International Journal of Industrial Ergonomics 48 (2015) 117–126

Contents lists available at ScienceDirect

International Journal of Industrial Ergonomics

journal homepage: www.elsevier.com/locate/ergon

Equations for defining the mismatch between students and school furniture: A systematic review

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ARTICLE INFO

Article history:
Received 13 September 2013
Received in revised form
11 April 2015
Accepted 1 May 2015
Available online 20 May 2015

Keywords:
Classroom
Fit
Furniture
Anthropometry
Match

ABSTRACT

The present study reviews the scientific literature that describes the criteria equations for defining the mismatch between students and school furniture. This mismatch may negatively affect students' performance and comfort. Seventeen studies met the criteria of this review and twenty-one equations to test six furniture dimensions were identified. There was substantial mismatch between the relative heights of chairs and tables. Some systematic errors have been found during the application of the different equations, such as the assumption that students are sitting on chairs with a proper seat height. Only one study considered the cumulative fit. Finally, some equations are based on contradictory criteria and need to develop and evaluate new equations for these cases.

Relevance to industry: Ultimately, the present work is a contribution toward improving the evaluation of school furniture and could be used to design ergonomic-oriented classroom furniture.

1. Introduction

Students' work is sedentary, the location of which is where permanent sitting habits are formed (Lueder and Rice, 2008; Zacharkow, 1987). It is proven that the longer a particular habit endures, the more difficult it is to change it. As such, it is of the greatest importance to instil and maintain good sitting habits as early in the life of the individuals as possible (Floyd and Ward, 1969). Considering this, it is fundamental that school furniture fulfil the children's requirements (Savanur et al., 2007). For example, it should allow for the changes of posture (Yeats, 1997) to enable students to benefit from using furniture that accommodates their body sizes (Wingrat and Exner, 2005).

Adjustable school furniture promotes better and more comfortable posture (Jung, 2005) and may improve overall academic performance (Koskelo et al., 2007).

However, most of the currently used school furniture has fixed dimensions. In addition, there are some standards that promote different sizes for a specific population (BSI, 2006; CEN, 2012; INN, 2002; JIS, 2011). This situation may be associated with the large number of studies published worldwide that show a clear mismatch between anthropometric characteristics and the dimensions of the furniture under study. For example: Castellucci et al. (2010), Chung and Wong (2007), Dianat et al. (2013), Gouvali and Boudolos (2006), Panagiotopoulou et al. (2004), Parcells et al. (1999) and Saarni et al. (2007).

This mismatch is likely to result in a number of negative effects. For example, learning can be affected since uncomfortable and awkward body postures can decrease a student's interest in learning, even during the most stimulating and interesting lessons (Hira, 1980). Murphy et al. (2007), concluded that chairs that are too low have a significant association with the occurrence of neck pain, upper back pain and lower back pain. A chair's backrest that is too high has been significantly associated with lower back pain. While it is acknowledged that there is a multifactorial nature of causality of adolescent spinal symptoms, it is contended that the degree of mismatch between child anthropometry and school furniture set-up should be further examined as being a strong and plausible factor in the occurrence of adolescent lower back pain (Milanese and Grimmer, 2004).

However, Gouvali and Boudolos (2006) state that the equations used to examine the match or mismatch between school furniture and anthropometric dimensions can be problematic in the sense

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http://dx.doi.org/10.1016/j.ergon.2015.05.002
0169-8141/

that they are sometimes based on contradictory criteria. Also, a series of mismatch equations were determined on the basis of either the prevailing or the more frequently stated viewpoints of other researchers.

Accordingly, the aim of this paper is to review the literature describing the criteria equations for defining the mismatch between students and school furniture. This is done by summarizing the level of mismatch found in the literature under review by discussing the various criteria equations and by proposing a methodology to evaluate school furniture suitability.

2. Methodology

A scientific publications database, SciVerse Scopus, was used to identify the studies carried out in the field of the influence of school furniture on students' performance and physical aspects. The authors used only SciVerse Scopus since it covers a wider journal range, assisting both in keyword searches and citation analysis (Falagas et al., 2008). The search terms used were 'school furniture' and 'classroom furniture'. Inclusion criteria were established as all the reviewed articles were original studies, written in English and published between January 1980 and January 2015. The review was oriented toward the definition and application of mismatch equations in the used school furniture (6–18 years old), but excluding the studies carried out in university settings, such as the examples of Musa and Ismaila (2014) and Tunay and Melemez (2008).

Additionally, all the studies that presented a proposal of a new set size for school furniture based on the application of mismatch equation or percentiles were also excluded, such as the example of Garcia-Acosta and Lange-Morales (2007) and Musa (2011). Finally, the studies analyzing the level of mismatch through the application of statistical methods were not considered. Examples of the latter are the studies using percentiles (e.g. Reis et al., 2012), quartiles (e.g. Milanese and Grimmer, 2004) and arithmetical mean (e.g. Dhara et al., 2009; Domljan et al., 2008; Feathers et al., 2013).

Potential mismatch equations were grouped according to the specific type of school furniture under consideration:

- Chair dimensions;
- Table dimensions;
- Interaction between chair and table dimensions.

All mismatch equations, both one- and two-way, were considered. When the situation under analysis had a minimum and maximum limit, a two-way equation was considered appropriate and when it only had a maximum or a minimum limit, a one-way equation was the required option.

3. Results and discussion

3.1. Generalities

The searches resulted in a total of 455 registries, but only 17 studies met the criteria described before. The results from the studies included in the present review are shown in Table 1. The selected studies were undertaken in 13 different countries, covering Europe, Asia, Africa and America. All of the studies were cross-sectional and were published between 1999 and 2013.

The furniture and anthropometric dimensions were not all the same across the studies (Figs. 1 and 2). Regarding chair dimensions, Table 1 shows that all the studies considered needed to apply an equation to test the fit of the seat height (SH). This fact demonstrates that SH is the most important measure for the development of mismatch criterion. Furthermore, SH should be considered as the starting point and the most important variable for the design of classroom furniture (Molenbroek et al., 2003; Castellucci et al., 2010). Seat Depth (SD) was used in the majority of studies (16), being the second most common measurement. Only a few studies (6) applied a mismatch equation to test Seat Width (SW) and the Upper Edge of Backrest (UEB). Finally, on the topic of chair dimensions, none of the studies evaluated the Lower Edge of Backrest (LEBR), Width of Backrest (WBR) or Height of Backrest (HBR).

Concerning table dimensions, it is important to mention that there are two dimensions, namely Desk Width (DW) and Desk Depth (DD), for which no mismatch equations were found. Castellucci et al. (2010), defined these dimensions according to functional criteria, such as the need for available desk surface to perform school activities, for instance reading and writing. On the other hand, Desk Height (DH) and Underneath Desk Height (UDH) were evaluated in eight and nine studies, respectively.

The interaction between chair and table dimensions is measured by Seat to Desk Clearance (SDC), which results from the difference between UDH and SH, and was only used once. This mismatch equation tests the same furniture dimension as UDH, but in this paper, it is shown that a number of authors have not correctly applied the equation. Furthermore, the same can be said of Seat to Desk Height (SDH) dimensions, which were used four times and result from the difference between DH and SH.

Finally, Table 2 shows a summary of relationships between anthropometric measures and school furniture dimensions.

3.2. Criteria equations for mismatch of chair dimensions

3.2.1. Seat height

Most of the researchers have concluded that Popliteal Height (PH) should be higher than SH (Marschall et al., 1995; Mokdad and Al-Ansari, 2009; Molenbroek and Ramaekers, 1996; Parcells et al., 1999), otherwise most students will be unable to rest their feet on the floor properly, thus generating increased tissue pressure on the posterior surface of the knee (García-Molina et al., 1992; UNESCO, 2001; Milanese and Grimmer, 2004). However, if SH is significantly lower than PH, this increases the compression in the buttock region (García-Molina et al., 1992), while also increasing the degree of lumbar flexion involved in sitting (Pheasant, 2003). Furthermore, Knight and Noyes (1999) shows that the PH and SH relationship suggests peaks of non-standard sitting when PH is either a few centimetres less than SH or when it is in excess of 5 cm. This leads to two of the main equations to be found in the literature. One is based on the angles of the knee (Eq. (1)), considering that SH needs to be lower than PH so that the lower leg forms a 5–30° angle relative to the vertical. The other equation includes two options (Eqs. (2) and (3)), but both are based on the fact that SH has to be evaluated in relation to the PH percentage.

One can find the following equations in the literature, where SC is shoe correction:

$$(PH + SC)\cos 30^\circ \leq SH \leq (PH + SC)\cos 5^\circ \quad (1)$$

$$0.88PH \leq SH \leq 0.95PH \quad (2)$$

$$0.80PH \leq SH \leq 0.99PH \quad (3)$$

In the three different equations, two-way mismatch criterion is considered. In all the studies that were analyzed, the anthropometric measurements were made without shoes. Only one equation (Eq. (1)) considers the use of shoe correction with a height between 2 cm (Agha, 2010; Dianat et al., 2013; Gouvali and Boudolos, 2006) and 3 cm (Castellucci et al., 2010). It is also necessary to consider that SC may naturally vary according to culture, fashion and country. For example, other authors also