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Original Article

Interrelationship between postural balance and body posture in children and adolescents

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Abstract. [Purpose] This study examined possible interrelationships between postural sway and posture parameters in children and adolescents with a particular focus on posture weakness. [Subjects and Methods] 308 healthy children and adolescents (124 girls, 184 boys, aged 12.3 ± 2.5 years) participated in the study. Posture parameters (posture index, head protrusion, trunk inclination) were determined based on posture photos in the sagittal plane. Postural sway was measured during 20 seconds on a force plate. The Pearson's product-moment correlation coefficients between the anthropometric and posture parameters and the sway path length (SPL) were calculated, as well as the coefficient of determination R^2. [Results] There is a weak but significant correlation between age or body mass index of the test subjects and the SPL. There is no statistically significant correlation between posture parameters and the SPL. Children and adolescents with posture weakness do not exhibit a changed SPL. [Conclusion] Therefore, therapy of poor posture must be considered separately from therapeutic measures for the improvement of balance skills.

Key words: Balance, Posture, Adolescence

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INTRODUCTION

Postural balance is the ability to keep the body in equilibrium and to regain balance after the shift of body segments[1)]. This fundamental motor skill is learned at an early age and represents an essential basic for daily routine tasks and athletic activities[2)]. Disturbances in postural balance are stated with a prevalence of 10 up to 29% for children and adolescents[3–5)]. Eliminating these disturbances is an important task of pediatric physical therapy[6)]. Apart from that, posture weakness is identified by visible changes in body posture, for example a hyperlordosis, an increased anterior pelvic tilt, or a forward head posture[7)]. Posture weakness is described with a prevalence of 22 to 65% in adolescence[8–10)]. It is the result of a disturbed neuromuscular balance[11)] and held responsible for the occurrence of disorders in adult age[12)].

While postural balance and its disturbances correspond to a neurological point of view of body posture, which analyzes the quality of neuromuscular control processes[13, 14)], weakness in posture has so far been an orthopedic topic in particular. Both 'macroscopically' visible posture weaknesses and 'microscopically' measurable body sway[14)] are the result of a control process of the central nervous system, which purposefully activates the postural musculature[15)].

Therefore, the question arises whether visible posture weakness interrelates with a disturbance of postural balance. This is of therapeutic interest because therapeutic treatment of posture weakness can be implemented using various approaches, for example changing muscular balances by means of strength and stretch exercises, improving proprioception, or a combination of both[16–19)].

This study is aiming to answer the following questions:

1. Is there an interrelationship between posture parameters and postural balance?
2. Is there an interrelationship between weak posture and postural balance?

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Table 1. Anthropometric data (mean ± standard deviation) of the subjects (n=308)

	Age (years)	Height (cm)	Weight (kg)	BMI (kg/m²)
Girls (n=124)	12.1 ± 2.6	155.3 ± 15.0	44.5 ± 13.0	17.9 ± 3.1
Boys (n=184)	12.3 ± 2.4	158.8 ± 17.2	48.9 ± 16.1	18.9 ± 3.3

Table 2. Pearson's product-moment correlation coefficients between anthropometric and posture variables and the sway path length (SPL)

Variables	BMI	PI	HP	INC	SPL	$R^2_{(SPL)}$
Age	0.395*	0.065	−0.268*	−0.005	−0.221*	0.049
BMI		−0.106	−0.168*	−0.137*	−0.143*	0.020
PI			0.260*	0.637*	−0.029	0.001
HP					0.025	0.001
INC					−0.048	0.002

BMI: body mass index; PI: posture index; HP: head protrusion; INC: trunk inclination; SPL: sway path length; R^2: coefficient of determination
*p<0.05

SUBJECTS AND METHODS

The study was performed within the framework of an interdisciplinary survey (Kid-Check, Saarland University, Germany, www.kidcheck.de) in the years 2014 to 2016. 308 children and adolescents (124 girls, 184 boys; for anthropometric data see Table 1) participated. Exclusion criteria included acute orthopedic (e.g. dorsal pain, pain in the musculoskeletal system, scoliosis, acute inflammations), or neurological problems (e.g. imbalance, acute vertigo, acute headache), and differences in leg lengths exceeding 5 mm.

The participants and their parents or guardians were informed prior to the trial, in accordance with the requirements of the Helsinki Declaration of 2013[20], about trial objective and trial procedure and gave their written informed consent. The ethics commission of the Saarland University had approved the study.

Height and weight were determined on site and the BMI was calculated. Posture data was gathered based on posture images taken in the sagittal plane. For these images, the test persons wore swimwear and stood on a force plate in front of a measuring wall that served to calibrate the camera. Reflecting marker points (Ø 12 mm) or marker balls (Ø 10 mm) were attached to several anatomic landmarks (malleolus lateralis, trochanter major, PSIS, ASIS, sternum, thoracic kyphosis, lumbar lordosis, C7, acromion)[21]. The test persons stood upright, looking straight ahead, arms hanging down loosely. A posture image was obtained using a high-resolution camera (Olympus SP510UZ, resolution 2,304 × 3,072 pixels), which was placed on a tripod at hip-height.

The postural balance was recorded by means of a force plate (Zebris PDM, Zebris Medical, Isny, Germany) with 2,560 calibrated sensors. The test persons had to stand still for 20 seconds. Based on the pressure shift, the sway path length of the center of pressure (COP) was calculated. This parameter has proved valuable as a measurand for posture balance[22–24].

The posture photographs were analyzed using the Corpus concepts software (AFG, Idar-Oberstein, Germany). The following posture parameters were calculated:

A. Trunk inclination angle INC: angle of the junction of hip and C7 marker from the vertical.
B. Posture index PI: The posture index is a complex measurand that numerically records the position of multiple marker points relative to each other, thus assessing the body posture. The test quality of this parameter is proven[22] and its consistency during the aging process is known[25].
C. Head protrusion HP: Horizontal distance of the ear canal to the perpendicular through the malleolus lateralis (in percent of trunk height).

The statistical parameters were calculated using the XLSTAT Version 2016.02 (Addinson, New York, USA) for Windows Excel software. The Pearson's product-moment correlation coefficients between the anthropometric and posture variables and the sway path length SPL were calculated as well as the coefficient of determination R^2, which indicates the percentage of variability of the sway path length which is explained by the anthropometric and posture variables. The significance level was set to $p<0.05$.

RESULTS

There is a weak but significant correlation between the age of the test persons and the SPL. The same is true for the correlation between body mass index and SPL. There is no statistically significant correlation between posture parameters and the SPL; the explained variance is practically zero (Table 2). Values which point to posture weaknesses occur across all SPL values.

A multiple linear regression with age and BMI as explanatory variables produce an R^2 of 0.052 ($F(2, 305)=8.421$, $p<0.001$). This means that only 5.2% of the variability of the SPL can be explained by age and BMI.

DISCUSSION

This study aimed to show a potential interrelationship between postural balance and posture parameters.

Balance is a multi-dimensional motor skill whose nuances can be recorded by means of motor test procedures or instrumental methods[15]. In our study, postural sway was analyzed as a reliable parameter[26]. Balance regulation is based on the interaction of sensor information, its processing in the central nervous system (CNS), and the generation of adequate motor programs[27, 28]. Proprioceptive function of the sensorimotor control system matures at 3 to 4 years of age[29] and is stabilized at 6 years[30]. Differences in postural strategies or somatosensory integration between children and adolescents were not found[31]. It can therefore be assumed that the children and adolescents examined by us exhibited sufficiently developed sensorimotor performance[32].

Body posture can be parameterized through biomechanical parameters in the sagittal plane[21, 25]. The parameters analyzed (trunk inclination, posture index, and head protrusion) describe various aspects of body posture that changes during aging[25, 33]. We can safely assume that posture weaknesses are the result of neuromuscular imbalances[34]. Due to muscular (im) balance, individual body segments take specific positions. For example, it is known that weak abdominal and gluteus muscles and a hypertension of the hip flexion muscles lead to increased pelvic tilt, which in turn results in a hyperlordosis of the lumbar spine[35, 36].

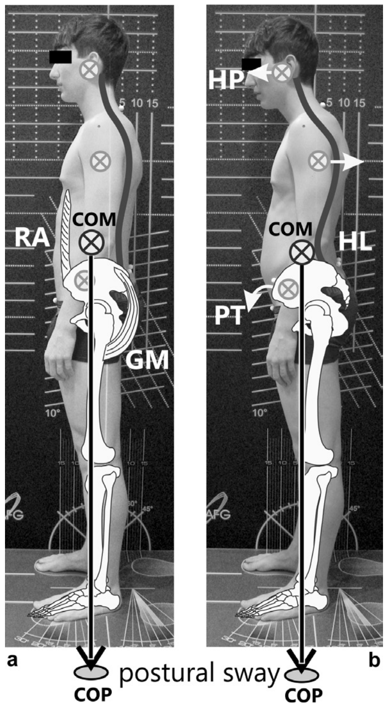

Fig. 1. a. An equilibrium of hip flexors and extensors (RA: rectus abdominis, GM: gluteus maximus) leads to a stable position of the pelvis. b. Changed activity leads to an increased pelvic tilt (PT) with hyperlordosis of the lumbar spine (HL). Compensatory strategies, such as head protrusion (HP) and leaning back the trunk shift the segmental centers of mass (circles) in order to stabilize the global center of mass (COM). In both cases, the center of pressure (COP) and the postural sway may remain the same.

This study did not find any correlations between postural sway and body posture. Children and adolescents with weak posture did not exhibit changed balance skills.

Similar results are known from examinations of scoliosis patients[37, 38]. Anthropometric parameters exerted a stronger influence on postural sway than the posture parameters analyzed. Alonso et al.[39] found comparable influences of height and weight and thus confirmed the results of other studies[40, 41].

Body posture is a complex controlled process that is influenced by a number of biomechanical and neurophysiological mechanisms[15]. Postural control includes the alignment of body segments through muscular activity[26]. The fluctuation of the COP measured via postural sway, however, seems to be independent of the "macroscopic" body posture and applies its own control strategies[42, 43]. We know several scientific approaches able to explain the complex control strategies that body posture and postural sway are based on. Feedback mechanisms and sensory reweighting play a key role in these strategies[44, 45].

Our results can be explained by current motor control theories. The "uncontrolled manifold concept (UCM)"[46] assumes that the CNS strives to keep certain variables, such as the position of the center of mass (COM) invariant by varying joint positions and muscle strength[47]. This also includes the shift of body segments against each other, which we can observe in typical weak postures[48]. According to the UCM theory, these partial movements are executed in such a way that the COM is retained as unchanged as possible[49]. In this case, postural sway (or the COP sway, respectively) is comparable between the different posture positions because it reflects the shift of the COM. Based on the assumption that weak posture is the result of changed muscular balance, positioning control of the COM would not be affected by a new state of balance (Fig. 1). This can explain the independence of the "microscopic" COP sway of the "macroscopic" posture variants found in our study.

Recent studies show an interrelationship between individual posture parameters (or posture weaknesses) and the occurrence of lower back pain[50, 51], leading to clear therapeutic approaches. On the other hand, Mazaheri et al.[52] did not identify any interrelationship between postural sway and lower back pain in their comprehensive review. Likewise, McCaskey et al.[16] showed in a review that proprioceptive exercises did not have any additional effect in the therapy of lower back pain patients. Therefore, therapy of posture weaknesses for the prophylaxis of back pain must be considered separately from therapeutic measures to improve balance skills.

Conflicts of interest

None.

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