Postural stability in pre-pubertal school children: sex and maturity-associated variation

Carlos Marta
Polytechnic Institute of Guarda

Pedro Tiago Esteves
Polytechnic Institute of Guarda

Ana Ruivo Alves
Polytechnic Institute of Beja

Mikel Izquierdo
Universidad Pública de Navarra

Postural stability in pre-pubertal school children: sex and maturity-associated variation

Carlos Marta[1,2], Pedro T. Esteves[1,2,4], Ana R. Alves[3], Daniel Marinho[3,4], Mikel Izquierdo[5] and Mário Marques[3,4]

[1]Department of Sport Sciences, Polytechnic Institute of Guarda (IPG, Guarda, Portugal); [2]Research Unit for Inland Development (UDI, Portugal); [3]Department of Sport Sciences, University of Beira Interior (UBI, Covilhã, Portugal); [4]Research Centre in Sports, Health and Human Development (CIDESD, Portugal); [5]Department of Health Sciences, Public University of Navarre (Navarre, Spain).

Palavras-chave
Equilíbrio postural, Maturação, Educação Física, Performance.

RESUMO
As crianças pré-púberes encontram-se num período dinâmico de desenvolvimento marcado por rápidas mudanças no tamanho, forma e composição corporal, cuja magnitude depende do sexo e do estado de maturação. O objetivo deste estudo foi analisar a variação da estabilidade postural associada ao sexo e à maturação num momento de mudanças rápidas, como é o salto de crescimento pré-púberal. Trata-se de um estudo transversal envolvendo 312 crianças (10.8 ± 0.4 anos), 152 rapazes e 160 raparigas, autoavaliados nos estádios de Tanner I (n = 209) e II (n = 103). O equilíbrio postural foi avaliado através do teste de equilíbrio Flamingo. Foram ainda realizadas medições antropométricas e morfológicas. As crianças pré-púberes biologicamente mais maduras evidenciaram maior peso, índice de massa corporal, percentagem de gordura corporal e componente endomórfica do que as crianças menos maduras. Não foi observada, no entanto, nenhuma vantagem das crianças biologicamente mais maduras em comparação com seus pares com menor maturação. Curiosamente, as raparigas superaram os rapazes no teste de estabilidade postural, mas não se verificou qualquer interação entre o sexo e o estado de maturação. A particularidade das mudanças antropométricas e morfológicas no salto de crescimento pré-púberal, juntamente com as influências sensoriais (sistema vestibular) e ambientais, pode ter influenciado o impacto do estado de maturação na estabilidade postural. Estas conclusões poderão ser relevantes no sentido dos professores e treinadores adaptarem as suas tarefas práticas ao estado de maturação e ao sexo.

*Correspondência - Pedro Tiago Esteves - ptesteves@gmail.com

Keywords
Postural balance, Maturity, Physical education, Performance.

ABSTRACT

Prepubescent children experience a dynamic developmental period marked by rapid changes in body size, shape and composition, whose magnitude depends on sex and maturity status. The purpose of this study was to analyze sex and maturity- associated variation on the postural stability at a time of rapid changes such as the pre-pubertal growth spurt. This was a cross-sectional study involving 312 children (10.8 ± 0.4 years), 152 boys and 160 girls, who were self-assessed as belonging to Tanner stages I (n= 209) and II (n=103). Postural balance control was evaluated using the single-legged flamingo balance test. Anthropometric and morphological measurements were also carried out. The more biologically mature prepubescent children expressed higher weight, body mass index, body fat percentage and endomorphic component than the less mature. However, no advantage of biologically mature children in postural stability was found compared with their less mature peers. Interestingly, girls outperformed boys in the postural stability test, but no interaction between sex and maturity status was observed. The particularity of anthropometric and morphological changes in the pre-pubertal growth spurt, together with sensorial (i.e., vestibular system) and environmental influences, may have influenced the impact of maturity status on postural stability. This could be considered important to teachers and coaches to adapt practical tasks related to maturity status and sex.

***Correspondência - Pedro Tiago Esteves - ptesteves@gmail.com**

Introduction

Postural balance is related to the ability to maintain the center of gravity with respect to the base of support (Hue et al., 2007; Shumway-Cook & Woollacott, 2012). Balance is a paramount premise for motor performance (i.e., special orientation, multi-limb coordination, spatial orientation, limbs steadiness, visual acuity, reaction time, mechanical aptitude and kinesthetic sensitivity) in all age groups (Franjoine, Darr, Held, Kott, & Young, 2010; Kauranen, 1999; Payne & Issacs, 2017). It is recognized that the balance development is related to motor development and fundamental movement skills in children (Fisher, et al., 2005; Haywood & Getchell, 2014). When stability is compromised, child's ability to master fundamental movement skills and, in turn, to perform in sporting activities may be hindered (Mickle, Munro, & Steele, 2011). These arguments highlight the importance to explore postural stability in young scholars.

Previous studies have been focused on the growth-related changes and development of postural stability in children. Postural balance depends essentially on afferent information transmitted from three sensory systems (visual, vestibular and somatosensory) to the central nervous system (Nagy et al., 2004). When incorrect information is provided by one or more of the three sensory systems, postural balance may be confounded (Hohne, Stark, Bruggemann, & Arampatzis, 2011). Before 7 years old, children have difficulties using sensory information and sway more than older children (12-years) and adults (Ferronato & Barela, 2011). However, there is a transition phase which occur around 7–8 years old (Rival, Ceyte, & Olivier, 2005). Later, between 9 and 10-year-old, standing balance appears to be adult-like yet not fully matured (Riach & Starkes, 1994). Comparisons between adolescents and young adults showed that the former are not yet capable to express similar postural performance levels to those observed in adults (Viel, Vaugoyeau, & Assaiante, 2009).

In fact, balance improvement has been associated to the age, to the maturational process (Roncesvalles, Woollacott, & Jensen, 2001), but also with the physical fitness levels (Burgi et al., 2011). Prepubescent children aged 10-11 years old, located in Tanner stages 1 or 2 are developing changes in body size, shape, and composition (Malina & Bouchard, 1991; Rogol, Clark, & Roemmich, 2000). At this period, there is a solid growth tendency followed by an increase in subcutaneous adipose tissue, which is more pronounced in girls (Haywood & Getchell, 2014). However, there are evidences that abovementioned factors influence the postural stability (Lee & Lin, 2007).

The particularity of anthropometric and morphological changes in the pre-pubertal growth spurt, together with sensorial (i.e., vestibular system) and environmental influences, may have influenced the impact of maturity status on postural stability. Therefore, it seems to be relevant to clarify how postural stability evolves at different stages of biological maturation. Actually, this could be considered important to teachers, coaches and researchers in way to adapt practical tasks related to maturity status and sex.

According to our best knowledge, there is no study related to different maturity status and sex in the postural stability, at a time of rapid changes such as the pre-pubertal growth spurt. The purpose of this study was to analyze sex and maturity- associated variation (Tanner stages I and II) on the postural stability at a time of rapid changes such as the pre-pubertal growth spurt. It was hypothesized that the biological maturity positively impacts on the postural balance control of prepubescent to early post pubescent children.

Methods

Sample Procedures

Three hundred and twelve prepubescent children (n = 312; 160 girls and 152 boys) were recruited from a Portuguese public-school cluster to perform the single-legged flamingo balance test, all of whom volunteered for this study. 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 and without regular extra-curricular physical activity (i.e., practice of a sport at an academy) within the last 6 months. 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 study was conducted according to the declaration of Helsinki and was approved by the institutional review boards of the University of Beira Interior (UBI), Polytechnic Institute of Guarda (IPG) and Research Centre in Sports, Health and Human Development (CIDESD), Portugal.

Testing Procedures

All anthropometric and morphological measurements were carried out before the postural balance test. The single-legged 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 facility (with temperature between 15ºC and 18ºC).

Measures

All anthropometric measurements were assessed according to international standards for anthropometric assessment (Marfell-Jones, Olds, Stewart, & Carter, 2006). Body mass (kg) was measured to the nearest 0.1 kg using a standard digital floor scale (Seca, model 841, Hamburg, Germany). Body height was assessed with a precision stadiometer to the nearest 0.10 cm (Seca, model 213, Hamburg, Germany). For perimeter measurement a circumference tape was used (Seca, model 200, Hamburg, Germany). The bi-condyle femoral and humeral diameters were assessed (Campbell, 20, Ross Craft, Canada). The body fat (%) from skinfold anthropometry was calculated following Slaughter et al. (1988). As such, triceps and subscapular skinfolds were determined by internationally recommended methods (Marfell-Jones, Olds, Stewart, & Carter, 2006). The principal components of the morphological typology, endomorphy (END), mesomorphy (MES), and ectomorphy (ECT), were calculated using the method described by Heath and Carter (1971). The maturity level was determined based on Tanner stage (Duke, Litt, & Gross, 1980) through self-assessment. Subjects were asked to choose from photographs and line drawings of the five Tanner stages of sexual maturation the stage that most closely corresponded to their present stage of sexual maturation. Male subjects were asked to choose the most appropriate genital and pubic hair stage, and female subjects the most appropriate breast and pubic hair stage. Postural balance was evaluated using the single-legged flamingo balance test (Deforche, et al., 2003; Sundstrup, et al., 2010). 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), assumed as faults, was counted and used as a measure of postural balance. A 1 min period of familiarization was performed before the test. The flamingo balance test has shown an intraclass correlation coefficient (ICC) of 0.93.

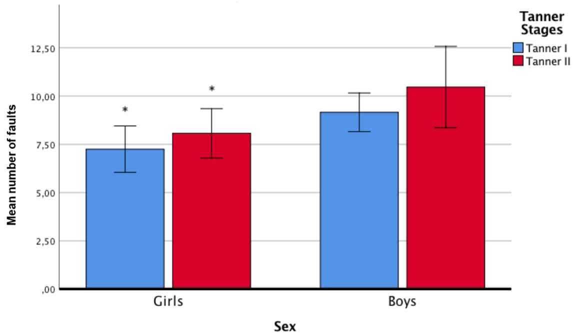
Analysis

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 ICC. A t-Student test was applied to determine whether there are differences between two groups (sex and biological maturity) in all measured variables. A one-way, between-subjects ANCOVA design was applied to the data to determine whether there were main effects of biological maturity (Tanner I or II), sex (boy or girl) and biological maturity*sex interactions on the postural stability. Statistical analyses were carried out by using the statistical packages for SPSS 24.0 for Windows (SPSS Inc., Chicago, IL, USA). The statistical significance was set at $p \leq 0.05$.

Results

A one-way ANCOVA was conducted to compare the postural stability between sex and biological maturity whilst controlling for body mass index. Levene's test and normality checks were carried out and the assumptions met. There were no significant interactions between sex and biological maturity in postural stability ($F_{1,307} = 0.110$, $p=0.740$), whilst adjusting for body mass index (Fig. 1). However, analyzing the main effects of each factors there were only found significant differences in sex ($F_{1,307} = 4.767$, $p=0.030$). It also can be seen that for sex the effect size is small (0.12). Boys showed a greater mean number of faults (9.34 ± 5.79 faults) on the flamingo balance test than the girls (7.68 ± 5.74 faults). Although more biologically mature prepubescent children performed poorer (8.92 ± 6.23 faults) than their less mature peers (8.28 ± 5.60 faults), these differences were not statistically significant.

Figure 1 - *Estimated marginal means of single-legged flamingo balance performance expressed by the number of faults per sex (boys and girls) and biological maturity (Tanner stage I and stage II).*



After performed descriptive analysis, it was found significant differences in the weight ($t = -2.111$, $p = 0.036$), body mass index ($t = -2.322$, $p = 0.021$), body fat percentage ($t = -2.072$, $p = 0.039$) and endomorphic component ($t = -2.281$, $p = 0.023$) between children in the Tanner stage I and II. However, no significant differences were found in the decimal age ($t = -0.885$, $p = 0.377$), height ($t = -0.760$, $p = 0.448$), mesomorphic ($t = -0.107$, $p = 0.915$), ectomorphic ($t = 1.924$, $p = 0.055$) components, and flamingo test ($t=-0.914$, $p=0.362$).
But it was also found differences in anthropometric and morphological parameters and postural stability

between boys and girls. While girls presented larger mean values of body fat percentage, endomorphic and ectomorphic component, boys showed larger mean values of body mass, body height, body mass index, mesomorphic component, and postural stability. These differences were statistically significant in the body mass (t = -2.322, p = 0.021), body mass index (t = -2.543, p = 0.011), mesomorphic (t = -7.897, p = 0.000) and ectomorphic (t = 2.161, p = 0.031) components. Nevertheless, no significant differences were found in the decimal age (t= -0.094, p=0.925), body height (t= -0.960, p= 0.338), body fat percentage (t= 0.809, p= 0.419), and endomorphic component (t= 1.828, p= 0.068) (table 1).

Table 1 - *Descriptive data of anthropometric and morphological parameters and single-legged flamingo balance test per sex and biological maturity.*

	Tanner I (*n*=209)	Tanner II (*n*=103)	Boys (*n*=152)	Girls (*n*=160)
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Decimal age (years)	10.81 ± 0.44	10.85 ± 0.41	10.83 ± 0.43	10.82 ± 0.43
Body mass (kg)	39.32 ± 8.16*	41.65 ± 9.66*	41.26 ± 8.74*	38.98 ± 8.61*
Body height (cm)	144.56 ± 7.84	145.31 ± 8.66	145.26 ± 7.40	144.38 ± 8.74
BMI	18.72 ± 2.90*	19.58 ± 3.39*	19.46 ± 3.20*	18.57 ± 2.93*
Body Fat (%)	22.10 ± 7.52*	24.05 ± 8.33*	22.38 ± 8.65	23.10 ± 6.99
Endomorphy	3.64 ± 1.58*	4.10 ± 1.79*	3.62 ± 1.71	3.96 ± 1.60
Mesomorphy	4.17 ± 1.17	4.18 ± 1.34	4.69 ± 1.16**	3.68 ± 1.09**
Ectomorphy	2.78 ± 1.46	2.45 ± 1.43	2.49 ± 1.45*	2.85 ± 1.45*
Flamingo test (faults)	8.28 ± 5.60	8.92 ± 6.23	9.34 ± 5.79*	7.68 ± 5.74*

Note: Mean ± SD of decimal age (years), body mass (kg), body height (cm), body mass index (BMI), body fat (%), endomorphy, mesomorphy, ectomorphy, and flamingo test (faults); *(p< 0.05), **(p< 0.01).

Discussion

This study aimed to analyze the effect of the biological maturity on the postural stability in the pre-pubertal growth spurt. It was found no significant interactions between sex and biological maturity in postural stability. The biological maturity did not influence postural control of elementary school-aged children. There was a significant influence of sex on postural stability, indicating higher performance in girls than boys.

Contrary to our expectations, biological maturity did not influence postural stability of prepubescent to early post pubescent children. Interestingly, girls showed to outperform boys in the postural stability test. Some peculiarities during the pre-pubertal growth spurt may help to understand these findings. Between the prepubescent to early post pubescent children, there is a dynamic and complex developmental period with notable changes in different indicators such as weight, height, body size and composition (Rogol et al., 2000). In this child-development period, differences in height between boys and girls tend to gradually decrease. Our results are in line with this thinking as no significant differences in body height between boys and girls were found. This tendency may be explained by the fact that the growth velocity of girls at this stage is higher than boys, reaching earlier the peak height velocity (Haywood & Getchell, 2014). In turn, this earlier achievement may have created advantageous conditions for girls exhibiting better performance in the postural stability test. We also observed that boys were significantly heavier than girls, which is consistent with the fact that the weight growth curve in boys and girls intersects for a time, referred as "crossing over", when girls overtake boys in weight, a stage which coincides with pre-puberty (Malina & Bouchard, 1991). Furthermore, it has been established that in pre-puberty there is already a fairly stable somatotype, considering 8 years the age by which somatotype stability becomes manifest (Haywood & Getchell, 2014). The same authors argue that boys tend to show a slight increase of the mesomorphic (relative muscle-skeletal magnitude) values, while girls tend to present an increase of the endomorphy (relative adiposity) and a slight reduction of the ectomorphic (relative thinness) values. Our results do not support completely this tendency, especially for the endomorphic component. In fact, there were no significant differences between sex, despite the slightly higher values for girls. While the endomorphic component expresses the degree of adiposity development, ectomorphic component represents the relative thickness of the subject (i.e., relatively low muscle component and high height-weight ratio) (Malina & Bouchard, 1991). Both issues have been negatively associated with postural and balance tasks (Lee & Lin, 2007). In turn, the mesomorphic children have significantly higher portion of muscular profile (Lee & Lin, 2007) and muscular strength has been highlighted as important for balance control (Condon & Cremin, 2014). The abovementioned results do not seem to support the superiority found in the stability test for girls. The differences found in postural stability between sex may be due to the fact that girls may develop other strategies for maintaining balance that depend less on body composition (Alonso et al., 2012). Peterson, Christou, & Rosengren (2006) suggested that pre-pubertal girls have an efficient use of vestibular information and consequently reduce the body sway when compared with boys of the same age. Furthermore, differences in balance between boys and girls 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.

We also observed that the more biologically mature children (Tanner II) showed higher weight, body mass index, body fat percentage and endomorphic component than their less mature peers. It is still unclear how excessive body mass affects postural stability of children (Deforche et al., 2009). Recently, Condon, & Cremin (2014) reported weak correlations between weight, balance and postural stability in 6 to 7-year-old children and no correlation in older ages (>10 year). However, other studies reported an association between children which have higher body mass with an increase of balance oscillations and risk of falling (McGraw, McClenaghan, Williams, Dickerson, & Ward, 2000). Deforche et al. (2009) showed that overweight children have a lower force production when raising the body to a standing position, due the insufficient leg strength to lift the excess body weight. They had also greater sway velocity in standing position, indicating that the difficulties were in decelerating the forward trunk motion following the movement. This could also result from lower strength relative to mass. Unlike the body mass, there is a consensus in the literature that increased height worsens balance (Hue, et al., 2007; Kejonen, Kauranen, & Vaharanta, 2003). This is because a higher stature leads to a high body's center of mass, responsible to increase postural instability on balance exercises (Lee & Lin, 2007). In a recent study, conducted by Alonso et al. (2012), the height was the anthropometric variable that most influenced postural balance. Concerning to the higher body fat percentage of children located in the Tanner stage II, there are few studies attending to the effect of this parameter 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 body fat percentage was negatively correlated with the postural balance. Furthermore, reported that differences in body size, shape and composition are closely linked to the genetic determinism, observed on the morphoconstitutional issue. In our study, children in Tanner stage II showed higher values in the endomorphic component (statistically significant differences between Tanner I vs II). This primary component of the morphological typology expresses the degree of adiposity development (Malina & Bouchard, 1991) and, as abovementioned, the fat mass is negatively correlated with balance tasks (Lee & Lin, 2007). Nevertheless, we should also address study's limitations. First, due to the methodological approach, it was not possible to disclose the effect of other factors underlying the postural balance control (e.g., maturation of the neurological, visual, vestibular and proprioceptive systems). Secondly, we have examined postural stability using field-based assessments. It is possible that the implementation of different methods of evaluating postural stability (e.g., the use of a laboratory-based force platform) could have enhanced precision and reliability. Lastly, the maturity level was determined through sample self-assessment. It would be perhaps more accurate if an experience physician in determination of sexual maturation stage had been added to the study. Further research should support the study about the effects of the biological maturation on postural stability considering experimental sample on the different stages of adolescence (i.e., early, middle, late).

Conclusions

Our findings suggest that more biologically mature prepubescent children seem to have no advantage in postural stability compared with their less mature peers. Additionally, girls showed better performance in postural stability comparing with boys. The particularity of anthropometric and morphological changes in the pre-pubertal growth spurt, together with sensorial (i.e., vestibular system) and environmental influences, may have influenced the impact of maturity status on postural stability. This knowledge should be taken into account by professionals in physical education or youth sport, in way to adapt practical tasks related to maturity status and sex.

Conflict of interest

The Authors declare that there is no conflict of interest.

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