

**Seated buttock contours: a pilot study of Australian senior high school students**

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## **Abstract**

Both posture and comfort of a chair are influenced by the contour and characteristics of the seat. Knowledge of seat contours of a student population could thus be useful in the design of school chairs. This study investigated seated buttock contours of senior high school students in order to determine: i) their general characteristics, ii) the effect of gender and sitting posture, and iii) the relationship between the contours and selected anthropometric variables (stature and mass). A contour measurement device was developed and used to measure buttock contours in five sitting postures (typing, sitting up, sitting back, slumping and writing). Buttock contours were quantified by constructing anterior-posterior (AP) and lateral profiles from which six discrete profile dimension measurements were made. AP and lateral profiles were found to have a consistent shape across all participants. Five out of six profile dimensions were significantly different between genders, with just one significantly different between sitting postures (typing and sitting back). Correlations between anthropometric measures and profile dimensions were relatively low ( $r < 0.34$ ) with no clear patterns evident. Overall results of this study suggest that buttock contours are influenced by gender to a greater extent than sitting posture.

## 1. Introduction

Sitting in school chairs has been related to a high incidence of discomfort in school students (Goodman and McGrath 1991; Evans *et al.* 1992) and is also believed to affect students' mood (Hariku and Suzuki 1994), and attention and performance (Linton 1994; Vercruyssen 1994). The two most important factors in overall sitting comfort affected by the chair are considered to be posture and the comfort of the seat (Kamijo *et al.* 1982). The contours of the front and back portions of the seat influence sitting posture (Tuttle *et al.* 2007) and the whole of the seat contour affects seat comfort (Hertzberg 1972; Gross *et al.* 1994; Serber 1994). The contour of the seat thus affects the two most important factors influencing the comfort of a chair.

Although not specific to school seating, several variations of contours of the region of the seat in front of the ischial tuberosities have been proposed to improve sitting posture. One type of contour consisting of the front of the seat sloping forward with a horizontal region under the pelvis has been proposed for sewing machinists (Yu and Keyserling 1988) and office workers (Graf *et al.* 1993). This contour is meant to assist in maintaining a lumbar lordosis by allowing the thighs to slope downward while still providing a stable base for the pelvis. A second type of contour which has been proposed for wheelchair seats (Jay 1994), office chairs (Gregory 1987) and automotive seats (Sperr 1985) is an effectively raised area in front of the ischial tuberosities to assist the user's posture by preventing the pelvis from sliding forward on the seat. A raised central portion of the front of the seat as occurs in horse saddles has also been proposed as a means of reducing the tendency for the pelvis to slide forward (Gale *et al.* 1989). Such a contour is intended to encourage a desirable lumbar lordosis by maintaining the

pelvis in an anteriorly rotated position. A raised contour at the rear of the seat however has long been considered undesirable due to a tendency of the contour to slide the occupant forward on the seat producing a flexed lumbar posture (Bennett 1928). The contours in front of and behind the ischial tuberosities thus have different but potentially interrelated effects on seated postures.

Unlike the effects of seat contour on posture which are different for different regions of the seat, the effects of seat contour on seat comfort or discomfort appear to be similar for all parts of the seat (Sember 1994). A reduction in nutrient supply to the buttocks is responsible for seat discomfort and when more severe and in a disabled population with reduced sensation also produces pressure sores. This reduction in nutrient supply appears to be related to tissue distortion which in turn appear to be more related to pressure gradients rather than peak pressures as previously thought (Gross *et al.* 1994).

The contour of the buttocks and posterior thighs (buttock contours) have been measured for specific individuals or populations and used to improve seats for pilots (Hertzberg 1972), automobiles (Yamazaki 1992), sewing machinists (Yu and Keyserling 1988) and wheelchair users (Springle *et al.* 1990a; Brienza *et al.* 1991) but apparently not for school students. In each of these applications the contours were measured for only a single task-specific posture. However school students use a variety of sitting postures including sitting forward when writing and sitting back when watching or listening (Schroder 1997). Since buttock contours and pressure distribution have been found to be different with different postures (Hertzberg 1972; Hobson 1992; Shields and Cook 1992; Henderson *et al.* 1994; Koo *et al.* 1996; Kernozek and Lewin 1997), data on the

buttock contours of school students in a representative sample of postures would be expected to be more useful for designing improved school seats than data on only a single posture.

The task of measuring buttock contours is complicated by the fact that the interface used in the measurement affects the contour to be measured. Thus buttock contours measured by different means may yield different results. Non weight-bearing buttock contours had been thought to adequately represent weight-bearing contours by assuming an even distribution of pressure and that the buttocks behave according to a hydrostatic model (Yamazaki 1992). Unfortunately not only are non-weight-bearing buttock contours different from weight-bearing contours (Sember 1994), but the weight-bearing contours are also affected by the characteristics of the buttock/seat interface (Koo *et al.* 1996). Since an even density of pressure gradients appear to be the most reliable factor for predicting seat comfort (Gross *et al.* 1994) a measurement of seat contours using an interface which provides an even distribution of pressure gradients is perhaps most suitable if the data collected is to be relevant to seat comfort.

A number of methods have been used for measuring buttock contours including passive methods of direct moulding, displacement of a grid of spring-loaded plungers (Brienza *et al.* 1991) and displacement of a grid of points on the surface of a block of foam (Springle *et al.* 1990a). In addition to these passive systems, active systems have been advocated which mechanically adjust the seat contour to equalise pressure (Brienza *et al.* 1993) or even adjusted the contour such that the relative pressure at each point was inversely proportional to the overlying tissue stiffness (Brienza *et al.* 1996).

In the current study, a device was designed and constructed to measure the weight-bearing buttock contours of senior high school students using an interface intended to evenly distribute pressure gradients. The purpose of the study was to determine the effect of gender and sitting posture on seated buttock contours and to examine the relationship between buttock contours and selected anthropometric variables (stature and mass) in senior high school students.

## **2. Methods**

### *2.1. Participants*

Following approval of the study by the Griffith University Human Research Ethics Committee, 16 students (six male and ten female) in Year 11 (age 16-17 years) at a local private high school voluntarily participated in the study. The students 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. Students had a mean stature of 174 cm (SD = 9 cm) and mean body mass 60 kg (SD = 9 kg).

### *2.2. Apparatus*

An experimental chair was constructed consisting of a contour measuring device (bumograph) in place of the seat and a moulded plastic backrest from a commercial school chair (DuraPos size 6, Woods Furniture, Richmond Victoria) mounted on a commercial office chair mechanism (Taskmaster, Richard Small Pty. Ltd. Melbourne,

Victoria) and five star base (mounted on glides rather than the usual castors) (figure 1).

[insert figure 1 about here]

The bumograph was constructed of a slab of high-density ILD 45 polyurethane foam (EN38200 Dunlop Flexible Foams) 400 mm x 400 mm x 75 mm. The pressure between a point on a block of polyurethane foam and its indenter approximates a linear function for up to 60% compression of the foam (Springle *et al.* 1990b; Brienza *et al.* 1999).

Other advantages of using polyurethane foam are its durability, ease of fabrication and low cost. A grid of 96 sensors (compared with 64 points used by Springle *et al.*, 1990a) were distributed with a greater density in the regions of smaller radii of curvature (under the ischial tuberosities) and a lesser density in the regions of larger radii (under the thighs) in the pattern as shown in figure 2a. Each sensor consisted of a 25 mm domed roofing washer on the surface of the foam connected by a bicycle cable passing through a vertical hole to a linear potentiometer (RSAON1119 ALPS Electric Co., Ltd. Tokyo) mounted on a frame below. Because polyurethane foam is 4 to 5 times stiffer in shear and ten times stiffer in tension than compression (Springle *et al.* 1990b), a pattern of 10 mm deep vertical cuts were made into the surface of the foam to minimise distortions of the contour from forces resulting from tension or shear of the foam.

[insert figure 2 about here]

The potentiometers operating as voltage dividers were electrically isolated from mains power and multiplexed using purpose-built circuitry connected to a desktop PC through

a DAQ card (P1200 National Instruments). A customised software program was used for calibration, data acquisition and storage of displacement data for the 96 points (Labview V 3.5 National Instruments). The grid of displacements from the 96 sensors were later interpolated using a method of least squares to a 35 by 35 cm surface contour containing a grid of points spaced at 10mm centres (Matlab version 5.3). This interpolated grid of displacement values was used for subsequent analyses.

Following calibration, assessing the accuracy of the device by taking measurements from all sensors at five displacements (10, 15, 20, 25, and 30 mm) resulted in a standard error for each vertical displacement of less than 0.1 mm. For assessing horizontal accuracy, the bumograph was indented by two spheres (100 and 125 mm diameter) with known distances between centres (100, 125, 150 and 200 mm.). Two trials were performed for each of the four horizontal distances. The standard error of the difference between the distances between centres of the spheres and the two deepest points on the interpolated contour was 10.1 mm.

The bumograph was mounted on the experimental chair such that when students sat the experimental chair their position after compressing the foam would correspond with the position determined experimentally for Year 11 students (Tuttle *et al.* 2007) (front seat height = 44.5 cm, seat angle  $-1$  to  $+0.4$  degrees). The backrest was positioned as on the original chair school chair (centred 27 cm above the compressed seat and reclined by an angle of ten degrees from the vertical).

### *2.3. Data collection*

The students sat on the experimental chair at a desk identical to their usual school desks (horizontal desk surface 73.5 cm high) and were required to adopt, in random order, two trials each of five representative postures: Typing - using computer keyboard; Sitting back - sitting reclined using backrest with feet in front of chair; Sitting-up - sitting upright with feet flat on floor without using the backrest; Slumping - sitting with lumbar and thoracic flexion without using the backrest, and; Writing – writing at a standard school desk.

Once the student had correctly assumed the test position, contour data was sampled at 0.5 Hz for a minimum of five seconds. The student was required to stand before assuming the next posture. One sample at least 2 seconds from either end of the collection period for each trial of each posture was used for subsequent analysis.

### *2.4. Data analysis*

Three profiles were extracted to characterise each 35 x 35 point contour grid (figure 2b). An anterior-posterior (AP) profile on each side of each measured contour was taken through the line connecting the deepest displacement on the rear half of the seat (although the anatomical location of the deepest point was not confirmed, the deepest point on each side will be referred to as the ischial tuberosity) and the deepest point on the front edge on that side of the seat. One lateral profile was taken through the line connecting the ischial tuberosities on either side of the rear half of the seat.

Students sat on slightly different places on the bumograph and the foam was compressed to different extents by different students. To enable direct comparison, the profiles were adjusted prior to analysis. Only the portion of the AP profiles that was available for all students would be used in further analysis so AP profiles were truncated 23 centimetres forward of the ischial tuberosities. The raw AP profiles were aligned such that the point at the front of each profile and the ischial tuberosity of each profile corresponded horizontally and vertically. The AP profile for each participant for each posture was the average of the aligned AP profiles from both sides for the two trials for each posture. The raw lateral profiles were aligned vertically such that the ischial tuberosities on each side had a displacement of zero and horizontally such that the right ischial tuberosity of each sample corresponded. The lateral profile for each participant for each posture was the average of the aligned lateral profiles from the two trials for each posture. The average of the AP and lateral profiles were calculated by participant, posture and gender.

A total of six measurements were made on the AP and lateral profiles (figure 3). The 4 vertical profile dimensions were: Anterior height - the height at the highest point in front of the ischial tuberosity on the AP profile; Posterior height - the height 8 cm posterior to the ischial tuberosity on the AP profile; Lateral height - the height 10 cm to the right of the right ischial tuberosity on the lateral profile; Inter-tuberosity (IT) height - the height at the highest point between the ischial tuberosities on the lateral profile. The 2 horizontal profile dimensions were: Anterior distance - the distance between the ischial tuberosity and the highest point in front of the ischial tuberosity on the AP profile, and; IT distance - the distance between the right and left ischial tuberosities on

the lateral profile.

[insert figure 3 about here]

A full-factorial 2-way ANOVA was used to determine the effect of gender and posture on the 6 profile dimensions (anterior height, posterior height, lateral height, IT height, anterior distance, and posterior distance), with post-hoc Scheffe used to determine specific differences between groups. Pearson correlation coefficients were used to determine if significant correlations existed between mass or stature and the 6 profile

dimensions). Significance levels for all statistical tests were set to  $P < 0.05$ .

### **3. Results**

Buttock contours were found to have common characteristics across all participants in the AP and lateral directions (figure 4a). The AP profiles were a sigmoid shape rising between the front of the seat and the ischial tuberosities and again behind the ischial tuberosities. The lateral profiles were a 'W' shape rising between and on either side of the ischial tuberosities.

[insert figure 4 about here]

Comparison of the profiles for males and females showed several significant differences

(figure 4b and table 1). Males had significantly larger displacements than the females for all vertical profile dimensions (anterior height, posterior height, lateral height and IT height). One horizontal profile dimension, anterior distance, was significantly less for males than females.

[insert table 1 about here]

The AP profiles were similar across the five postures with IT height the only profile dimension to demonstrate significant differences due to sitting posture ( $F= 4.6$ ,  $P < 0.05$ ). Post hoc Scheffe tests revealed that the typing and sitting back postures were significantly different (Table 1). No gender by sitting posture interactions were detected.

Although there were significant correlations between both mass and stature and some profile dimensions, no overall pattern emerged (table 2). Mass demonstrated significant positive correlations with two horizontal dimensions (anterior distance and IT distance) and a significant negative correlation with one vertical dimension (posterior height). Stature demonstrated significant positive correlations with the horizontal dimension of IT distance and the vertical dimensions of anterior height and lateral height.

[insert Table 2 about here]

#### **4. Discussion**

The current study was undertaken to collect data on buttock contours of students from which more effective school chair seats could be developed. The data showed consistent patterns in the general shape of both the AP and lateral profiles. The buttock portions of the contours resembled spheres elongated towards the thigh as opposed to symmetrical ball or football shapes previously described from non-weight-bearing contours (Waku *et al.* 1988). The vertical dimensions show much greater variation between participants than the horizontal dimensions indicating that the main differences between participants are in the depths of the profiles.

The AP profiles in front of the ischial tuberosities in the current study resembled the seat profiles proposed by Yu and Keyserling (1988) and Graf (1991). Yu and Keyserling (1988) measured the non-weightbearing profile of the posterior thigh of seated participants and proposed an angled seat profile with a horizontal surface under the ischial tuberosities and the front 15 cm sloping downward by 24 degrees. Participants studied by Graf (1991) preferred a similar angled seat profile (front 18 cm sloping down by eight degrees) to a more traditional seat shape. The recommendations of both studies differed from the contours measured in the current study in that neither advocated a raised profile behind the ischial tuberosities.

All profile dimensions with the exception of IT distance were significantly different between males and females. The greater height for all vertical measures for males than females is consistent with findings by (Springle *et al.* 1990a) and has been related to gender differences in the shape of the pelvis and body fat distribution. The shorter

anterior distance for males may simply be the result of the deeper contours produced by males than the females.

Differences in the buttock contours were expected due to the effect of sitting posture (Liu and Bodnar 1992; Reinecke *et al.* 1994; Kernozek and Lewin 1997), mass and possibly stature (Waku *et al.* 1988). The only observed difference in relation to posture however was a lower IT height for the sitting back posture compared with typing posture. The lower IT height for the sitting back posture is consistent with weight-bearing occurring on the posterior pelvis and sacrum rather than on the ischial tuberosities as with the more upright postures. Although several correlations exist between the anthropometric measures (mass and stature) and the profile dimensions, no recognisable pattern was observed.

The measurements of buttock contours collected in the current study provide the preliminary data that may be useful in the design of future school chair seats. Overall results of this study suggest that buttock contours have common characteristics, and are influenced by gender to a greater extent than sitting posture. A simple average of the contours of a population is therefore unlikely to provide the best fit for the population (Melzer and Moffitt 1996). A challenge for future research will thus be to determine a seat contour to achieve a best fit between the relatively rigid surface of a school seat and the buttock contours of a student population while still allowing or even supporting the postural changes necessary in the school setting.

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Figure 1

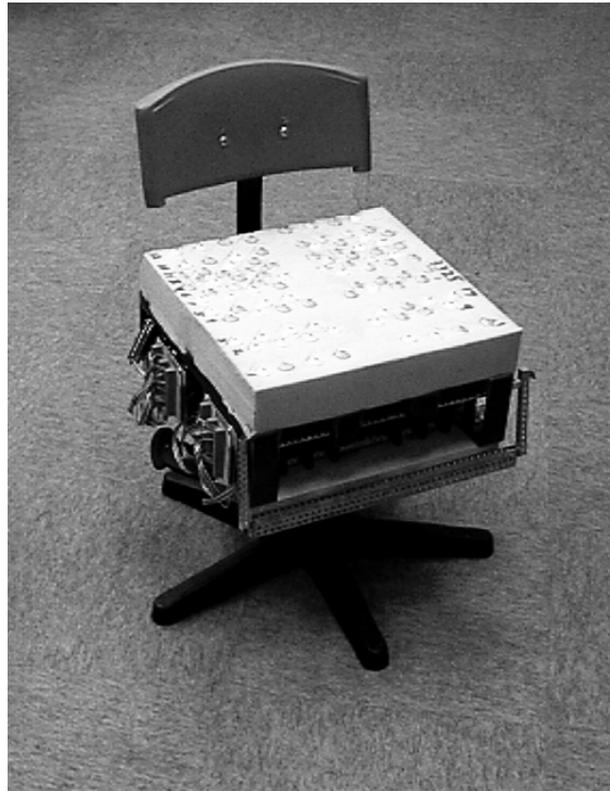
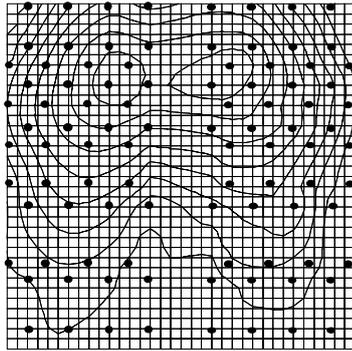
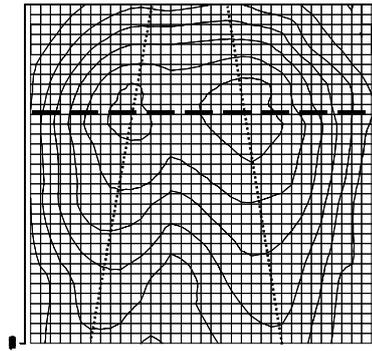


Figure 2



a



b

Figure 3

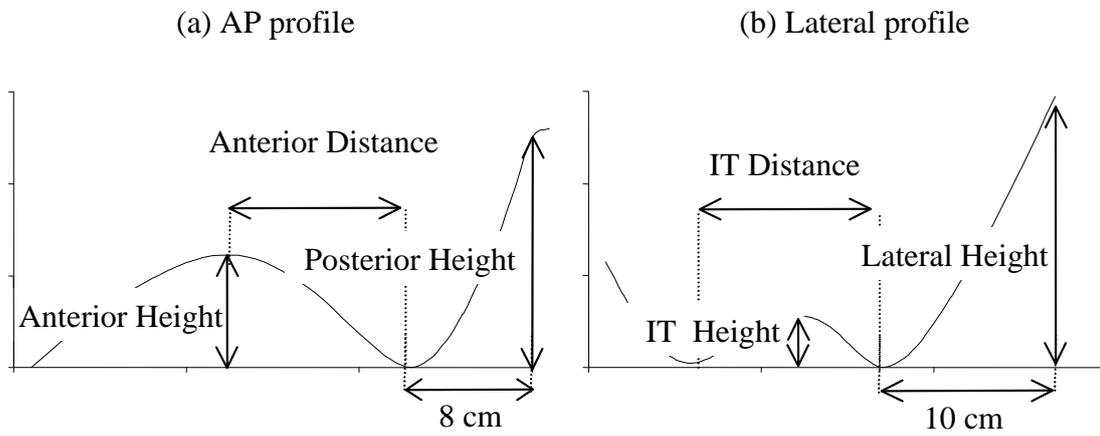


Figure 4

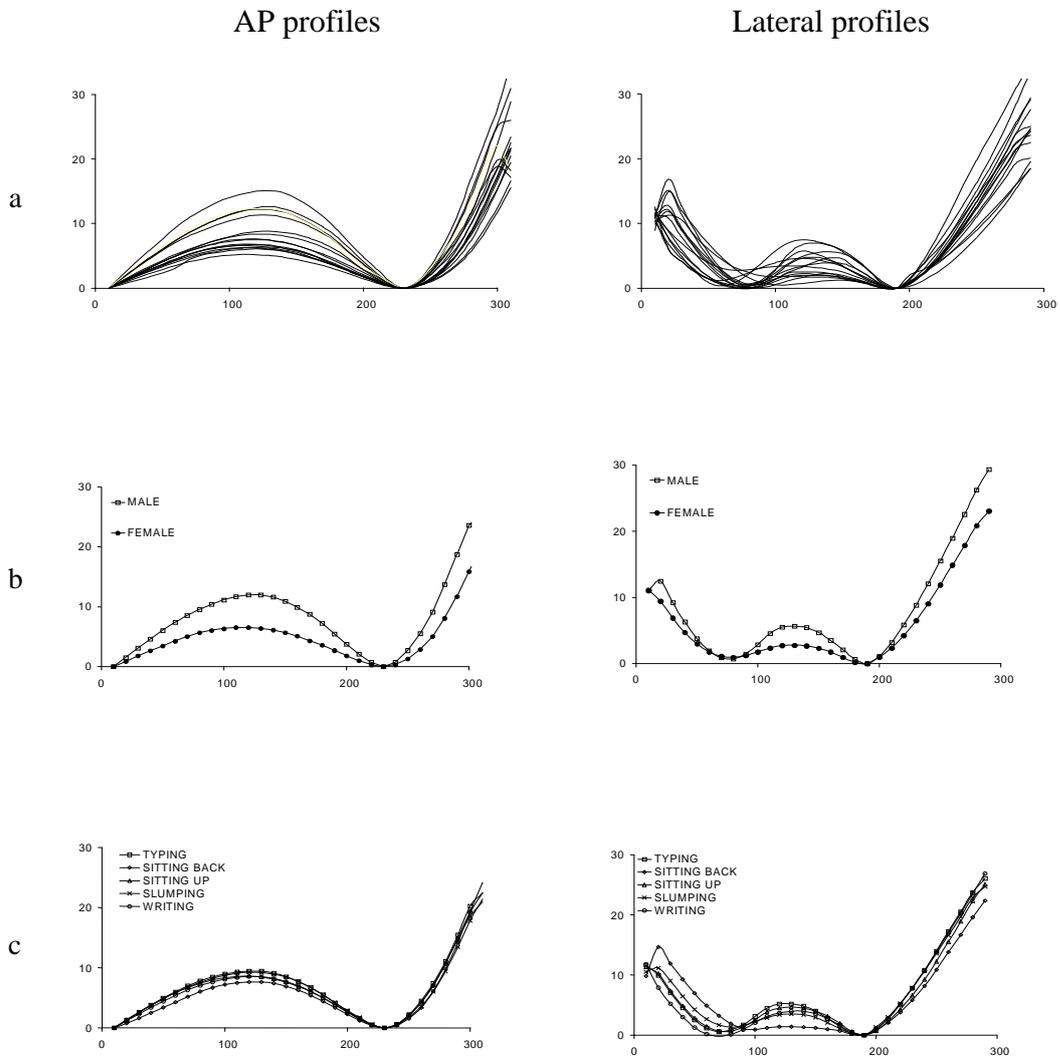


Table 1. AP and lateral profile dimensions (Mean  $\pm$  SD) by gender, sitting posture and combined.

Condition	AP profile dimensions (mm)			Lateral profile dimensions (mm)		
	Anterior	Anterior	Posterior	IT	IT	Lateral
	Height	Distance	Height	Height#	Distance	Height*
Male	12.1 (2.5) *	10.5 (0.7) *	23.6 (5.1) *	6.2 (2.4) *	11.1 (1.1)	29.4 (3.3) *
Female	6.8 (1.2) *	11.3 (1.0) *	16.3 (4.3) *	3.7 (2.3) *	10.9 (1.6)	23.1 (5.4) *
Typing	9.5 (3.4)	11.4 (2.2)	22.4 (7.7)	5.7 (2.6) #	11.7 (1.2)	26.0 (7.1)
Sitting back	7.8 (2.8)	10.6 (1.1)	24.2 (7.0)	3.3 (3.0) #	9.8 (1.5)	22.3 (6.8)
Sitting up	8.7 (3.0)	11.4 (0.8)	21.0 (5.8)	5.1 (2.3)	11.3 (1.0)	25.0 (5.1)
Slumping	9.4 (3.4)	10.9 (1.2)	21.4 (6.8)	4.7 (2.6)	10.5 (2.2)	24.7 (9.2)
Writing	8.6 (3.1)	10.8 (0.8)	22.5 (8.0)	4.4 (2.2)	11.8 (1.2)	26.9 (5.3)
Combined	8.8 (3.1)	11.0 (1.0)	19.0 (5.8)	4.7 (2.6)	11.0 (1.5)	25.4 (6.5)

\*Indicates significant difference due to gender ( $P < 0.05$ )

#Indicates significant difference due to sitting posture ( $P < 0.05$ )

Table 2. Pearson correlation coefficients for relationship between anthropometric measures (stature and mass) and AP and lateral profile dimensions.

Anthropometric Measure	AP profile dimensions			Lateral profile dimensions		
	Anterior Height	Anterior Distance	Posterior Height	IT Height	IT Distance	Lateral Height
Mass	-0.022	0.238*	-0.339*	0.105	0.231*	0.047
Stature	0.301*	0.172	-0.009	0.244*	0.298*	0.132

\*Indicates significant correlation ( $P < 0.05$ )

## Figure captions

Figure 1. Bumograph mounted on experimental chair.

Figure 2. Typical contours for an (a) male and (b) female student during keyboard posture. Contour lines are at 5 mm intervals and the intersections of the gridlines represent the interpolated points. The black dots in (a) represent the positions of the sensors on the bumograph. The dotted and dashed lines in (b) represent the positions of the AP and lateral profiles respectively.

Figure.3. (a) AP and (b) lateral profiles showing the profiles dimensions assessed in the study. The four vertical dimensions are the anterior height, posterior height, lateral height, and IT height. The two horizontal dimensions are the anterior distance and the IT distance.

Figure 4. AP profiles and lateral profiles grouped by (a) participant, (b) gender and (c) posture. Vertical and horizontal distances are in mm.