# EFFECTS OF BODY SIZE, SHAPE AND COMPOSITION ON THE POSTURAL STABILITY IN THE PRE-PUBERTAL GROWTH SPURT

EFEITOS DO TAMANHO, FORMA E COMPOSIÇÃO CORPORAL NA ESTABILIDADE CORPORAL DURANTE O SALTO PRÉ-PUBERTÁRIO EFECTOS DEL TAMAÑO, LA FORMA Y LA COMPOSICIÓN DEL CUERPO EN LA ESTABILIDAD POSTURAL EN EL DERRAME DE CRECIMIENTO PRE-PUBERTAL

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### ABSTRACT

Children aged 10-11 years go through a dynamic developmental period marked by rapid changes in body size, shape, and composition, all of which are sexually dimorphic. The purpose of this study is to analyze the effects of these factors on postural stability in the pre-pubertal growth spurt. This represents a cross-sectional study involving 312 children (152 boys, 160 girls), from 5th and 6th grade (10.8  $\pm$  0.4 years), who were self-assessed as belonging to Tanner stages I and II. Postural balance control was evaluated using the single-legged flamingo balance test. The ectomorphy, body mass and body height on postural stability were observed. Body fat variables, endomorphy and mesomorphy did not have a statistically significant influence. Additionally, boys and girls aged 10-11 years seem to display a similar performance. Determining these anthropometric and morphological parameters effects and gender differences in postural stability are important in many practical fields such as physical education and youth sport.

Keywords: balance, pre-pubertal, school, performance.

## RESUMO

As crianças entre os 10 e 11 anos de idade experienciam uma fase de desenvolvimento com forte dinâmica, caracterizada por mudanças no tamanho corporal, na forma e na composição que, por sua vez, se associam a um claro dimorfismo sexual. O propósito deste estudo foi o de analisar os efeitos destes fatores na estabilidade postural durante o período pré-pubertário. Este estudo envolveu 312 crianças (152 rapazes e 160 raparigas) do 5º e 6º anos de escolaridade (10.8 ± 0.4 anos), que se auto-avaliaram como pertencentes ao estádio I e II de Tanner. O controlo do equilíbrio postural foi avaliado a partir do teste unilateral do Flamingo. Os resultados indicaram um efeito significativo do ectomorfismo, massa corporal e altura na estabilidade corporal. As variáveis massa gorda,

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endomorfismo e mesomorfismo não apresentaram diferenças estatisticamente significativas. Em paralelo, observou-se um desempenho equivalente entre rapazes e raparigas. A possibilidade de avaliar o impacto dos parâmetros antropométricos e morfológicos, bem como o efeito das diferenças associadas ao género, poderá constituir-se como uma relevante fonte de conhecimento para o contexto prático de intervenção no âmbito da educação física e desporto para jovens.

Palavras Chave: equilíbrio, período pré-pubertário, escola, desempenho.

### RESUMEN

Los niños de 10 a 11 años pasan por un período de desarrollo dinámico marcado por cambios rápidos en el tamaño del cuerpo, la forma y la composición, lo que hacen que sean todos sexualmente dimorfos. El propósito de este estudio fue analizar los efectos de estos factores sobre la estabilidad postural en el brote de crecimiento prepuberal. Este fue un estudio transversal en el que participaron 312 niños (152 niños, 160 niñas), de 5º y 6º grado (10,8±0,4 años), que fueron autoevaluados como pertenecientes a las etapas I y II de Tanner. El control del equilibrio postural se evaluó utilizando la prueba de equilibrio de flamingo con una sola pierna. Se observó un efecto significativo de la ectomorfía, masa corporal y altura corporal sobre la estabilidad postural. Las variables grasa corporal, endomorfía y mesomorfía no tuvieron influencia estadísticamente significativa. Además, los niños y niñas de 10 a 11 años de edad parecen tener un rendimiento similar. La determinación de los efectos de estos parámetros antropométricos y morfológicos y las diferencias de género en la estabilidad postural es importante para muchos campos prácticos, como la educación física y el deporte juvenil.

Palabras clave: equilibrio, prepuberal, escuela, rendimiento.

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### INTRODUCTION

Postural stability refers to the inherent ability of a person to maintain, achieve or restore a specific state of balance and not to fall (Pollock, Durward, Rowe, & Paul, 2000). The ability to maintain postural stability is an essential pre-requisite to competently perform most activities of daily living (Roncesvalles, Woollacott, & Jensen, 2001). Furthermore, postural stability is considered to be an important indicator of musculoskeletal health and therefore could be of importance in view of clinical issues (Pollock et al., 2000). In children, balance is inextricably linked to motor development and fundamental movement skills (Fisher et al., 2005).

As balance abilities become refined during childhood, the factors influencing balance have been reported to include, among others (e.g. leisure preferences and development of visual, vestibular, and somatosensory systems), anthropometric and morphological parameters (Lee & Lin, 2007). What happens is that children aged 10-11 years are going through a dynamic developmental period that is marked by rapid changes in body size, shape, and composition, all of which are sexually dimorphic (Malina & Bouchard, 1991), and we believe that the effects of these factors on the postural stability in the pre-pubertal growth spurt require further clarification.

During this developmental stage, which precedes peak height velocity, the children show very great growth (about 20% of adult height) (Malina & Bouchard, 1991). At this period, the growth and the great dimensional increase are not accompanied by muscle development because the effects of circulating androgens, particularly testosterone, only manifest themselves at puberty (Ramsay et al., 1990), which confers on the child a degree of weakness and hypotonia. Also, there is marked increase in subcutaneous adipose tissue during this period, which is more pronounced in girls (Malina & Bouchard, 1991).

Some studies have shown that girls outperform boys on static and dynamic balance tasks. Lee and Lin (2007) speculated that the gender difference could have been due to the larger body weight of the boys. There is some evidence that excess body mass not only influences balance during the gait cycle but also affects postural control during standing and balance performance (Deforche et al., 2009). However this may not be the case if we consider that the height and weight growth curves in male and female intersect for a time, referred to as "crossing over", when girls overtake boys in stature and weight, a stage which coincides with pre-puberty (Malina & Bouchard, 1991). Recently, Marta et al. (2012) reported a smaller size effect of gender on the static standing balance in elementary school children, and they hypothesized that could be due to the fact that in pre-pubertal period the difference in stature between boys and girls gradually decrease, due to the growth velocity of girls at this stage be higher than for boys, reaching the peak height velocity (PHV) earlier (Malina & Bouchard, 1991).

A greater stature leads to a high body's center of mass, in turn responsible for increased postural instability on balance exercises (Allard, Nault, Hinse, Leblawc, & Labelle, 2001). Furthermore, reported differences in body size, shape and composition are closely linked to the genetic determinism, observed from the morphoconstitutional point of view, and there is evidence that by pre-puberty the boys tend to show a slight increase of the mesomorphic (relative muscle-skeletal magnitude) values, and the girls show an increase of the endomorphy (relative adiposity) and a slight reduction of the ectomorphic (relative thinness) values (Malina, Bouchard, & Bar-Or, 2004).

According to our best knowledge, no large sample reference studies and none studies that compared the influence of body size, shape and composition on postural stability in the prepubertal growth spurt have been reported. Therefore, the aim of this study was to investigate

### Procedures

Decimal age (years)

Body mass (kg)

Ectomorphy

Flamingo balance (faults)

#### Anthropometric and morphological measurements

All anthropometric measurements were assessed according to international standards for anthropometric assessment (Marfell-Jones, Olds, Stewart, & Carter, 2006). Body mass (kg)

Body height (cm)	145.26	7.408	144,38	8.744	144.81	
BMI	19.462	3.206	18.578	2.931	19.009	
Body Fat (%)	22.383	8.658	23.102	6.993	22.752	
Endomorphy	3.620	1.716	3.963	1.602	3.796	
Mesomorphy	4.693	1.161	3.685	1.092	4.176	

1.453

5.793

SD

.434

8.740

Mean

10.830

41.264

2.495

9.342

Table 1. Descriptive data of anthropometric and morphological parameters and single-legged flamingo balance test performance

Subjects
The sample, cross-sectional in type, consisted of 312 prepubescent children (160 girls, 152 boys) all of whom volunteered for this study. The distribution of students according to their maturation stage was as follows: (i) girls: stage I, 53.1% and stage II, 46.9%; (ii) boys: stage I, 81.6% and stage II, 18.4%. Subjects were carefully informed about the design of the study and, subsequently, the children's parents signed an informed consent document prior to the start of the study. The experimental procedures were performed with compliance with the ethical standards as laid down in the Declaration of Helsinki. Anthropometric and morphological parameters and performance in the flamingo balance test were ascertained for all subjects

facility (with temperature between 15°C and 18°C). The data collection lasted one month.

### Experimental Approach to the Problem

determine how this was moderated by gender, anthropometric and morphological parameters.

Three hundred and twelve students were recruited from a Portuguese public school cluster to perform the single-legged flamingo balance test. Inclusion criteria were: children aged 10 to 11.5 years (5th and 6th graders), who were self-assessed as belonging to Tanner stages I and II, with no chronic pediatric diseases or orthopedic limitations. All anthropometric and morphological measurements were carried out before the postural balance test. The singlelegged flamingo balance test was performed after a 10 min warm up period (7 min running with intensity sufficient to raise breathe rate, 3 min stretching and joint specific warm up). All

#### measurements were performed by the same investigator, in the first periods in the morning, and the testing assessment procedures were always conducted in the same indoor sportive

MFTHODS

Boys Girls Overall sample

Mean

10.825

38.982

2.850

7.687

SD

.438

8.618

1.450

5.742

SD

435

8.739

8.119 3.095 7.843 1.665

1.232 1.460

5.817

Mean

10.827

40.094

2.677

8.493

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was measured to the nearest 0.1 kg using a standard digital floor scale (Seca, model 841, Germany). Standing height was assessed with a precision stadiometer to the nearest 0.10 cm (Seca, model 214, Germany). For perimeter measurement a circumference tape was used (Seca 200). The bi-condyle femoral and humeral diameters were assessed (Campbell, 20, Ross Craft, Canada). The percentage body fat (%BF) from skinfold anthropometry was calculated following Slaughter et al., (1988). As such, triceps and subscapular skinfolds were determined by internationally recommended methods (Marfell-Jones et al., 2006). The principal components of the morphological typology, endomorphy (END), mesomorphy (MES), and ectomorphy (ECT), were calculated using the method described by Heath & Carter (1971). A girth measurement of the biceps and calf, corrected for using the skinfold measures was used. Maturity level based on Tanner stages (Tanner, 1962) was self-assessed.

#### Testing procedures

Postural balance control was evaluated using the single-legged flamingo balance test (Deforche et al., 2003). Subjects were instructed to stand on the preferred leg (with shoes removed) with their eyes open on a 3 cm wide and 5 cm high bar, while the free leg was flexed at the knee joint and held at the ankle joint close to the buttocks. One minute of stance was performed and the number of losses of balance (either by falling off the beam or letting go of the foot being held) was counted and used as a measure of postural balance. A 1 min period of familiarization was performed before the test. The Flamingo balance has shown an ICC of 0.93.

#### Statistical Analyses

Standard statistical methods were used for calculation of the means and standard deviations. The normality of the distribution was checked by applying the Kolmogorov-Smirnov test. The within-subject reliability of the postural stability test was determined by the intraclass correlation coefficient (ICC). To determine the effects of body size, shape and composition on the postural balance control it was estimated an analysis of covariance (ANCOVA), with gender as factor and body height, body weight, fat mass and somatotype as covariates. Statistical analyses were carried out by using the statistical packages for SPSS 17.0 for Windows (SPSS Inc., Chicago, IL, USA). The statistical significance was set at  $p \le 0.05$ .

### RESULTS

Through the ANCOVA, it was observed a significant but small-sized effect of the ectomorphy (p= 0.002, *Effect size*= 0.032) on the postural stability, followed by body mass (p= 0.004, *Effect size*= 0.027) and body height (p= 0.035, *Effect size*= 0.014). The variables body fat (p= 0.400, *Effect size*= 0.002), endomorphy (p= 0.588, *Effect size*= 0.001) and mesomorphy (p= 0.116, *Effect size*= 0.008) did not have a statistically significant influence. (Figure 1)

Additionally, as expected, the boys had a greater number of faults (9.34 $\pm$ 5.79 faults) on the flamingo balance test than the girls (7.69 $\pm$ 5.74 faults). However there were no statistically significant effect of the factor gender (*p*= 0.337, *Effect size*= 0.003) in the performance of this test.

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Figure 1. Effect size of body weight, height, fat mass percent, endomorphy, mesomorphy and ectomorphy on the postural stability (\*\*p< 0.01; \*p< 0.05)

### DISCUSSION

According to Rival, Ceyte, and Olivier (2005) investigating developmental changes of postural control in children with respect to standing balance, a transition phase should occur around 7–8 years. In 9 to 10 year olds standing balance appeared to be adult-like, however, not fully matured (Rival et al., 2005). After these ages, the children are in going through a dynamic developmental period, which precedes peak height velocity, marked by rapid changes in anthropometric and morphological parameters (Malina & Bouchard, 2005). In this period, the results of our study seem to show a significant effect of body weight, height and ectomorphy on the postural stability, while the fat mass, endomorphy and mesomorphy seem to have no significant influence. Furthermore, boys and girls aged 10-11 years seem to have similar performance.

It is not clear what effects excess body mass has on postural stability of children (Deforche et al., 2009). Previous studies reported that increased body weight in children (McGraw, McClenaghan, Williams, Dickerson, & Allard, 2000) is associated with increased oscillations and likely increases the risk of falling. Additionally, a decrease in body weight leads to improved balance control (Teasdale et al., 2007). Deforche et al. (2009) showed that overweight children showed an inferior force production in raising the body to a standing position, due to insufficient leg strength to lift the excess body weight. They also had greater sway velocity in standing position, indicating that they have difficulties decelerating the forward trunk motion following the rise. This could also result from lower strength relative to mass. Another reason for suggesting that balance control is perturbed with increased body weight is that plantar mechanoreceptors may be less receptive due to the continuous pressure of supporting a large mass (Teasdale et al., 2013). However, some investigations that were performed on stable surfaces with individuals who were overweight or with normal body mass have shown that balance does not appear to be affected in such situations (Molikova et al., 2006; Chiari, Rocchi, & Capello, 2002). More recently, Condon and Cremin (2014) also reported that correlations for weight and balance were only weak in the younger age groups (6-7-year-old age group), but not correlated in older ages (>10 year).

Unlike the body weight, there is a consensus in the literature that increased height worsens balance. This is because a greater stature leads to a high body's center of mass, in turn responsible for increased postural instability on balance exercises (Lee & Lin, 2007; Allard et

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al., 2001). Furthermore, Berger, Trippel, Dische, and Dietz (1992) have stated that ankle displacement and the response of the gastrocnemius increased with increasing height. In a recent study conducted by Alonso et al. (2012), the height was the anthropometric variable that most influenced postural balance.

There are few studies of body composition variables for comparative purposes. Mainenti et al. (2011) observed that elderly women with greater fat mass exhibited worse performance. Alonso et al. (2012) reported similar results in young adults, showing that the percentage of fat mass correlated negatively with the postural balance. In their study, the fat mass showed negative correlations with the mediolateral sway and the displacement velocity in the whole group. On the contrary, greater lean mass correlated with significantly greater postural control (Alonso et al., 2012).

Previous studies have identified height and weight as important factors affecting quiet standing stability but few studies have addressed body morphology as a global factor. The study of Lee and Lin (2007) showed that the mesomorphic, muscular children had significantly smaller mean radius of center of pressure distribution on a force platform than the endomorphic, fatty children and the ectomorphic, linear children during the single-leg upright standing postural stability test. For the authors, the explanation for somatotype differences might be due to the significantly lower body height and higher portion of muscular strength is important for balance control (Condon & Cremin, 2014; Handrigan et al., 2010). In reverse, Allard et al. (2001) attributed the decrease in standing posture stability of the ectomorphic children to a relatively low muscle component, a high height weight ratio and an elevated position of the body center of mass.

Many studies have shown that girls outperform boys on static and dynamic balance tasks. In particular, the boys had significantly greater sway when standing on one leg than the girls (Mickle, Munro, & Steele, 2011). It is possible that maturation of the neurological, visual, vestibular and proprioceptive systems occurs earlier in girls such that they can perform the complex task of balancing on one leg more efficiently (Cratty, 1970). Lee and Lin (2007) found similar gender differences in the postural stability of healthy children, whereby 9- to 11-yearold boys displayed greater center of pressure excursion during a one-legged task than girls. The same authors speculated that the gender difference could have been due to the larger body weight of the boys; and this may be the case in the present study as the boys were slightly heavier than the girls (this difference was statistically significant). On the contrary, in the present study there was no significant difference in body height between boys and girls. This may be due to the fact that in pre-pubertal period the difference in stature between boys and girls gradually decreased, because the growth velocity of girls at this stage is higher than for boys, reaching the peak height velocity (PHV) earlier (Malina & Bouchard, 1991). A greater stature leads to a high body's center of mass, in turn responsible for increased postural instability on balance exercises (Allard et al., 2001).

Regarding the morphological typology, the girls studied showed higher values of body fat percentage, endomorphy and ectomorphy compared with that shown by the boys. The ectomorphic component represents the relative thinness of the subject (i.e. relatively low muscle component and high height weight ratio) and therefore associates negatively with postural balance control (Lee & Lin, 2007). Additionally, the endomorphic component expresses the degree of adiposity development (Malina & Bouchard, 1991) inversely correlated with balance tasks (Lee & Lin, 2007). However, as reported by Alonso et al. (2012) the women may have developed other strategies for maintaining balance that depended less on body composition. Peterson, Christou, and Rosengren (2006) suggested that pre-pubertal girls have better use of vestibular information and consequently reduce the body sway as

compared to boys of the same age. Generally, boys lag behind with their physical growth as well as the development of their neuromuscular system.

Nevertheless, there are some limitations of the study that should be addressed : (i) due to the methodological approach, it was not possible to clarify the effect of other factors underlying the postural balance control (e.g., maturation of the neurological, visual, vestibular and proprioceptive systems); (ii) we have examined postural stability using field-based assessments. Different methods of evaluating postural stability (e.g., the use of a laboratory-based force platform) may lead to data bias; (iii) any differences in balance between genders can be environmentally induced (e.g. sex-role development) rather than biologically induced, such as different practice opportunities or the preference for activities that require more balance.

### CONCLUSION

In brief, our data suggested that ectomorphy, body mass and body height influence postural stability. However, body fat, endomorphy and mesomorphy did not influence postural stability. Additionally, boys and girls showed similar performance on the postural stability. Determining these anthropometric and morphological parameters effects and gender differences in postural stability is important for many practical fields such as physical education and youth sport.

## CONFLICT OF INTEREST

The authors have no conflict of interest in this study.

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