Preferred seat orientation of senior high school students

Neil Tuttle, Rod Barrett and Elizabeth Gass

School of Physiotherapy and Exercise Science, Griffith University, Queensland,

Australia

21 May 2007

Corresponding author:

Neil Tuttle

School of Physiotherapy and Exercise Science,

Griffith University, Gold Coast Campus

Queensland, Australia

PMB50 Gold Coast Mail Centre 9762

Tel: +61 7 5594 8934

Fax: + 61 7 5594 8674

Email: n.tuttle@griffth.edu.au

Abstract

The height of the front of the seat is the primary determinant of appropriate seat size in the school setting. In the present study this dimension was fixed at 445 mm and, using a brief adjustment period, students adjusted the angle of the seat to their preferred rear seat height (PRSH) under three fixed and one adjustable desk height conditions and for one desk height, under two time conditions. PRSH was significantly greater at an 800 mm desk height (454 ± 14 mm) compared to 735 mm (447 ± 15 mm) and 720 mm (444 ± 16 mm). When desk height as well as rear seat height were adjustable, PRSH was 446 ± 15 mm and preferred desk height 751 ± 25 mm. Taller students or those with larger popliteal heights selected lower PRSHs at all desk heights, with PRSH more strongly related to popliteal height ($r = -0.54$ to -0.59) than stature ($r = -0.44$ to -0.50). No differences were found in PRSH between short (< 5 min) and long (30 min) adjustment periods for the 735 mm desk height. The nearly horizontal seat positions found in this study were between those recommended by other authors.

1. Introduction

School chairs present several particular design difficulties. The need for low cost and durability dictate the use of a firm non-adjustable chair. The design of a chair to provide the best fit for a population is not simply a matter of fitting the average size person from the population. The appropriate dimensions of a chair to provide the best fit for a population can be determined by ensuring that 'the smallest can fit and the largest can reach.' Just as the anthropometric dimension of an average size person is not necessarily the appropriate dimension to use for determining a dimension of a chair for that population, so too the angles and contours suitable for an average size person are not necessarily the most suitable for the population as a whole. Unfortunately clear principles that enable fitting the dimensions of a chair to a population do not appear to exist for fitting the angles and contours of a chair to a population, particularly a school population.

It is not viable to have a different size school chair to suit each student in the classroom due to cost and other practical considerations. Although adjustable school chairs would be ideal from an ergonomic viewpoint, a limited number of chair sizes are typically used to accommodate the range of ages and sizes of school students from preschool through to high school. For example six different chair sizes are used in Australian schools (StandardsAustralia 1995), eleven in Korea (Cho 1994) and nine in Japan (Hibaru and Watanabe 1994). Any one of these chair sizes would therefore be expected to accommodate a range of students of different shapes and sizes.

Two of the most important design features of school chairs are seat height and seat angle. Standards Australia (1995), Parcells *et al.* (1999) and Noro (1994) recommended that seat height measured at the front of the seat be determined by the users popliteal

height. In contrast Mandal (1984; 1994) recommended that seat heights measured at the rear of the seat be 10 to 15 cm higher than the popliteal height providing that the seat was inclined (angled forward) by approximately 15 degrees. When this forward inclination of the seat is taken into account, the front seat height from Mandal's recommendation again approximates the user's popliteal height. Regardless of which of the recommended seat angles is used the height of the front of the seat of a fixed height chair would need to be such that the majority of students could sit with their feet flat on the floor. Typically this is accomplished by the front seat height for each chair size being equal to the fifth percentile (Pheasant 1992) or first percentile (Molenbroek *et al.* 2003) of the users shod popliteal height.

While there is relative agreement that the height of the front of the seat should be determined by the user's popliteal height, there is disagreement regarding rear seat height. Recommendations range from Mandal (1984,1994) advocating a 15 degree incline and Standards Australia (1995) allowing a recline of up to 5 degrees.

Kroemer (1994) reviewed methods used to assess seating and concluded that preference of the user and performance of the required tasks were the most valid criteria for evaluating chair design features. Student's performance would be difficult to assess against a continuous variable such as seat height. Student preferences on the other hand have previously been found to be a reliable means of assessing school seating (Aagaard-Hansen and Storr-Paulsen 1995) and provide a viable means of assessing a continuous variable such as rear seat height.

Factors that may influence the choice of preferred rear seat height (PRSH) of school chairs include the duration and nature of tasks to be performed, the seat and desk

heights and angles, the nature of the seat surface, the nature of the backrest and the anthropometric characteristics of the population. The purposes of the current study were to determine: (i) the PRSH for year eleven students; (ii) if desk height or anthropometric measurements influence PRSH, and; (iii) if the time taken to determine PRSH influences PRSH.

2. Methods

2.1 Participants

Following approval of the study by the Griffith University Human Research Ethics Committee, students in Year 11 at a private high school were recruited to participate in the study. Students in the second semester of Year 11 (age 16-17 years) were chosen for the current study as they approximate the midpoint in age of the students in Years 11 and 12 who use the largest size chair in Australian schools. The students were not selected for gender or anthropometric characteristics and were dressed in their usual school uniforms including shoes. Informed consent was obtained from the students, their parent or guardian and a representative of the school prior to participation in the study.

2.2 Experimental design

Two related experiments were conducted whereby students selected their PRSH for a range different desk heights during a short adjustment period or a period of simulated classroom activity. The simulated classroom activity consisted of a combination of sitting forward writing and sitting back (Yeats 1977) while watching and listening to a video.

In the first experiment 16 students (6 male and 10 female, stature 1740 ± 91 mm,

popliteal height 510 ± 38 mm (5th percentile = 480) and mass of 60 ± 9 kg) while seated at 3 set desk heights (720 mm (Sebel 1995), 735 mm (the desk height normally used by the students), or 800 mm (Mandal 1984)) were asked to adjust the height of the rear of their seat to the position they would choose if they were doing normal classroom activities. The final eight students also adjusted both the desk and chair to their preferred height. The short adjustment period used by these students had been previously used by Mandal (1984) and although assessment of seat comfort takes at least three hours, appropriate adjustment, at least for adults is thought to be possible in a few minutes (Fernandez and Poonawala 1998).

In the second experiment a further 16 students (5 male and 11 female, stature 1722 ± 81 mm, popliteal height 517 ± 38 mm (5th percentile = 473 mm) and mass 61 ± 13 kg) were required to identify their PRSH at a single standard desk height of 735 mm during 30 minutes of simulated classroom activity. Adjusting to PRSH was analogous to ranking the comfort of the various positions. Since ranking of chair comfort was not found to change significantly after 30 minutes (Fernandez and Poonawala 1998), the longer 30 minute period was used with this group to assess the assumption that a brief adjustment period was adequate when applied to school children as well as adults. All students were tested between mid-day and 2 PM.

2.3 Experimental chair and desk

Two identical experimental chairs were constructed (figure 1). The chairs consisted of: (i) a commercial five-star office chair base on glides rather than the usual castors, a screw pedestal height adjustment to enable the height to be set accurately and a seat mechanism with an adjustable seat angle which maintained a constant height at the front of the seat (Taskmaster, Richard Small Pty. Ltd. Melbourne, Victoria); and (ii) an

injection moulded plastic seat and backrest from a commercial school chair (Dura Pos size 6, Woods Furniture, Richmond, Victoria). The backrest was mounted in the same position in relation to the seat as on the original chair (175 mm above the back of the seat forming an angle of 95 degrees with the seat). The seats on the experimental chairs had a slightly textured surface, were flat front to back under the weight-bearing surface with a rounded front edge (20 mm radius) and had a maximum lateral dishing of 15 mm.

<Insert figure 1 about here>

The mechanism allowed the seat including attached backrest to be adjusted and locked in any position through a range of 15 degrees. The maximum recline was set at –5 degrees (Standards Australia 1995) which allowed a forward tilt of + 10 degrees (a horizontal seat is deemed to be zero degrees with an inclined seat expressed as a positive seat angle and a reclined seat as a negative seat angle). The height of the front of the seat was set at 445 mm, which approximates the fifth percentile popliteal height for Australian students in Years 11 and 12 (Sebel 1995).

Flat horizontal desk surfaces as used in the students' classrooms were used in the current study. Students were instructed how to adjust the rear seat height of the chair and the height of the desk and were required to demonstrate their ability to make the required adjustments prior to commencement of the experiment.

2.4 Measurement of preferred rear seat height (PRSH) and preferred desk height (PDH)

At the completion of each adjustment period, each student was asked if they were satisfied that they had found their PRSH and/or PDH. Data from any student who was not satisfied with their adjustments was discarded. PRSH was measured from the floor to the midline of the rear weight-bearing surface (300 mm from the front of the seat, approximately under the ischial tuberosities). PDH was measured from the floor to the top surface of the desk.

2.5 Anthropometric measurements

Stature and popliteal height were measured with shoes on to reflect the functional dimensions of the students in the classroom. Stature was measured to the nearest 5 mm using a stadiometer. Popliteal height was measured with the students sitting on a table with the front edge of the table touching the back of the knees. A horizontal surface under the feet was raised until both the heels and soles of the shoes rested on the surface (Molenbroek *et al.* 2003). The vertical distance between this horizontal surface and the table was measured with a tape measure to the nearest 5 mm. Although the popliteal height from this method is up to 60 mm higher than popliteal height measured by the traditional anatomical method (Tuttle 2004), the weight-bearing method was used as it was considered to represent a more functional measure of the shod popliteal height. Body mass was measured to the nearest kilogram using a spring scale.

2.6 Statistical analysis

The mean PRSH and preferred desk height calculated from two trials for each

participant using each desk condition were used for subsequent analysis. Pearson product moment correlation coefficients were determined for the relationship between stature, popliteal height and desk height on PRSH during the short adjustment period. A test of parallelism was also conducted to determine if the regression lines describing the relationship between popliteal height and PRSH and stature and PRSH were significantly different for each desk height (Neter *et al.* 1989). Stepwise multiple linear regression was used to determine what factors explained the most variance in PRSH. Independent sample t-tests were used to determine the effect of the long versus short adjustment period on PRSH. All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS, Ver7.5.1), with descriptive statistics reported as means ± one standard deviation. Significance levels for all tests were set to 0.05.

3. Results

3.1 Effect of desk height on PRSH

All students required less than five minutes to adjust their chair (and, for the final eight students their desk) to their preferred positions. Desk height was found to have a significant main effect on PRSH ($p < 0.05$). Post hoc comparisons revealed that PRSH was significantly higher at the 800 mm desk height (454 ± 14 mm, 1.7 ± 2.7 degrees) than the 735 mm (447 ± 15 mm, 0.4 ± 2.9 degrees) and the 720 mm (444 ± 16 mm, -0.2 ± 3.1 degrees) conditions. When students were required to adjust desk height and seat height, PRSH and PDH were 751 ± 25 mm and of 446 ± 15 mm respectively.

3.2 Effect of adjustment period duration on PRSH

All students stated that they had adjusted the chair to their satisfaction and none adjusted their seat in the final five minutes of the simulated classroom activity. Only

two students readjusted their chairs after the first five minutes of the activity. PRSH was not significantly different between the short adjustment period (447 ± 15 mm, 0.4 ± 2.9 degrees) and the simulated classroom activity (439 ±14 mm, –1.1 ± 2.7 degrees) when assessed at the student's usual desk height of 735 mm ($p > 0.05$).

3.3 Relationship between PRSH and anthropometric factors and desk height

The mean PRSH for the three desk heights was 25-26% of mean stature or 87-89% of mean popliteal height. Significant negative correlations ranging from $r = –0.54$ to $r = -0.59$ were detected for the relationship between PRSH and popliteal height for all desk heights (figure 2a). Similarly significant negative correlations ranging from $r = –0.44$ to $r = -0.50$ were detected for the relationship between PRSH and stature for all desk heights (figure 2b). PRSH was therefore found to correlate more strongly with popliteal height than stature at all desk heights. Coefficients of Determination (R^2) for regression of popliteal height on PRSH for each desk height (800, 735 and 720 mm) were 0.29, 0.31 and 0.36. For regression of stature on PRSH the R^2 values for each desk height were 0.19, 0.24 and 0.24 respectively. No differences were detected for the slope or the intercept of the regression lines on each height for the relationship between PRSH and popliteal height and stature.

<Insert figure 2 about here>

Results of the multiple stepwise linear regression indicated that popliteal height and desk height together accounted for 36% of the variation in PRSH according to the following equation (all measures are in mm).

$$PRSH = 461 − 0.226 \times \text{Popliteal Height} + 0.136 \times \text{Desk Height} \qquad (R^2=0.36)$$

4. Discussion

The range of the average PRSH for students using the three desk heights in this study expressed as a seat angle (-1.1 to +1.7 degrees) extends beyond the upper limit of the range of seat angles of zero to –5 degrees proposed by Australian Standards (1995). The range of PRSH (444 to 454 mm) is however much lower than the average popliteal height (510 mm) which would correspond to the findings of Noro (1994) or the 30% of stature (522 mm) recommended by Mandal (1984). Studies by Mandal (1984) and Noro (1994) used a constant seat angle and found participants' preferred heights of the front of the seat to centre on their popliteal heights. In these previous studies taller people tended to choose higher seat heights and shorter people tended to choose lower seat heights suggesting that people of different sizes prefer a similar range of postures if the seat angle remains constant.

The finding in the current study that taller students or those with larger popliteal heights selected a lower PRSH when the front of seat height was fixed demonstrated an interrelationship between seat height and seat angle. When the height of the front of the seat was predetermined, it was no longer physically possible for people with different shod popliteal heights to sit with their legs and trunk in the same postures. Taller students or those with higher shod popliteal heights therefore sit with more extended knees or with increased hip flexion (figure 3a) compared to smaller students (figure 3b) when sitting in the same size chair.

Yasukouchi and Isayama (1995) and Riener and Edrich (1999) describe how increased hip flexion and / or knee extension increases the passive tension in the biarticular hamstrings (which exert a torque on the pelvis. All else remaining equal, the pelvis will rotate posteriorly and the trunk will be either more reclined or the lumbar spine more

flexed. Alternatively, other forces – either in the form of active muscle contraction or forces from the chair acting on the pelvis – must balance the torques acting on the pelvis. The taller student can reduce these torques by sliding forward on the seat and reclining the trunk. Alternatively, the lower rear seat height selected by taller participants in the current study may reduce the degree of knee extension thus reducing the torques acting to rotate the pelvis posteriorly.

The choice of smaller (or more negative) seat angles by taller students may be a means of reducing the torques acting on the pelvis and thereby reducing the effort necessary to maintain a sitting posture. The decreased leg flexibility occurring in the mid-teen years (Zacharkow 1988) may contribute to the lower PRSH of the taller students, and the common, although anecdotal observation of more slumped postures adopted by taller students. This slumped posture by taller students may therefore be related to biomechanical factors rather than the common interpretation of it being a reflection of the student's attitude or motivation.

<Insert figure 3 about here>

Sashaku is a Japanese term used in relation to school furniture design that refers to the vertical distance between the desk and seat as a function of sitting height (Cho 1994; Noro 1994). According to the principle of Sashaku, for a given desk height, taller students would be expected to choose lower rear seat heights as found in the current study. If PRSH corresponded to the principle of Sashaku however, a change in desk height should also result in a change in PRSH of similar magnitude. The mean increase in PRSH between the 720 mm and 800 mm desk height conditions although not statistically significant was just 10 mm rather than the 80 mm difference predicted by

Sashaku. This 10 mm difference is probably is not of practical significance and is much smaller than the 40 mm decrease in PRSH that occurred with a 150 mm difference in popliteal height. Furthermore if the height of the desk in relation to the student's arms or head were the more important factor influencing PRSH, stature would be expected to demonstrate a stronger correlation with PRSH than popliteal height as stature relates more closely to sitting height than does popliteal height. The stronger correlation between popliteal height and PRSH suggests that the PRSH is more influenced by what occurs below the level of the desk than in relation to the desk.

Zacharkow (1988) suggested that the time necessary for assessing chairs should correspond to the duration of usual use. Mandal (1984), however, used a brief duration of sitting to determine the users' preferences. No significant difference was found between the PRSHs in the thirty minute simulated classroom situation and when the students found their PRSH at their own pace. A student determining his or her preference with reference to the required tasks without imposing a mandatory time period thus appears to be a valid means of assessing preferred seat position.

5. Conclusions

For year eleven students, when the height of the front of the seat of the was set at 450 mm, user preferences indicate that the rear seat height be in the range of 444 to 454 mm, which corresponds with a seat angle of –0.2 degrees and +1.7 degrees. This finding is within the –5 to +30 degree range of values reported in the literature. The finding that popliteal height was more strongly correlated with PRSH than stature seems to indicate that the factors influencing seat height that occur below the desk are more important determinants of PRSH than the factors directly related to desk height. Popliteal height and desk height together accounted for 36% of the variation in PRSH. Other factors that

may influence PRSH include seat contour and variation in postural preference. No differences were detected in PRSH for a short adjustment period versus a longer adjustment period corresponding to their usual classroom usage. A short adjustment period therefore seems an acceptable time period for determining PRSH.

References

AAGAARD-HANSEN, J., and STORR-PAULSEN, A., 1995, A comparative study of three different kinds of school furniture. *Ergonomics*, **38**, 1025-1035.

CHO, A., 1994, Fitting the chair to the school child in Korea, in R. Lueder and K. Noro (Eds), *Hard facts about soft machines: the ergonomics of seating,* pp. 279-288 (London: Taylor & Francis).

FERNANDEZ, J.E., and POONAWALA, M.F., 1998, How long should it take to evaluate seats subjectively? *International Journal of Industrial Ergonomics*, **22**, 483.

HIBARU, T., and WATANABE, T., 1994, A procedure for allocating chairs to school children, in R. Lueder and K. Noro (Eds), *Hard facts about soft machines: the ergonomics of seating,* pp. 289-296 (London: Taylor & Francis).

KROEMER, K.H.E., 1994, Sitting (or standing) at the computer workplace, in R. Lueder and K. Noro (Eds), *Hard facts about soft machines: the ergonomics of seating,* pp. 181-191 (London: Taylor & Francis).

MANDAL, A.C., 1984, The correct height of school furniture. *Physiotherapy*, **70**, 48-53.

MANDAL, A.C., 1994, The prevention of back pain in school children, in R. Lueder and K. Noro (Eds), *Hard facts about soft machines: the ergonomics of seating,* pp. 269-277 (London: Taylor & Francis).

MOLENBROEK, J.F.M., KROON-RAMAEKERES, Y.M.T., and SNIJDERS, C.J., 2003, Revision of the design of a standard for the dimensions of school furniture. *Ergonomics*, **46**, 681-694.

NETER, J., WASSERMAN, W., and KUTNER, M., 1989, *Applied linear regression models.* Homewood, Ill., Irwin.

PARCELLS, C., STOMEL, M., and HUBBARD, R.P., 1999, Mismatch of classroom furniture and student body dimensions: empirical findings and health implications: *Journal of Adolescent Health*, **24**, 265-273.

PHEASANT, S., 1992, *Bodyspace: Anthropometry, ergonomics and design.* London, Taylor & Francis.

RIENER, R., and EDRICH, T., 1999, Identification of passive elastic joint moments in the lower extremities. *Journal of Biomechanics*, **32**, 539-544.

SEBEL, F.L., 1995, *Educational furniture research*, Sebel Furniture, Ltd.

STANDARDSAUSTRALIA, 1995, Australia/New Zealand Standard 951026 School and educational furniture, Standards Australia.

TUTTLE, N., 2004, A comparison of methods used for measuring popliteal height. *Ergonomics Australia*, **18**, 14-18.

YASUKOUCHI, A., and ISAYAMA, T., 1995, The relationships between lumbar curves, pelvic tilt and joint mobilities in different sitting postures in young adult males. *Appl Human Sci*, **14**, 15-21.

YEATS, B., 1977, Factors that influence the postural health of schoolchildren (K-12). *Work*, **9**, 45-55.

ZACHARKOW, D., 1988, *Posture: sitting, standing, chair design and exercise*. Springfield, Ill, Charles C. Thomas.

Figure captions

Figure 1. Experimental chairs showing their range of adjustment.

Figure 2. Relationship between PRSH and (a) popliteal height and (b) stature at each desk height (800, 735 and 720 mm). Symbols represent observed data and lines represent fitted data.

Figure 3. Extremes of size students using the largest size Australian school chair (Sebel 1995) recommended for Year 11 students (Australian Standards 1995). (a) 95th percentile, and (b) 5th percentile.
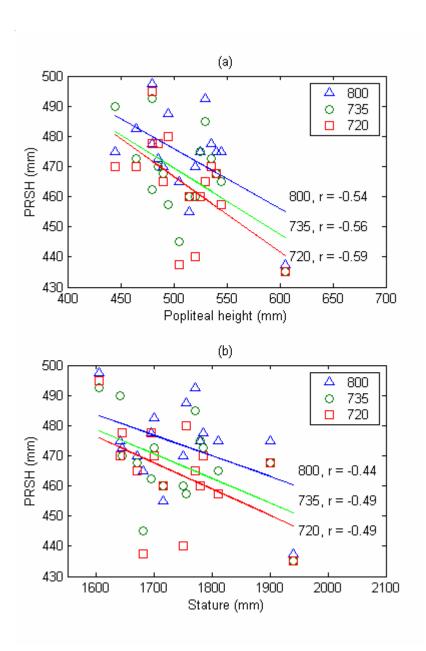
Figure 1

Figure 2

Figure 3

(a)   (b)