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Differences in intermittent postural control between normal-weight and obese children

Israel Villarrasa-Sapiña[a], Xavier García-Massó[b,*], Pilar Serra-Añó[c], Consolación Garcia-Lucerga[c], Luis-Millán Gonzalez[a], Empar Lurbe[d,e]

[a] Departamento de Educación Física y Deportiva, Universidad de Valencia, Valencia Spain
[b] Departamento de Didáctica de la Expresión Musical, Plástica y Corporal, Universidad de Valencia, Valencia, Spain
[c] Departamento de Fisioterapia, Universidad de Valencia, Valencia, Spain
[d] Department of Pediatrics, Consorcio Hospital General, University of Valencia, Spain
[e] Ciber Fisiopatología de la Obesidad y Nutrición, Instituto de Salud Carlos III, Madrid Spain

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ABSTRACT

Aim: The main objective of this study was to determine differences in postural control between obese and non-obese children.
Methods: The study design was cross-sectional, prospective, between-subjects. Postural control variables were obtained from a group of obese children and a normal-weight control group under two different postural conditions: bipedal standing position with eyes open and bipedal standing with eyes closed. Variables were obtained for each balance condition using time domain and sway-density plot analysis of the center of pressure signals acquired by means of a force plate.
Results: Pairwise comparisons revealed significant differences between obese and normal-weight children in mean velocity in antero-posterior and medio-lateral directions, ellipse area and mean distance with both eyes open and eyes closed. Normal-weight subjects obtained lower values in all these variables than obese subjects. Furthermore, there were differences between both groups in mean peaks with eyes open and in mean time with eyes closed.
Conclusion: Alterations were detected in the intermittent postural control in obese children. According to the results obtained, active anticipatory control produces higher center of pressure displacement responses in obese children and the periods during which balance is maintained by passive control and reflex mechanisms are of shorter duration.

1. Introduction

Obesity is a highly prevalent condition [1] that has serious consequences for children's health. For example, excess body weight has been associated with cardiovascular diseases, hormonal disturbances [2–7]. Moreover, an increase in body weight could reduce functionality and increase the risk of injury during daily physical activities [8]. This means obese people are more likely to suffer falls [9], due to their reduced postural stability and control, as has been shown by previous studies [8,10,11]. Obesity-related postural control impairments have also been found in children [12,13].

There are two hypotheses to explain the impaired postural control of the obese. The first is based on the biomechanics of the inverted pendulum model. If the mass of the pendulum increases, the muscles must generate torques of higher amplitude faster to maintain balance [14], so that if the muscles cannot respond quickly there is a greater risk of falling. The increased magnitude of the motor commands leads to a greater variability of these commands that has been related to a faster center of pressure (CoP) velocity [15]. The second hypothesis is based on the physiological effects of obesity since plantar cutaneous sensory receptors may be altered due to excessive pressure [16]. In this regard, D'Hondt et al. [13] compared sensory organization impairments in obese children to those in normal-weight children. Their results showed that obese children had less plantar cutaneous sensation than normal-weight children, although they did not find any differences in the sensory reweight between obese and their non-obese partners in altered sensory conditions. Later, Wu and Madigan found low to moderate correlations between plantar sensitivity

* Corresponding author at: Departamento de didáctica de la expresión musical, plástica y corporal. Universidad de Valencia, Avda. dels Tarongers 4, 46022 Valencia, Spain.
E-mail address: xavier.garcia@uv.es (X. García-Massó).

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and postural control [17]. On the other hand, Bernard et al. [18], who compared the postural control of obese and non-obese subjects on a foam surface, suggests that the difference in balance could also be related to problems of sensory reweighting.

Due to the effects of obesity on the mechanical and sensorial systems involved in postural control, the central nervous system has to adapt its control actions to maintain balance. Quiet standing control modelling is a wide research area, and several models of control have been proposed [19–21]. An intermittent control theory has recently been proposed to monitor quiet standing balance, using the inverted pendulum as the biomechanical model [19,20].

Taking the intermittent control model as a framework, Baratto et al. [22] proposed the sway-density plot (SDP) analysis that has been applied in several studies reporting on balance control analyses [22–24]. This analysis method considers an intermittent control in which two control actions are alternated. The first is *intrinsic feedback*, which originates in the mechanical properties of the ankle muscles, and is a short-term mechanism that reduces the natural falling movement of an inverted pendulum. The second involves *anticipatory muscular activation* (active control), which can be modelled as a *feedback* or *feedforward* control system. The latter is a long-term action whose function is to restore the reference position of the body's center of mass (CoM).

This analysis has previously been applied to studying the effect of obesity in adults' postural control. Hue et al. [25] found that SDP variables were correlated with body mass. Also, Teasdale et al. [16] concluded that obese people had longer stable periods after losing weight and the consecutive stable regions were separated by smaller distances in these subjects than before they lost weight. According to the physiological interpretation of the SDP analysis given by Baratto et al. [22], obese people use passive control for shorter periods of time and the descending anticipatory commands are of greater amplitude. Although obesity seems to have an effect on postural control mechanisms in obese adults, no studies have been made to date on how obesity affects the postural control mechanisms of obese children using the SDP.

The main objective of this study was thus to determine the differences in postural control between obese and non-obese children, applying the time domain and SDP analysis of the CoP signal.

2. Methods

2.1. Subjects

The study design was cross-sectional, prospective, between-subjects and sought to establish differences in postural control variables between a group of obese children and a group of normal-weight children. A non-probabilistic sampling method was chosen to select the subjects, who were recruited from the Paediatric Endocrinology Department of the Valencia General Hospital. The inclusion criteria were: i) normal-weight or obese biotype, ii) between 12 and 15 years old and iii) absence of any motor control pathology. All subjects suffering from a pathological condition or under drug treatment that could alter sensory inputs were excluded. Thirty-two children participated in the study, ten females and twenty-two males. The subjects' characteristics are shown in Table 1. The normal-weight and obesity selection was performed using the BMI percentile ranking obtained from the Centers for Disease Control and Prevention website, according to the subjects' sex and age (http://nccd.cdc.gov/dnpabmi/Calculator.aspx).

Previous approval was obtained from The Institutional Review Board (IRB) of the University of Valencia. Written informed consent forms were obtained from parents prior to participation in this study.

Table 1
Subject's characteristics.

Variables	Normal-weight group ($n = 13$)	Obese group ($n = 19$)
Sex (n)		
Boys	9	13
Girls	4	6
Weight (kg)	44.97 (1.82) [38.25–48.54]	73.16 (3.43)* [66.44–79.88]
Height (m)	1.54 (0.02) [1.5–1.58]	1.57 (0.02) [1.53–1.61]
IMC ($kg\,m^{-2}$)	18.78 (0.6) [17.39–19.96]	29.36 (0.71)* [27.97–30.75]
Age (years)	12.92 (0.21) [12.41–13.33]	11.95 (0.26) [11.44–12.46]

Data expressed as mean (SEM). The confidence intervals are reported between square brackets.
* Indicates significant differences between groups ($p < 0.05$ after Bonferroni correction).

2.2. Anthropometric measures

The anthropometric measurements of subjects concerned weight and height. Weight was obtained to the nearest 0.1 kg from a force platform (Dinascan/IBV, Biomechanics Institute of Valencia, Valencia, Spain) and height was measured to the nearest 0.5 cm by a stadiometer. During weight measurements, the subjects were asked to maintain a standing position, with heels separated by a distance equal to their shoulder width and arms relaxed at their sides.

2.3. Static posturography

The postural control test was performed using the force platform (Dinascan/IBV, Biomechanics Institute of Valencia, Valencia, Spain). The platform is composed of a 600 mm × 370 mm × 100 mm plate with four force transducers. The platform was placed on a stable surface on the floor to avoid distortion and noise in the signal. Subjects were asked to take a comfortable barefoot bipedal standing position, with feet placed shoulder-width apart and toes pointing outward at an angle of 20° from the sagittal midline and arms relaxed at sides of the body. The same foot position was adopted in all the trials, according to the manufacturer's specifications. A reference point (5 cm in diameter) was situated 2 m in front of the subject at eye level. All the subjects were briefed on the importance of keeping this position and were asked to move as little as possible. The subjects performed two 30 s trials under two different conditions: i) bipedal standing position with eyes open (EO), ii) bipedal standing position with eyes closed (EC).

2.4. Data analysis

In each postural control trial, signals were registered at a frequency of 40 Hz by an amplified analogue-to-digital converter. Data representing the forces exerted on the platform along three axes (*x*, *y*, *z*) was saved on a hard disk for subsequent analysis. The CoP displacement data were obtained in both medio-lateral (ML) and antero-posterior (AP) directions using NedSVE/IBV analysis software (Biomechanics Institute of Valencia, Valencia, Spain).

The CoP signals were pre-processed to attenuate noise using a low pass Equiripple FIR filter (cut off frequency 6 Hz, 16 order). The first 10 s of each trial were excluded from the analysis, as delayed stabilization had previously been reported [26,27]. Ellipse area (EA; 95% confidence interval) and mean velocity in antero-