Evaluation of three types of school furniture according to prEN 1729

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Abstract

Children, teenagers and college students spend a lot of time sitting at school. The aim of this study was to identify the most back and neck saving type of school furniture. Traditional seating (chair 45 cm, flat table 75 cm) was compared to upright seating (chair 0°, table 15°) and open hip angle seating (higher and 10° forward sloped chair, table 15°) according to the sizemarks of the European Standard draft prEN 1729. The sitting posture of 17 students was video monitored during writing, copying from a blackboard and watching a screen. Head tilt, flexion of the neck, trunk and hips were manually sampled. The open hip angle seating concept resulted in less hip flexion whilst writing and copying. Upright seating produced a more backward trunk lean watching the screen. A desk with a 15° inclination reduced the forward head tilt and the neck and trunk flexion, independently of the table height. The existing furniture provoked during none of the activities the best sitting postures. When designing or buying new school furniture, it is recommended to consider a slanted desk top, a forward sloping chair and different sizes of furniture corresponding to the body dimensions of the students.

Keywords: school furniture, sitting position, open hip angle

1. Introduction

Children, teenagers and college students spend a lot of time sitting at school. Mostly, they sit in a forward leaning position like during writing and painting. While resting or attending to the teacher, students adopt a backward position leaning against the backrest [1]. The design of suitable school furniture is complicated not only by the fact that school work involves a variety of tasks and postures, but also by the diversity of students' body dimensions [2].

There exists a substantial degree of mismatch between the sizes of the furniture and the anthropometric data of its users. For children between 7 and 14 years old, the chair is too high and too deep and the table is too high [3, 4, 5]. On the other hand, in the age group 12 to 18 years, it was found that the smallest students had the best fit. Taller students were more at risk of developing spinal pain [6].

To provide a better fit and to encourage good postures, the ISO 5970 standard was developed [7]. It provides functional sizes of chairs and tables for educational institutions derived from anthropometric data. Seven sizemarks should fit for the 900 – 1900 mm stature range. Although it is appreciated that pupils in school may adopt many sitting positions, a reference posture is defined to assess the fit of chair and table: sitting up straight with the feet flat on the floor, seat at popliteal height, the front edge of the table at elbow level and a backrest that supports the back in the lumbar region. This is called the upright seating concept.

However, few people can maintain this position for more than a few minutes. Mandal [8] proposes a higher chair with a significant forward tilt of the seat pan combined with a raised and tilted desk with an

inclination of 0-20°. This creates an open hip angle between the trunk and thighs and may decrease the load on the spine, especially in a forward leaning position. When sitting backwards the child leans against the backrest with the feet supported. The student can vary between two positions. This concept of open hip angle has led to the design of Back Up school furniture.

In adults it was already found that a forward inclination of the seat decreased the backward tilt of the pelvis and increased lumbar lordosis [9,10,11,12]. The muscle activity of m. Erector Spinae also decreased [13]. A desk with a 10° inclination required less trunk and neck flexion [14,15]. Schoolchildren subjectively preferred the Back Up furniture [16,17] and reported less musculoskeletal complaints [18]. They did not appreciate lower furniture with a backward sloped chair and a pronounced back support [19].

In 2004 a European Standard draft prEN 1729 -1 about the dimensions of school furniture was proposed to stimulate good sitting positions [20]. There are 8 sizemarks, so in one class room there are chairs and tables of different heights. The height of the furniture can be selected based on the popliteal height. This provides a better fit because the correlation between the body dimensions is not perfect. Children with the same stature can differ in popliteal height and so in best fitting sizemark [21]. Further are in the prEN 1729 all seating concepts are allowed: sitting at a horizontal, backward or forward sloped chair. A formula gives the corresponding dimensions.

The aim of this study was to compare these different seating concepts according to the measures of the European Standard draft. The sitting position was video monitored and analysed during different school activities. The existing furniture had a fixed height for all the students and served as reference. The hypothesis was that this would give the worst sitting positions during all tasks. The upright furniture with horizontal seat and sloped desk was expected to be beneficial during watching a projection screen. The child was supported by the backrest similar to the reference position of the ISO standard. The open hip angle furniture with forward sloped chair and tilted desk was thought to provoke the best postures during writing in a forward leaning position.

2. Methodology

2.1. Participants

Seventeen secondary school students between 16 and 18 years participated in this study. The parents and adolescents were informed and filled in a written consent. This age group was chosen because the growth spurt is at end, there are clear sex differences [22] and they sit for longer periods of time [1].

2.2. School furniture

Three types of furniture were compared. New adjustable desks were used for all the test situations to exclude placebo effects. The chair had fixed dimensions according to the prEN 1729 for each sizemark. The three largest categories covered the studied population.

Existing furniture. The chair had a flat surface of 45 cm high and 40 cm deep. This corresponded respectively with the average popliteal height plus shoe sole and the smallest buttock-popliteal length minus a margin to prevent pressure at the back of the thighs. The flat table had a height of 75 cm, which was 4 cm above the average sitting elbow height.

Upright seating furniture. The sizemark of each participant was chosen based on the popliteal height without shoes (table 1). In each category the smallest lower leg length determines the seating height. Every student could support the feet flat on the floor and sat at or below popliteal height. The table had a fixed inclination of 15°.

Open hip angle furniture. The front part of the seat pan was inclined 10° forwards. To prevent sliding the rear part remained horizontal. The seat was also treated with friction varnish. A slope of 10° was chosen because the corresponding values in the prEN 1729 were the most in agreement with the heights of the Back Up furniture. This resulted in 14 to 17 cm higher chairs and tables. The slope of the table was fixed at 15°. There was a footrest on the chair and the desk according to the prescribed heights of the Standard draft.

Table 1
Dimensions of the seating concepts according prEN 1729

Popliteal height	Upright seating		Open hip angle seating	
	Chair	Table	Chair	Table
200-250	210	400	290	480
250-280	260	460	350	550
280-315	310	530	410	630
315-355	350	590	460	700
355-405	380	640	500	760
405-435	430	710	570	850
435-485	460	760	610	910
+ 485	510	820	680	990

All dimensions are in mm.

2.3. Protocol

The students in this study wrote a text, watched a movie on a projection screen and copied a text from the blackboard in front of the classroom. These tasks were considered to be representative for real school activities and the adopted postures. Each task was performed during 5 minutes. After 15 minutes the furniture was adjusted and the participants could walk around. The sequence of the tasks and furniture was changed systematically to equalize the influence of eventual fatigue. A video camera (Sony DCR-PC350) was placed lateral to the students and monitored continuously the sitting postures. Afterwards, a two-dimensional image was captured every 15 seconds. With a graphical program (CorelDRAW 9) the angles between the body segments were measured. The average angles of each furniture during each task were compared using one-way ANOVA procedures. For the significant main effects a post hoc Tuckey test was performed to identify the specific mean differences. Results were defined as significant at $p<0,05$.

2.4. Video analysis

The students wore a tight short and singlet. Markers with a diameter of 1 cm were attached to anatomical landmarks: external auditory meatus, outer cantus of the eye, spinous process of C7, femoral greater trochanter, and the lateral condyle of the knee. The angles were defined as:

Head tilt. Angle between ear-eye line and a horizontal line. A negative angle means the head is tilted forward below a horizontal line.

Neck flexion. Angle between the line through C7 and external auditory and a vertical line.

Trunk angle. Angle between the line through C7 and the femoral greater trochanter and a vertical line.

Hip angle. Angle between the line through the lateral acromion and the femoral greater trochanter and the line through this trochanter and the lateral condyle of the knee.

3. Results

Table 2 shows the mean angles (SD) for each task and each furniture. The differences are mentioned below between parentheses and are statistically significant, unless mentioned otherwise.

3.1. Existing furniture

At furniture with average heights students bent their trunk more forward during writing and copying a text (3 to 5°). Compared to the other furniture with an inclined desk, the head (10°) and neck (8-9°) were also more flexed during writing. The hip angle was smaller while copying a text and watching TV (4 to 16°).

3.2. Upright seating furniture

Students leaned 8 to 9° more backwards watching the projection screen when they were sitting at the upright seating furniture. The hip angle showed no significant difference compared to the open hip angle concept. During this passive activity the neck was also less flexed (9 to 13°). The other tasks occurred in a forward sitting position. The posture of the head, neck and trunk were similar to sitting on a forward sloped chair. The hip angle however was significantly smaller (10 to 16°).

3.3. Open hip angle furniture

The furniture with a sloped chair and desk resulted in larger hip angles during active writing (16-18°) and the combination task (5-16°). Watching TV, this angle tended to be smaller, however not significant, compared to upright seating. Students bent the trunk less backwards (8°) and their neck more forwards (9°).

Table 2
Mean angles (SD) for each furniture and each activity

	Existing	Upright	Open hip angle
Writing			
Head tilt	-22 (15)	-12 (12)	-12 (12)
Neck flexion	80 (12)	72 (12)	71 (13)
Trunk flexion	18 (6)	14 (8)	14 (9)
Hip angle	77 (6)	79 (12)	95 (10)
Copying writing			
Head tilt	4 (14)	6 (16)	6 (9)
Neck flexion	61 (17)	59 (15)	55 (12)
Trunk flexion	18 (6)	14 (9)	13 (9)
Hip angle	80 (6)	85 (18)	95 (9)
Copying watching			
Head tilt	31 (6)	29 (8)	27 (10)
Neck flexion	45 (14)	43 (9)	46 (12)
Trunk flexion	15 (6)	11 (10)	12 (11)
Hip angle	82 (5)	86 (17)	98 (12)
Watching			
Head tilt	32 (9)	33 (6)	27 (12)
Neck flexion	39 (15)	26 (11)	35 (15)
Trunk flexion	-4 (17)	-13 (11)	-5 (15)
Hip angle	103 (16)	115 (12)	111 (14)

3.4. Writing task

During this active working task students bent their head and neck the most. The forward lean of the trunk was comparable whilst copying a text from the blackboard. The hip flexion was also similar except at the upright furniture (6 to 7° smaller).

3.5. Copying from the blackboard

The head tilt and neck flexion were more pronounced during the writing part than during the watching part of this combined task. The position of the head was comparable to this whilst watching a movie, the neck was more flexed (6 to 17°). The forward trunk lean and hip angle were similar for both aspects of the task. At the existing furniture the hips were flexed more than at the upright (4 to 5°) and the open hip angle (15 to 16°) seating concepts.

3.6. Watching on a projection screen

This backward leaning activity resulted in the least bending of the neck and trunk. The hip angle was clearly larger compared to the other tasks (13 to 36°).

4. Discussion

4.1. Existing furniture

The heights of the existing furniture were based on the average body dimensions of the target group. The chair and table were flat. This resulted during none of the activities in the best sitting position. The students flexed their head, neck and trunk more forwards compared to the other types of furniture whilst writing. This can be explained by the 15° inclined desktop.

Other research with adults found that a horizontal desk resulted in a forward bent position of the neck with the highest muscular loads [23]. With a sloped table of 10° the head and trunk showed a more upright posture whilst reading and writing [14,15]. The load on the back decreased with 29% and on the neck with 21% because of a lower gravitational moment. This inclination is easy to use whilst reading and is not an inconvenience when writing. Pens and paper do not slide down [14]. In this study the decrease in head tilt was 10°, in neck flexion 8-9°. The trunk remained 4° more upright. This is similar to earlier findings [14,15]. A larger inclination had no effect on the trunk angle and a relatively low effect on the neck [9].

Schoolchildren strongly preferred an inclined table top independently of the height of the furniture. The slope should be adjustable between 0° and 20° [16]. This makes it still possible for children to work together in groups with flat tables.

4.2. Upright seating concept

When the students were watching to the screen, their trunk was bent backwards at all types of furniture. Using a backrest reduces the pressure in the intervertebral discs [24,25]. It is favourable to adopt this posture at regular times during the day, because the load on the back is low [24].

Sitting according the upright seating concept showed the largest backward lean of the trunk. Because the inclination of the backrest was the same for all the chairs, this indicates that more students used the back support at the upright furniture. Only one student did

not use the backrest. As hypothesized this seating concept provoked the best sitting postures during passive activities. Though, the hip angle was not significantly different compared to a forward sloped chair. The open hip angle furniture also resulted in acceptable seating positions while watching the screen.

Upright seating showed also less neck flexion sitting backwards. At first sight this seems favourable, because the gross moment on spinal extensor muscles is reduced. However, for studies of postural analysis it may be more appropriate to interpret data relative to an individual's resting posture, rather than considering absolute segment postures. A resting posture may be the most efficient body position with a load optimization that minimizes overall stress on both active and passive tissues [26]. In this study the resting posture was not determined. Based on reference values summarized by Briggs et al. [27], the deviation of the neck from the resting posture would be more when students sat at the upright furniture. This results in muscular co-contractions to stabilize the spine and a less efficient length-tension relationship [28].

4.3. Open hip angle concept

The hypothesis was that this type of furniture would be advantageous in the forward working position. Indeed, the hip angle remained significantly larger during writing and copying a text form the blackboard. Because the angle between the thighs and the trunk remains larger than 90°, this concept is called "open" hip angle. A reduced hip flexion in combination with a forward sloped chair showed an increase of the lumbar lordosis. The natural curves of the adult spine were more preserved because a posterior rotation of the pelvis was counteracted [12]. This pelvic tilt is related to the lumbar curvature [10,11]. The natural curves of the spine distribute the load more equal on the vertebral discs and result in a more stable position [29]. The hip angle on a forward sloped chair is also related to the sitting height [10]. In this study the seat surface (horizontal part) remained 9-16 cm above the students' popliteal height.

Less hip flexion was shown while writing and copying a text from the blackboard. Even during this combination task, in which writing and watching had to be altered, students sat in a forward bent position. Schoolchildren spend 57% of the time sitting at school in this position against 43% leaning backwards [1]. During this most adopted and most back loading forward position the open hip angle furniture showed better sitting postures. The advantage was the most pronounced while writing. At the horizontal furniture the hips were clearly more flexed during the active working positions.

In this study, the dimensions of the higher and sloped furniture were based on the prEN 1729, to approximate the values of the Back Up furniture. The global assessment of the Back Up alternative was perceived clearly positive by 7 to 11 year old children [16,17,18]. Chair and table height, the reading position and the backrest were preferred subjectively. There was also a remarkable appreciation of the tiltable desk-tops [16]. However, no difference in the prevalence of back pain was found. All prolonged static postures caused undesirable physiological strain [17]. Linton et al. [18] noted a reduction in musculoskeletal symptoms and found the furniture to be significantly more comfortable. However, no clear improvement in actual sitting behaviour was observed.

4.4. Allocation of furniture

To become a good individual fitting the allocation of furniture should be based on an anthropometric dimension rather than on class year [30]. The prEN 1729 provides 8 classes of stature and popliteal height. Because children with the same body length can have different segment lengths, an allocation based on the popliteal height is more accurate [21].

However the relation with the buttock-popliteal length which determines the seat depth is also not perfect. A chair can have a good height, but this does not mean the seat depth is fitting. At the upright furniture some students could not touch the backrest sitting up straight. With the open hip angle furniture, the seat depth is less crucial because of the forward sloped chair. The table height was also found to be less critical for children, because they prefer a wide range of heights [31]. The popliteal height of the children needs to be measured twice a year to determine the best fitting furniture. [21].

5. Conclusion

The higher and forward sloped chair showed clearly larger hip angles during active working. The resting postures were also acceptable and less back loading. The inclination of the desktop resulted in a more neutral position of the head, neck and trunk compared to a flat table. The upright seating concept revealed a

more backward lean during passive activities. The flexed hips however in the forward postures are a burden for the spine, like at the existing furniture. In total, the open hip angle furniture was the most back and neck saving seating concept. The introduction of alternative furniture does not exclude other preventive measures as part of a multidimensional prevention program where exercise, ergonomics and psychosocial relationships are significant factors.

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