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Proposal for a universal measurement system for school chairs and desks for children from 6 to 10 years old

Vitor Carneiro [a, *], Ângela Gomes [a], Bárbara Rangel [b]

[a] Faculdade de Engenharia da Universidade do Porto, Rua Doutor Roberto Frias s/n, 4200-465, Porto, Portugal
[b] DESIGNSTUDIO, Faculdade de Engenharia da Universidade do Porto, Rua Doutor Roberto Frias s/n, 4200-465, Porto, Portugal

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ABSTRACT

In a primary education classroom of any country, children of the same age have very different statures, reaching variations of 200 mm (Gonçalves, 2012). However, the school furniture provided is not suitable or adaptable to these differences. Designing school furniture able to respond to these variations is, therefore, a challenge for ergonomics and design in a global market. It is clearly not viable for industries to adapt productions for each country. When competitiveness and limitation of resources are essential for the viability of any product it becomes essential to find a universal system adapted to the requisites of any country.

Taking as prescription measure the popliteal height obtained from the data of different countries, a universal measurement system for the school chair and desk set is proposed, combining the ellipse methodology used by Molenbroek et al. (2003) and the (mis)match equations mentioned by Castellucci et al. (2014b).

From the results obtained, it can be concluded that only 5 sizes are needed to implement this new measurement system of evolutionary school furniture for the primary education classroom.

1. Introduction

Growth is defined as the measurable physical changes of the body (Newman and Newman, 2012) that occur from birth to around 18–23 years old (Gonçalves, 2012; Ribeiro, 2012). Although growth depends on genetic potential, its pace and quality can, at any point, be disturbed by extrinsic factors (Ministério da Saúde do Brasil, 2002), such as bad posture during school years.

The constraints related to a sitting posture are considered more harmful for the human body than standing, therefore the design of the furniture used has a significant influence. Poorly designed school furniture may lead to bad posture habits which may have a direct impact on the growth process because they are likely to remain unchanged into adolescence or adulthood (Gonçalves, 2012; Gouvali and Boudolos, 2006; Panagiotopoulou et al., 2004; Parcells et al., 1999). Accordingly with Molenbroek et al. (2003) and Parcells et al. (1999) bad posture may lead to back, leg, arm, neck, shoulder and feet pain in school age children.

There are however contradictions about the direct relationship between poor posture and ergonomic school furniture. Troussier (1999) concludes that there is no modification of back pain prevalence in 8–11 year old schoolchildren using ergonomically designed furniture.

Despite these contradictory findings between studies and in a prevention perspective we considered important to take account of the hypothesis described by Molenbroek et al. (2003) and Parcells et al. (1999).

Chairs are the largest contributors to incorrect posture among children because they are not appropriate for the anthropometric and biomechanical characteristics of their users. Despite the fact that stature differences at the same age can reach 200 mm, it is nonetheless common to use the same seat size for all students in the same class.

School furniture along with good posture training could address this issue. The primary goal of school furniture, in particular chairs and desks, is to promote comfort and good posture and thus enhance school performance (Castellucci et al., 2014b; Domljan et al., 2010; Gonçalves, 2012; Guat-Lin, 1984; Moro, 2005; Parcells et al., 1999). In their consideration of child anthropometry, many authors (Castellucci et al., 2015; Gonçalves, 2012; Molenbroek et al.,

* Corresponding author. Address: Rua S. Tiago Nº46, 4590-064, Carvalhosa PFR, Porto, Portugal.
E-mail address: vitorcarneiro10@hotmail.com (V. Carneiro).

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2003; Panagiotopoulou et al., 2004; Parcells et al., 1999) have commented that school furniture should be adapted to the anthropometric changes that take place during growth.

The design of school furniture is guided by national and regularity standards. The countries in the European Union follow the Normative EN 1729-1, while in Brazil the NBR-14006 and NBR 14007 (Reis, 2003; Reis et al., 2005), and in the USA the ISO 5970 (Poston, 2002). Unfortunately, these standards do not always comply with the anthropometric reality of the users. For example, Gonçalves (2012) and Molenbroek et al. (2003) show that the European Standard does not fit the anthropometric reality of European children, demonstrating sizing gaps. For its part, Reis et al. (2005) shows that the Brazilian Standard is not fully implemented in terms of its practical application, revealing that Brazilian schools only use a single size of chairs and school desks for 7–17 years old leading to inadequate postures and musculoskeletal pathologies. Parcells et al. (1999) concludes that the furniture used in some North American schools is unsuitable with less than 20% of the students having a chair and desk compatible with their anthropometric dimensions. It can be seen, therefore, that there is a poor relationship between the actual anthropometric measures of each country and the dimensioning considered by their particular standards.

As demonstrated in the studies of Castellucci et al. (2015), Molenbroek et al. (2003), Gouvali and Boudolos (2006), among others, the anthropometric measures are directly related to the dimensions of the chair and desk. When the (mis)match equations are applied it is possible to obtain the optimal values for the considered sample.

Given the need of global manufacturing and the inherent diversity in the global market, it becomes a priority to develop an adaptable chair and desk for primary school children. A methodology of sizing, able to support the design of this adaptable chair and desk set and having as a prescribed criteria the popliteal height (PH), as advocated by Molenbroek et al. (2003) and Castellucci et al. (2015), which when compared with stature presents a *"better cumulative fit or match"*.

This methodology can be an important instrument to justify the designer's decision during the conceptual and development phases. An adjustable chair can be adapted to children with different statures from different countries. For the industry this is a very convenient solution, with one chair is possible to respond to the needs of different markets, enhancing responsiveness in production efficiency, environmental impact, market management and economic sustainability of the product.

2. Material and methods

The criteria of age selection in this study, between 6 and 10 years old, correspond to the school ages according to ISCED 1 – International Standard Classification of Education 2011 (UNESCO, 2012). The popliteal height (PH) was taken as prescription criteria for the selection of the proper size of the chair and desk, as recommended by Molenbroek et al. (2003) and Castellucci et al. (2015). The (mis) match equations presented by Castellucci et al. (2014b) were taken in to account for sizing the universal chair.

The application of the equations requires anthropometric data. Therefore, anthropometric data/studies published in different counties addressing the anthropometric measures necessary for the sizing of the chair and desk set were taken into consideration.

The ellipses method of Molenbroek et al. (2003) was applied to the anthropometric data/studies, in order to determine how many sizes were required to cover the considered sample. From the number of sizes obtained, and depending on the other anthropometric data, the anthropometric values within the limits defined by the 5th and 95th percentiles of each size were achieved. Applying the values of the obtained limits from the selected (mis)match equations, the optimal values for the universal system of chair and school desk size for children from 6 to 10 years old were established.

2.1. Sample

With reference to the International Standard Classification of Education 2011 (UNESCO, 2012) it is in ISCED 1, primary school, that children have their first contact with school (Eurydice, 2014). Although there are some national variations. Attendance in primary schools generally starts between 5 and 7 years, with an average of 6 years old, and its duration is rarely less than 4 years. From this analysis it was decided to consider ages between 6 and 10 years old for the sample (Table 1).

2.2. The popliteal height as a prescription measure

Currently, most school furniture standards suggest stature as the prescription measure, taking as the basis the Pearson Correlation Coefficient (Castellucci et al., 2015). This coefficient shows that there is a strong positive correlation between stature and the other anthropometric variables, enabling a constant relationship to be established between the various segments of the body and stature through ratios (Guat-Lin, 1984). However, authors such as Molenbroek et al. (2003) and Castellucci et al. (2015) consider that this is not the most reliable criteria. Molenbroek et al. (2003) shows that when stature is used as the prescript criteria there may be ambiguity in the choice of size. For instances, the same stature can correspond to more than one size and, as a consequence, a higher chair can be chosen for children with a low popliteal height (PH). This happens because individuals with the same stature may have a range of different popliteal heights (PH) (Fig. 1). As Panero and Zelnik (1996) explain, the many anthropometric dimensions of an individual correspond to different percentiles.

Castellucci et al. (2015) shows that the popliteal height (PH), when compared with stature, is more precise and as such is the most appropriate anthropometric measure for the selection of the furniture's size. It is important to note that the starting point for the sizing of the chair and desk set is the seat height (SH) (Castellucci et al., 2010a, 2015; Molenbroek et al., 2003) and the seat height (SH) is defined by the popliteal height (PH) (Fig. 2).

Although, in schools, unlike stature, the knowledge about the measurement of the popliteal height is absent (Molenbroek et al., 2003). However, as shown by Castellucci et al. (2015), its measurement is not more difficult and/or time-consuming than stature when using simple strategies such as 'Peter lower leg meter', therefore their meaning is easily understood. Such simple measurement techniques can prevent incorrect choices of size. Molenbroek et al. (2003) also recommends the measurement of the popliteal height (PH), at least twice during a school year.

2.3. (mis)Match equations and respective sizing criteria

To design a system of measurements for school furniture the adoption of ergonomic criteria is necessary. In this development process, the dimensions of the furniture are related to the anthropometric dimensions of children, taking into account the (mis)match equations. This happens because, for example, the seat depth (SD) is based on the buttock-popliteal length (BPL), but if the seat depth (SD) corresponds to the exact measures of this anthropometric dimension a compression will occur on the back of the knee making the blood circulation in the legs and feet difficult (Gonçalves, 2012; Parcells et al., 1999; Reis, 2003) (Fig. 3).