



The effect of balance training intervention on postural stability in children with asthma

Zuzana Kováčiková, Katerina Neumannova, Jana Rydlova, Lucia Bizovská & Miroslav Janura

To cite this article: Zuzana Kováčiková, Katerina Neumannova, Jana Rydlova, Lucia Bizovská & Miroslav Janura (2017): The effect of balance training intervention on postural stability in children with asthma, Journal of Asthma, DOI: [10.1080/02770903.2017.1342257](https://doi.org/10.1080/02770903.2017.1342257)

To link to this article: <http://dx.doi.org/10.1080/02770903.2017.1342257>



Accepted author version posted online: 12 Jul 2017.
Published online: 12 Jul 2017.



Submit your article to this journal [↗](#)



Article views: 24



View related articles [↗](#)



View Crossmark data [↗](#)



The effect of balance training intervention on postural stability in children with asthma

Zuzana Kováčiková, PhD^{a,b}, Katerina Neumannova, PhD^b, Jana Rydlova, MD^c, Lucia Bizovská, MSc^b, and Miroslav Janura, PhD^b

^aDepartment of Sports Kinanthropology, Faculty of Physical Education and Sports, Comenius University in Bratislava, Slovakia; ^bFaculty of Physical Culture, Palacký University in Olomouc, Czech Republic; ^cMiramonti Children's Medical Institution, Luhacovice Spa, Luhacovice, Czech Republic

ABSTRACT

Objective: Pulmonary rehabilitation is mainly focused on exercise training and breathing retraining in children with asthma. Conversely, balance training is not usually recommended for the treatment, although postural deficits were found in these patients. Therefore, this study assessed the effect of balance training intervention on postural stability in children with asthma. **Methods:** Nineteen children with mild intermittent asthma (age 11.1 ± 2.1 years, height 147.6 ± 13.9 cm, weight 41.8 ± 13.3 kg) were randomly assigned to an experimental group or a control group and completed a four-week physiotherapy program including breathing exercises and aerobic physical training (six times/week, 45 minutes). Both groups performed the same training, but only the experimental group underwent exercises on balance devices. The center of pressure (CoP) velocity in the anteroposterior (V_y) and mediolateral (V_x) directions, and total CoP velocity (V_{tot}) were recorded before and after training in the preferred and the adjusted stances under eyes open (EO) and eyes closed (EC) conditions. **Results:** The addition of balance intervention led to significant improvements of V_{tot} ($p = 0.02$, $p = 0.04$) in both types of stance, V_x in the preferred stance ($p = 0.03$) and V_y in the adjusted stance ($p = 0.01$) under EO conditions. Significant improvements were also found in V_y in the adjusted stance ($p = 0.01$) under EC conditions. **Conclusions:** Results of this study support the effectiveness of balance training as a part of physiotherapy treatment for improving balance performance, predominantly under EO conditions, in children with mild asthma.

ARTICLE HISTORY

Received 8 April 2017
Revised 14 May 2017
Accepted 10 June 2017

KEYWORDS

Mild intermittent asthma; physical training; breathing exercises; balance devices; center of pressure velocity; pulmonary spa treatment

Introduction

Asthma can lead to musculoskeletal dysfunctions and alterations in posture due to the excessive use of accessory respiratory muscles and mouth breathing [1–5]. Decreased thoracic mobility, elevated and adducted shoulders, winged scapulae, increased kyphosis and shortening of the muscles (pectoral muscles, neck muscles, etc.) have been observed in children with asthma. These children might also have shortening of the knee and hip flexors [4], and knee flexors are considered as one of the major muscles required for postural stability. A relationship between mouth breathing and postural alterations has been found in children [6–8]. Moreover, a high prevalence of mouth breathing in children with asthma could indicate that this is an important factor affecting postural stability. Poor postural stability in patients with asthma may be also associated with compromised stabilization function of diaphragm in people with respiratory diseases, when respiratory demand is increased [9,10]. However, all these assumptions have not been

conclusively confirmed in patients with different stages of bronchial asthma. Despite this fact, scientists suggest that this is the reason for poor postural stability observed in patients with asthma.

Poorer balance performance has been found in children with asthma compared with non-asthmatic individuals [11–13]. These studies assessed balance performance by comparing the center of pressure (CoP) velocity or CoP displacement between healthy children and children with asthma in different types of stance. CoP velocity is one of the most widely used variables in studies assessing balance performance in children and adults [13–17]. It is used as an indicator of postural control system where increased CoP velocity means poorer balance and vice versa. Although previous studies differ in the type of diagnostic tools used, protocols and variables, the data obtained from these studies form the basis for the hypothesis that postural stability can be impaired in patients with asthma compared to healthy people.

Proprioceptive balance training seems to be a useful tool for improving postural stability in patients with impaired balance due to various diagnoses [18–20]. To the best of our knowledge, this type of training has not been applied to children or adults with asthma across a wide range of severities. Only a few studies focused on balance changes after a rehabilitation program has been conducted for another common lung disease – chronic obstructive pulmonary disease (COPD). Although COPD is typically a disease of the adult population, it has been shown that a pulmonary rehabilitation program without any specific proprioceptive balance training resulted in only minor improvements in balance and had no effect on balance confidence [21]. In contrast, a combination of pulmonary rehabilitation treatment and balance training significantly improved balance performance in patients with COPD in comparison to patients who received only standard pulmonary rehabilitation treatment [22].

Asthmatic symptoms can negatively influence a child's participation in school and physical activities, and can decrease their health-related quality of life [23, 24]. For this reason, an exercise training program for children with asthma was designed, and was aimed to enhance self-confidence and improve health-related fitness and quality of life [25–31]. Balance improvement can lead to better self-confidence and an increased likelihood of participation in physical activities on a regular basis [32].

The hypothesis of this study was that balance training applied to a standard physiotherapy program may have a beneficial effect on postural stability for children with asthma. Therefore, the aim of our study was to assess the effect of balance intervention, as part of four-week physiotherapy program including breathing exercises and aerobic physical training, on postural stability in children with mild intermittent asthma.

Methods

Subjects

A total of 19 school children with mild intermittent asthma were randomly assigned to an experimental group ($n = 9$; age 10.2 ± 2.4 years, height 139.3 ± 12.5 cm, and weight 33.2 ± 12.3 kg) or to a control group ($n = 10$; age 11.8 ± 1.3 years, height 141.3 ± 6.5 cm, and weight 33.4 ± 10.5 kg). Children with a medically stable phase of asthma and without any exacerbations within the previous eight weeks were recruited from referrals to the pulmonary rehabilitation program of the Miramonti Children's Medical Institution. Mild intermittent asthma

was diagnosed by an allergist according to the Global Initiative for Asthma Criteria (<http://www.ginasthma.org>, Accessed March 19, 2017) at least one year prior to the enrollment in the study.

Inclusion criteria for both groups were a diagnosis of well-controlled mild bronchial asthma without any restriction for participating in the pulmonary rehabilitation program. This asthma severity was selected to allow all children to complete the pulmonary rehabilitation program. Children with exacerbation of their disease in the previous eight weeks were not included in this study to avoid the possible effect of exacerbation on their exercise tolerance and muscle strength which could negatively affect the results of this study. The exclusion criteria for both groups were any other diseases known to affect the sensorimotor control mechanisms underlying balance. When the total number of participating children in this study was known, the children were randomly assigned to either experimental or control group, where the randomization process was as follows. Each child had to choose an envelope. The envelope contained either number 1 or number 2. Children who chose an envelope with number 1 were assigned to the experimental group, while children who chose an envelope with number 2 were assigned to the control group (Figure 1).

The procedures were in accordance with the ethical standards on human experimentation and were approved by an institutional review board. All parents of the children included in this study were informed about the procedure and gave their written informed consent.

Balance assessment

Basic balance parameters during the tests were monitored using Kistler force plates (9286AA, Kistler Instrumente AG, Winterthur, Switzerland) at baseline and after the treatment (the following day after the completion of a four-week physiotherapy program) (Figure 1). The system consisted of two force plates with a sampling rate of 200 Hz. The children performed two static balance tests with different foot position configurations (preferred stance and adjusted stance) in a randomized order. In the preferred stance, they adopted their preferred stance with their feet positioned comfortably. In the adjusted stance, the foot position was designated a 30° angle between the medial borders of the feet with the heels 5 cm apart. All tests were administered with the subject's eyes open (EO) and eyes closed (EC). One experimental trial was performed prior to each test. Each test was performed twice for 30 seconds, and the children had 5 seconds to stabilize their posture prior to each measurement.

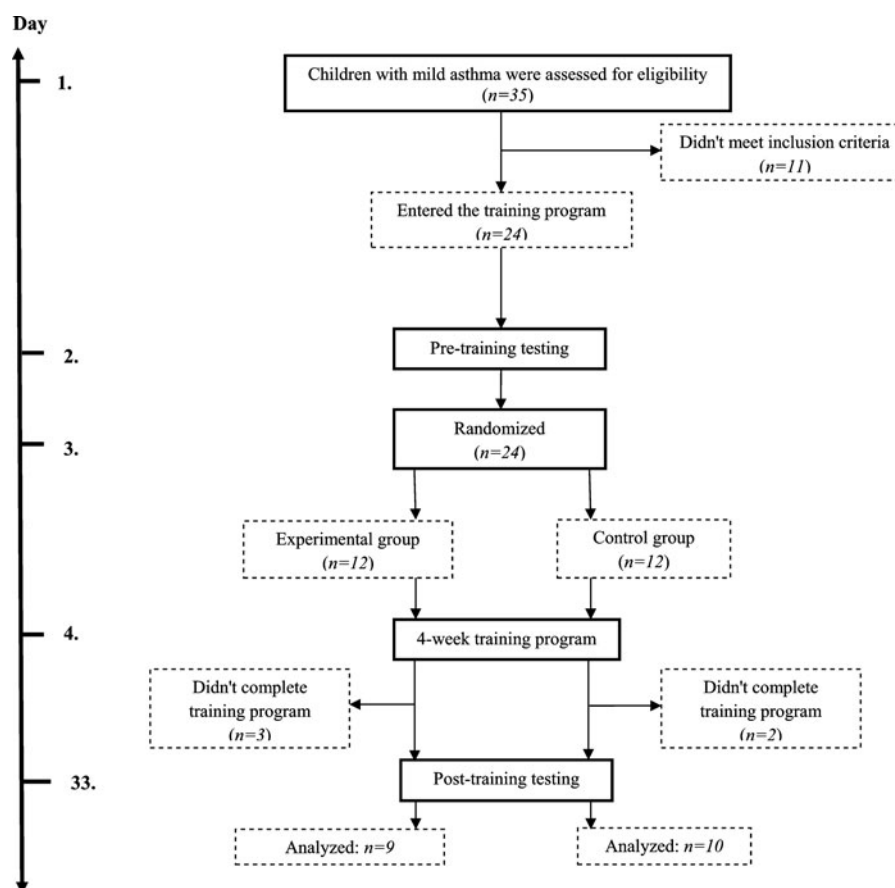


Figure 1. Study flow diagram.

Assessment of ventilatory parameters

Ventilatory parameters were assessed for both groups at baseline and after the treatment (Figure 1). Lung function tests were performed using a ZAN 100 Handy USB spirometer (nSpire Health Inc., Oberthulba, Germany), and further analysis was performed to determine the vital capacity (VC), forced expiratory volume in 1 second (FEV₁), and peak expiratory flow. Respiratory muscle strength was assessed non-invasively using a respiratory pressure meter (Micro Respiratory Pressure Meter, Care Fusion, San Diego, CA) to measure maximal inspiratory mouth pressure (MIP) and maximal expiratory mouth pressure (MEP). All these maneuvers were performed in a sitting position. The tested parameter values from the lung function tests and respiratory muscle strength were expressed as a percentage of the predicted values.

Exercise protocol

All subjects from both groups completed a four-week physiotherapy program six times per week during a spa treatment. The physiotherapy program included breathing exercises and aerobic physical training. Each training session lasted a total of 45 minutes and was divided

into 5 minutes of warm-up, 5 minutes of stretching, 10 minutes of breathing exercises, 20 minutes of aerobic physical training and 5 minutes of cool-down. Breathing training included diaphragmatic breathing, pursed lip breathing and thoracic expansion exercises. Children also learned airway clearance techniques (autogenic drainage and active cycle of breathing techniques). Children completed three sets of 10 repetitions of each breathing exercise followed by a 1-minute relaxation pause with controlled breathing. While the control group performed the breathing exercises in an upright sitting position on a chair and in a standing position (bipedal and unipedal conditions) on a firm surface, the experimental group performed the same exercises on balance devices (i.e., Airex Pad, Soft Gym Overball, Bosu® Balance Trainer PROFI and Original Pezzi® Gymnastik Ball Standard). Standard aerobic physical training as an adjunctive therapy in asthma treatment was focused on the improvement of physical fitness using a set of exercises which includes the following: proprioceptive exercises, functional strength exercises (lower limbs, upper limbs and core), hand-eye coordination exercises and endurance training. All exercises were selected with respect to age. Exercises were also carefully selected so that it was possible to perform them on balance devices (75% of all exercises). While

the control group performed the proprioceptive exercises, functional strength exercises and hand–eye coordination exercises on a firm surface, the experimental group performed the same exercises on unstable devices.

Data analysis

The data were filtered using a fourth-order low-pass Butterworth filter with a cut-off frequency of 7 Hz in MATLAB (MATLAB R2010b, MathWorks, Inc., Natick, MA). Prior to and after the training, the CoP velocity (cm s^{-1}), an indicator of postural stability, was recorded in the mediolateral direction (V_x) and the anteroposterior direction (V_y) along with the total velocity (V_{tot}) for each group. The average of two trials was analyzed. Both groups were tested at the baseline (pre) and end (post) of the training program and were statistically analyzed. Pre- to post-training changes (delta change, Δ) were calculated for each parameter in each group separately and were then used for the between-group comparison to determine the training effect. Similarly, the delta change was also calculated for the ventilatory parameters. A statistical analysis of the collected data was performed using the Statistica program (version 10, StatSoft, Inc., Tulsa, OK). The Kolmogorov–Smirnov test for the normality distribution was performed on all variables. Because the data did not fit a normal distribution, the Mann–Whitney U -test was used to assess the differences between groups. The effect of treatment was assessed using the Wilcoxon test for repeated measurements. Group characteristics are presented as the mean and standard deviation. All data are presented as the median and interquartile ranges. The criterion for significance was set at $p < .05$. The effect size was evaluated using Cohen's d (large effect $d > 0.8$, medium effect $0.5 \leq d \leq 0.8$, and small effect $d < 0.5$).

Results

No significant between-group differences were found in any of the baseline characteristics, variables or ventilation parameters prior to the training intervention ($p > 0.05$) (Table 1).

The addition of balance training intervention to the physiotherapy program led to significant improvements of V_{tot} ($p = 0.02$, $p = 0.04$) in both types of stance, V_x in the preferred stance ($p = 0.03$) and V_y in the adjusted stance ($p = 0.01$) under EO conditions. Significant improvements were also found in V_y in the adjusted stance ($p = 0.01$) under EC conditions. This finding was corroborated by the large effect sizes ($d > 0.8$) (Table 5).

In the experimental group, the balance training resulted in a significantly lower CoP velocity in V_x ($p = 0.04$), V_y ($p = 0.02$) and V_{tot} ($p = 0.02$) in the adjusted

Table 1. Baseline characteristics.

	Experimental group	Control group	p
Age (years)	10.2 $\pm$ 2.4	11.8 $\pm$ 1.3	0.35
Height (cm)	139.2 $\pm$ 12.5	141.3 $\pm$ 6.5	0.77
Weight (kg)	33.2 $\pm$ 12.3	33.4 $\pm$ 10.5	0.25
Preferred stance EO			
V_x (cm s^{-1})	0.88 (0.75–1.40)	0.77 (0.54–0.87)	0.18
V_y (cm s^{-1})	1.30 (1.06–1.54)	1.16 (0.95–1.43)	0.97
V_{tot} (cm s^{-1})	1.84 (1.43–2.26)	1.63 (1.13–1.82)	0.49
Preferred stance EC			
V_x (cm s^{-1})	1.05 (0.71–1.11)	0.88 (0.70–0.94)	0.19
V_y (cm s^{-1})	1.26 (1.25–1.52)	1.24 (0.97–1.68)	0.98
V_{tot} (cm s^{-1})	1.83 (1.65–1.86)	1.66 (1.27–2.07)	0.49
Adjusted stance EO			
V_x (cm s^{-1})	0.95 (0.73–1.10)	0.78 (0.64–1.06)	0.39
V_y (cm s^{-1})	2.19 (1.87–2.83)	1.78 (1.49–1.97)	0.08
V_{tot} (cm s^{-1})	2.59 (2.24–3.28)	2.26 (1.72–2.47)	0.11
Adjusted stance EC			
V_x (cm s^{-1})	0.84 (0.76–0.84)	0.90 (0.65–1.10)	0.99
V_y (cm s^{-1})	2.34 (2.08–2.86)	1.97 (1.70–2.11)	0.09
V_{tot} (cm s^{-1})	2.73 (2.42–3.12)	2.36 (2.02–2.57)	0.11
Ventilatory parameters			
VC (%)	88.0 (86.0–90.0)	91.5 (84.0–98.0)	0.39
FEV ₁ (%)	97.0 (95.0–102.0)	93.5 (88.0–96.0)	0.12
PEF (%)	91.0 (80.0–97.0)	88.5 (74.0–99.0)	1.00
MEP (%)	76.2 (70.3–107.6)	104.6 (70.6–111.1)	0.60
MIP (%)	125.6 (116.8–127.6)	102.1 (72.8–119.0)	0.09

Notes. Preferred stance, feet were positioned comfortably; adjusted stance, foot position was designated a 30° angle between the medial borders of the feet with the heels 5 cm apart; EO, eyes open; V_x , center of pressure velocity in the mediolateral direction; V_y , center of pressure velocity in the anteroposterior direction; V_{tot} , total center of pressure velocity; EC, eyes closed; VC, vital capacity; FEV₁, forced expiratory volume in 1 second; PEF, peak expiratory flow; MEP, maximal expiratory mouth pressure; MIP, maximal inspiratory mouth pressure. * $p \leq .05$. Age, height and weight values are presented as mean $\pm$ SD. CoP and ventilatory values are presented as the median (interquartile range).

stance, and in V_x ($p = 0.03$) and V_{tot} ($p = 0.03$) in the preferred stance under EO conditions only. This finding was corroborated by the large effect sizes ($d > 0.8$). On the other hand, no significant improvements were found under EC conditions for either stance (Table 2).

The control group showed no significant improvement in any of the measured conditions or variables ($p > .05$) (Table 3).

Similarly, significant improvements of VC and FEV₁ were observed after treatment only in the experimental group (Table 4). Moreover, FEV₁ was lower in the control group after treatment. Compared with the changes observed in the control group, the improvement in the experimental group was greater for FEV₁ ($p = 0.01$) (Table 5). We confirmed the effect of breathing exercises on expiratory muscle strength in the experimental group ($p = 0.01$) and the control group ($p = 0.01$), but there were no between-group differences found for changes in MEP ($p = 0.39$). On the other hand, inspiratory muscle strength improved in both groups but significant improvement was confirmed only in the experimental group ($p = 0.04$). No

Table 2. CoP variables in preferred and adjusted stances before and after the four-week physiotherapy program in the experimental group.

	Eyes open				Eyes closed			
	Baseline	After treatment	<i>p</i>	Cohen's <i>d</i>	Baseline	After treatment	<i>p</i>	Cohen's <i>d</i>
Preferred stance								
V_x (cm s ⁻¹)	0.88 (0.75–1.40)	0.66 (0.60–0.82)	0.03*	0.86 [†]	1.05 (0.71–1.11)	0.82 (0.63–1.19)	0.21	0.55
V_y (cm s ⁻¹)	1.30 (1.06–1.54)	1.25 (0.82–1.29)	0.09	0.49	1.26 (1.25–1.52)	1.75 (1.34–1.91)	0.21	0.71
V_{tot} (cm s ⁻¹)	1.84 (1.43–2.26)	1.55 (1.31–1.66)	0.03*	0.92 [†]	1.83 (1.65–1.86)	2.09 (1.49–2.41)	0.86	0.15
Adjusted stance								
V_x (cm s ⁻¹)	0.95 (0.73–1.10)	0.64 (0.56–0.70)	0.04*	0.86 [†]	0.84 (0.76–0.84)	0.79 (0.43–0.98)	0.68	0.10
V_y (cm s ⁻¹)	2.19 (1.87–2.83)	1.57 (1.38–1.93)	0.02*	1.50 [†]	2.34 (2.08–2.86)	1.91 (1.64–2.31)	0.86	0.59
V_{tot} (cm s ⁻¹)	2.59 (2.24–3.28)	1.86 (1.63–2.21)	0.02*	1.32 [†]	2.73 (2.42–3.12)	2.25 (1.74–2.79)	0.14	0.45

Notes. Preferred stance, feet were positioned comfortably; adjusted stance, foot position was designated a 30° angle between the medial borders of the feet with the heels 5 cm apart; V_x , center of pressure velocity in the mediolateral direction; V_y , center of pressure velocity in the anteroposterior direction; V_{tot} , total center of pressure velocity. * $p \leq .05$. [†]Large effect. Values are presented as the median (interquartile range).

Table 3. CoP variables in preferred and adjusted stances before and after the four-week physiotherapy program in the control group.

	Eyes open				Eyes closed			
	Baseline	After treatment	<i>p</i>	Cohen's <i>d</i>	Baseline	After treatment	<i>p</i>	Cohen's <i>d</i>
Preferred stance								
V_x (cm s ⁻¹)	0.77 (0.54–0.87)	0.66 (0.48–0.88)	0.96	0.10	0.88 (0.70–0.94)	0.76 (0.59–0.93)	0.24	0.51
V_y (cm s ⁻¹)	1.16 (0.95–1.43)	1.25 (0.88–1.38)	0.87	0.00	1.24 (0.97–1.68)	1.43 (1.02–1.85)	0.4	0.21
V_{tot} (cm s ⁻¹)	1.63 (1.13–1.82)	1.40 (1.27–1.84)	0.65	0.20	1.66 (1.27–2.07)	1.88 (1.24–2.19)	0.5	0.03
Adjusted stance								
V_x (cm s ⁻¹)	0.78 (0.64–1.06)	0.78 (0.52–0.99)	0.65	0.21	0.90 (0.65–1.10)	0.81 (0.58–1.01)	0.36	0.21
V_y (cm s ⁻¹)	1.78 (1.49–1.97)	1.80 (1.40–2.15)	0.65	0.19	1.97 (1.70–2.11)	1.99 (1.59–2.48)	0.29	0.36
V_{tot} (cm s ⁻¹)	2.26 (1.72–2.47)	2.14 (1.65–2.65)	0.72	0.02	2.36 (2.02–2.57)	2.35 (1.88–2.86)	0.65	0.15

Notes. Preferred stance, feet were positioned comfortably; adjusted stance, foot position was designated a 30° angle between the medial borders of the feet with the heels 5 cm apart; V_x , center of pressure velocity in the mediolateral direction; V_y , center of pressure velocity in the anteroposterior direction; V_{tot} , total center of pressure velocity. * $p \leq .05$. [†]Large effect. Values are presented as the median (interquartile range).

between-group differences were found for changes in MIP (Table 5).

Discussion

Although poorer postural stability was found in patients with asthma [12, 13, 33], balance training is not a commonly recommended type of treatment in these patients. We hypothesized that balance training added to a standard physiotherapy program including breathing exercises and aerobic physical training may have a beneficial effect on postural stability in children with mild asthma.

The addition of balance training to a physiotherapy program resulted in significantly improved overall postural stability under EO conditions for both types of stance. In the preferred stance, improved overall postural stability was related to significantly improved mediolateral stability. Conversely, in the adjusted stance, improved overall postural stability was related to significantly improved anteroposterior stability. Additionally, significant improvements in anteroposterior stability were only found in the adjusted stance under EC conditions. The reason postural stability was not significantly improved in other EC conditions may be because the majority of exercises were performed with eye control

Table 4. Changes in ventilatory parameters before and after the four-week physiotherapy program in experimental and control groups.

	Experimental group				Control group			
	Baseline	After treatment	<i>p</i>	Cohen's <i>d</i>	Baseline	After treatment	<i>p</i>	Cohen's <i>d</i>
Preferred stance								
VC (%)	88.0 (86.0–90.0)	92.0 (89.0–100.0)	0.02*	1.00 [†]	91.5 (84.0–98.0)	92.5 (84.0–101.0)	0.85	0.15
FEV ₁ (%)	97.0 (95.0–102.0)	103.0 (99.0–104.0)	0.02*	0.94 [†]	93.5 (88.0–96.0)	88.0 (85.0–95.0)	0.29	0.41
PEF (%)	91.0 (80.0–97.0)	95.0 (88.0–103.0)	0.28	0.37	88.5 (74.0–99.0)	86.5 (75.0–99.0)	0.47	0.17
MEP (%)	76.2 (70.3–107.6)	92.1 (86.9–132.2)	0.01*	0.83 [†]	104.6 (70.6–111.1)	114.5 (84.1–120.8)	0.01*	0.50
MIP (%)	125.6 (116.8–127.6)	140.1 (115.3–182.4)	0.04*	0.67	102.1 (72.8–119.0)	107.2 (100.9–113.9)	0.24	0.40

Notes. VC, vital capacity; FEV₁, forced expiratory volume in 1 second; PEF, peak expiratory flow; MEP, maximal expiratory mouth pressure; MIP, maximal inspiratory mouth pressure. * $p < 0.05$. [†]Large effect. Values are presented as the median (interquartile range).

Table 5. Outcome measures for experimental and control groups.

Δ	Experimental group	Control group	<i>P</i>	Cohen's <i>d</i>
Preferred stance EO				
V_x (cm s ⁻¹)	0.41 (0.12–0.78)	– 0.03 (–0.06–0.13)	0.03*	1.15 [†]
V_y (cm s ⁻¹)	0.17 (0.13–0.29)	– 0.06 (–0.41–0.13)	0.07	0.82 [†]
V_{tot} (cm s ⁻¹)	0.48 (0.24–0.72)	0.04 (–0.44–0.25)	0.02*	1.18 [†]
Preferred stance EC				
V_x (cm s ⁻¹)	0.19 (–0.11–0.67)	0.08 (–0.02–0.13)	0.49	0.36
V_y (cm s ⁻¹)	– 0.24 (–0.63–0.16)	– 0.11 (–0.30–0.23)	0.65	0.37
V_{tot} (cm s ⁻¹)	– 0.21 (–0.54–0.61)	– 0.09 (–0.42–0.23)	0.97	0.18
Adjusted stance EO				
V_x (cm s ⁻¹)	0.31 (0.04–0.45)	0.03 (–0.12–0.14)	0.18	0.54
V_y (cm s ⁻¹)	0.64 (0.53–0.99)	– 0.08 (–0.42–0.18)	0.01*	1.60 [†]
V_{tot} (cm s ⁻¹)	0.73 (0.56–1.07)	– 0.10 (–0.32–0.58)	0.04*	1.25 [†]
Adjusted stance EC				
V_x (cm s ⁻¹)	0.15 (–0.21–0.42)	– 0.06 (–0.13–0.33)	0.84	0.00
V_y (cm s ⁻¹)	0.43 (0.38–0.59)	– 0.19 (–0.44–0.22)	0.01*	0.91 [†]
V_{tot} (cm s ⁻¹)	0.49 (0.33–0.68)	– 0.21 (–0.58–0.42)	0.11	0.49
Ventilatory parameters				
VC (%)	4.00 (2.00–12.00)	– 1.00 (–6.00–12.00)	0.19	0.57
FEV ₁ (%)	3.00 (2.00–5.00)	– 0.50 (–11.00–1.00)	0.01*	1.18 [†]
PEF (%)	5.00 (–3.00–14.00)	– 2.50 (–8.00–6.00)	0.27	0.51
MEP (%)	15.84 (13.15–20.20)	12.19 (7.32–20.43)	0.39	0.45
MIP (%)	13.84 (0.00–33.35)	15.87 (–4.07–29.15)	0.49	0.51

Notes. Δ , delta (the difference in velocities and ventilatory parameters before and after training); preferred stance, feet were positioned comfortably; adjusted stance, foot position was designated a 30° angle between the medial borders of the feet with the heels 5 cm apart; EO, eyes open; V_x , center of pressure velocity in the mediolateral direction; V_y , center of pressure velocity in the anteroposterior direction; V_{tot} , total center of pressure velocity; EC, eyes closed; VC, vital capacity; FEV₁, forced expiratory volume in 1 second; PEF, peak expiratory flow; MEP, maximal expiratory mouth pressure; MIP, maximal inspiratory mouth pressure.

* $p \leq .05$. [†]Large effect. Values are presented as the median (interquartile range).

(80%). The results seem to demonstrate that the hypothesis was verified.

Significant improvement of anteroposterior stability in the more challenging adjusted stance under EO and EC conditions may be associated with the nature of balance training in the experimental group. It is known that in healthy people, somatosensory information plays the greatest role (70%) in balance performance [34]. Young individuals predominantly use ankle strategy for maintaining balance. Ankle strategy is used for postural disturbances corrections in the anteroposterior direction and depends more on feedback from the proprioception system. This could be another reason why it is important to add proprioceptive balance training to comprehensive treatment in children with asthma. Proprioceptive balance training induces increased stress on the motor control system, providing greater neuromuscular control challenges, which might have led to lower CoP values and better postural stability.

The anteroposterior stability improvements might also be associated with a better control of body segment positions, especially with an upright position without head and shoulder protraction, decreased internal rotation of the shoulder and higher chest wall expansion, which was associated with the improvement of VC in the experimental group. Similar findings were confirmed by Almeida et al. [17]; their study found a significant correlation between horizontal alignment of the head (anterior view) and VC.

It is known that mediolateral stability can be impaired in people with breathing problems due to an inadequate contribution of the trunk muscles toward balance [35]. An impaired postural contribution of inspiratory muscles toward trunk stability has been confirmed in patients with COPD with inspiratory muscle weakness [36]. Although inspiratory muscle strength was sufficient in both groups of children with asthma in the current study, a significant improvement in inspiratory muscle strength was confirmed in the experimental group, which may be another reason why improvements in postural stability after treatment were observed only in this group.

Both groups performed breathing exercises and aerobic physical training as part of a standard physiotherapy program. However, only the experimental group performed this program concurrently with balance training. This combination seems to be effective for inducing significant changes in postural stability. Our results are similar to the results of Beauchamp et al. [22], who confirmed that a combined balance training and pulmonary rehabilitation program improved balance in patients with COPD. The same authors found in a previous study [21] that a pulmonary rehabilitation program without any specific balance training did not lead to balance improvement in patients with COPD.

As expected, in children with intermittent asthma, ventilatory parameters reached more than 80% of the predicted values. Almost all values were higher after treatment in both groups, although significant improvements

were confirmed only for VC and FEV₁ in the experimental group. The effect of breathing retraining on ventilatory parameters in patients with asthma has been confirmed in some previous studies [37, 38]. On the other hand, Thomas et al. [39] confirmed the positive effect of breathing retraining on asthma-specific health status in adults with asthma, which was assessed using the Hospital Anxiety and Depression Scale and the Nijmegen Questionnaire for hyperventilation, but not on asthma pathophysiology. The reason for greater improvements in the experimental group may be associated with the performance of breathing exercises in more demanding positions. It is known that respiratory muscles are responsible not only for breathing but also for trunk stabilization and upper extremity movements [40, 41]. It is well documented that the breathing function of respiratory muscles has to be coordinated with the other non-respiratory functions of respiratory muscles [9]. Therefore, breathing retraining associated with proprioceptive balance training in more challenging positions may be beneficial for improving breathing patterns and for better co-activation of respiratory muscle fibers in different tasks.

This improvement of respiratory and non-respiratory functions of respiratory muscles may result in higher alleviation of asthmatic symptoms. Decreased presence of asthmatic symptoms can be associated with better self-confidence for participating in various physical activities without any breathing problems and with the confidence to try new activities that could encourage children with asthma to embrace a positive attitude about being physically active in their life. Another advantage of this balance improvement can be associated with decreased risk of fall during activities of daily living and during various physical activities.

The optimal duration of balance training interventions is still under discussion and varies from study to study. The length of our intervention was established according to the current literature [42, 43]. Previous studies confirmed postural stability improvements in healthy people after a four-week balance training. Similar findings were observed in our study. Four-week balance training added to a physiotherapy program including breathing exercises and aerobic physical training resulted in significant improvement of postural stability and ventilatory parameters in children with mild intermittent asthma. We admit that this effect is questionable for more severe stages of asthma and needs to be further evaluated. Therefore, more studies are necessary to determine the optimal duration of this program for children and adults with mild persistent, moderate persistent and severe asthma disease.

There are a few limitations of this study. First, we assessed children who only had mild intermittent bronchial asthma; so the results might not be

representative for children with moderate and severe asthma. Second, we assessed postural stability and ventilatory parameters one day after completing a physiotherapy program; therefore, we cannot assess the long-term effect of this therapy.

Conclusions

Results of this study support the effectiveness of balance training as a part of physiotherapy treatment for improving balance performance, predominantly under EO conditions, in children with mild asthma. Moreover, this intervention seems to be effective for inducing significant improvements in the ventilatory function. Therefore, focus on postural stability improvement as part of a comprehensive treatment could be targeted toward school-age children with lower stages of asthma as a prevention of future postural deterioration and reduced injury risk.

Acknowledgements

The authors thank Petr Stepanik for technical support and also thank Helena Trncikova, Andrea Korandova, Zuzana Jarosova, Eliska Kordikova and Gabriela Koprivova who helped to coordinate this research.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

Funding

This study was supported by the projects:

“Support for the creation of excellent research teams and intersectoral mobility at Palacky University in Olomouc” Reg. No. CZ.1.07/2.3.00/30.0004.

The Palacky University grant IGA_FTK_2015_006.

The project APVV-15-0704 “Split-Core Trainer Strengthening System for athletes and untrained individuals with functional back pain.”

References

1. Strunk RC, Mascia AV, Lipkowitz MA, Wolf SI. Rehabilitation of a patient with asthma in the outpatient setting. *J Allergy Clin Immunol* 1991;87(3):601–611.
2. Gonzalez HE, Manns A. Forward head posture: its structural and functional influence on the stomatognathic system, a conceptual study. *J Craniomandib Pract* 1996;14(1):71–80.
3. Robles-Ribeiro PG, Ribeiro M, Lianza S. Relationship between peak expiratory flow rate and shoulders posture in healthy individuals and moderate to severe asthmatic patients. *J Asthma* 2005;42(9):783–786.

4. Belli JFC, Chaves TC, De Oliveira AS, Grossi DB. Analysis of body posture in children with mild to moderate asthma. *Eur J Pediatr* 2009;168(10):1207–1216.
5. Lunardi AC, Marques da Silva CCB, Rodrigues Mendes FA, Marques AP, Stelmach R, Fernandes Carvalho CR. Musculoskeletal dysfunction and pain in adults with asthma. *J Asthma* 2011;48(1):105–110.
6. Lima LCDO, Baraúna MA, Sologurem MJJ, Canto RSDT, Gastaldi AC. Postural alterations in children with mouth breathing assessed by computerized biophotogrammetry. *J Appl Oral Sci* 2004;12(3):232–237.
7. Corrêa EC, Bérzin F. Efficacy of physical therapy on cervical muscle activity and on body posture in school-age mouth breathing children. *Int J Pediatr Otorhinolaryngol* 2007;71(10):1527–1535.
8. Neiva PD, Kirkwood RN, Godinho R. Orientation and position of head posture, scapula and thoracic spine in mouth-breathing children. *Int J Pediatr Otorhinolaryngol* 2009;73(2):227–236.
9. Hodges PW, Heijnen I, Gandevia SC. Postural activity of the diaphragm is reduced in humans when respiratory demand increases. *J Physiol* 2001;537(3):999–1008.
10. Hodge PW, Gurfinkel VS, Brumagne S, Smith TC, Cordo PC. Coexistence of stability and mobility in postural control: evidence from postural compensation for respiration. *Exp Brain Res* 2002;144:293–302.
11. Cunha ÂG, Nunes MP, Ramos RT, Carvalo-Pinto RM, Boffino CC, Martins FC, et al. Balance disturbances in asthmatic patients. *J Asthma* 2013;50(3):282–286.
12. Silva MCRD, Corazza ST, Katzer JI, Mota CB, Soares JC. Balance in children and teenagers asthmatics and without asthma. *Motriz: Rev Educ Fis* 2013;19(2):480–486.
13. Kovacikova Z, Neumannova K, Bizovska L, Rydlova J, Siska M, Janura M. Postural stability in school-age children with mild bronchial asthma disease (a pilot study). *J Asthma* 2016;53(1):11–14.
14. Nolan L, Grigorenko A, Thorstensson A. Balance control: sex and age differences in 9-to 16-source-olds. *Dev Med Child Neurol* 2005;47(7):449–454.
15. Garcia C, Barela JA, Viana AR, Barela AMF. Influence of gymnastics training on the development of postural control. *Neurosci Lett* 2011;492(1):29–32.
16. Smith A, Ulmer F, Wong D. Gender differences in postural stability among children. *J Hum Kinet* 2012;33:25–32.
17. Almeida VPD, Guimaraes FS, Moco VJR, Ferreira ADS, Menezes SLSD, Lopes AJ. Is there an association between postural balance and pulmonary function in adults with asthma? *Clinics* 2013;68(11):1421–1427.
18. Hale SA, Hertel J, Olmsted-Kramer LC. The effect of a 4-week comprehensive rehabilitation program on postural control and lower extremity function in individuals with chronic ankle instability. *J Orthop Sports Phys Ther* 2007;37(6):303–311.
19. Madureira MM, Takayama L, Gallinaro AL, Caparbo VF, Costa RA, Pereira RM. Balance training program is highly effective in improving functional status and reducing the risk of falls in elderly women with osteoporosis: a randomized controlled trial. *Osteoporos Int* 2007;18(4):419–425.
20. Hirsch MA, Toole T, Maitland CG, Rider RA. The effects of balance training and high-intensity resistance training on persons with idiopathic Parkinson's disease. *Arch Phys Med Rehabil* 2003;84(8):1109–1117.
21. Beauchamp MK, O'Hoski S, Goldstein RS, Brooks D. Effect of pulmonary rehabilitation on balance in persons with chronic obstructive pulmonary disease. *Arch Phys Med Rehabil* 2010;91(9):1460–1465.
22. Beauchamp MK, Janaudis-Ferreira T, Parreira V, Romano JM, Woon L, Goldstein RS, et al. A randomized controlled trial of balance training during pulmonary rehabilitation for individuals with COPD. *Chest J* 2013;144(6):1803–1810.
23. Fanelli A, Cabral ALB, Neder JA, Martins MA, Carvalho CRF. Exercise training on disease control and quality of life in asthmatic children. *Med Sci Sports Exerc* 2007;39(9):1474.
24. van den Bemt L, Kooijman S, Linssen V, Lucassen P, Muris J, Slabbers G, et al. How does asthma influence the daily life of children? Results of focus group interviews. *Health Qual Life Outcomes* 2010;8(1):5.
25. Crosbie A. The effect of physical training in children with asthma on pulmonary function, aerobic capacity and health-related quality of life: a systematic review of randomized control trials. *Pediatr Exerc Sci* 2012;24(3):472–489.
26. Eijkemans M, Mommers M, Jos MT, Thijs C, Prins MH. Physical activity and asthma: a systematic review and meta-analysis. *PLoS ONE* 2012;7(12):e50775.
27. Chandratilleke MG, Carson KV, Picot J, Brinn MP, Esterman AJ, Smith BJ. Physical training for asthma. *Cochrane Database Syst Rev* 2012;(5):1116.
28. Eichenberger PA, Diener SN, Kofmehl R, Spengler CM. Effects of exercise training on airway hyperreactivity in asthma: a systematic review and meta-analysis. *Sports Med* 2013;43(11):1157–1170.
29. Pakhale S, Luks V, Burkett A, Turner L. Effect of physical training on airway inflammation in bronchial asthma: a systematic review. *BMC Pulm Med* 2013;13(1):38.
30. Wanrooij VH, Willeboordse M, Dompeling E, van de Kant KD. Exercise training in children with asthma: a systematic review. *Br J Sports Med* 2014;48(13):1024–1031.
31. Orenstein DM. Asthma and sports. In: Bar-Or O, ed. *The child and the adolescent athlete*. London: Blackwell. 1996:433–454.
32. Claxton DB, Troy M, Dupree S. A question of balance. *J Physic Educ Recre Dance* 2006;77(3):32–37.
33. Lopes AJ, Almeida VP, Menezes SLS, Guimarães FS. Balance deficits are correlated with bronchial obstruction markers in subjects with asthma. *J Phys Ther Sci* 2014;26(3):393.
34. Peterka RJ. Sensorimotor integration in human postural control. *J Neurophysiol* 2002;88(3):1097–1118.
35. Smith MD, Chang AT, Seale HE, Walsh JR, Hodges PW. Balance is impaired in people with chronic obstructive pulmonary disease. *Gait Posture* 2010;31(4):456–460.
36. Janssens L, Brumagne S, McConnell AK, Claeys K, Pijnenburg M, Burtin C, et al. Proprioceptive changes impair balance control in individuals with chronic obstructive pulmonary disease. *PLoS ONE* 2013;8(3):e57949.
37. Salvi D, Agarwal R, Salvi S, Barthwal BM, Khandagale S. Effect of diaphragmatic breathing on spirometric parameters in asthma patients and normal individuals. *Indian J Phys Occup Ther* 2014;8(3):43.
38. Grammatopoulou EP, Skordilis EK, Stavrou N, Myrianthefs P, Karteroliotis K, Baltopoulos G, et al.

- The effect of physiotherapy-based breathing retraining on asthma control. *J Asthma* 2011;48(6):593–601.
39. Thomas M, McKinley RK, Mellor S, Watkin G, Holloway E, Scullion J, et al. Breathing exercises for asthma: a randomised controlled trial. *Thorax* 2009;64(1): 55–61.
 40. Kolar P, Sulc J, Kyncl M, Sanda J, Neuwirth J, Bokarius AV, et al. Stabilizing function of the diaphragm: dynamic MRI and synchronized spirometric assessment. *J Appl Physiol* 2010;109(4):1064–1071.
 41. Hodges PW, Gandevia SC. Changes in intra-abdominal pressure during postural and respiratory activation of the human diaphragm. *J Appl Physiol* 2000;89(3):967–976.
 42. Rasool J, George K. The impact of single-leg dynamic balance training on dynamic stability. *Phys Ther Sport* 2007;8(4):177–184.
 43. Granacher U, Gollhofer A, Kriemler S. Effects of balance training on postural sway, leg extensor strength, and jumping height in adolescents. *Res Quarter Exer Sport* 2010;81(3):245–251.