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Impaired Postural Stability as a Complication of Childhood Obesity

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ABSTRACT
Objective: The paper aims to compare postural stability between two groups of research subjects: obese children and athletes.
Methods: Both these groups were examined for postural control with two tests – Limits of Stability (LOS) and the Sensory Organization Test (SOT). Based on the test results, differences between the groups were compared and statistically evaluated.
Results: The paper demonstrated a significant impact that obesity has on the postural stability of an individual. Statistically significant differences were found in both the reaction time (RT) and the maximum excursion in the LOS test and in the selection of motion strategies aimed at maintaining postural stability in the SOT test.
Conclusions: In physiotherapy of children with obesity, physical activities need to focus on improving the overall posture and postural stability, for instance through functional training.

KEY WORDS
postural stability, physiotherapy, obesity, physical activities

INTRODUCTION
Obesity is one of the most serious health problems of the late 20th and early 21st centuries. In childhood the vast majority of obesity is alimentary, which is developed based on energy imbalance due to excess energy intake and insufficient energy expenditure. (Goldemund, 2003) Prevalence of obesity in the Czech Republic is on the rise not only among adults but also in children. In 2001, the proportion of obese children aged 6 to 11 grew by 1.9% in boys and by 1.5% in girls. The proportion of obese boys was 6.6% and obese girls 5.6% in this age group. Hence, the group of obese boys grew by 3.6% and the group of obese girls by 2.6%. With age, the proportion of overweight and obese individuals drops, while the proportion of individuals with low weight rises. (Vignerová, 2008) Childhood obesity is a major risk factor leading to the development of severe metabolic, cardiovascular, respiratory, mental, and physical complications. In 70–80%, childhood obesity persists into adulthood, where these individuals become chronically obese adults with serious health and psychosocial complications that fully develop already in productive age. (Marinov, 2012) The most common musculoskeletal disorders in obese children include impaired posture, i. e. incorrect balance, dominated by forward head posture, shoulder protraction, weakened abdominal wall, pelvic anteversion, internal rotation of the hip, and subsequently valgus knees. Obese children place excessive load on the arch of the foot; in consequence the head of the ankle bone suffers a plantar and medial drop, the heel bone stands in valgus, and its front section turns externally, along with the entire forefoot. The center of gravity thus shifts to the inside of the foot, which results in overloading, which may subsequently lead to pain on the inside as well as increased fatigue of the foot through increased energy demands when walking. (Pastucha, 2011) In the event that contracture of triceps surae muscle has developed,

the load is followed by calf pain. The triceps surae muscle as a whole is generally responsible for plantar flexion of the foot, contributing to the elevation of the body when walking and maintaining the correct position of the lower leg to the foot. Therefore, in addition to the correction of posture, passive stretching of the retracted calf muscles is of great importance. (Mayer, Konečný, 1998)

Postural stability is a process of maintaining balance of the body and its parts in a constantly changing environment. It is the body's motor regulatory mechanism that precedes movement, and once the movement is carried out, the system tries to maintain the position reached. Postural balance depends mainly on the axial structures of the body, the muscular system, and the central and peripheral nervous systems of an individual. According to Kolář (2001), when muscles are involved in the postural functions, the phasic and tonic systems respond as a functional unit and both systems are linked on the reflex level. When the diameter of the center of gravity shifts closer to the edges of the support base, maintaining stability of upright position becomes more demanding, and the individual is forced to simultaneously use multiple balance mechanisms or combine strategies. (Véle, 2006)

OBJECTIVE

The aim of this study was to compare postural stability in obese children and athletes and consider the results when selecting appropriate physical activities.

METHODS

Description of participants

A total of 24 probands, of which 12 were obese children (A) and 12 athletes from the Olomouc Athletic Club (B) participated in the research. Children from the Athletic Club completed general athletic training aimed at developing an overall physical fitness and versatility. Each group was made up of the same gender representation, 6 girls and 6 boys. All participants were from the Olomouc region. Their average age at the time of the research was 13.3 ± 0.98. The average body height of the subjects was 163 ± 12.41 cm. The mean body weight in Group A was 81.9 ± 9.7 kg and 54.9 ± 15.7 kg in Group B. The group of obese children only included children with a BMI above the 97th percentile according to the 6th National Anthropological Research on Children and Youth in the Czech Republic, held in 2001. (Vignerová, 2001) Children in the control group of athletes had a BMI percentile from 25 to 90 percentile.

Statistical data processing

Statistic comparison used the nonparametric Mann-Whitney U-test for non-normally distributed data and Two-Sample Student's T-test for normally distributed data. The normality of data distribution was verified using the Shapiro Wilk Test. The tests were carried out with 0.05 significance.

Posturography Test

A method examining postural stability and reactibility, posturography is based on the measurement of reaction forces and moments of these forces on the force platform, both in static and dynamic situations. The Equitest Smart System by NeuroCom®Balance was used for the posturographic analysis in a kinesiology lab, facilitating the evaluation of both the static and dynamic components of postural stability. The system consists of a mobile dual tensiometric platform and a mobile cab. Two tests were selected to assess the postural behaviour and stability in both the research groups. The SOT was held first, followed by the LOS test. In both tests, a space is marked out on the tensiometric platform, where the subjects place their feet. The proband stands upright, looking straight ahead, with arms along their side. The subject must not be holding or leaning against anything during the test to prevent any distortion of the results. Likewise, the feet must remain touching the mat, and neither the heels nor the toes are raised.

The first position to be tested was standing stability in response to a change in sensory perceptions, in order to identify the proportion of visual, vestibular and somatosensory systems on postural stabilization in an upright bipedal stance. A total of 6 situations (see Table 1, Fig. 1) were tested, each repeated 3 times. Each test took 20 seconds, with subjects standing upright on the platform without changing the position of their feet during the test, and with their eyes closed.

Table 1 Changes of conditions in SOT

Test situations	Eyes	Cab	Platform
1	open	not moving	not moving
2	closed	not moving	not moving
3	open	moving	not moving
4	open	not moving	moving
5	closed	not moving	moving
6	open	moving	moving

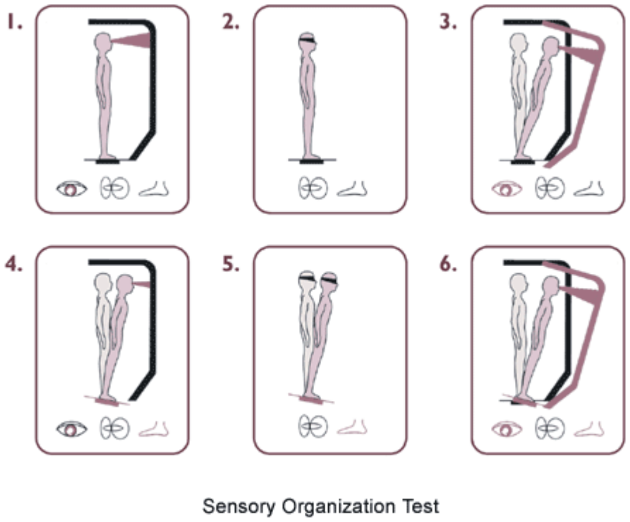

Fig. 1 SOT test situations

The other test, LOS, involved an active shift of COG (Centre of Gravity) in a pre-determined direction. The shifting of the COG is continuously monitored and transferred to the screen so that the research subject may, based on visual feedback, adjust the required direction of the COG movement according to his/her abilities. During the test, we evaluated a total of four situations in a defined order – leaning forward, to the right, backward, and to the left. During the test, no change was allowed in the character of the support base, an area marked out with the outermost boundaries of support areas (Kolář et al., 2010). The default location of the COG always appeared (for biofeedback) in the centre of the screen. The probands were instructed to wait for a sound signal and then reach, as quickly and accurately as possible, a selected point on the screen (which corresponds to 100% of limits of stability standardized for healthy individuals), and subsequently try to maintain this position, i. e. the maximum reached point until the signal beeped again.

Monitored parameters

SOT test parameters:

- Strategy Analysis – the value determines whether it is the hip or the ankle strategy that prevails in maintaining balance.

LOS test parameters:

- Reaction Time (RT) – how fast the subject responds to the sound signal.
- Maximum Excursion (MXE) – the maximum COG deflection in the required direction, the stability limit (%).
- Directional Control (DCL) (%).

RESULTS

The Two-Sample Student's T-test showed statistically significant ($p = 0.014$) lower RT in athletes ($0.501 + 0.13$ s) compared to obese children ($0.84 + 0.38$ s) concerning the probands' leaning to the left. No statistically significant difference was found in the reaction time when leaning forward and to the right between obese children and athletes.

The nonparametric Mann-Whitney U-test demonstrated statistically significantly higher values of the MXE parameter in the shift forward in athletes as compared with obese children. The median of MXE values in the shift forward was 97.5% in athletes (range 81–114%). The median of MXE values in the shift forward was 83.0% in obese children (range 79–104%). This difference is statistically significant ($p = 0.015$). No statistically significant difference between obese children and athletes was detected in the MXE values for the movement of the platform to the right, backward or to the left.

The statistical tests showed no significant difference between the group of obese children and athletes concerning the DCL parameter values for the probands' leaning forward, to the right, backward or to the left. The level of the test significance ranged from $p = 0.311$ to $p = 1.000$.

The tests indicated statistically significantly higher values in athletes' parameter Strategy Analysis in the SOT test in the following instances:

- with the cab moving. The average SOT in athletes was 96.5; the average SOT in obese children was 93.2 ($p = 0.008$).
- with the platform moving and the eyes open. The SOT median in athletes was 88.7; the SOT median in obese children was 81.3 ($p = 0.0001$).
- with the platform moving and the eyes closed. The SOT median in athletes was 80.7; the SOT median in obese children was 69.0 ($p = 0.001$).
- with the platform and the cab moving and the eyes open. The SOT median in athletes was 83.2; the SOT median in obese children was 73.3 ($p = 0.002$).

Measuring the SOT parameter with the eyes open or closed did not reveal any statistically significant difference between the two groups.

The Pearson correlation coefficients were calculated to establish if the correlation coefficient was significantly non-zero. This analysis demonstrated a significant correlation between BMI values and the length of reaction time in the LOS postural test. A direct linear relationship between BMI values and the probands' reaction time of leaning to the right ($r = 0.469$) and leaning to the left ($r = 0.545$) was established. This is a moderate dependence (i. e. the value of Pearson's correlation coefficient ranges from 0.4 to 0.6).

DISCUSSION AND CONCLUSION

The posturographic test yielded interesting results. The ability to control shifting the COG above the support base is critical for maintaining postural stability. The space in which a person can move their COG without changing the support base is referred to as the limits of stability (Anonymous, 2001). When evaluating the reaction time parameter, we found statistically significant differences between athletes and obese children in the movement to the left. The reaction time of both the groups was the longest in moving forward, but the group of athletes had lower RT values. The overall trend showed that in almost all situations tested, the athletes were slightly faster and had lower values of RT.

Due to an increased amount of adipose tissue, obesity mechanically increases the total body weight that we need to work with in postural control and balance strategies. Excess weight puts strain on the body's joints, deteriorates physical coordination, and thus increases the risk of falls and fractures. Body weight was shown to be a significant factor affecting postural stability, and weight loss is directly linked with the improvement of postural control. Obesity also contributes to a reduced ability to carry out specific movements in the upright position, because these movements require adequate postural control, which is limited in obese individuals.

It was also established that an obese person walks slower, has a wider gait, and spends longer time in double support (Colné et al., 2008). Colné also argues that overweight leads to an inability to move faster. Likewise, a statistical significance ($p < 0.01$) was identified between SOT and the proband's height in cm (Molíková, 2007).

Another difference observed during the LOS test involved the MXE parameter. In leaning to the right, backward, and left, the values of both tested groups were almost equal, but in leaning forward the athletes scored significantly higher values than the obese. This may be related to the training and the character of athletic disciplines and, of course, the better torso stability and muscle coordination of the athletes. The non-ideal body configuration could also play an important role.

In terms of the DCL parameter, there were no significant differences between the two groups. In our research, we also tested the use of motion strategies in the SOT test. The findings showed that with increased postural demands in the test, the athletes reached significantly better results. The athletes maintained their stability predominantly with the help of the ankle strategy, which is the most advantageous. Athletes are used to "listening to their bodies", to precisely selecting and receiving afferent information from the environment, processing it quickly and responding with correct muscle activation timing, which generally leads to a quicker postural adjustment. If the COG diameter is shifted closer to the edges of the support base, maintaining the stability of an upright position becomes more demanding, and the individual is forced to simultaneously use multiple balance mechanisms or combine strategies. (Véle, 2006) This is exactly the case that we monitored in obese children, who were forced to even apply the hip strategy in difficult situations, which testifies to their poorer postural stability.

A direct linear relationship between BMI and RT of probands' leaning sideways was established. The higher the BMI was, the longer the reaction time of leaning to the right or to the left. Again, excess weight and difficulties in shifting the massive and largely passive mass to the sides contributed to the results. A posturography exam shows statistically significant results concerning the reaction time and the maximum excursion in the LOS test and in the selection of motion strategies aimed at maintaining postural stability in the SOT test. A linear dependence of RT on BMI was also demonstrated in the mediolateral direction. The postural response of obese children, including the shifting of the center of gravity was slightly slower, and we found that they also suffer from lower limits of stability, i. e. the ability of active "excursion" of COG in a particular direction, than athletes. This may be related to the location of the center of gravity of the body, impaired mechanoreception but also slower proprioception or slower distribution and evaluation of afferent sensations with latency in subsequent response, or to a deliberately selected strategy to prevent an accidental fall. Most obese children lack basic motor skills and habits that they should be familiar with from compulsory physical education at school. Muscle activity tires them out sooner than children with normal body weight. In addition to excess weight and loose mesenchymal tissue (occurring in some obese children), another cause behind this phenomenon is incorrect breathing, which leads to a postural-respiratory conflict in the sense that the individual does not know or is unable to adequately coordinate breathing with posture and movement. Obese children usually require much more practising than children of normal weight to acquire specific motor skills. (Malinčíková et al., 2011)

These results should be taken into account when planning physical activities for obese children within physiotherapy. Targeted exercise therapy and physiotherapy clearly form an integral component of multidisciplinary collaboration in the treatment of childhood obesity and need to receive adequate attention. (Pastucha et al, 2010)

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