as a whole, thanks to the analysis of postural strategies and reactions, both in groups of children and adults, the elderly and athletes.

STUDY AIM

The aim of the study was to assess balance in a group of children and adolescents performing various sports activities, as well as to answer the following research questions:

1. Are there mutual correlations between selected balance parameters (MF, MA, SP) in the group of subjects, and what is the relationship between the level of the total path of the statokinesiogram and the radius length and frequency of changes in CoP location?

2. Are there correlations between the selected examined parameters of static balance and age, sex, body height and mass, and which sex demonstrates a better level of balance?

3. Does the level of sports activity affect the level of examined parameters regarding static balance?

4. Does the support plane and the additional task affect the selected parameters and how?

MATERIALS AND METHODS

The study involved 64 children and adolescents aged 10 to 13 years, with the average age of 11 ± 0.75 years, including 32 girls and 32 boys (Table 1). Based on the level of sports activity, the subjects included in the
All participants were assessed for postural stability using the CQStab2P stabilometric platform.

Due to the fact that balance is influenced not only by visual and acoustic stimuli, but also by level of fatigue, the tests were carried out in the morning in separate rooms to ensure conditions of peace, quiet and thermal comfort. Furthermore, a 10-minute rest before each trial provided the appropriate level of relaxation and concentration.

For each participant, 4 trials were carried out: standing on both feet, on the left and right limbs, and in free standing position with an additional task.

In the first 3 trials, the subjects were obliged to assume a motionless standing position. To facilitate concentration, the subject looked at a selected point (black circle) placed at the height of the head, 3 metres from the platform. The final attempt to assess balance in the free state with an additional task, the purpose of which was to distract the subject, was performed with a Rubik’s cube. Each measurement lasted 30 seconds.

Table 1
Anthropometric data for study participants

| Group size | Age [years] | Body height [cm] | Body mass [kg] | BMI [kg/m²] |
|------------|-------------|------------------|----------------|-------------|
| Group I    |             |                  |                |             |
| n=32       | 12.17 ±0.72 | 154.72 ±9.47     | 45.11 ±9.50    | 18.72 ±2.74 |
| Range      | 10.22-13.02 | 140.00-179.00    | 28.0-73.60     | 13.89-25.37 |
| Group II   |             |                  |                |             |
| n=32       | 11.74 ±0.79 | 150.72 ±7.08     | 43.43 ±10.62   | 18.99 ±3.69 |
| Range      | 9.60-12.99  | 140.00-164.00    | 28.80-72.90    | 14.08-29.58 |

Table 2
Compared parameters

| SP (Sway Path) | MA (Mean Amplitude) | MF (Mean Frequency) |
|----------------|---------------------|--------------------|
| Total length of statokinesiogram path length determined by CoP, measured in both directions (xiy) [mm] | Mean length of radius measured from the beginning of the coordinate system to CoP [mm] | Mean frequency of changes in CoP position [Hz] |

Table 3
Descriptive statistics of total statokinesiogram path length (SP), mean radius length (MA), mean frequency of changes in CoP (MF) (n = 64)

| R          | M        | SD       | Sk       | Kurt     | W        |
|------------|----------|----------|----------|----------|----------|
| SP-L [mm]  | 612-2899 | 1306.22  | 499.84   | 1.06     | 1.09     | 0.92**   |
| SP-R [mm]  | 664-2567 | 1379.59  | 461.95   | 0.64     | 0.10     | 0.96*    |
| SP-B [mm]  | 206-750  | 405.09   | 104.24   | 1.19     | 2.00     | 0.92**   |
| SP-T [mm]  | 305-1384 | 573.31   | 193.29   | 1.94     | 4.92     | 0.83**   |
| MA-L [mm]  | 4.50-15.80| 7.97     | 2.08     | 1.00     | 2.13     | 0.94**   |
| MA-R [mm]  | 4.10-14.10| 8.58     | 2.04     | 0.43     | 0.05     | 0.98     |
| MA-B [mm]  | 1.40-10.70| 3.53     | 1.54     | 1.98     | 6.60     | 0.85**   |
| MA-T [mm]  | 2.20-37.70| 8.19     | 5.81     | 3.02     | 11.52    | 0.69**   |
| MF-L [Hz]  | 37-1.45  | 0.87     | 0.23     | 0.68     | 0.29     | 0.96*    |
| MF-R [Hz]  | 42-1.58  | 0.87     | 0.26     | 0.78     | 0.60     | 0.95*    |
| MF-B [Hz]  | 29-1.41  | 0.69     | 0.27     | 0.63     | -0.37    | 0.95*    |
| MF-T [Hz]  | 10-0.92  | 0.45     | 0.16     | 0.51     | 0.43     | 0.98     |

*p < 0.05; **p < 0.01
SP – total statokinesiogram path length; MA – mean radius length; MF – mean frequency of changes in CoP position; L – trial standing on left lower limb; B – trial standing on both feet; T – trial standing on both feet with additional task.

Kurt - Kurtosis of distribution; M – Mean; p - p-value / statistical significance of test; R – Range; SD - Standard deviation; Sk - Skewness of distribution.
The analysed variables are presented in Table 2.

The results obtained in the study on the stabilometric platform were compared between groups 1 (training) and 2 (non-training), considering the division into sex. The following comparisons of parameters were made (SP, MA, MF):

- non-training boys – training boys;
- non-training girls – training girls;
- non-training boys – non-training girls;
- training boys – training girls.

**Statistical tests**

In all study participants, the indices of total path length of the statokinesiogram (SP), mean radius length (MA) and mean frequency of CoP position changes (MF) were analysed (Table 3). To determine the shapes of the obtained distributions, the following were calculated: range (min-max), measures of central tendency (mean) and dispersion (standard deviation), measures of asymmetry and concentration (skewness, kurtosis) and tests for normal distribution. Additionally, the Shapiro-Wilk tests were applied, the usage of which is suggested in the case of a relatively small sample size.

**RESULTS**

The obtained statistical values showed statistically significant differences from normal distribution in the majority of subjects - the exceptions being MA-R and MF-T. By analysing the SP-L, SP-B, SP-T, MA-B, MA-T indices, the prevalence of low results in the tested sample (right-skewness of distribution) and a clear concentration around the mean (leptokurticity of distributions) was observed. In connection with the above, non-parametric tests were used for correlation analyses.

**Correlations**

Spearman’s rho nonparametric correlation coefficients (Table 4) were calculated to determine correlations between the statokinesiogram total path length (SP), mean radius length (MA), mean frequency of CoP position changes (MF) as well as age, body height and mass. The obtained correlation measures showed that along with the increase in SP-L and SP-R, the level of MF-L, MF-R, MA-L and MA-R indices also increased. Statistically significant positive correlations were also observed between SP-B and MF-L, MF-R, MF-B, MF-T and MA-R, as well as between SP-T and MA-L and MA-T, while strong negative correlations were noted between MF-B and MA-B, MF-T and MA-T. A weak negative correlation was also observed between MF-B and MA-T. It has been shown that MF-T decreases with age, while a relationship was observed between height and selected indices - the greater the height of the subjects, the greater the MA-T and MA-B indices. There was a negative correlation between MF-B and MF-T with both the body height and mass of the subjects. Furthermore, there was a positive correlation between body mass and MA-T and a negative correlation with SP-B, MF-B and MF-T.

**Relationship between sex and training on SA, MA, MF**

To assess whether gender (boys vs. girls), training (non-training vs. training)
ing) and test conditions [standing on both feet (B) vs. left leg standing (L) vs. standing on the right limb (R) vs. standing on the foot with an additional task (T)], differentiate the level of indices of statokinesiogram total path length (SP), the mean radius length (MA) and the average frequency of changes in the position of CoP (MF), three models of variance analysis were calculated in a mixed diagram: $2 \times 2 \times (4)$. There was no significant relationship between gender and training: $\chi^2 (1, N = 64) = 0.25$, $p = 0.617$.

The first model concerned the statokinesiogram total path length (SP) index (Table 5). The conducted analyses showed a statistically significant main effect of the test condition (the type of measurement was named as a test condition depending on the support plane and additional task). The SP index was statistically significantly higher in the condition of measuring the left and right limbs than in the condition of both legs, and in the condition the attempt to stand both feet with an additional task. The obtained results in the latter condition were significantly higher than in the condition of trying to stand on both feet without an additional task. The main effect of gender turned out to be statistically significant (boys obtained higher results compared to girls) and the main effect of training (participants obtained higher results compared to non-training ones). A statistically significant effect was observed in the interaction of gender, gender and training, training and test condition. Post-hoc tests demonstrated a significantly higher total length of the statokinesiogram pathway in boys than in girls regarding the condition of standing on one leg, while the sex factor was not significant in the test performed while standing on one leg with and without an additional task (Figure 1). Moreover, the non-training girls were characterised by a statistically significantly lower level of the SP index compared to the non-training boys and girls (no differences were found within the group of training persons) (Figure 2). The effect of interaction between training and test condition was that in the trial executed by standing on the right lower limb, training subjects obtained statistically significantly higher SP scores than non-training subjects (Figure 3). The effect of the gender x training x measurement condition interaction turned out to be without statistical significance.

The correlation between sex, training advancement and measurement condition on the average radius length was analysed (Table 6). Only the main effect of the measurement condition and training turned out to be statistically significant. In the condition of standing both feet, the length of the MA was statistically significantly lower than in the other conditions. Moreover, the SA index in the condition of trying to stand on the right lower limb was statistically significantly higher in relation to the radius length while standing on the left limb. Those training had a higher average radius compared to the non-training subjects.

In the third model, which was calculated for the mean frequency of changes in CoP position index, a statistically significant main effect of the measurement condition, the main effect of sex and the interaction of both of these factors, were observed (Table 7). In the condition of standing on both feet and standing on both feet with an additional task, the results of MF were statistically significantly lower compared to the condition of trying to stand on the right and left lower limbs. Boys obtained higher frequency rates of CoP position changes than girls. Post-hoc tests used to evaluate the interaction effect showed that when trying to stand on the right limb, the results were significantly higher in boys than girls, while in other trials, the differences were not significant (Figure 4).

**DISCUSSION**

Posturography is an extremely accurate examination that allows to detect changes in the position of the centre of gravity of the body to the nearest 1 mm, with an accuracy no worse than 0.1%. It is used in many disciplines of medical sciences as a diagnostic method, but also for monitoring the progress of treatment or preventing postoperative complications. Paediatrics and geriatrics are areas in which posturography is of particular importance. Due to immaturity of the balance system or, on the other hand, involuntary changes, the possibility of deviations in the statics of the body increases the risk of falls. Testing on a stabilometric platform allows to detect minimal imbalances caused by changes in body statics that are invisible to the naked eye, but it can also be used to monitor effectiveness of the applied therapy.

Maintaining body balance is a complicated process that requires coordination of several systems, including those visual, proprioceptive and vestibular. Its shaping is influenced by many factors, both in the process of child’s balance development and during adult life. These include regular physical activity and practicing a specific sports discipline. The type of sports discipline may have influence on the feeling of static balance.

Scientific reports present various types of experiments carried out among people of all ages, proving that physical activity undertaken at every stage of development significantly supports the control of stability and functioning of the sense of balance. Africa and Deventer focused their research on children and adolescents aged 9 to 12 years. After 12 weeks of motor skill training, they achieved slight improvement in balance compared to the control group. Similar results were obtained by Ruiz et al. and Pyda-Dulewicz et al.

The presented research showed worse stability in training girls. This may be due to the fact that some sports disturb postural stability, positively influencing that dynamic and vice versa. A similar stance is presented by João et al. This is certainly an interesting phenomenon and requires further research in this direction. According to Herpin et al., the type of sports activity influences the development of certain sensorimotor abilities and strategies. Their research included comparison of selected parameters of balance control in professional firearms shooters and hurdle
### Table 5
Influence of sex and training advancement on statokinesiogram total path length

|       | M     | SD    | F       | p      | η²   | Post-hoc                                      |
|-------|-------|-------|---------|--------|------|-----------------------------------------------|
| A     | 1306.22 | 499.84 | 223.55  | < 0.001 | 0.75 | A > C**                                      |
|       |        |       |         |        |      | A > D**                                      |
| B     | 1379.59 | 461.95 |         |        |      | C < D**                                      |
| C     | 405.09  | 104.24 |         |        |      | B > C**                                      |
| D     | 573.31  | 193.29 |         |        |      | B > D**                                      |
|       |        |       |         |        |      |                                              |
| I     | Boys   | 1024.32 | 636.09 | 16.23  | < 0.001 | I > II**                                   |
| II    | Girls  | 807.79  | 448.60  |         |        |                                              |
| a     | Non-training | 834.05  | 514.31  | 8.64  | 0.005 | a < b**                                      |
| b     | Training | 998.05  | 592.90  |         |        |                                              |
| I.A   | Boys L | 1533.34 | 531.22  | 9.79  | < 0.001 | I.A > I.C**, I.A > I.D**, I.C < I.D**, I.B > I.C**, I.B > I.D**, II.A > II.C**, II.A > II.D**, II.C < II.D**, II.B > II.C**, II.B > II.D**, II.A < I.A**, II.B < I.B** |
| I.B   | Boys R | 1551.41 | 432.95  |         |        |                                              |
| I.C   | Boys B | 413.25  | 108.47  |         |        |                                              |
| I.D   | Boys T | 599.28  | 223.66  |         |        |                                              |
| II.A  | Girls L | 1079.09 | 345.03  |         |        |                                              |
| II.B  | Girls R | 1207.78 | 430.45  |         |        |                                              |
| II.C  | Girls B | 396.94  | 100.89  |         |        |                                              |
| II.D  | Girls R | 547.34  | 156.57  |         |        |                                              |
| I.a   | Non-training boys | 1014.37 | 639.46  | 6.63  | 0.013 | I.a > II.a**                                 |
| I.b   | Training boys | 1033.10 | 637.74  |         |        |                                             |
| I.a   | Non-training girls | 674.96  | 294.10  |         |        |                                             |
| I.b   | Training girls | 958.33  | 539.97  |         |        |                                             |
| a.A   | Non-training L | 1212.72 | 503.51  | 4.02  | 0.020 | a.B < b.B**, a.A > a.C**, a.A > a.D**, a.B > a.C**, a.B > a.D**, b.A > b.C**, b.A > b.B, b.A > b.D**, b.C < b.D**, b.B > b.C**, b.B > b.D** |
| a.B   | Non-training R | 1200.72 | 443.36  |         |        |                                             |
| a.C   | Non-training B | 386.00  | 92.58   |         |        |                                             |
| a.D   | Non-training T | 536.78  | 199.35  |         |        |                                             |
| b.A   | Training L | 1399.72 | 485.98  |         |        |                                             |
| b.B   | Training R | 1558.47 | 413.59  |         |        |                                             |
| b.C   | Training B | 424.19  | 112.98  |         |        |                                             |
| b.D   | Training T | 609.84  | 182.85  |         |        |                                             |
| I.a.A | Non-training boys L | 1548.73 | 532.64  | 2.41  | 0.094 | n-s                                          |
| I.a.B | Non-training boys R | 1505.07 | 454.42  |         |        |                                             |
| I.a.C | Non-training boys B | 410.73  | 103.40  |         |        |                                             |
| I.a.D | Non-training boys T | 592.93  | 278.82  |         |        |                                             |
| I.b.A | Training boys L | 1519.76 | 545.98  |         |        |                                             |
| I.b.B | Training boys R | 1592.29 | 422.74  |         |        |                                             |
| I.b.C | Training boys B | 415.47  | 115.90  |         |        |                                             |
| I.b.D | Training boys T | 604.88  | 169.77  |         |        |                                             |
| I.a.A | Non-training girls L | 916.24  | 209.06  |         |        |                                             |
| I.a.B | Non-training girls R | 932.18  | 191.60  |         |        |                                             |
| I.a.C | Non-training girls B | 364.18  | 78.56   |         |        |                                             |
| I.a.D | Non-training girls T | 487.24  | 58.37   |         |        |                                             |
| I.b.A | Training girls L | 1263.67 | 380.71  |         |        |                                             |
| I.b.B | Training girls R | 1520.13 | 414.20  |         |        |                                             |
| I.b.C | Training girls B | 434.07  | 112.72  |         |        |                                             |
| I.b.D | Training girls T | 615.47  | 202.56  |         |        |                                             |

* p < 0.05; ** p < 0.01

η² – Power measure of eta² effect; F – ANOVA test result; M – Mean; N; p - p-value / statistical significance of test; SD – Standard deviation
runners with a group of participants not practicing various sports professionally. It has been shown that static exercise in the sport of shooting improves the control of body movements. Hurdle runners showed better results of balance control on unstable ground, while on static ground, they obtained worse results compared to the control group. Analysing the results of our research, the concept that some sports disciplines may adversely affect static balance, thus being a good training type for dynamic balance, was confirmed. It is also surprising that the group of non-training girls obtained better results than the group of training girls in terms of all balance parameters and types of trials. On the other hand, the comparative results obtained for the group of non-training boys and girls showed clearly worse balance in boys than in girls from the same age group (10-13 years). This can be explained by the high sensitivity of sense of balance to many factors, both those internal and external.

In reports found in professional literature, it is also suggested that fatigue, ambient temperature, state of nervous arousal, level of resistance to stress, individual sensitivity, sound intensity in the room where the measurement is performed, atmospheric pressure or taken medications have significant influence. According to the research conducted by Mikler et al., women achieve much better results in both balance and stability training. Significant interactions regarding gender were noticed, mainly on the basis of the Star Excursion Balance Test in the youngest subjects. In our own research carried out among an analogous group of training boys and girls, no significant differences were noted between the results obtained for representatives of both sexes. Since such differences were not observed between non-training and training boys, it seems that the only group significantly differing from the whole study population comprised non-training girls. In the analysis of our own research, non-training girls obtained the best results on the stabilometric platform. It is noteworthy that in the group of training participants, a lower level of concentration on task performance and higher level of mental arousal than in the non-training group were noticed during the study, which could negatively affect the stabilogram results achieved in the group of physically active children. Thus, the disturbance of postural stability may be caused both by the body’s own motor activity and by interaction with the environment. This is all the more likely that in the study on the placebo effect and concentration of attention on postural stability, among others, Pujszo et al. showed that the level of concentration is a significant variable in the conditions of static testing.

Based on the above considerations, it may be concluded that the level of postural control and thus, the associated static balance, depends not so much on the fact of regularly performing physical activity, but on the type of training undertaken, as well as the specificity of a given sports activity.

In studies on balance performed on a stabilometric platform, various dis-
tractors or deconcentrating factors that affect body balance results can be used. It is possible to introduce platform movement, unstable ground or changes in the surrounding image. It is also proposed to perform the test in a darkened room, where moving projections are displayed or using a moving environment.

The comparison of the mean results regarding selected parameters obtained in the sample group and with the additional task showed that the scattering factor worsened the subjects’ balance. This conclusion is also confirmed by other authors, including Brandt et al.19 and Fabrii et al.20.

On the other hand, comparative analysis of the test results depending on the support plane clearly showed more significant stabilometric results in standing of both feet than standing on one lower limb, which is confirmed in specialist literature. In the groups of training boys and girls, the comparison of results regarding standing on the left and right lower limbs consistently indicated more favourable values for standing on the right lower limb. In the other two groups, one or the other limb was dominant, depending on the compared parameter. However, these differences were small for the majority of subjects.

The presented research system is often used in clinical practice by both doctors and physiotherapists who deal with the metrology of the musculoskeletal system on a daily basis in the diagnosis of various types of disorders or in the assessment of treatment results. The analysed quantitative parameters are very useful in monitoring treatment among various medical specialisation, for groups of different ages and different origins with musculoskeletal disorders. Future extension of the project based on more numerous groups and the use of other distractors will allow verification of the study results.

CONCLUSIONS

Analysis of the research results allowed to formulate the following conclusions:

1. A number of mutual correlations of the analysed variables were found in the subjects included in the study, along with a strong positive relationship between SP, MF, MA. The higher the level of the total statokinesiogram path defined by the CoP, the higher the average radius length and the frequency of CoP position changes.

2. It has been shown that MF-T decreases with age, while the higher the body height of the subjects, the greater the MA-T and MA-B indices. The parameters MF-B and MF-T turned out to be negatively correlated with both the body height and mass of the subjects. Moreover, body mass was positively correlated with MA-T and negatively associated with SP-B, MF-B and MF-T. In the studied group of children and adolescents, boys showed a better level of balance than girls.
Table 6

| Description          | M  | SD | F      | p     | $\eta^2$ | Post-hoc |
|----------------------|----|----|--------|-------|----------|----------|
| A                    | 7.97 | 2.08 | 39.29  | < 0.001 | 0.38     | A < B    |
| B                    | 8.58 | 2.04 |        |        |          |          |
| C                    | 3.53 | 1.54 |        |        |          |          |
| D                    | 8.19 | 5.81 |        |        |          |          |
| I                    | 7.49 | 4.73 | 2.51   | 0.118  | 0.04     | n-s      |
| II                   | 6.65 | 2.84 | 2.65   | 0.109  | 0.07     |          |
| a                    | 6.53 | 3.08 | 4.56   | 0.037  | 0.07     | a < b*   |
| b                    | 7.61 | 4.54 |        |        |          |          |
| I.A                  | 8.63 | 2.13 | 1.63   | 0.207  | 0.02 n-s |          |
| I.B                  | 8.68 | 2.01 | 2.01   | 0.137  | 0.01     |          |
| I.C                  | 3.44 | 1.77 |        |        |          |          |
| I.D                  | 9.20 | 7.56 |        |        |          |          |
| II.A                 | 7.32 | 1.84 | 1.84   | 0.179  | 0.02     | n-s      |
| II.B                 | 8.49 | 2.09 | 2.09   | 0.137  | 0.01     |          |
| II.C                 | 3.62 | 1.29 | 1.29   | 0.262  | 0.02     |          |
| II.D                 | 7.19 | 3.05 | 3.05   | 0.079  | 0.02     |          |
| I.a                  | 7.16 | 3.61 | 0.74   | 0.394  | 0.01     | n-s      |
| I.b                  | 7.78 | 5.55 | 5.55   | 0.021  | 0.02     |          |
| I.a                  | 5.97 | 2.41 | 2.41   | 0.137  | 0.01     |          |
| II.b                 | 7.42 | 3.06 | 3.06   | 0.079  | 0.02     |          |
| a.A                  | 7.66 | 2.37 | 1.82   | 0.179  | 0.02     | n-s      |
| a.B                  | 7.99 | 2.16 | 2.16   | 0.137  | 0.01     |          |
| a.C                  | 3.52 | 1.67 | 1.67   | 0.212  | 0.02     |          |
| a.D                  | 9.94 | 3.56 | 3.56   | 0.079  | 0.02     |          |
| b.A                  | 8.29 | 1.73 | 1.73   | 0.212  | 0.02     |          |
| b.B                  | 9.18 | 1.75 | 1.75   | 0.212  | 0.02     |          |
| b.C                  | 3.53 | 1.42 | 1.42   | 0.212  | 0.02     |          |
| b.D                  | 9.45 | 7.26 | 7.26   | 0.01   | 0.02     |          |
| I.a.A                | 7.86 | 2.61 | 1.75   | 0.189  | 0.02     | n-s      |
| I.a.B                | 8.58 | 2.34 | 2.34   | 0.137  | 0.01     |          |
| I.a.C                | 3.83 | 2.19 | 2.19   | 0.137  | 0.01     |          |
| I.a.D                | 7.36 | 4.54 | 4.54   | 0.079  | 0.02     |          |
| I.b.A                | 8.44 | 1.67 | 1.67   | 0.212  | 0.02     |          |
| I.b.B                | 8.76 | 1.74 | 1.74   | 0.212  | 0.02     |          |
| I.b.C                | 3.09 | 1.25 | 1.25   | 0.212  | 0.02     |          |
| I.b.D                | 10.82| 9.31 | 9.31   | 0.01   | 0.02     |          |
| II.a.A               | 6.59 | 1.54 | 1.54   | 0.212  | 0.02     |          |
| II.a.B               | 7.47 | 1.89 | 1.89   | 0.212  | 0.02     |          |
| II.a.C               | 3.25 | 1.03 | 1.03   | 0.212  | 0.02     |          |
| II.a.D               | 6.57 | 2.49 | 2.49   | 0.212  | 0.02     |          |
| II.b.A               | 8.13 | 1.85 | 1.85   | 0.212  | 0.02     |          |
| II.b.B               | 9.65 | 1.69 | 1.69   | 0.212  | 0.02     |          |
| II.b.C               | 4.03 | 1.46 | 1.46   | 0.212  | 0.02     |          |
| II.b.D               | 7.89 | 3.54 | 3.54   | 0.212  | 0.02     |          |

* p < 0.05; ** p < 0.01
$\eta^2$ – Power measure of eta-2 effect; F – ANOVA test result; M – Mean; p – p-value / statistical significance of test; SD – Standard deviation
### Table 7
Influence of sex and training advancement on frequency in CoP point pressure changes

|       | M   | SD  | F     | p      | $\eta^2$ | Post-hoc                  |
|-------|-----|-----|-------|--------|----------|---------------------------|
| A     |     |     |       |        |          |                           |
| L     | 0.87| 0.23| 63.62 | < 0.001| 0.49     | C < A**                   |
| B     | 0.87| 0.26| 3.08  | 0.048  | 0.02     | II.A < I.A*; II.B < I.B** |
| C     | 0.69| 0.27|       |        |          |                           |
| D     | 0.45| 0.16|       |        |          |                           |
| I     |     |     |       |        |          |                           |
| Boys  | 0.77| 0.32| 8.89  | 0.004  | 0.13     | II < I**                  |
| Girls | 0.66| 0.24|       |        |          |                           |
| a     | 0.69| 0.27| 1.84  | 0.180  | 0.03     | n-s                       |
| b     | 0.75| 0.31|       |        |          |                           |
| I.A   |     |     |       |        |          |                           |
| Boys L| 0.94| 0.25| 3.08  | 0.048  | 0.02     | I.C < I.A**; I.C < I.B**  |
| I.B   |     |     |       |        |          |                           |
| Boys R| 0.97| 0.27|       |        |          |                           |
| I.C   |     |     |       |        |          |                           |
| Boys B| 0.74| 0.29|       |        |          |                           |
| I.D   |     |     |       |        |          |                           |
| Boys T| 0.44| 0.17|       |        |          |                           |
| I.A   |     |     |       |        |          |                           |
| Girls L| 0.79| 0.19|       |        |          |                           |
| II.A  |     |     |       |        |          |                           |
| Girls R| 0.77| 0.21|       |        |          |                           |
| II.C  |     |     |       |        |          |                           |
| Girls B| 0.64| 0.24|       |        |          |                           |
| II.D  |     |     |       |        |          |                           |
| Girls T| 0.45| 0.16|       |        |          |                           |
| I.a   |     |     |       |        |          |                           |
| Boys non-training | 0.75| 0.31| 6.00  | 0.00   | 0.00     | n-s                       |
| I.b   |     |     |       |        |          |                           |
| Training boys | 0.79| 0.33|       |        |          |                           |
| I.a   |     |     |       |        |          |                           |
| Girls non-training | 0.63| 0.22|       |        |          |                           |
| I.b   |     |     |       |        |          |                           |
| Training girls | 0.69| 0.26|       |        |          |                           |
| a.a   |     |     |       |        |          |                           |
| Boys non-training L| 0.85| 0.23| 6.00  | 0.00   | 0.00     | n.i.                      |
| a.b   |     |     |       |        |          |                           |
| Boys non-training R| 0.82| 0.29|       |        |          |                           |
| a.c   |     |     |       |        |          |                           |
| Boys non-training B| 0.64| 0.21|       |        |          |                           |
| a.d   |     |     |       |        |          |                           |
| Boys non-training T| 0.45| 0.12|       |        |          |                           |
| b.a   |     |     |       |        |          |                           |
| Boys L| 0.89| 0.23|       |        |          |                           |
| b.b   |     |     |       |        |          |                           |
| Boys R| 0.91| 0.22|       |        |          |                           |
| b.c   |     |     |       |        |          |                           |
| Boys T| 0.73| 0.31|       |        |          |                           |
| b.d   |     |     |       |        |          |                           |
| Boys T| 0.45| 0.20|       |        |          |                           |
| II.a.A |     |     |       |        |          |                           |
| Boys non-training L| 0.94| 0.26| 1.66  | 0.194  | 0.01     | n-s                       |
| II.a.B |     |     |       |        |          |                           |
| Boys non-training R| 0.96| 0.31|       |        |          |                           |
| II.a.C |     |     |       |        |          |                           |
| Boys non-training B| 0.65| 0.22|       |        |          |                           |
| II.a.D |     |     |       |        |          |                           |
| Boys non-training T| 0.46| 0.11|       |        |          |                           |
| II.b.A |     |     |       |        |          |                           |
| Boys training L| 0.94| 0.24|       |        |          |                           |
| II.b.B |     |     |       |        |          |                           |
| Boys training R| 0.97| 0.24|       |        |          |                           |
| II.b.C |     |     |       |        |          |                           |
| Boys training B| 0.82| 0.32|       |        |          |                           |
| II.b.D |     |     |       |        |          |                           |
| Boys training T| 0.43| 0.21|       |        |          |                           |
| II.a.A |     |     |       |        |          |                           |
| Girls non-training L| 0.76| 0.18|       |        |          |                           |
| II.a.B |     |     |       |        |          |                           |
| Girls non-training R| 0.70| 0.21|       |        |          |                           |
| II.a.C |     |     |       |        |          |                           |
| Girls non-training B| 0.64| 0.20|       |        |          |                           |
| II.a.D |     |     |       |        |          |                           |
| Girls non-training T| 0.44| 0.13|       |        |          |                           |
| II.b.A |     |     |       |        |          |                           |
| Girls training L| 0.83| 0.21|       |        |          |                           |
| II.b.B |     |     |       |        |          |                           |
| Girls training R| 0.84| 0.18|       |        |          |                           |
| II.b.C |     |     |       |        |          |                           |
| Girls training B| 0.64| 0.29|       |        |          |                           |
| II.b.D |     |     |       |        |          |                           |
| Girls training T| 0.47| 0.18|       |        |          |                           |

* $p < 0.05$; ** $p < 0.01$

$\eta^2$ – Power measure of eta-squared effect; F – ANOVA test result; M – Mean; p - p-value / statistical significance of test; SD – Standard deviation
3. Physical activity has a positive effect on selected posturographic variables, including a significantly lower level of the SP index in the group of non-training girls.

4. The support plane and the additional task adversely affect stabilometric results in the free-standing test. One-legged standing causes greater difficulties in maintaining balance, which is manifested in an increase of the mean values related to the parameters in both of the examined groups.

Conflict of interest: none

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