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Does bad posture affect the standing balance?

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Abstract: Introduction: Bad posture is a well-known problem in children and adolescents, and it has a negative effect in adulthood. It can be hypothesized that due to bad posture, changes in the body's position cause changes in standing balance.

Objective: The objective of the study is to determine the influence of bad posture on the standing balance of school-aged children based on independent time–distance- and frequency-based foot centre-of-pressure parameters.

Subjects and Methods: Subjects included 171 children (113 with neutral posture (70 boys and 73 girls), mean age: 10.7 ± 1.1 years (range: 9–13), and 68 with bad posture (22 boys and 46 girls), mean age: 10.7 ± 1.2 (range: 9–13)). The parameters were derived from the motion of the centre of pressure on a platform equipped with pressure sensors, on which the subjects were standing for 60 s with both feet and open eyes.

Results: When comparing the two groups, the load distribution difference between the legs and the medium–high-frequency band power ratio in the medio-lateral direction showed a significant difference out of 17 centre-of-pressure parameters. However, the other 15 parameters did not show any significant differences.

Conclusion: There is no clearly significant degradation of postural control in children with bad posture, as the effects of altered posture are continuously corrected by the central nervous system. The asymmetric load between the two sides may further degrade muscular imbalance; thus, correcting bad posture is an important task of physiotherapy.

Subjects: Biomedical Engineering; Physiotherapy and Sports Medicine; Orthopedics; Rehabilitation Medicine; Physiotherapy

Keywords: standing balance; COP; children; bad posture

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PUBLIC INTEREST STATEMENT

Bad posture is a well-known problem in children and adolescents, and it has a negative effect in adulthood. It can be hypothesized that due to bad posture, changes in the body's position cause changes in standing balance. The goal of the study is to determine the influence of bad posture on the standing balance of school-aged children based on time–distance- and frequency-based foot centre-of-pressure parameters.

1. Introduction

Keeping balance is a dynamic central nervous system (CNS)-controlled process, which could be affected by visual, vestibular and various orthopaedic lesions (Pauk, Daunoraviciene, Ihnatouski, Griskevicius, & Raso, 2010). According to the definition, standing balance (or static postural control) is the ability to keep the body "motionless" in a given circumstance and in a given position, i.e., to stabilize and minimize the movements of the centre of mass (COM) (Hasan et al., 1996; Panzer, Bandinelli, & Hallett, 1995). With the help of the inverted pendulum principle, it can be proved that during standing, the movement of the COM can be characterized properly by the movement of the foot centre of pressure (COP) (Hasan et al., 1996). During standing, COP excursions are computed from the ground reaction forces, which provide an indication of postural control during quiet standing. Numerous COP parameters can be derived from the acquired two-dimensional COP coordinates during the measurement interval (Scoppa, Capra, Gallamini, & Shiffer, 2013; Verbecque, Vereeck, & Hallemans, 2016). The posture and standing balance in children and in young adults are usually characterized by the postural index (PI), which is assessed by dropping a vertical plumb line from the C7 vertebral body centre and quantifying the distance of other anatomical landmarks from this vertical. Several studies have shown that spinal deformities in children and in young adults have a significant influence on standing balance, which is characterized by the PI (Dubousset, 1994; El Fegoun et al., 2005; Glassman et al., 2005; Jackson, Peterson, McManus, & Hales, 1998).

Bad posture is a well-known problem in children and young adults, and it has a negative effect in adulthood (Aggarwal, Anand, Kishore, & Ingle, 2013; Schmidt et al., 2014). With bad posture, there is no structural abnormality on the spine; thus, the child is able to briefly produce normal posture with attention. Bad posture is the most widespread two-dimensional spine deformity. The abnormal curvature of the spine occurs only in the sagittal plane. The clinical characteristics are forward-falling shoulders, protruding scapula and protruding belly. The child is capable of moving out from the bad posture but find the long-term maintenance of the correct posture challenging. However, on the basis of the results of non-invasive measurement, it can be established that the posture significantly affects spinal curvatures (thoracic kyphosis (TK) and lumbar lordosis (LL)), inclination (total trunk inclination (TTI) and lateral inclination (LI)), (Takács, Rudner, Kovács, Orlovits, & Kiss, 2015) and the postural index (PI) (Ludwig, Mazet, Mazet, Hammes, & Schmitt, 2016).

Even small deviations in body position are regulated by postural adjustments relying on both feedback and feedforward control mechanisms (Bottaro, Casadio, Morasso, & Sanguineti, 2005; Collins & De Luca, 1993). This regulation is obtained through appropriate torques produced by the feet on the base of support (Morasso & Schieppati, 1999).

Ludwig (2017) established that there is no significant correlation between PI and the sway path length calculated from COP movements. His research proved that due to bad posture, the sway path lengths calculated from the COP values measured in a 20-s-long bipedal open-eyed position did not show any significant differences. No other research has been found on the analysis of the effect of bad posture on standing balance in children. However, this topic is very important, as standing balance is constantly evolving and significantly changing in childhood (Verbecque et al., 2016). The aim of this study is to investigate whether bad posture influences standing balance parameters among school-aged children compared to those of school-aged children with neutral posture. It is hypothesized that bad posture significantly affects standing balance, which is reflected in COP motion. In the present study, 17 independent time–distance- and frequency-based parameters determined from COP motion were used to characterize standing balance (Nagymáté & Kiss, 2016a, 2016b).

2. Materials and methods

2.1. Subjects

The basic criterion for the subjects was being 6–14 years of age. A total of 347 children were screened for the study (102 boys and 245 girls). Conditions for exclusion included the following: any minor orthopaedic lesion of the lower limbs, surgery in the past 6 months, lower extremity injury, spine deformity (scoliosis, Scheuermann's disease), pronated (pes planus) or supinated foot structure, cerebral palsy, cerebral concussion, visual or vestibular disorder, ±5 dioptres of vision correction, inner ear infection at the time of the examination, upper respiratory infection or head cold. We also excluded children who regularly performed exercises that improve balancing ability at high levels (e.g., ballet, sailing, tai chi). The research was authorized by the Research Ethics Committee of MÁV Hospital (license number: FI/5-93/2007). The parents of the subjects received detailed verbal and written information in each case before they signed the consent form.

The children who had been selected as described above were divided, using a physical orthopaedic examination, into two groups based on their posture. During the body's natural posture, if no spinal deformity, asymmetry on the trunk, abnormal shoulders or shoulder blades were observed, the child was considered to have normal body posture. Children with protruding shoulder blades, rounded shoulders and protruding abdomen were classified into the bad posture group. Body posture can be characterized by TK and LL angles. X-ray images were not taken in children with normal or bad posture. The body posture characterizers TK, LL, TTI and LI were determined with a non-invasive method, the ZEBRIS spine examination method (Takács et al., 2015), after the groups had been formed. Two groups—one with 113 children of neutral posture and another with 58 children of bad posture—were formed.

2.2. Measurement method

Standing balance measurements were carried out with a Zebris FDM-S multifunctional Force Distribution Measuring plate (320 mm × 470 mm measuring surface with 1504 pcs. load cells) (ZEBRIS GmbH, Isny, Germany) at the Biomechanical Laboratory of MÁV Hospital (Szolnok, Hungary). Vertical force distribution was recorded by the Zebris WinPDMS processing software (v1.2, ZEBRIS GmbH, Isny, Germany) at 100 Hz.

Each subject performed 60-s trials of barefoot bipedal stances with their eyes open in daylight. The subjects were positioned in a relaxed bipedal standing, while the distance between the two ankle joint centres was equal to the distance between the right and left anterior superior iliac spines. Both limbs were in full knee extension, the heels were aligned in a line, the feet were parallel and faced forward and the arms were resting by the sides. The subjects focused on a black mark placed approximately 3 m away at eye level on a white wall in front of them. Correct feet placement had to be held throughout the examinations because changes could affect stabilometry parameters (Chiari, Rocchi, & Cappello, 2002). Every subject was asked to perform the required 60-s bipedal standing as motionlessly as possible. Subjects were given one practice and one test trial, with 1-min rest periods between the consecutive trials. The trials were accepted only when the subjects maintained the required position for a minimum of 60 consecutive seconds. If they were not able to keep balance, they could repeat the measurements once more. If they could not succeed, they were excluded from the study.

2.3. Calculated parameters

Further data processing and COP parameter calculations were carried out on exported raw measurement data in a custom application written in LabVIEW v2013 (National Instruments Inc., Austin, Texas). The calculated instantaneous COP coordinates were filtered with a Butterworth low-pass digital filter with a cut-off frequency of 10 Hz, as recommended by Ruhe, Fejer, and Walker (2010). From the COP position signals, a power spectrum was obtained using the fast Fourier transformation (FFT) with a Hanning filtering window. A total of 17 time–distance- and frequency-based parameters were calculated from the COP position (Table 1), which are recommended as independent parameters (Nagymáté & Kiss, 2016a, 2016b).

2.4. Statistical methods

To analyse the impact of bad posture, the average and standard deviation of the selected parameters were calculated for both groups as basic statistical features. Normal distributions of the samples were tested with the Shapiro–Wilk normality test. As each of the parameters failed to fit the hypothesized normal distribution of the data ($p < 0.05$ in the Shapiro–Wilk test), the Mann–Whitney U test was used to compare means. The effect size was calculated according to Cohen (1988) as $r = Z/\sqrt{N}$, where Z is the value from the Mann–Whitney U test and N is the overall sample size. The means were compared between the control group and the bad posture group for mixed genders and also by gender. These analyses were carried out with SPSS Statistics version 22 (IBM Corporation, New York, USA). The achieved statistical power for the mixed group comparisons and the significant deviations in the gender-wise comparison was calculated from the effect size and group sample sizes for two-tailed Wilcoxon–Mann–Whitney test by G*Power version 3.1.9.2 (Faul, Erdfelder, Lang, & Buchner, 2007)

3. Results

A total of 347 children were screened for the study. According to the inclusion and exclusion criteria, 12 children were excluded due to minor orthopaedic lesions, surgery or injuries; 24 were excluded due to scoliosis or Scheuermann's disease; 91 children due to pes planus (pronated, flat arched); 28 children due to supinated foot type; 3 due to cerebral concussions or visual or vestibular disorders; 2 due to a visual correction of ±5 dioptres; and 6 due to the regular performance of exercises that greatly improve balancing ability. The remaining 181 children were divided into two groups according to posture. A neutral posture group with 113 children and a bad posture group with 68 children were formed. The characteristics of the subjects in the two groups (neutral and bad posture) are shown in Table 2. Anthropometric data (age, height and weight), TK and TTI did not differ significantly, whereas LL and LI differed significantly in the two groups.

All subjects in the neutral group (113) were able to perform the 60-s bipedal open-eyed standing activity on their first attempt, whereas the test had to be repeated due to a loss of balance in the case of 12 out of 68 children in the bad posture group. However, nobody was excluded. The average and standard values of the selected parameters in both groups are shown in Table 3.

When the means of the control group and the bad posture group were compared, significant differences were found in the load distribution difference (LDD) between the legs ($p = 0.021$) and in the mediolateral directional medium–high-frequency band power ratio (ML MHR) ($p = 0.002$). For the other parameters, the differences were not significant ($p \geq 0.108$). From gender comparisons (Table 4), it can be seen that not many parameters show differences compared to the mixed group; however, COP path length is significantly longer in the bad posture group for girls ($p = 0.041$, power = 0.16) and did not show significant differences in the mixed group or for the boys. On the other hand, the AP LA parameter shows improvement ($p = 0.039$, power = 0.15) in boys with bad posture compared to the boys in the control group (Table 4).

4. Discussion

Bad posture was found in 68 out of 347 subjects based on the inclusion and exclusion criteria. Significant differences were found in the case of LL and LI, which indicate the differences in the posture of the groups (Table 2). This finding is consistent with our previous research findings (Takács et al., 2015). It is also known from the literature that even a slight change in body posture can be detected in the standing balance (Bottaro et al., 2005; Collins & De Luca, 1993). The aim of the study is to investigate whether bad posture influences the standing balance parameters in school-aged children compared to neutral posture. By studying the literature, it can be stated that only one research study analysed standing balance in children with bad posture on the basis of sway path length; however, the results were not compared to the results of children with neutral posture (Ludwig, 2017). Our study characterizes the standing balance of children with bad posture using 17 independent parameters (Nagymáté & Kiss, 2016a, 2016b) based on the results of 68 children's measurements (Table 3).

In the neutral group, the maximum velocity, the 95% CE area and the path length (Table 3) are consistent with the results previously found in young subjects (Sakaguchi, Taguchi, Miyashita, &

Table 1. Studied parameters

Parameter name	Dimension	Description
Time–distance parameters		
Confidence ellipse area (CE area)	mm^2	The area of the 95% confidence ellipse around the COP trajectory (Oliveira, Simpson, & Nadal, 1996).
Confidence ellipse axis ratio (CE axis ratio)	1	The ratio between the major and the minor axes of the 95% confidence ellipse that describes the shape of the COP's trajectory expansion.
Path length	mm	The length of the total COP trajectory during the measurement.
Maximum path velocity	mm/s	The filtered maximum distance between consecutive COP points divided by the sampling interval.
AP–ML range ratio	1	The ratio of the largest COP path expansions in the anteroposterior (AP) and mediolateral (ML) directions that describes the relation of the largest random errors of postural control between the two anatomical directions.
Anterior (AP+) and posterior (AP-) maximum deviations	mm	The maximum excursions in the anterior and posterior direction relative to the average COP point in the AP–ML plane
Largest amplitude during balancing (LA)	mm	The largest continuous motion in both the AP and the ML directions, which are not necessarily equal to the corresponding COP range. This parameter is similar to the sub-movement size that was defined by Hernandez, Ashton-Miller, and Alexander (2012) for targeted COP movements.
Frequency parameters		
Frequency power ratios between low–medium- and medium–high-frequency bands (LMR, MHR)	1	Provide information about the power distribution of postural sway in the frequency domain. The defined limits of the compared frequency bands are low- (0–0.3 Hz), medium- (0.3–1 Hz) and high-frequency (1–5 Hz) bands (Nagy et al., 2004).

(*Continued*)

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Table1. (*Continued*)

Parameter name	Dimension	Description
Mean power frequency (MPF)	Hz	A weighted-average frequency where f_j frequency components are weighted by their P_j power. M is the number of frequency bins. MPF is calculated as proposed by Oskoei and Hu (2008), according to the following equation: $MPF = \sum_{j=1}^{M} f_j P_j / \sum_{j=1}^{M} P_j$
Spectral power ratio (SPR)	1	The ratio of the total spectral power in the AP direction and the total spectral power in the ML direction. SPR characterizes the rate of the power distribution of postural sway frequencies in the AP/ML directions.
Other		
Load distribution difference (LDD)	%	Shows the difference in the weight load on the lower limbs. This parameter is not derived from COP motion, but it is used by the original Zebris WinPDMS software, together with the COP parameters, and is proven to be very useful in biomechanical analyses (Duffell, Gulati, Southgate, & McGregor, 2013; Nagymate, Pethes, Szabo, Bejek, & Kiss, 2015).

Table 2. Data of the subjects (mean ± standard deviation)

	Neutral posture group		Bad posture group	
N	113		68	
	40 boys	73 girls	22 boys	46 girls
Age (years)	10.78 ± 0.95 (range: 9–13)	10.73 ± 1.17 (range: 9–13)	10.82 ± 0.96 (range: 10–13)	10.67 ± 1.27 (range: 9–13)
Weight (kg)	41.85 ± 9.23	50.77 ± 23.07	39.91 ± 8.93	42.54 ± 11.73
Height (cm)	151.08 ± 7.42	145.96 ± 25.16	149.91 ± 11.55	153.43 ± 9.58
Thoracic kyphosis (degree)	40.44 ± 8.67	40.08 ± 8.34	44.84 ± 9.68	38.06 ± 8.34
Lumbar lordosis (degree)	30.37 ± 9.81	36.25 ± 8.63	31.30 ± 13.55	32.55 ± 9.31
Total trunk inclination (degree)	5.04 ± 2.56	4.12 ± 2.62	4.11 ± 2.83	4.23 ± 2.48
Lateral inclination (degree)	2.34 ± 2.02	1.99 ± 1.67	1.91 ± 1.62	1.81 ± 1.43

Table 3. Statistical comparison of the standing balance of the neutral and bad posture groups based on COP parameters (mean ± standard deviation)

	Neutral group	Bad posture	Mann–Whitney U test significance level (*p*)	Observed power
95% CE axis ratio	1.70 ± 0.59	1.59 ± 0.48	0.285	0.079
95% CE area [mm^2]	289.83 ± 209.67	279.67 ± 204.33	0.967	0.05
Path length [mm]	923.13 ± 350.32	975.95 ± 326.67	0.158	0.102
Max velocity [mm/s]	130.22 ± 79.86	158.89 ± 167.85	0.329	0.074
AP–ML range ratio	1.28 ± 0.59	1.23 ± 0.38	0.68	0.054
LDD [%]	**6.25 ± 5.19**	**8.15 ± 5.9**	**0.021**	**0.192**
AP LA [mm]	31.13 ± 17.24	28.45 ± 12.32	0.633	0.056
ML LA [mm]	26.92 ± 14.91	26.64 ± 16.32	0.788	0.052
A max. dev. [mm]	28.86 ± 14.23	27.39 ± 12.97	0.489	0.062
P max. dev. [mm]	28.35 ± 13.09	28.24 ± 14.06	0.763	0.052
AP MPF [Hz]	0.15 ± 0.07	0.16 ± 0.07	0.56	0.059
ML MPF [Hz]	0.19 ± 0.07	0.19 ± 0.09	0.484	0.063
SPR	2.22 ± 3.14	1.90 ± 1.92	0.341	0.073
AP LMR	10.69 ± 9.50	9.80 ± 10.08	0.427	0.066
AP MHR	11.72 ± 6.25	10.37 ± 5.52	0.108	0.118
ML LMR	6.54 ± 5.85	7.59 ± 7.19	0.486	0.062
ML MHR	**11.53 ± 5.00**	**9.18 ± 4.25**	**0.002**	**0.05**

CE: confidence ellipse; AP: anteroposterior; ML: mediolateral; LDD: load distribution difference between legs; LA: largest amplitude; A: anterior; P: posterior; max. dev.: maximum deviation; MPF: mean power frequency; SPR: spectral power ratio; LMR: low-medium band power ratio; MHR: medium–high-frequency band power ratio; bold: significant difference.

Katsuno, 1994). To our knowledge, this is the first article on standing balance analysed with distance-, time- and frequency-based parameters and calculated from the results of 60-s measurements of children with bad posture. Thus, there were no reference values for many examined time–distance- and frequency-based parameters published earlier in the literature (Verbecque

Table 4. Statistical comparison of the standing balance of the neutral and bad posture groups by gender (mean ± standard deviation)

	Difference of means for boys [bad posture—control]	Difference of means for girls [bad posture—control]	Mann–Whitney U test *p*-value	
			Boys	Girls
95% CE axis ratio	−0.23	−0.06	0.317	0.548
95% CE area [mm^2]	−111.84	44.19	0.066	0.128
Path length [mm]	3.46	**85.58**	0.702	**0.041**
Max velocity [mm/s]	33.45	27.44	0.791	0.321
AP–ML range ratio	−0.01	−0.07	0.769	0.823
LDD [%]	1.49	**2.13**	0.245	**0.036**
AP LA [mm]	−4.78	−1.48	0.257	0.781
ML LA [mm]	−3.27	1.53	0.185	0.416
A max. dev. [mm]	**−5.85**	0.96	**0.039**	0.471
P max. dev. [mm]	−4.37	2.24	0.096	0.377
AP MPF [Hz]	0.01	0.01	0.67	0.559
ML MPF [Hz]	0.03	−0.02	0.659	0.247
SPR	−0.23	−0.39	0.537	0.448
AP LMR	−2.22	−0.31	0.724	0.422
AP MHR	−1.27	−1.5	0.402	0.166
ML LMR	−1.48	2.3	0.825	0.31
ML MHR	**−4.38**	−1.32	**0.001**	0.138

CE: confidence ellipse; AP: anteroposterior; ML: mediolateral; LDD: load distribution difference between legs; LA: largest amplitude; A: anterior; P: posterior; max. dev.: maximum deviation; MPF: mean power frequency; SPR: spectral power ratio; LMR: low-medium band power ratio MHR: medium–high-frequency band power ratio; bold: significant difference.

et al., 2016) because those results were calculated from only 30-s measurements, despite the standardization recommendations of 60-s measurements (Scoppa et al., 2013).

Balance is a multidimensional motor skill (Sousa, Silva, & Tavares, 2012). Balance regulation is based on the interaction of sensory information and its processing in the CNS (Chiba, Takakusaki, Yozu, & Haga, 2016; Kouzaki & Masani, 2012). The proprioceptive function of the sensorimotor control system matures at 3 to 4 years of age and is stabilized at 6 years (Steindl, Kunz, Schrott-Fischer, & Scholtz, 2006). Therefore, it can be stated that the sensorimotor control of the children involved in the study (Table 2) is stable and no difference in balance due to age should occur (age range 9–13 years).

Based on our results (Table 3), the standing balance of children with bad posture is similar to that of children with neutral posture; however, significant differences were found in LDD and in ML MHR. The other parameters did not show any significant deviations (Table 3), meaning that our hypothesis is not fully justified. In a previously published study (Ludwig, 2017), only the change of the path length was analysed. Our results are similar to those of Ludwig (2017): the path length value is increased due to bad posture, but the difference is not significant (Table 3). When the means are compared by gender, interesting differences can be observed. The boys with bad posture balance better than the girls with bad posture. While boys introduced improvement in the AP LA parameter, showing smaller COP deviations in the AP direction, the girls yielded elongated COP path length. Both of these parameters are considered reliable COP measures (Nagymáté, Orlovits, & Kiss, 2018); therefore, these significant differences are remarkable. On the other hand, due to the effect size and sample count, these results are supported by poor statistical power.

It is known from the literature (Ludwig, 2017; Nourbakhsh & Arab, 2002) that bad posture is a consequence of neuromuscular imbalance. Body posture and standing balance are both complex and controlled processes influenced by biomechanical and neurophysiological mechanisms (Sousa et al., 2012). The effect of muscular imbalance is counterbalanced by feedback mechanisms and by sensory reweighting (Assländer & Peterka, 2014; Peterka, 2002). It can be hypothesized that the CNS tries to keep the COP in place, in spite of the different positions of the body segments (forehead, shoulders, projecting shoulder blades, pretensioned abdomen), so the movements of the COP change only a little in spite of the weak muscles and the altered body posture (Park, Reimann, & Schöner, 2016). The reason for bad posture is also that maintaining balance in the improper posture takes less work. This idea is reflected in the measurement of the boys, whose TK is 6° larger compared to girls, yet the path length does not show degradation, while the AP LA shows improvement. The observed worsening of distance-type parameters, which is not significant ($p \geq 0.158$) (Table 3), shows that the CNS can properly correct balancing problems caused by the change in body posture. This finding also confirms the hypothesis that bad posture is primarily a result of the inadequate condition and weakness of the muscles, which children can still correct with care. The compensatory role of the CNS may occur in the frequency-specific ML MHR parameter, which is significantly lower in the case of bad-postured subjects than in healthy subjects ($p = 0.002$) (Table 3). This change represents relatively increased motion in the middle-frequency range (0.3–1 Hz) (Nagymáté & Kiss, 2016b) in the ML direction compared to higher frequencies. Additionally, the decrement in the SPR parameter, which is a ratio of AP to ML, indicates the relatively greater degree of motion in the ML direction as the CNS compensates.

A change of LI (Table 2) is clearly shown by the fact that the LDD value—which is the difference between the loadings of the two sides—increased significantly ($p = 0.021$) (Table 3). As a result of altered inclination caused by bad posture, the symmetrical load between the two sides is overturned, and the load on one side is significantly increased. This draws attention to the fact that as a result of bad posture, an asymmetric load develops, which further deteriorates muscular balance.

The large number of subjects (347) made it possible to determine exclusion criteria accurately and to create homogenous groups. The present study is unique because the values of the parameters characterizing standing balance were determined according to various criteria in a large number of children with bad posture. Based on the statistical analysis of the results (Table 3), bad posture significantly affects only the LDD between the legs ($p = 0.021$) and the medium–high-frequency band power ratio in the mediolateral direction (ML MHR) ($p = 0.002$) of the 17 parameters. However, the other 15 time–distance- and frequency-based parameters do not show any significant differences. Based on this, it cannot be clearly stated that bad posture significantly worsens standing balance. The (non-significant) differences in most parameters between the two groups (Table 3) show that standing balance parameters are deteriorating due to muscular imbalance. The effects of the altered posture are continuously corrected by the CNS, which is indicated by the significant change in the medio-lateral directional medium–high-frequency band power ratio (ML MHR) parameter. In addition, changes in the spectral power ratio indicate increased motion in the mediolateral direction as a result of CNS compensation. A significant change in LI appears in the significant increase in the LDD parameter. An asymmetric load between the two sides may further degrade muscular imbalance, so correcting it is an important task of physiotherapy.

The limitation of this study was the fact that the examinations were not performed during a single leg stance with eyes open and closed, as well as during a bipedal stance with closed eyes due to accident prevention considerations.

5. Conclusions

There is no clearly significant degradation of postural control in children with bad posture, as the effects of altered posture are continuously corrected by the CNS. Some differences could be found in postural control, but these deviations are weakly justified. Due to bad posture, the asymmetric load between the two sides may further degrade muscular imbalance. The correction of bad posture is an important task of physiotherapy, which should improve the posture and balance.

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Supplementary material
Supplementary material for this article can be accessed here.

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