Are the desks and chairs at school appropriate?

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Abstract

The aim of the study was to find out how the measures of chairs and desks match with the anthropometrics of schoolchildren and how schoolchildren sit during a lesson in their classroom. This paper reports the baseline measurements of an intervention study. Participants of this study were 6th and 8th grade (12 and 14 year old) schoolchildren from two comprehensive schools in Finland (N=101, 57 girls and 44 boys). The main outcome measures were the differences between desk height and elbow-floor height, and chair height and popliteal height. Forty-three participants were randomized for sitting posture analysis by video recordings. The study showed that desks were on average 13 cm above elbow-floor height and chairs 2 cm below popliteal height. For 56% of time participants sat with their backs flexed >20º and/or rotated >45º. For 70% of time they sat with their necks flexed >20º or rotated >45º. The results indicate that there is a mismatch between school furniture and the anthropometrics of schoolchildren. Schoolchildren sit in disadvantaged posture for a substantial part of school lessons.

Statement of relevance: It is unclear how large a part inappropriate desks and chairs play in schoolchildren's sitting at poor postures. This study investigated whether schoolchildren have inappropriate workstations and if they sit in stooped or disadvantaged postures during lessons at school.

Keywords: schoolchildren, anthropometrics, sitting posture, desk, chair

1. Introduction

The appropriateness of school furniture has attracted wide interest during the last few years when research showed an increase in neck-shoulder pain (NSP) and low back pain (LBP) among teenagers (Currie *et al.* 2000, Hakala *et al.* 2002). A possible factor behind the increase could be sitting for extended periods in stooped, static or otherwise awkward postures at school, particularly when combined with increased sitting at computers, and a sedentary lifestyle in general.

Sitting posture as such, and stooped sitting posture in particular increases stress to spinal structures (Keegan 1953, Szeto *et al.* 2002, Vergara and Page 2002). The pressure on the lumbar intervertebral discs increases when the pelvis is rotated backward and the lumbar spine and torso are flexed (Keegan 1953, Andersson *et al.* 1974, Horst and Brinckmann 1981). Degeneration of the lower lumbar discs has been detected even among 15-year-old children, and children with disc degeneration or protrusion have LBP more frequently than those without (Salminen *et al.* 1995, Salminen *et al.* 1999). A longitudinal study of 24-26-year-olds showed that NSP is related to disc herniation of the cervical spine (Siivola *et al.* 2002). These results further emphasise the importance of good sitting postures at school.

Only few studies have concerned the appropriateness of school furniture and related it to schoolchildren's anthropometrics. A mismatch between measures of school furniture and anthropometrics has been reported in some studies together with a more disadvantaged sitting posture (more neck and back flexion and less hip angle) (Mandal 1982, Marschall *et al.* 1995, Murphy *et al.* 2003). Bruynel *et al.* (1985) reported that desks and chairs of schoolchildren aged 13-14 were too low in relation to their anthropometrics, whereas Parcells *et al*. (1999), Legg *et al.* (2003), Panagiotopoulou *et al.* (2004) and Gouvali and Boudolos (2006) claimed the contrary. It should be noted, however, that they used different criteria and the study populations differed by domicile, age and anthropometric dimensions. In the studies comparing ergonomic and traditional workstations (Linton *et al* 1994, Aagaard-Hansen and Storr-Paulsen 1995, Marchall *et al*. 1995 and Troussier *et al.* 1999), children preferred the ergonomic workstation and described it as more comfortable than the traditional one. According to Mandal (1982), ergonomically designed and adjusted desks and chairs at school had a significant effect on schoolchildren's sitting posture when working, while Linton *et al.* (1994) gave a contradictory report. Mandal (1982) emphasised that more attention should be paid to chair height and design in order to reach more upright postures of schoolchildren while sitting. The stress on the back could be reduced by sitting in a more upright posture and allowing for variation in postures and loads. Likewise, the use of armrests supports the weight of the arms thereby reducing disc pressure in the spine when working at a desk (Schüldt *et al.* 1986, Chaffin and Andersson 1991). Among adults, ergonomic workstation modifications and adjustments improved the postures of neck and upper back area while working in a sitting posture (Ketola *et al.* 2002).

Some studies have dealt with musculoskeletal symptoms and school furniture. Ergonomically designed chairs, like a curved seat, widening the angle between trunk and thigh and enhancing the lordotic curve, have reduced schoolchildren's musculoskeletal symptoms (Linton *et al.* 1994). In contrast, however, Troussier *et al.* (1999) compared two designs of desks and chairs among schoolchildren and found no difference in the prevalence of low back pain.

This paper is based on the baseline measurements of an intervention study. Its purpose is to study how conventional desks and chairs at school match with the anthropometrics of children and whether children sit in appropriate postures during lessons at school.

2. Methods

2.1 *Participants*

This study involved all 6th (age 12) and 8th (age 14) grade children of two Swedish speaking comprehensive schools in two Finnish cities. The total number of participants was 101 (57 girls and 44 boys). After written information to the parents, and both written and verbal information to the children and headmasters of the schools, written consent was obtained from parents, children and headmasters. The Ethics Committee of the Hospital District of Pirkanmaa approved the protocol.

2.2 *Anthropometric measures*

Height was determined as the vertical distance from the floor to the top of the head, and measured with the participant standing without shoes, erect and looking straight ahead. The plastic measuring instrument was situated on the wall and the participant stood with his/her back against the measuring instrument. Sitting height was determined as the vertical distance from the surface of the chair to the top of the head, and measured with the participants seated erect on a standard chair with flat horizontal surface (the quality of which was the same in both schools) with knees bent 90º and the back against the measuring instrument. Participants who didn't reach exactly to the 90º angle of the knees, elevated their heels slightly up and supported their legs on the balls of the foot so that their knee angle was 90^{o}. Weight was measured with digital weighing scales. Height, weight and sitting height were taken individually in the school nurse's room by the first author, trained in physiotherapy. A plastic ruler, metal right angle, wooden measure board and digital scales were used.

Elbow height (seated) was the vertical distance from the participants' seated surface to the tip of the olecranon (under the elbow), and measured with arm at side (0° of abduction) and elbow flexion of 90^{o}. Elbow-floor height (seated) was the sum of elbow height and chair height. Popliteal height (seated, with shoes) was the vertical distance from the floor to the posterior surface of the knee (popliteal angle, underside of knee). Elbow height and popliteal height were measured in the participants' regular classroom during lesson on the left side of the body by the first and third authors. The participant sat at his/her usual desk and chair during measurements. The dimensions were taken with a plastic ruler, metal right angle and wooden measure board.

2.3 *Measures of desks and chairs*

The desks and chairs were measured in the classrooms by the above-mentioned two researchers, while children sat at their usual chairs and desks. These dimensions were also taken using wooden and plastic rulers.

The desk height was the vertical distance from the floor to the top of the front edge of the desk, and the chair height was the vertical distance from the floor to the highest point on the rear end of the seat (almost all chairs were at the same level). These measures were used to define the differences between desk height and elbow-floor height and between chair height and popliteal height. The differences were reported by using means and also the lowest and highest values of the optimal differences according to the standards and guidelines.

2.4 *Reference standards and guidelines*

No guidelines on those optimal differences exist for children. The guidelines were designed for adults' workplaces with different types of worksites. The optimal differences were based on guidelines for work in which support of the arms is needed, and also for sitting worksite.

Measures of desks and chairs obtained in our study were compared with the existing standard for heights of chairs and tables meant for educational institutions (SFS-ENV 1729-1). Also the guidelines of the Finnish Institute of Occupational Health (1986) given for the optimal difference between desks/chairs and anthropometric measures were used as a reference.

2.5 *Video recording and analysis*

Video recordings were carried out during lessons in participants' regular classroom by the first author, and the video analysis group was a random sample of the entire group (N=43, 21 girls and 22 boys). During these lessons they had mathematics, Swedish, other languages, religious education or history. Recordings took place either during morning or afternoon lessons. One video camera was set up sagittally towards the chosen participant, and a second video camera was placed in the front or back of the classroom, diagonally towards the participant. The sagittal view camera covered the participant from thighs up to the top of the head. During the 45-minute lesson, recording focused on one schoolchild for an average of 37 minutes. The recording time varied on account of the participants' dynamic moving on and off the chair or of other children blocking the view.

Analysing children's working postures from video recordings is an appropriate quantitative method to evaluate loads on low back and neck-shoulder areas (Marschall *et al.* 1995, Murphy *et al*. 2002). The Ovako Working posture Analysing System (OWAS) is a tool used in posture analysis (Karhu *et al.* 1977). In this study, each videotape was analysed using the modified OWAS method. Observations of working postures were done at an interval of 15 seconds. The number of observations during one lesson (one child) was on average 134.

OWAS categories were modified to sitting postures at school as follows: back - straight, flexed, rotated, or flexed and rotated; upper limbs (arms) - neither supported, one supported, or both supported on desk; buttocks and lower limbs - buttocks resting on the rear of chair, front of chair, or standing or walking; neck - straight, flexed, or rotated. All postures were recorded in relation to an upright sitting posture. The neck and back positions were defined as flexed when flexion was >20º, and rotated when rotation was >45º.

2.6 *Outcome measures*

The difference between desk height and elbow-floor height was calculated by subtracting elbow-floor height from desk height. Likewise, the difference between chair height and popliteal height was calculated by subtracting popliteal height from chair height. These results were reported in centimetres.

For analyses, back and neck postures were classified as straight or flexed and/or rotated and correspondingly, postures of arms neither supported on desk or one/both supported on desk. The percentage of flexed and/or rotated postures of all recorded sitting postures was calculated for each child. The same percentage calculation was performed on supported postures. These measures were used as an approximate of the sitting time in each posture during a lesson.

All data was entered into SPSS 11.0 for Windows spreadsheets and percentages of the detailed variables and the differences between furniture dimensions and anthropometrics were calculated.

3. Results

The mean height of the participants (N=101) was 164.0 cm (SD 10.2). The boys were on average 5.7 cm taller than girls, 167.2 cm (SD 11.2), 161.5 cm (SD 8.7), respectively. The mean weight of the participants was 56.2 kg (SD 11.4), the boys were also heavier than the girls, 59.9 kg (SD 13.3), 53.4 kg (SD 8.8), respectively. The sitting height of the participants differed less between genders than height and weight; the mean sitting height was 85.2 cm (SD5.2), with boys 86.5 cm (SD 6.2) and girls 84.1 cm (SD 4.2).

Means and standard deviations in desk height and elbow-floor height are presented in table 1. Comparing desk height with the standard showed that the desks were on average five centimetres too high. The desk height was 12.8 cm above the elbow-floor height on average. When compared to the guidelines on optimal difference, the desks were on average 6.8 cm too high (table 1). In the 6th grade the difference was on average 14.9 cm (SD 2.2) and in the 8th grade on average 10.9 cm (SD 4.8), hence the deviance from the optimal was on average 8.9 cm and 4.9 cm, respectively.

Means and standard deviations in chair height and popliteal height are presented in table 2. The comparison of chair height with the standard showed that the chairs were on average 2.5 centimetres too high. The chair height was 2.1 cm below the popliteal height on average. When compared to the guidelines on optimal difference, the chairs were on average 2.1 cm too low (table 2). In the 6th grade the difference was on average -1.1 cm (SD 2.0) and in the 8th grade on average -3.0 cm (SD 2.6), hence the deviance from the optimal was on average 1.1 cm and 3.0 cm, respectively.

Despite the overly large difference between desk height and elbow-floor height, schoolchildren sat in flexed and/or rotated posture more than half of the time during the lesson. In girls, the proportion of time sitting neck flexed or rotated was higher than in boys, but the proportion of time sitting in back flexed and/or rotated was more equal. For 34% of the time, schoolchildren sat in back and neck flexed and/or rotated posture while they supported arm/arms on the desk (table 3) (figure 1).

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4. Discussion

The present study indicates that the school furniture did not match up with the schoolchildren's anthropometric measures on average. The desks were too high and chairs too low when compared to the guidelines (Finnish Institute of Occupational Health 1986). Our findings also agreed with those of Parcells *et al.* (1999) in that desks were too high. Despite the results of difference measurements, schoolchildren sat more often in flexed than upright postures. This may partly be explained by the fact that conventional chairs do not allow to maintain optimal lumbar curvature (Bendix 1984, Bridger *et al.* 1989).

Studies have shown that sitting in a normal stenographic type of chair with no back support increases the flexed posture of the lumbar spine. Consequently, the compressive forces on the low back increase. In general, multiple different postures and cycles between them exist in the lumbar spine during sitting with the result that the motion appears to prevent static loads on the spine (Callaghan and McGill 2001). One of the objectives of sitting ergonomics is to promote erect sitting posture that reduces load on the intervertebral discs and other structures of the back to a minimum. Improper design and inappropriateness of desks and chairs lead to an imbalanced and more kyphotic posture of lumbar spine and require more muscle control to maintain the upright stability and sitting posture (Keegan 1953). Consequently, schoolchildren have more difficulties in maintaining this kind of balanced sitting posture if they have the wrong size and design of desks and chairs (Mandal 1981, Mandal 1982, Marschall *et al.* 1995).

Already in the early 1980s, Mandal (1981) discussed school furniture and its effect on the health of schoolchildren's backs, especially concerning tall schoolchildren. In the present study, too low and on average horizontal chairs may encourage flexed sitting posture. Schoolchildren sat with back and neck flexed and/or rotated for on average 41% of the time. Girls sat in this bad posture more often than boys.

In the schools where our study was conducted, some desks and chairs were adjustable and desks tiltable, but only rarely adjusted to the size of the child. Having desks and chairs with more adjustability does not call for greater numbers in furniture. Also, the adjustability already available should be taken better advantage of. In some other studies there have been attempts to upgrade the design of desks and chairs so that they could be more appropriate and more easily adjustable (de Wall *et al.* 1991, Aagaard-Hansen and Storr-Paulsen 1995, Marschall *et al.* 1995, Knight and Noyes 1999). However, very few have taken into account the anatomical structures in their pursuit of better sitting postures (Bendix *et al*. 1985, Linton *et al.* 1994).

When changing from a standing posture to an unsupported sitting posture on a conventional, low chair while doing some work at the desk, the pelvis rotates backwards, lumbar lordosis becomes more kyphotic, hips turn more flexed, and the cervical spine becomes more extended (Bendix *et al.* 1985). Moreover, the unsupported sitting posture is unstable without an external support (backrest) due to the fact that balance is maintained by the muscles of the hip joint and trunk. Armrests provide another important body stabiliser. Sitting with arms supported on desk is a posture allowing for stability while relieving trunk muscles from greater exertion. This kind of arm supported sitting posture at conventional desks also tends to draw head and shoulders forward into a stooped, disadvantaged posture (Bendix *et al.* 1985, Zacharkow 1988). Regarding neck posture, the above findings were supported by our study.

The measures of differences between desk height and elbow-floor height, as well as between chair height and popliteal height are useful methods to show the appropriateness of desks and chairs to schoolchildren's anthropometrics. At the same time, however, the differences that exist in the optimal and standard heights for desks and chairs leave grounds for further dispute. The present study differed from most others in that the anthropometrics of the children were measured when they were using their own usual chair. Although we feel that our approach is in keeping with the general principle of ergonomic use of functional anthropometric measurements, we recognise that making measurements in this way may slightly over- or under-estimate 'standardised posture' measurements, particularly for elbow height. For popliteal height, this was partially addressed by requiring the children who didn't reach exactly to the 90º angle of the knees, to elevate their heels slightly and support their legs on the balls of the foot so that their knee angle was 90^{o}.

Working posture analysing system (OWAS) is based on a simple and systematic classification of work postures combined with observations of work tasks. It gives information about the frequency of the postures and can be used in real time observations or in post-analyses of video recordings displaying postures at given time intervals. In analysing sitting postures by modified OWAS –method, information is available about the frequencies of the postures that can be used to estimate time spent in each posture. The method is not able to describe the dynamics of sitting, e.g. how long the person sits in each posture at a time (Murphy *et al.* 2002). However, frequencies at 15 seconds' interval, as used in this study (on average 134 observations during one lesson), provide quite adequate information, and fail in only few observations, about the sitting postures of schoolchildren during one lesson at school.

Although our study included only two schools in two cities, it seems justifiable to generalise the results at least to most schools in Finland. In the School Health Promotion Study (SHPS, 1998-2001), about 30% of schoolchildren aged 14-17 years reported that inappropriate desks and chairs at school impede their schoolwork. Moreover, according to Salminen (1984), on average 59% of schoolchildren (11-17 years) reports present neck and/or back symptoms while sitting. The problems of inappropriate school furniture are general but probably still poorly recognised in schools and among the politicians who should allocate resources for new school furniture.

It remains unclear how large a part the inappropriate desks and chairs play in the case of schoolchildren sitting at poor postures and having more frequent back and neck pain. There is an urgent need for carefully designed studies and interventions focusing on schoolchildren's sitting postures, work at school, and back and neck symptoms in general (Trevelyan and Legg 2006).

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Table 1. Elbow-floor height, desk height, desk height deviance from the standard, difference between desk height and elbow-floor height, and deviance of this difference from the optimal. All measures are given in centimetres. (SD = standard deviation).

DESK	Boys (n=44)	Girls (n=57)	Total (n=101)
Elbow-floor height			
Mean	60.5	60.5	60.5
SD	2.8	3.2	3.0
Desk height			
Mean	73.6	73.0	73.3
SD	3.5	2.8	3.1
Desk height deviance from the standard (1)			
Mean	+5.6	+5.0	+5.3
Range	+3.6 - +7.6	+3.0 - +7.0	+3.3 - +7.3
Difference between desk height and elbow-floor height			
Mean	13.2	12.5	12.8
SD	3.8	4.7	4.3
Deviance of observed desk height – elbow-floor height difference from the optimal difference (2)			
Mean	+7.2	+6.5	+6.8
Range	+6.2 – +8.2	+5.5 - +7.5	+5.8 – +7.8

1) Optimal desk height according to popliteal/chair height is 68 cm (±2 cm) (SFS-ENV 1729-1, 2001)
2) Optimal difference is 6 cm (±1 cm) (Finnish Institute of Occupational Health, 1986)

Table 2. Popliteal height, chair height, chair height deviance from the standard, difference between chair height and popliteal height and deviance of this difference from the optimal. All measures are given in centimetres. (SD = standard deviation).

CHAIR	Boys (n=44)	Girls (n=57)	Total (n=101)
Popliteal height			
Mean	46.3	45.1	45.6
SD	2.4	2.8	2.7
Chair height			
Mean	43.6	43.5	43.5
SD	1.4	1.1	1.2
Chair height deviance from the standard (1)			
Mean	+2.6	+2.5	+2.5
Range	+1.1 – +4.1	+1.0 – +4.0	+1.0 - +4.0
Difference between chair height and popliteal height			
Mean	-2.8	-1.6	-2.1
SD	2.2	2.7	2.5
Deviance of observed chair height - popliteal height difference from the optimal difference (2)			
Mean	-2.8	-1.6	-2.1

1) Optimal chair height according to popliteal height is 41 cm (±1.5 cm) (SFS-ENV 1729-1, 2001)
2) Optimal difference is 0 cm (Finnish Institute of Occupational Health, 1986)

Table 3. Percentage of time spent in four different sitting postures during one lesson at school

SITTING POSTURE	Boys (n=22)		Girls (n=21)		Total (n=43)	
	Mean	SD	Mean	SD	Mean	SD
Back flexion >20º and/or rotation >45º	51.9	27.9	59.0	23.9	55.3	25.9
Neck flexion >20º or rotation >45º	62.8	25.0	76.5	17.4	69.4	22.5
Back and neck flexion >20º and/or rotation >45º	34.4	22.0	46.8	23.3	40.5	23.3
Back and neck flexion >20º and/or rotation >45º and arms supported	31.3	21.7	35.8	17.7	33.5	19.7

Figure 1 The participants sitting at traditionally used school furniture.