School Furniture and Anthropometric Fit, the Gap Between Theory and Practice

By Renate de Bruin & Héctor I. Castellucci

FEATURE AT A GLANCE:
School is the place where permanent habits of sitting are formed and settled. Considering this, it is fundamental that school furniture fulfills two fundamental variables: furniture Form and Dimensions. However, there are some issues that need to be addressed to implement the knowledge of anthropometry, ergonomics, and design related to school furniture. The intervention must have a systems-oriented perspective, following the principles of systems ergonomics or macro-ergonomics. Also, it is important to involve the different stakeholders and give a clear message related to the impact in productivity and well-being. Finally new standards need to considered dynamic sitting.

KEYWORDS:
school ergonomics, workstation, anthropometry, match, sitting

Students take part in one of the most sedentary occupations (Lueder & Berg Rice, 2008). Furthermore, poor sitting habits acquired during childhood are very difficult to change later in adolescence and/or adulthood (Yeats, 1997). In this workplace situation, school furniture is a key factor for the adoption of proper postures and, consequently, it has implications in the learning process. Considering the above, it is fundamental that school furniture fulfills the children's specific requirements (Savanur et al., 2007). For example, it should allow for the changing of postures (Yeats, 1997) and as a result, students will show better sitting and task behaviors from using furniture that fits their body size (Wingrat & Exner, 2005).

INTRODUCTION

To design and develop an appropriate school furniture, it is necessary to address two fundamental variables: school furniture *Form factor* and school furniture *Dimensions factor*. The Form factor is related to design characteristics such as tilt tables and seats, sit-stand furniture, table with slight concave curve in the front, saddle chairs, etc. The Dimensions factor is related to the scalability of the design to fit the anthropometrics of children of different age groups (often expressed in size marks), as well as the combination of relevant dimensions within each size mark that together define a well-balanced fit of the seating system as a whole, involving not only chair seating height, but also seating depth, legroom space, table-top height, and activities. The latter is especially imperative since the ratio of two anthropometric variables is not constant between individuals–as is often falsely assumed—but also distributed. This implies that a person with an average P50 popliteal height can very well have a P95 buttock-popliteal length (Molenbroek, 1994) and not all children with equal body stature will have the same popliteal heights (see Figure 1). Applying univariate (one-dimensional) statistics to multivariate (many dimensional) situations may therefore be the underlying cause of bad fit (Robinette, 2012).

Regarding School furniture dimensions, students are usually exposed to furniture with fixed dimensions, which makes it almost impossible to adjust to the "growing" anthropometrics along their school life and neither does it accommodate multidimensional fit very well. The main reason for not having height adjustable school furniture is mainly due to viability issues related to increased costs and maintenance requirements, both of great concern for the school system in general. School furniture also must withstand intensive use and practice learns that fixed furniture solutions are often also the most durable solutions. For the same reasons, standards use grading- or scalability-techniques, which are based on the use of different equations to define sizes (e.g., like clothing S, M, L, XL, and XXL).

A complicating factor of anthropometric accommodation through a system of several fixed size marks is that guidelines are needed to decide on an individual level what size would fit a student best. In the old days "age" generally was used as a guideline or main predictor of good fit. Because children of the same age can vary much in stature, this changed to "stature" later on. Currently "popliteal height" is regarded as the better predictor of correct fit over stature (Castellucci et al., 2015; Molenbroek et al.,

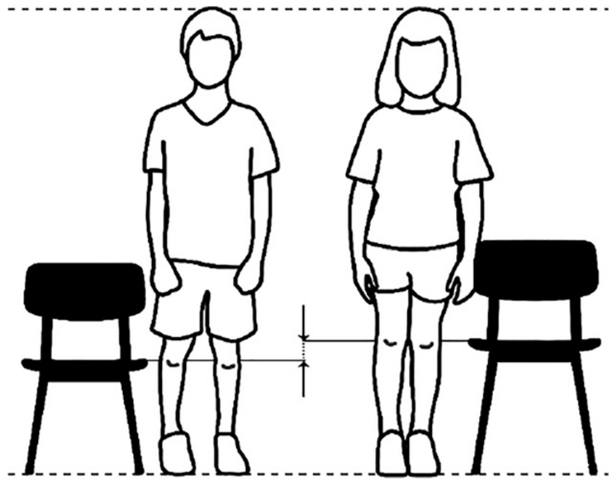

Figure 1. Stature and Popliteal height. Not all children with equal body stature have the same popliteal heights, and therefore the error in predicting furniture size using popliteal height is smaller than when stature is used. (Child dimensioned drawings by courtesy of Dimension.com).

2003). Nevertheless, these easy “univariate” guidelines may not always do justice to needs on “multivariate statistics” individual level.

In this article, we present some points that need to be addressed in schools to implement the knowledge of anthropometry, ergonomics, and design related to school furniture.

School Furniture and Its Stakeholders

In designing, developing and implementing an appropriate school furniture, obviously an important role exists for the discipline of ergonomics/human factors. Following Wilson (2014), we recognize that a systems-view is essential, though often current studies and interventions attend to a micro view on the human factors involved, often because of project boundaries due to impracticalities or resources. Consequently, a lot of studies on school furniture focus on the mismatch between furniture and child anthropometrics, though little research focuses on the topic from a broader perspective; How does the process of matching school furniture to the child take place inside a classroom, inside a school building, and within a school system? What kind of obstacles are hindering this process or in other ways cause suboptimal results? From a systems perspective these factors seem to define just as well, or even more so, the success of any intervention that intends to improve sitting behavior of children in schools.

Illustrative is the case as described in (Castellucci et al., 2016). Despite the legal obligation to comply with the Chilean Standard 2566, only one out of 18 analyzed schools used furniture size marks as indicated in beforementioned standard to match the anthropometrics of the pupils (aged 6–18 years). However, this school did not buy all size marks as indicated in the standard, though only 3 out of the 5. Furthermore, the same study concluded that there were high levels of mismatch between the school furniture and student anthropometric characteristics.

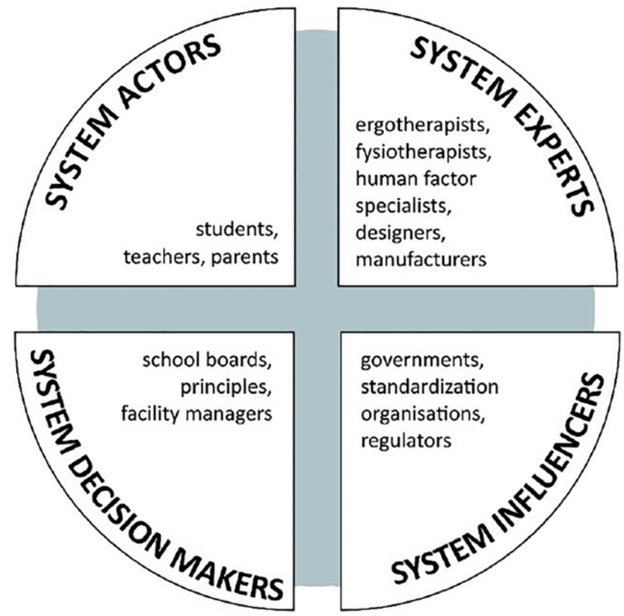

Figure 2. The four main system stakeholder groups of school furniture ergonomics.

Clearly academic correspondence on ergonomics of sitting does not reach practice. More academic study might not be the solution to overcome the gaps between theory and practice. It might be worthwhile to investigate what factors may hinder or facilitate “ergonomic” sitting in schools. And we must send out this message to the community. Also, we must send the message about ergonomics to the children themselves. For they are the adults, the actors, experts, decision-makers, and influencers of the future.

Applying the four main stakeholders groups (see Figure 2) as proposed by Dul et al.(2012), we recognize several crucial issues:

- System actors: students, parents, and teachers who are part of the system and who are directly or indirectly affected by its design and who, directly or indirectly, affect its performance.

What kind of obstacles do students, parents, and teachers encounter when it comes to school furniture at the moment, or how can they be involved to promote better ergonomics at school? It seems that increasing awareness about healthy sitting ergonomics is vital in this stakeholder group. When students are aware they can be the promoters of good ergonomics, because they literally experience the mismatch; they are the ones that know first when furniture does not fit anymore because they have outgrown it. Parents can help when

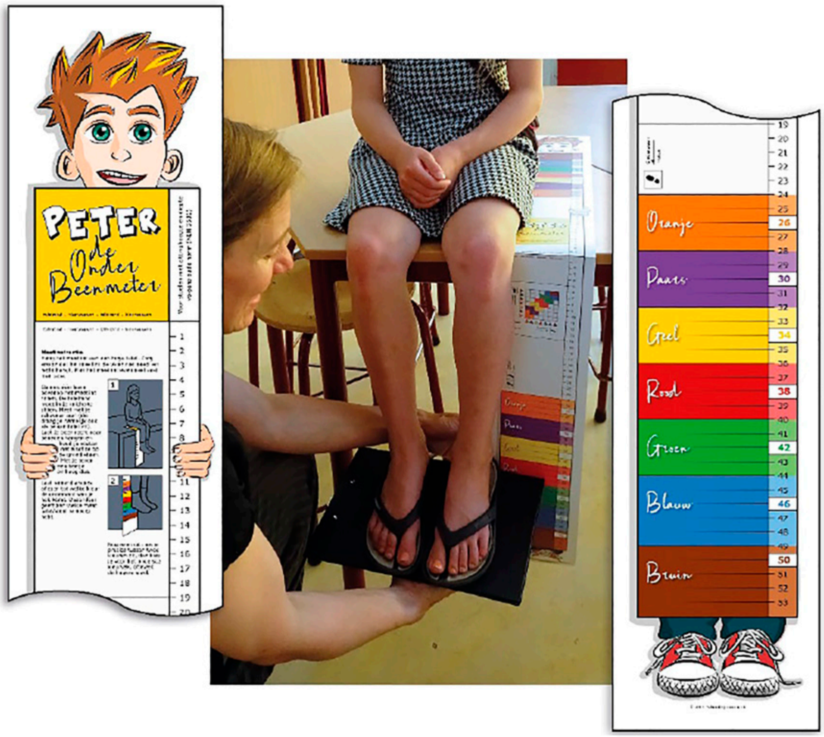

Figure 3. Measuring tool for finding fit between individual child anthropometrics and chair size mark.

representing the voice of their children's health and well-being to initiate the conversation needed with system experts or decision-makers. Teachers can help facilitate anthropometric measuring and logistics needed to accommodate every child to the right size mark or furniture adjustment. In order to be successfully adopted; however, these tasks should take only a minimal amount of time. Easy to understand measuring tools can help, especially when they tap into the child level of understanding (see Figure 3); children can even measure themselves and their enthusiasm will keep the teacher faithful to the method.

- System experts: physiotherapists, ergonomist, and other professionals who contribute to the design of the system based on their specific professional backgrounds by fitting the environment to humans (in case of adjustable furniture) and designers/human factor specialists, manufacturers (in case of fixed sized furniture).

The system expert's awareness of ergonomics/human factors is not a problem, providing clear guidelines and practical instructions for "fitting the product to the human" is needed though. For instance, experts are consulted when furniture needs to be adjusted to the child anthropometrics or they need to decide on correct size marks. Standards and literature certainly provide these guidelines only to a certain extent and often in academic language style, which make them less suitable for stakeholders with a more practical mindset. In addition, current guidelines focus mainly on anthropometric fit. Form design of school furniture (f.i. tables with or without drawers below tabletop), classroom organization (f.i. individual tables vs. shared tables, working in groups vs. working in rows), and type of activities (handwriting, reading, handicraft work or laptop use; different tasks may demand different table-top heights) are often neglected, but can be the cause of deviating from the guidelines either unconsciously by stakeholders (because they will seek the most comfortable situation) or consciously by HF/E experts that take into account the macro-ergonomics.

- System decision makers: Principles, school boards., etc. decision-makers about the requirements for the system design, the purchasing of the system, its implementation and its use.

On one side, decision-makers here are the people responsible for school budgets and purchase decisions, like school principals, school boards, and facility managers. On the other side, there are school furniture manufacturers that are decision-makers as well; they decide on the products that are available to purchase and what service is provided. Both can influence the outcome of the system as a whole. School furniture typically involves a high investment and depreciation/subsidiary arrangements are carried out over long time periods (f.i. in the Netherlands 20 yrs. for student sets, 40 yrs. for other types of furniture). Schools therefore must be provided with sound information on the amount and type of furniture that will fit their needs. That process, in itself, is already quite difficult since it involves knowledge on the anthropometric needs of a total school population, let alone the difficulty of forecasting what is necessary when needs change over time. To add to the complexity, schools currently base buying decisions on interior design aesthetics, for instance guided by interior design architects rather than human factor specialists.

Manufacturers could tap into this lack of proper guidance, for instance, through offering user manuals on how to use their products in a correct and healthy way. They could also offer services that provide maintenance, storage, and management of stock. In this way, they can not only build a strong connection with their markets but offer a constant ergonomics knowledge base, and a guarantee of up to date and sound furniture.

- System influencers: governments, standardization organizations, and regulators, who have general-public interest in work systems and product/service system design.

When it comes to regulations on school furniture there are national and international standards for school furniture. Historically, standards often are the result of many years of input of and deliberations between ergonomics/human factors/anthropometric experts and manufacturers. Childrens' anthropometric databases are rare and expensive to update regularly. The data used to build the standards, consequently, may not reflect secular trends in growth (such as obesity) very well, leading to yet another potential cause for mismatch.

For adults regulations are in place to ensure healthy working conditions, amongst other ergonomic furniture provisions. However, when it comes to children there is a poor base for regulations since they cannot be arranged under official "labor" conditions. Even though most system decision-makers still choose for furniture that is made according to standards, it also opens the way for schools to introduce furniture that does not meet those standards, also in settings for which standards are typically relevant.

Addressing Form Factor

In Chile, as in other countries, school furniture design form factor is defined in the Chilean Standard (Chs) 2566. Both, international and Chs 2566, are based on the posture proposed by the German designer Staffel at the end of the 19th century. Staffel's position is based on the principle that the hip, knee, and ankle joints must maintain an angle of 90°, also known as cubist approach (Dainoff et al., 1994). This posture, when maintained for a long duration, is known to generate several problems, amongst others: retroversion of the pelvis and rectification of the lumbar spine (Keegan, 1953); increase in intradiscal pressure at the spine's lumbar level; overall decreased movement capacity of the spine and reduced circulation in the legs due to lack of muscular activity (Stranden, 2000).

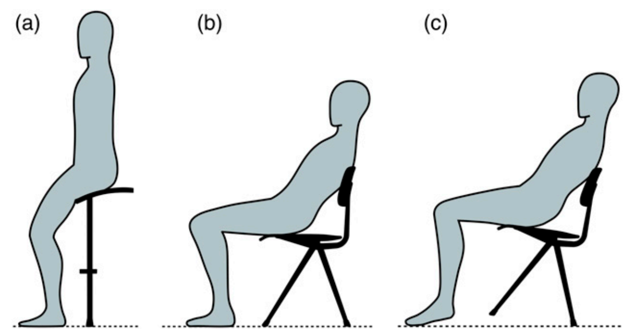

Figure 4. Different sitting postures.

In general, the equations currently in use to establish the school furniture dimensions and standards are based on Staffel's posture or cubist approach. This approach simplifies the communication of design recommendations, though from ergonomic design perspective certainly is not the holy grail. As Dainoff et al. (1994) puts it: "designs with highchairs and positive or anterior angles benefit users; however, they complicate the work of writing standards." The latter is illustrated by the current European standard EN 1729-1 (2015), which contains several annexes full of tables and figures to detail and dimension the size marks of high chairs and chairs with positive and anterior angles. Such complicated standards may jeopardize readability and comprehension, increase the risk of inconsistencies as well as blur what is mainly important; provide a well-balanced scaling system with even steps between size marks to optimally fit the variety within the population.

Alternative designs have used other approaches. Most studies on alternative school furniture design have based their designs on the position proposed by Mandal (1982), which seeks an angle close to 130° between the thighs and trunk without losing verticality, also known as "astronaut posture" (Figure 4(a)) (Castellucci et al., 2017). This position presents several advantages compared against Staffel's, mainly, an anteversion of the pelvis, thus maintaining the lumbar lordosis and decreasing intradiscal pressure, reducing postural risk (Noro et al., 2012). The "astronaut" posture is hard to attain while using "traditional" furniture (such as in all ChS 2566 furniture), since it is reached by sliding the gluteus anteriorly (Figure 4(b)) or leaning on the back legs of the chair (Figure 4(c)). This position of collapsing or swinging in the chair, could be considered as a compensation mechanism in order to get closer to Mandal's posture. The problem with postures in Figure 4(b) and (c), is that the possibility of carrying out some type of activities, such as reading or writing, is hindered.

Furthermore a recent review has shown that sit to stand workstations (dynamic sitting) most significantly impact behavioral changes (e.g., sitting for less time) and reduce discomfort (Chambers et al., 2019); while also tending to improve physiological (e.g., energy expenditure), psychological (e.g., work satisfaction), and posture outcomes. All the previous aspects are highly relevant, especially energy expenditure, when considering the worldwide obesity epidemic, which can be observed in Chilean adults and children (MINSAL, 2017; Vio del Rio, 2018).

It is important to mention that when the school furniture standards incorporate dynamic sitting it will be necessary to present a new procedure (equations) to generate good scalability/grading and ensure the match between school furniture and the anthropometric measurements of students at different levels (Castellucci et al., 2021). However, in the European standard (2015) there is also some attention for furniture that allows for a different—more open- and dynamic-postures. Problem there is that tables with dimensions become a lot more complex and are easily incorrectly filled or interpreted (or not used at all). It seems that when standards try to catch proper ergonomics into figures and tables, it can easily translate into a contra-productive outcome. From manufacturers' perspective, there is a need to test with certainty against numerical specifications and figures in standards to determine whether or not their furniture will be approved. However, from an ergonomics perspective, the rationale behind the figures often is much more relevant.

Addressing Dimensions Factor

The equations used to define school furniture dimensions (standards) or to evaluate the level of match/mismatch between anthropometric measures are used worldwide. However, it is not possible to define a convincing equation or special criteria for Desk Height, because of the contradicting needs of either enough vertical space for the legs—especially when furniture design has drawers beneath the tabletop—or a low enough desktop to support the arms at a correct position, the latter also dependent on the activities performed. Castellucci et al. (2014) showed that the interrelation between Desk Height and Seat to Desk Clearance can be contradictory, even in ideal conditions. From the data of 2261 students, the results showed that 37% of the students will use a higher than safely recommended Desk Height when using the current Chaffin and Anderson's principles (Chaffin & Anderson, 1991). This situation can also be explained by the different values of Elbow height sitting and Tight Thickness, where the latter is highly dependent on obesity and its increase in the population, which is the case of Chile (Vio del Rio, 2018). Therefore, it will be necessary to develop new equations for Desk Height, as it seems to be contradictory with the Seat to Desk Clearance equation.

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