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**DOI**
10.1080/00140139.2016.1170889

**Publication date**
2016

**Document Version**
Final published version

**Published in**
Ergonomics: an international journal of research and practice in human factors and ergonomics

**Citation (APA)**
Castellucci, HI., Arezes, PM., Molenbroek, J., de Bruin, R., & Viviani, C. (2016). The influence of school furniture on students' performance and physical responses: Results of a systematic review. *Ergonomics: an international journal of research and practice in human factors and ergonomics*, *60*(1), 93-110. https://doi.org/10.1080/00140139.2016.1170889

ERGONOMICS, 2017
VOL. 60, NO. 1, 93–110
http://dx.doi.org/10.1080/00140139.2016.1170889

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# The influence of school furniture on students' performance and physical responses: results of a systematic review

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**ABSTRACT**

The purpose of this study was to determine, using a systematic review, whether the design and/or dimensions of school furniture affect the students' physical responses and/or their performance. Of the review studies, 64% presented positive results, i.e. proven effects; 24% presented negative effects or no change/effect; and the remaining 12% showed an unclear effect. The compatibility between school furniture dimensions and students' anthropometric characteristics was identified as a key factor for improving some students' physical responses. Design characteristics such as high furniture, sit-stand furniture, and tilt tables and seats also present positive effects. Finally, we concluded that further research should be conducted exploring various aspects of those variables, particularly focusing on more objective measures complemented by controlled and prospective design.

**Practitioner Summary:** A systematic review of the literature presents a clearly positive effect of school furniture dimensions on students' performance and physical responses. Similar results appeared when school furniture design was tested. However, studying the effects of design and dimensions together produced an unclear positive effect.

**ARTICLE HISTORY**
Received 14 November 2014
Accepted 17 March 2016

**KEYWORDS**
Classroom; workstation; design; dimension

## 1. Introduction

Life as a student may be among the most sedentary of occupations (Zacharkow 1987), during which permanent habits of sitting develop (Lueder and Berg Rice 2008). Unfortunately, poor sitting habits acquired during childhood are quite difficult to change in adolescence and/or adulthood (Yeats 1997). Additionally, a group of authors (such as Grimes and Legg 2004; Harreby et al. 1999; Trevelyan and Legg 2010) has shown an association between low back pain and sitting in children.

Students are exposed to the first systematic tasks or activities that human beings conduct in their lives while at school; thus, school is our first 'workplace'. Legg and Jacobs (2008) mentioned that 'systems' within schools contain many different 'elements', some macro in nature (environment and organisation) and some micro in nature (school furniture, activities and school bags). de Bruin and Molenbroek (2010) proposed a diagram in which they included some of the relevant aspects of schools' characteristics. The new diagram proposed in this paper appears to justify considering a school a 'workplace' (Figure 1).

In schools, there is a conflict between children's natural impulses towards physical movement and the need to maintain a prolonged sedentary position for educational purposes.

In normal school environments, many factors influence the students' sitting posture. These factors include the anthropometric dimensions of schoolchildren as well as the measurement and design features of the school furniture (Murphy, Buckle, and Stubbs 2007). Some variables must be considered in the interaction between school furniture and students' characteristics (Figure 1).

### 1.1. School furniture design

In recent decades, the upright posture forced on students has required their sitting with the joints of their hips, knees and ankles at right angles. However, a 'normal' child can

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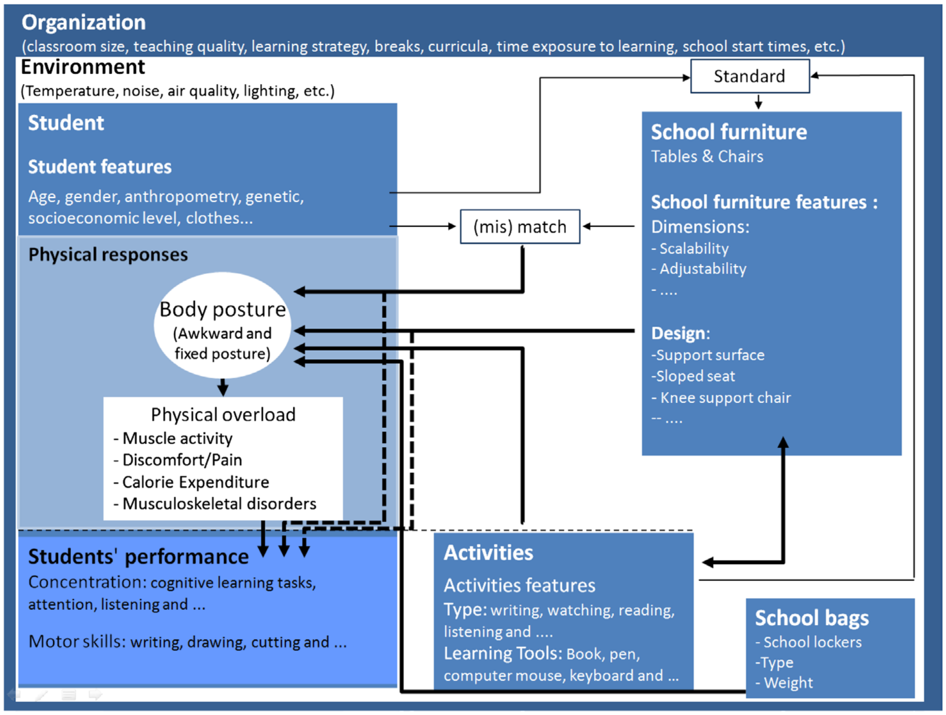


Figure 1. Diagram of school as a workplace situation.

maintain this posture for no longer than 1–2 min (Mandal 1981). Additionally, this posture can cause some biomechanical problems because a seated person has a hip joint flexion of approximately 60° and the pelvis has a sloping axis; therefore, the lumbar curve changes from a lordosis (standing position) to a kyphosis (sitting position) (Mandal 1994). This conclusion is supported by Schoberth (cited by Murphy, Buckle, and Stubbs 2004), who observed an average 60° hip flexion and 30° lumbar flexion from X-ray examinations of 25 people sitting upright. Many researchers have attempted to improve the sitting position by modifying some aspects of school furniture. Zacharkow's (1987) book includes some references to the relevance of the desk slope, such as those from Bennett (In requiring a child to sit erect at an ordinary desk while reading or writing, we are demanding a physical impossibility) and from Dresslar (I believe the chief defect in desks now on the market is that the desk top is too flat). This belief was supported more recently in an article by Motmans (2006) in which the author demonstrated that a desk with a 15° inclination reduced the forward head tilt and the neck and trunk flexion, independent of the table height.

The seat pan also represents an important element of school furniture because the pan carries approximately 80% of the trunk weight (Mandal 1994). Seat height (SH) is important because increasing SH in addition to the forward-sloping seat tended to increase lordosis (Freivalds 2004). Regarding the seat angle, a positive angle (or the forward-sloping seat) is based on the principles that most work activities require a forward-leaning posture, with no use of a backrest (Mandal cited by Lueder and Berg Rice 2008). Some authors argued that this design would reduce the forward bending of the lower back (lumbar flexion). Furthermore, the backrest or lumbar support will have a beneficial effect only if the chair presents a negative seat or a backward-sloping seat (Mandal 1994). However, in practice, the backrest may facilitate the forward movement of the buttocks and kyphosis of the lumbar spine to stabilise the trunk against the backrest (Bendix et al. 1996).

### 1.2. *School furniture dimensions*

Students are often exposed to fixed-dimension furniture throughout their school life, with little opportunity for adjustability to suit their own changing anthropometry. This concern is rendered clear by the large number of studies published worldwide in which a clear mismatch between anthropometric characteristics and the dimensions of the furniture under study has been identified (Parcells, Stommel, and Hubbard 1999; Cotton et al. 2002; Panagiotopoulou et al. 2004; Gouvali and Boudolos 2006; Chung and Wong 2007; Tunay and Melemez 2008; Brewer et al. 2009; Jayaratne and Fernando 2009; Agha 2010; Castellucci, Arezes, and Viviani 2010; Batistão et al. 2012; Jayaratne 2012; Dianat et al. 2013; Van Niekerk et al. 2013; Castellucci, Arezes, and Molenbroek 2014a).

To avoid the mismatch problem, one of the best possible solutions is adjustability. Yeats (1997) argued that it is difficult to encourage proper posture early in life without the support of adjustable chairs, desks and tables in the classroom. However, scalability became a more realistic and cheaper solution and is somehow reflected in the increase in the number of published standards regarding school furniture in various countries, including Chile (INN 2002), Colombia (ICONTEC 1999), the European Union (CEN 2012), Japan (JIS 2011) and the United Kingdom (BSI 2006).

As mentioned, to define school furniture dimensions (Standard) or quantify the level of mismatch, it is important to consider students' features. For example, age is important not only because of growth rate but also because of the manner of growth; before puberty, the legs grow more rapidly than the trunk, and in adolescence, the growth spurt is largely in the trunk (Bass et al. 1999). Furthermore, students' growth appears to be influenced by their socio-economic status. It has previously been observed that children of higher socio-economic status are, on average, taller than students of lower and medium socio-economic status (Castellucci, Arezes, and Viviani 2010). Regarding gender differences, it can be observed that until the onset of puberty, males and females have similar rates of growth and that after puberty, males present greater anthropometric values than females, with exceptions in some variables such as hip width (Lueder and Berg Rice 2008; Castellucci, Arezes, and Molenbroek 2015).

As a result of the interaction between the independent variables mentioned above (school furniture design and dimension), some changes are expected to occur in a group of dependent variables, such as physical responses and the students' performance (Figure 1). For example, Oxford (1969, cited by Grimes and Legg 2004) wrote that school children are repetitively exposed to the hazards of abnormal or awkward postures because of classroom furniture that is often too large or too small. Such size variations may also affect their academic performance, affecting learning, because uncomfortable and awkward body postures can decrease students' interest in learning, even during the most stimulating and interesting lessons (Hira 1980).

Physically, when the SH is higher than the popliteal height (PH), the majority of students are unable to properly rest their feet on the floor, compressing vascular and neural structures along the popliteal space (Milanese and Grimmer 2004). However, a SH significantly lower than PH, more than 4 cm (UNESCO 2001), increases the compression in the buttock region (García-Molina et al.1992). In the case of seat depth (SD), the support of at least 80% of buttock-popliteal length (BPL) is required to avoid the extra pressure on the back of the thighs, which could cause discomfort (Pheasant 2003). However, the SD cannot be greater than 95% of the BPL because the student will not be able to use the backrest of the seat and, consequently, will not be able to support the lumbar spine without compression of the popliteal surface (Milanese and Grimmer 2004). To avoid this situation, students will generally move their buttocks forward towards the edge of the seat, as suggested by Panagiotopoulou et al. (2004). This improper use of the backrest causes kyphotic posture (Pheasant 1991; Khalil et al. 1993). According to some authors (Evans, Courtney, and Fok 1988; Occhipinti et al. 1993; Orborne 1996; Oyewole, Haight, and Freivalds 2010), students who use narrow seats are not be able to relieve the pressure on the buttocks and cannot avoid discomfort and mobility restrictions. Students who use a higher than recommended desk height are forced to flex and abduct their arms as well as elevate their shoulders. This posture may cause more muscle work load, discomfort and pain in the shoulder region (García-Molina et al. 1992). If such a posture occurs in only one upper limb, an asymmetrical spinal posture will result (Zacharkow 1987).

Despite the large amount of research regarding school furniture, it is not clear whether the application of the different size and/or design of school furniture improves the students' performance and physical responses. Furthermore, Legg and Jacobs (2008) indicated that longitudinal case-controlled ergonomic intervention studies are required if the musculoskeletal discomfort, pain and injury problems experienced by schoolchildren identified in epidemiological studies are to be addressed. Therefore, considering the developed literature review, this paper seeks to determine whether the design and/or dimensions of school furniture affect the students' physical responses and/or their performance.

## 2. Methodology

A scientific publications database, SciVerse Scopus, was used to identify the field studies on the influence of school furniture on students' performance and physical qualities. The authors used only SciVerse Scopus because that programme covers a wider journal range, assisting both in keyword searches and citation analysis (Falagas et al. 2008). The search terms used were 'school furniture', 'classroom furniture' and 'school workstations'.

The adopted inclusion criteria included only original studies written in English and published between January 1980 and September 2014. The review was oriented towards the implication of the design and dimension of school furniture for students' physical responses and their performance. Studies that merely presented the variables but did not present any cause/effect or associations among the variables were not considered. Some examples

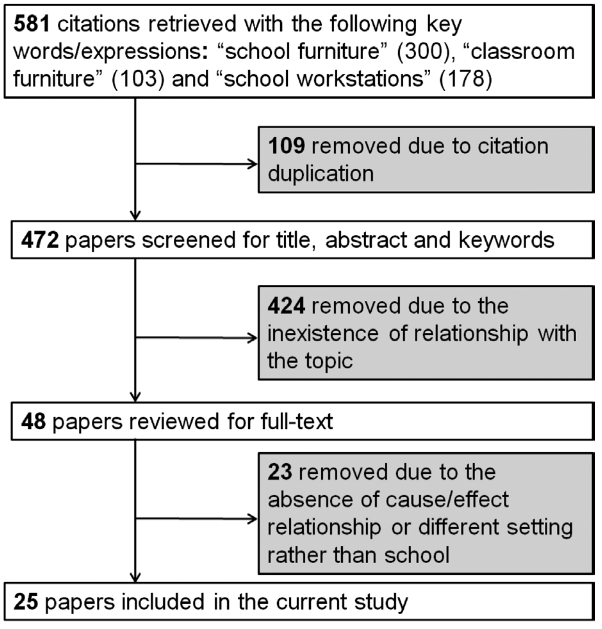


Figure 2. Diagram of the used search strategy and exclusion criteria.

Table 1. Summary of the reviewed studies.

| | Physical responses | Performance | Performance and physical responses | Total |
|---|---|---|---|---|
| Dimension | 7 | 1 | 0 | 8 |
| Design | 4 | 1 | 2 | 7 |
| Design and dimension | 6 | 1 | 3 | 10 |
| Total | 17 | 3 | 5 | 25 |

of this exclusion are papers by Dhara, Khaspuri, and Sau (2009), Panagiotopoulou et al. (2004), Reis et al. (2012), Rudolf and Griffiths (2009) and Savanur, Altekar, and De (2007). Several studies were not considered in this review because the considered sample comprised only university students (Straker et al. 2008) and secretaries (Mandal 1991) instead of younger school students.

The searches resulted in a total of 581 registries (Figure 2). Titles and abstracts of articles were scanned independently by the three authors to identify relevant articles to retrieve in full text. In cases in which articles appeared potentially eligible but no abstract was available, the full text of the paper was retrieved. Disagreements between authors were referred to the other two authors, leading to a deeper analysis of the paper; and a decision was then made regarding its inclusion. Full texts were independently reviewed for inclusion by the same three authors using a standardised data extraction form, and disagreements between authors were referred to the other two authors. Primary studies meeting the inclusion criteria, which were reported in included reviews, were identified and their data extracted.

The results were grouped according to the specific dependent and independent categories (Table 1). To avoid misunderstandings, the dimension was placed in an independent variable category when a mismatch level was considered (using equations or checklists) or when the school furniture was adapted to the body size of each individual child. Conversely, dimension was not considered an independent variable when the school furniture design proposed high furniture or stand-sit workstations without considering the students' body size or if dimension was not clearly mentioned in the article; in this case, the independent category variable was design. Finally, design and dimension of school furniture were considered together as independent variables when the school furniture presented a new type of design (ball chair, high furniture, slope desk or chair, stand-sit workstations, etc.), and the dimensions were adjusted to the students' anthropometric characteristics.

## 3. Results

Table 1 shows the variables considered by the 25 studies that fulfilled the inclusion criteria for this review. The design and dimensions of school furniture were the most considered independent variables, followed by dimension and design.

Before presenting the results regarding the dependent variables, it is important to mention the column with results presented in Tables 2–6. The effect of the independent variable was classified as (+) when the effect resulted in an improvement in the dependent variable, (−) when the effect was negative or no change was observed and (+/−) when the obtained results were not clear.

Considering the dependent variables, the overall results show that 64% of the reviewed studies presented positive (+) results, 24% presented negative (−) or no change, and the remaining 12% of the studies showed unclear results (+/−). For example, from Table 4, the study of Benden et al. (2013) showed positive results in discomfort but negative results in posture.

Regarding the independent variables, the level of positive results is nearly identical between design and dimensions, with values of 86 and 75%, respectively. However, only 40% of positive results can be observed when the reviewed studies under consideration manipulated the dimension and design variables together.

Although 25 studies were reviewed, the number of dependent variables was greater because more than half of the studies (14 of 25) presented more than one dependent variable. The total number of dependent variables was 44; the most studied dependent variable was the physical response, tested 29 times, followed by studies that presented students' performance, tested 9

Table 2. Synthesis of studies referring to the effect of classroom furniture on students' performance.

| Independent variable | Authors (year) | Sample (*n*), ages (yr), country (ies) (c) | Research design | Study description | Relevant results |
|---|---|---|---|---|---|
| Dimension | Smith-Zuzovsky and Exner (2004) | *n*: 40<br>yr: 6–7<br>c: USA (Maryland) | Experiment; prospective comparison | • Two different types of school furniture were tested in a laboratory setting (A; standard, but too large school furniture, B; standard school furniture adapted to the body size of each individual child)<br>• In-hand Manipulation Test Quality section (IMT-Q) was performed for 40–45 min | + The children who were seated in furniture that fit them well performed significantly better on the IMT-Q than those children who were seated in furniture that was too large |
| Design | Schilling et al. (2003) | *n*: 3<br>yr: 9<br>c: USA (Washington) | Single subject, A-B-A-B interrupted time series design | • The three subjects with Attention Deficit Hyperactivity Disorder (ADHD) used a conventional chair during language arts throughout the baseline phases. They used therapy balls during language arts throughout the intervention phases. The entire study was 12 weeks in length; each phase was 3 weeks long<br>• The in-seat behaviour and legible word productivity variables were tested | + Results demonstrated increases in in-seat behaviour and legible word productivity for the students with ADHD when seated on therapy balls<br>+ Social validity findings indicated that generally the teacher and students preferred therapy balls |
| Design and dimension | Ryan, Rigby, and Campbell (2010) | *n*: 30 with cerebral palsy<br>yr: 6–8<br>c: not specified | Randomised controlled trial design | • Subjects were randomly assigned to one of two conditions. Condition 1: Q-Learn Classic school chair, with a fixed, nominal 15° forward inclined seat surface and a seat height individually adjusted. The Q-Learn desk should be individually adjusted and the surface angled downwardly towards the child at 10° from the horizontal (Mandal's parameters). The desk has a semi-circular cut out with a raised lip. Condition 2: the suboptimal standard configuration was a Virco 9000 classic series school chair, with the fixed height and height-adjustable Virco model 785 school desk<br>• The children then performed a manual writing task and the quality of it was assessed by blind researcher using the Minnesota Handwriting Assessment (MHA) and behaviour on the seat | – Compared with standard school furniture, the use of specialty school furniture did not lead to immediate gains in printing legibility and other printing performance areas for children with cerebral palsy |

**Table 3.** Synthesis of studies referring to the effect of dimension classroom furniture on students' physical responses.

| Independent variable | Authors | Number (*n*), age (yr), country (c) | Research design | Study description | Relevant results |
|---|---|---|---|---|---|
| Dimension | Batistão et al. (2012) | *n*: 46<br>yr: mean 11.5 and 14.9 for 5th and 8th grade, respectively<br>c: Brazil (Sao Paulo) | Cross-sectional study | • Anthropometric and furniture measurements were obtained from a metric tape. The criteria used to classify the adequacy of the furniture (mismatch) were based on Parcells, Stommel, and Hubbard (1999)<br>• Inclinometers were used for recording postures and movements for the head, upper back and upper arms. Also, an audiovisual record with a digital camcorder was performed | + This study showed a relationship between furniture mismatch and postural overload. When the seat height is low students increase upper back left inclination and right upper arm elevation; when the seat is short students decrease the upper back flexion velocity and increase right upper arm elevation |
| | Brewer et al. (2009) | *n*: 137<br>yr: not specified (5th–12th grade)<br>c: USA (Ohio) | Cross-sectional study | • Anthropometric measure and school furniture dimensions were collected with an anthropometer and a tape measure. The mismatch level was calculated based on the criteria of Parcells, Stommel, and Hubbard (1999)<br>• The discomfort data of the previous month were also collected through a questionnaire | − Physical discomfort is not related to the degree of ergonomic mismatch. Furthermore, the significant relationship between ergonomic mismatch and body discomfort suggested a protective relationship |
| | Milanese and Grimmer (2004) | *n*: 1269<br>yr: 12–18 (8–12th grade)<br>c: Australia (Adelaide) | Cross-sectional study | • The ratios within each quartile for each subset of subjects (younger and older boys and girls) were calculated using the first quartile as the comparison group (best fit)<br>• The recent reports of spinal pain (neck, thoracic and low back) and headache were extracted from a larger data-set | + Despite the onset of symptoms for the musculoskeletal multifactorial in nature, the school furniture certainly can play a role in the onset of symptoms in adolescents |
| | Murphy, Buckle, and Stubbs (2007) | *n*: 679<br>yr: 11–14<br>c: England (Surrey) | Cross-sectional study | • The children answered a self-administered questionnaire on demographic characteristics, backache complaint history, school and leisure activities, school, general complaints and psychological factors. Also, details regarding school furniture were ascertained by the chair feature checklist<br>• After applying the questionnaire, logistic regression was used to assess the relationship between the variables | + Properties of the school furniture, such as the chair height being too low, were significantly associated with neck and upper back pain. Also, the backrest position was associated with lower back pain, but also other factors, such as emotional problems. The results of this study suggest that inadequate school furniture can contribute to the onset of pain in schoolchildren |
| | Ramadan (2011) | *n*: 124 | Quasi-experimental design | • Six sets of chairs and tables were used during three different activities (reading, writing and looking at the blackboard) and were the independent variables<br>• The dependent variables were evaluated. Mismatch between student body dimension and classroom furniture were measured for seat height and desk height. Evaluation of back force at the 5th lumbar vertebrae and the 1st sacrum (L5/S1) as well as subjective measures of discomfort were made | + Too low or too high chair and table heights relative to the students' body dimensions increased the stresses acting at L5/S1 as well as discomfort ratings. Also, the school furniture set with a better level of match presents the lowest levels of discomfort and was significantly less biomechanically stressful compared to the others for reading and looking at the blackboard |

| | | | | |
|---|---|---|---|---|
| | yr: 6–13<br>c: Saudi Arabia | | | |
| Skoffer (2007) | n: 546 subjects<br>yr: 14–17<br>c: Denmark | Cross-sectional survey with retrospective information on complaints | • Low back pain (LBP) survey. Anthropometrical measurements (body height, body weight, body mass index, length of the trunk, femoral length and crural length) and measurements of the school furniture were performed<br>• The relationship between body dimension and dimensions of the school furniture were computed | – LBP occurrence was not associated with the types or dimensions of the school furniture or body dimensions |
| Straker, Briggs, and Greig (2002) | n: 33<br>yr: 4–17<br>c: Australia | Quasi-experimental design | • A 2 × 3 × 2 mixed model design was used with one within subject factor (workstation set-up – standard and adjusted) and two between subject factors (age group – younger, middle and older; and gender – male and female)<br>• Workstation set-up, standard and adjusted, was used to assess the effects on the upper quadrant posture of the sagittal plane (head tilt, neck flexion, trunk flexion and gaze angle) and muscle activity was recorded from left and right of the cervical erector spine and upper trapezius muscles | + The adjustments resulted in increased head tilt, neck flexion, gaze angle, cervical erector spinae activity and a trend for lower right upper trapezius activity. The recent evidence that suggests more head and neck flexion is not necessarily worse is discussed and normative values for children's head tilt and neck flexion presented |

times. Another dependent variable that was considered in six of the reviewed studies but did not fit with the categories proposed in the present review was the variable 'preference'.

In all of the reviewed studies, the primary research approaches were quasi-experimental and experimental, observed in 10 studies each, followed by a cross-sectional study, used 5 times.

### 3.1. Effect of classroom furniture on students' performance

Of the studies that investigated effects on student performance, only three were reviewed that met the inclusion criteria (Table 2). These studies used an experimental or quasi-experimental approach, and the dependent variables motor skill performance, writing quality, word productivity and academic performance were equally assessed one time each.

### 3.2. Effect of classroom furniture on students' physical responses

The effect of school furniture on the children's physical responses was the most studied variable in the reviewed papers. Thus, and to fulfil the requirement of the publishing process, Tables 3, 4 and 5 present the synthesis of the studies according to the independent variables categories.

In Table 3, the most studied dependent variable was discomfort/pain. The positive results included five of the seven reviewed papers.

Regarding design (Table 4), three studies presented positive results using various interventions such as a standing workstation, high furniture and tilted seat and table.

Table 5 represents the reviewed papers regarding the effect of the design and dimensions of classroom furniture on physical responses. The most studied dependent variables were posture and discomfort/pain. It is also important to acknowledge that preference was considered three times, identical to the number of times the previously mentioned variables were considered.

### 3.3. Effect of classroom furniture on students' performance and physical responses

None of the reviewed studies that investigated the effect on students' performance and physical responses (Table 6) presented dimension as an independent variable. Design was considered in two studies, and three studies were reviewed that met the inclusion criteria of design and dimension.

Table 4. Synthesis of studies referring to the effect of design classroom furniture on students' physical responses.

| Independent variable | Authors | Number (n), age (yr), country (c) | Research design | Study description | Relevant results |
|---|---|---|---|---|---|
| Design | Benden et al. (2013) | n: 42 | Pilot study, quasi-experimental design | • Two classrooms that contained stand-biased workstations (15 students) featured a footrest and a stool, allowing the students to sit when desired and were adjusted to each student. The other two classrooms had traditionally seated workstations (27 students)<br>• A postural analysis based on the Portable Ergonomic Observation (PEO) method was used three times at 10 min intervals for a total of 30 min of observation for each student<br>• A body part discomfort survey was applied | – No significant difference was found between the two groups and time spent in non-preferred postures and body discomfort |
| | | yr: 7–9 | | | + The children using stand-biased workstations reported less discomfort overall |
| | | c: USA | | | |
| | Gonçalves and Arezes (2012) | n: 20 | Quasi-experimental design | • The sitting posture of the schoolchildren was video monitored during several activities, such as reading, writing and painting tasks, copying from a blackboard and working with a laptop computer. These activities were conducted during a 45 min period using three different types of school furniture (15 min each): (a) traditional furniture (a flat table and chair with a 5° backward tilt), (b) a traditional chair (with a 5° backward tilt) and a table (with a 12° tilt) and (c) a chair with a seat sloped 12° forward and a table top tilted 12°<br>• The methodology used to analyse the posture was that proposed by Murphy, Buckle, and Stubbs (2002) | + The combination (c) presents the higher percentage of observation time, with the angle tight-trunk over 90°. The same combination seems to be the most favourable for neck flexion. Despite the fact that combination (b) is the second safest combination, 95% of the children expressed it as the most comfortable combination |
| | | yr: 2nd to 4th grade (age not specified)<br>c: Portugal | | | |
| | Hinckson et al. (2013) | n: 30 | Experimental design (controlled trial) | • Two intervention classes (n: 23) received standing workstations; one control class retained usual sitting desks (n: 7)<br>• The children wore ActivPAL monitors over 7 days at baseline and during the fourth week of the intervention.<br>• Subjects completed the Nordic musculoskeletal questionnaire about musculoskeletal aches and pains<br>• Semi-structured interviews were conducted after interventions with two teachers, the principal and two parents, as well as focus groups with 16 children | + A small reduction in sitting time, a very likely large increase in standing time and a very likely reduction in the number of transitions from sitting to standing for the intervention group compared to the control |
| | | yr:10 | | | + The children spoke enthusiastically of the standing workstations and reported little to no musculoskeletal pain or fatigue |
| | | c: New Zealand (Auckland) | | | |
| | Linton et al. (1994) | n: 67 | Experiment; prospective comparison | • Two classes (n: 46) were randomly assigned to the experimental group (especially 'high' furniture) and one class (n: 21) served as a control group (standard furniture)<br>• In both groups, two questionnaires regarding different issues such as posture, comfort furniture, school interest and health problems were completed<br>• Sitting behaviour was observed twice before and after the intervention as well as at a 5-month follow-up periods | + The high furniture type was evaluated positively by the children and the group of children who sat on it experienced less back, neck, headache and fatigue than the control group |
| | | yr: 10 | | | +/– However, their posture did not improve. One half of the children improved their attitudes hugely, the other half did not |
| | | c: Sweden | | | |

**Table 5.** Synthesis of studies referring to the effect of design and dimension classroom furniture on students' physical responses.

| Independent variable | Authors | Number (n | Research design | Study description | Relevant results |
|---|---|---|---|---|---|
| Design and dimension | Aagaard and Storr-Paulsen, 1995 | n: 144<br>yr: 7–11<br>c: Denmark | Experi-mental, prospective comparison | • In the first phase, the 144 children had almost identical school furniture. In the second phase, according to a random allocation, the children received one of the three different types of school furniture (Type A: standard height, horizontal work surface; Type B: taller chair, forward sloping seat, adjustable desk height, slanted work surface; Type C: standard height, slanted work surface)<br>• The authors were present in order to explain the correct use of the new furniture and to make sure that it was adapted to the individuals<br>• All of the children were interviewed twice about the comfort of the furniture and the level of pain using a structured questionnaire. The test duration was about 1 month | – No difference was found in perceived physical complaints<br>+ Type B was evaluated as being significantly better than Types A and C regarding reading position, table height, back-rest, chair height and global comparison<br>+ Slanted desk-top surface was perceived to be significantly positive, independent of the height of the furniture (Type B and C) |
| | Saarni, Nygård, Rimpelä et al. (2007) | *n*: 97<br>yr: mean 12 and 14 for 6th and 8th grade, respectively<br>c: Finland | Quasi-experimental design | • Students were followed for one year. The intervention group/school (*n*: 47) received a new workstation (adjustable height saddle-type chairs with wheels and adjustable desks with comfort curve for the body). The control group/school (*n*: 50) continued using their conventional workstations. Some workstations were adjustable by height and desk slope<br>• Working postures were analysed using modified OWAS for a part of each group ($n = 21$, both groups), by means of video recording at baseline, before new workstations were introduced and during follow-up | + There was a significant increase in upright back and neck postures in the intervention group compared to controls during follow-up. The saddle-type chairs allowed significantly greater trunk-thigh angles among participants compared to conventional chairs<br>+ Using individually adjustable saddle-type chairs and desks improved working postures compared to the use of conventional workstations |
| | Saarni, Rimpela et al. (2009) | *n*: 43<br>yr: mean 12 and 14 for 6th and 8th grade, respectively<br>c: Finland | Quasi-experimental design | • Students were followed for 26 months. The intervention group/school (*n*: 23) received new workstations (adjustable height saddle-type chairs with wheels and adjustable desks with comfort curve for the body) and the match was ensured by regular adjustments on average once every 2 months. The control group/school (n: 20) continued using their conventional workstations; some workstations were adjustable by height and desk slope<br>• Musculoskeletal strain was gathered using the modified Borg scale once a day over one school week<br>• Musculoskeletal pain was assessed through a self-administered questionnaire using VAS | – No difference was found in physical symptoms between the control and intervention groups. However, the intervention group reduced exposure to ergonomic furniture by half |

(*Continued*)

**Table 5.** (*Continued*)

| Independent variable | Authors | Number (*n*), age (yr), country (c) | Research design | Study description | Relevant results |
|---|---|---|---|---|---|
| | Saarni, Nygård et al. (2009) | *n*: 43 | Quasi-experimental design | • Students were followed for 2 years. The intervention group/school (*n*: 26) received a new workstation (adjustable height saddle-type chairs with wheels and adjustable desks with comfort curve for the body) and the match was ensured by regular adjustments on average once every 2 months. The control group/school (*n*: 21) continued using their conventional workstations; some workstations were adjustable by height and desk slope.<br>• Spine positions and mobility were analysed (using a digital goniometer) four times, one before new workstations were introduced and three times during the follow-up<br>• Also, preference was assessed through a self-administered questionnaire using the visual analogue scale | – Lumbar lordosis, thoracic kyphosis and lumbar and sacral mobility did not differ between the intervention and control groups during the 24-month follow-up. However, in both groups the intra-group 12- and 24-month follow-up was statistically significant regarding time effects |
| | | yr: mean 12 and 14 for 6th and 8th grade, respectively | | | +/- New workstations were considered significantly better compared to the conventional workstation during the first 12-month follow-up. However, the effect was temporary and no difference was seen between the two groups in the second 12-month period |
| | | c: Finland | | | |
| | Schröder (1997) | *n*: 257 subjects | Quasi-experimental design; prospective comparison | • Two different types of school furniture were tested. The 'standardized school furniture' with different size variations for different body sizes and the 'non-standardized school furniture' with a higher seat and desk, equipped with a horizontal bar serving as a foot rest. Also, the seat is made up of two parts: a horizontal rear part and a front part with a slanting angle of 15°.<br>• The variable 'posture' was assessed by the classification of the movements and postures on the basis of a catalogue of 45 min per child | – The 'non-standardized school furniture' children showed less variation in foot movement. Especially with younger children, certain extreme postures were significantly less often assumed due to the type of furniture limits and the opportunities to interrupt monotonous permanent postures |
| | | yr: 7–9; 15–17 | | | Furthermore, the results suggest that the 'standardized school furniture' allows for a greater variety of postures |
| | | c: Germany (Kiel) | | | |
| | Troussier et al. (1999) | *n*: 263 | Case-control study, retrospective comparison | • Four or five years using one of these two different types of school furniture: the 'ISO standard furniture' with only one size (*n*: 125) and 'Mandal's furniture' which was adjusted each year according to the body size of the children<br>• All of the children answered a self-administered questionnaire regarding a subjective assessment of the furniture as well as physical complaints since the beginning of primary school and the point prevalence within the previous week<br>• Physical examination was made and was focused on scoliosis, kyphosis and stiffness of the hamstrings and lower back | – There were no significant differences in physical symptoms (pain) between the two groups |
| | | yr: 8–11 | | | – Also, the physical examination showed no differences between the two groups |
| | | c: France | | | + However, 'Mandal's furniture' scored better at writing posture and comfort |

**Table 6.** Synthesis of studies referring to the effect of classroom furniture on students' performance and physical responses.

| Independent variable | Authors | Number (*n*), age (yr), country (c) | Research design | Study description | Relevant results |
|---|---|---|---|---|---|
| Design | Benden et al. (2011) | *n*: 58<br>yr: 4th grade (age not specified)<br>c: USA (Texas) | Prospective experimental study | • The two treatment classrooms were converted into stand-sit workstations with stools, whereas the control classrooms remained unaltered for the entire school year<br>• Students were monitored with calorie expenditure measuring Body-Bugg armbands worn for 10 days in the fall and spring | + Students in the treatment group burned 17% more calories than did those in the control group<br>+ Interviews with teachers and parents of the students in the treatment group indicated a positive effect on child behaviour and classroom performance |
| | Blake, Benden, and Wendel (2012) | *n*: not specified<br>yr: 6 to7<br>c: USA (Texas) | Quasi-experimental pilot study | • Before the start of the fall semester, the two treatment classrooms were outfitted with stand/sit workstations and stools, and the third classroom was outfitted before the start of spring semester. The two control classrooms remained outfitted with the conventional furniture. Students were assessed four times throughout the school year<br>• Each student in the control and treatment groups was outfitted with a Body-Bugg to measure caloric expenditure for five consecutive days | + The stand/sit workstations increase passive calorie burn compared to regular workstations<br>+ The study also revealed possible behavioural effects related to students' attention and behaviour in the classroom |
| Design and dimension | Knight and Noyes 1999 | *n*: 21<br>yr: 9–10 | Experimental design | • Repeated measure design was used with the children's on-task and sitting behaviour observed over a 2-week period with their original classroom furniture, and then with their new furniture for a further 2 weeks (chair and Table 2000). The new chair provided a seat that sloped slightly back but with a somewhat deeper and shallower curving front edge than older conventional seating, and introduced a protruding back support approximately halfway up the rigid back of the chair<br>• Three observers were instructed in the criteria for 'on-task/off-task' and 'standard/non-standard sitting' behaviour (defined according to whether the feet were placed on the floor in front of the chair)<br>• A structured interview format was used for collecting information on individual children about comfort, preferred sitting positions and back pain using five-point Likert scales. In addition, children were asked their preferences for chair design by sitting on the three chairs and then ranking them for comfort | + The children showed a modest but significant improvement in on-task behaviour following the introduction of the newly designed furniture<br>+ The chair and Table 2000 resulted in a highly significant reduction in non-standard sitting behaviour. The popliteal/seat height relationship suggests peaks of non-standard sitting when popliteal height is either a few centimetres less than seat height or when it is in excess of 5 cm. The greater the seat depth compared to upper leg length, the less likely the child will be able to make effective use of the back rest |

(*Continued*)

**Table 6.** (*Continued*)

| Independent variable | Authors | Number (*n*), age (yr), country (c) | Research design | Study description | Relevant results |
|---|---|---|---|---|---|
| | | c: UK | | | +/− Chair preference was mixed; attitudes towards chair 2000 were rather polarised. The children either liked it 'best' or 'least of all' |
| | Koskelo, Vuorikari, and Hänninen (2007) | *n*: 30<br>yr:16 to 18<br>c: Finland | Quasi-experimental design, prospective comparison | • A comparison of the effects over 24 months of two types of school furniture. Control group: old non-adjustable traditional standard horizontal school desks and horizontal chairs. Intervention Group: adjustable saddle chair without backrest and five wheels. The desk was adjustable and could be tilted<br>• Assessment of posture, trunk muscle activity and strength, pain, furniture preference and academic performance. | + Intervention group of students' sitting postures standing kyphosis, scoliosis and lordosis became significantly better, both before and after growth cessation<br>+ Trunk muscle strength increased in intervention students whose muscle tension during classes fell significantly in the trapezius, whereas in the control students, lumbar tension increased<br>+ The neck-shoulder pains significantly decreased in both groups, but more in the intervention group<br>+ Intervention students reported that they experienced benefits from the adjustable tables and chairs. They also received significantly better overall marks |
| | Wingrat and Exner (2005) | *n*: 63<br>yr: 8–9<br>c: USA (Baltimore) | Experimental pilot study | • Three groups of 4th grade students were observed during their math class (55 min), four times in each of three conditions. The baseline condition consisted of a large chair and desk. The first intervention condition involved the same configuration as the original furniture but with the original furniture replaced with new appropriate-sized furniture. Furthermore, the desks presented a slight concave curve in the front and the chairs featured a convex and flexible back support. In the second intervention condition, the new furniture was placed in horizontal rows facing the front of the classroom<br>• The dependent variables were on-task and sitting behaviours using a checklist and observation form called Observing Pupils and Teachers in Classrooms (OPTIC). This instrument considered the position of the pelvis, feet, trunk, forearms and arms | + The children demonstrated better sitting and task behaviours when seated in the furniture of the intervention condition (it fit them better and presented convex and flexible back support)<br>+ Also, the same results were shown for task behaviours |

## 4. Discussion

The purpose of this study was to assess, by a critical review, whether school furniture characteristics, specifically dimensions and design, affect students' performance and/or various physical responses such as posture, reported pain, discomfort or other similar physical conditions. Reviewing the 25 papers selected according to the defined criteria indicates that there are some positive signs because 68% of the reviewed papers present positive results. These results are consistent with the review from Grimes and Legg (2004), who examined the literature on student posture in classroom environments and indicated that student posture, anthropometrics and furniture; computer use; pain reporting; and vision may influence the prevalence of musculoskeletal disorders among students. However, these results are different from the findings presented by Yeats (1997), who demonstrated only the effectiveness of ergonomic school furniture on schoolchildren in the single study reviewed. One possible explanation for this difference may be that 23 of the 25 reviewed papers in the current study were published after 1997.

Contextual factors varied greatly across the studies reviewed. However, the primary reason for engaging in this research was to determine whether school furniture affects the well-being of children – in scholastic performance, related measures or in their physical characteristics. In this section, the primary review findings are discussed separately according to each dependent variable, i.e. the effects on student performance, the effects on physical responses and the effects on performance and physical responses combined.

The authors realised that the diverse nature of the studies and the variables used in the reviewed studies were quite different, even when testing similar variables, and that different approaches have their strengths and weaknesses. Furthermore, there are many differences regarding the timeframe. For example, Benden et al. (2013) used a quasi-experimental design with a 30-min timeframe, and Troussier et al. (1999) used a case-control study with a retrospective comparison during four or five years of interventions. Despite the large differences in timeframes, the majority of the studies took less than six months (20/25 studies). Some features of the studies are also discussed for each dependent variable.

### 4.1. *Effects on students' performance*

Two of three studies concluded that performance was improved when students were seated in conditions different from 'normal' school furniture; the third did not observe any changes. The positive results were obtained when the independent variables dimension (Smith-Zuzovsky and Exner 2004) and design (Schilling et al. 2003) were manipulated. A common particularity identified in two of the three papers was that the analysed population comprised children with behavioural (ADHD) (Schilling et al. 2003) or neurological problems (cerebral palsy) (Ryan, Rigby, and Campbell 2010); thus, the findings may have been affected by their different physiology or sensitivity. The results of Ryan, Rigby, and Campbell (2010) show no differences in legible word productivity when the design and dimension variables were manipulated. Contrary to these results, Parush, Levanon-Erez, and Weintraub (1998) concluded that ergonomic factors such as sitting posture and positioning significantly affect handwriting performance.

The two studies that observed an effect on performance presented a significant difference between the considered samples, not only because of the type but also because of the number of participants. Schilling et al. (2003) used only three subjects with ADHD seated on therapy balls. Because the sample was small and used different physiology or sensitivity, the results should be read with caution. Furthermore, one may hypothesise that the therapy ball would facilitate 'dynamic sitting' because of children with ADHD increasing in-seat behaviour. However, the study by Kingma and van Dieën (2009), with a sample of 10 females, showed that the beneficial effects of more dynamics because of sitting on an exercise ball are questionable as far as the spine is concerned. Furthermore, the advantages of the physical loading of sitting on an exercise ball may not outweigh the associated disadvantages.

It was observed during the review conducted for this study that few authors have focused on the effects that school furniture characteristics may have on school activity performance, particularly using large samples, with the exception of Smith-Zuzovsky and Exner (2004). There are several reasons for this situation. First, it can be difficult to get all teachers to participate. Another factor that could reduce the validity of these studies is the several extraneous variables associated with school activity performance, which may also influence the results, such as the well-known Rosenthal and Hawthorne effects and socio-economic and psychological factors that may affect pain perception (Murphy, Buckle, and Stubbs 2007). Finally, another reason may be the explanation of Koskelo, Vuorikari, and Hänninen (2007), who stated that the type of studies with physiological and other follow-up measurements are possible only in small schools because, for example, the Finnish curricula today include many elective subjects, which are taught in specialised classrooms. The students in large schools generally move several times per day to different classrooms, which often are located in different buildings. This situation is corroborated by the studies of Saarni, Rimpela et al. (2009).

In the future, it would be interesting to see long-term prospective studies that assess performance associated with the use of new and improved furniture in school populations, assessing student performance as well as some behavioural issues.

### *4.2. Effects on physical responses*

The effect of school furniture on children's physical responses was the most studied variable in the reviewed papers. Physical responses include discomfort/pain, electromyography (EMG), energy expenditure and posture, which were studied either as a component of the entire body or as a specific body segment (i.e. trunk, neck, head and legs). Considered in Tables 3–6, the most studied dependent variables related to physical responses were posture and discomfort/pain, assessed 12 times; followed by energy expenditure and EMG, assessed 2 times; and physical examination, assessed once. Posture assessment techniques were generally conducted using observational analysis by video recordings, which later were analysed using postural analysis methods or biomechanical strain criteria such as joint angles.

With few exceptions, such as the work of Brewer et al. (2009) and Skoffer (2007), nearly all of the studies reviewed observed that a change in school furniture dimensions (better fit or match) resulted in an improvement in posture, EMG and discomfort/pain (Table 3). However, Skoffer (2007) noted that

> the idea function limiting LBP was positively associated with sitting on an adjustable chair at school. Using an adjustable chair as a cause of LBP is not probable. Rather, the explanation of this finding could be that the schoolchildren most bothered by pain had requested or had been offered an adjustable chair.

However, another explanation that could change the results and was not considered by the author is whether the students knew how to adjust the school furniture. This point is important because students do not automatically sit properly in ergonomically designed furniture; children require proper instructions and adjustment (Linton et al. 1994).

The positive overall results obtained when the school furniture dimensions fit the students' anthropometric measure (six of eight studies) indicate the necessity to pay closer attention to the students' anthropometric characteristics and to use adjustable furniture with proper instruction. However, implementing adjustable chairs and tables within every classroom is an expense that many school budgets may not be able to assume (Shinn et al. 2002). Because adjustability may be an expensive solution, scalability using school furniture standards became a cheaper solution. Furthermore, to avoid high levels of mismatch, school furniture standards must be updated over time because of the positive secular trend (Castellucci et al. 2014b).

Regarding design and physical responses, three of the four reviewed studies presented positive results. The modification of table and chair tilt presented positive results (Gonçalves and Arezes 2012). This result is reinforced by the study presented in Table 5 from Aagaard and Storr-Paulsen (1995). Additionally, the idea of high furniture and standing workstations appears to be beneficial regarding discomfort/pain. Furthermore, the standing workstation results could be supported by the fact that being seated for a long period of time on school furniture is associated with reports of musculoskeletal discomfort and pain (Fallon and Jameson 1996).

The four reviewed studies (Linton et al. 1994; Gonçalves and Arezes 2012; Benden et al. 2013; Hinckson et al. 2013) have some weaknesses that could have contributed to those results; thus, a small sample size, no random allocation of participants to experimental groups, a small observation time and lack of training on proper posture criteria were required.

Studies referring to the effects of the design and dimensions of classroom furniture on physical responses (Table 5) were expected to have high levels of positive results because design and dimension were examined independently. However, only one of the reviewed studies presented positive results. One explanation may be that 3 of 6 of the reviewed studies came from the same authors, Saarni, Rimpela et al. (2009), Saarni, Nygård et al. (2009), Saarni, Nygård, Rimpelä et al. (2007) and the study description was nearly identical (Table 5). Only one of the mentioned studies presented positive results regarding posture, using OWAS for the evaluation. Conversely, the variables discomfort, posture (digital goniometer), preference and musculoskeletal strain did not present differences between the two studied conditions. It is important to note that the three studies shared identical limitations, which can affect the results, and there was no random allocation of intervention, high experimental dropout and reduced exposure to ergonomic furniture in the intervention group because of teaching arrangements. Finally, an important issue was that these authors advised the participants not to self-adjust the furniture to avoid a conflict between anthropometrics and workstations. The matches between the elbow-floor height and desk height and the matches between the trunk-thigh angle and the chair height for each participant were checked on average every 2 months.

Schröder (1997) concluded that the furniture with a higher seat and desk and equipped with a horizontal bar serving as a foot rest allowed less variation of posture, a condition that is identified as a risk factor for lower back pain (Kumar and Mital 1992).

### 4.3. Effects on both student performance and physical responses

Only two studies from the same group of authors (Benden et al. 2011; Blake, Benden, and Wendel 2012) took a different approach, which was to assess the effect of furniture in energy expenditure. These authors tested to determine whether the use of sit-to-stand school furniture caused an increase in caloric consumption. Both studies identified a significant effect when using furniture different from the furniture traditionally assigned to children, specifically furniture that encouraged stand-sit with stools. The authors also observed a positive effect in child behaviour and classroom performance. However, it is important to mention that no objective tool was used to assess students' performance.

Only three studies presented the four categories of variables. These studies point to a more comprehensive perspective on school furniture studies because these studies consider both the physical and the academic effects that school furniture can have on students, thus contributing to focus and assessment interventions in a more holistic and structured manner.

All of the studies present positive results but different intervention designs. Koskelo, Vuorikari, and Hänninen (2007) used an adjustable saddle chair and a desk adjustable in height and tilt. This furniture follows the principles of Mandal, presented early in the introduction section. The only limitation of the study was that there was no random allocation of participants to either control or experimental groups.

Wingrat and Exner (2005) indicated that the experimental chairs were advantageous to the students for at least two reasons: (1) the chairs were smaller so the students could place their feet on the floor and (2) the chairs were designed to support the curvature of the student's spine with the convex back rest, which then allowed for a more neutral pelvic position. The second reason may not be consistent with the opinion of Bendix et al. (1996), who indicated that the backrest may facilitate the forward movement of the buttocks and kyphosis of the lumbar spine to stabilise the trunk against the backrest. Mandal (1982) also argued that the need for lumbar support is one of the four fallacious design principles of sitting.

The featured design principles must enforce the changes in posture (Dynamic Sitting) from sitting to standing, including half-standing positions. To complete this mission, the desk has a tilt angle, a slight concave curve in the front and an adjustable height. A high saddle chair is desirable; however, both feet must be on the floor and without a foot rest to avoid less variation in posture, as presented in the study of Schröder (1997). If the saddle chair is not possible, the seat must be presented in two sections: (1) the rear section being horizontal and (2) the front section slanting at an angle of 15°. This type of seat is similar to the type used by the University of Nottingham and presents a series of advantages, including decreased spinal loading and reduced discomfort (Corlett and Gregg 1994).

Finally, as mentioned in the introduction and presented previously by Grimes and Legg (2004), improving school working conditions should include an integrated ergonomics approach involving micro and macro ergonomic factors. However, the results of this review are supportive of the conclusions that classroom furniture design and dimension are key factors, not only for physical responses but also for student performance.

## 5. Limitations of this review

A probable limitation of this review includes the search process itself, which may not have allowed the identification of all studies showing the effects of the design and/or dimensions of school furniture on students' physical responses and/or their performance. The wide variety of research approaches adopted by the reviewed studies also rendered it difficult to summarise and obtain relevant findings for topics such as performance, in which subjective methods were primarily used to analyse the corresponding effect.

## 6. Conclusion

The results of the review provide a clearer picture of one of the school micro ergonomics variables. Twenty-five studies considering the effect of school furniture design and/or dimension characteristics on the students' performance and physical responses were reviewed.

Of the studies that tested only school performance, two of three presented positive results. Those findings should be considered with caution, primarily because of the small sample sizes involved and the participants' characteristics, which included either behavioural or neurological issues.

Of the studies that assessed children's physical responses, most studies reviewed observed that a change in school furniture dimensions resulted in an improvement in posture, EMG and discomfort/pain, with the latter being the most studied dependent variable. Proper care should be taken when using adjustable furniture because a lack of knowledge regarding proper settings and/or out-of-date standards may contribute to negative effects.

Only five studies analysed the effects on both student performance and physical responses. All of these studies presented positive relevant results, specifically an increase in energy expenditure and better academic performance in class behaviour and attention span.

The overall results indicate that some school furniture findings must be highlighted: the school furniture must fit student anthropometric characteristics, and the desk must have the possibility of a tilt angle and a slight concave curve in the front, with a high saddle chair also desirable.

The considered papers focused on assessing the effects of school furniture in terms of the physical responses. Only a few studies examined the effect on performance or both physical responses and performance. Further research should be conducted detailing the dependent variables, specifically using more objective measures, such as academic performance complemented with controlled and prospective design, to ultimately clarify the positive effects of school furniture on performance.

## Disclosure statement

No potential conflict of interest was reported by the authors.

## Funding

This work was supported by the Fondo Nacional de Investigación y Desarrollo en Salud (FONIS) [grant number N° SA11I2105], Gobierno de Chile (National Fund for Health Research and Development, Chilean Government).

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