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A comparison of posture and muscle activity means and variation amongst young children, older children and young adults whilst working with computers

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Abstract. Children and young adults are the most frequent users of computers. Whilst guidelines for adults have been based on research, available guidelines for children have had to assume children and adults are similar due to limited research evidence derived specifically from children. This study aimed to compare the posture and muscle activity of children with young adults. Thirty six adults aged 18–25 years, 24 children aged 10–12 years and 18 children aged 5–6 years participated in a series of laboratory studies. Upper body postures were measured using a 3D motion analysis system. Muscle activity of bilateral cervical erector spinae and upper trapezius muscles was assessed. Mean and variation were examined, the latter using both amplitude range and Exposure Variation Analysis matrix standard deviation. Mean postures assumed by children tended to show more spinal flexion and spinal asymmetry than adults. However children also tended to show more variation in posture and muscle activity. These findings suggest that whilst there may be differences in how children and adults use computers, basic principles of encouraging appropriate postures and variation should apply for both children and adults.

Keywords: Posture, muscle activity, musculoskeletal disorder, children, computers

1. Introduction

Growth in the availability of new forms of information technology has been extensive over the past few decades [5]. It is not only adults who have embraced this technology; the use of computers by children, including very young children, is also now widespread. In a study of 1600 five year old Australian children more than half reportedly used a computer each week [28]. In the USA, 39% of 4–6 year olds used a computer several times each week [18]. Prevalence of use by older school aged children is even greater; recent statistics show that 94% of Australian children aged 5–14 years use a computer at school and 84% have access to a home computer [1]. Hong Kong students aged 12–15 years reportedly use a computer for a mean of 16 hours per week [7] and a similar usage was reported for Australian students at schools which had mandatory laptop programmes [10]. Young adults also have considerable exposure to computers: in Britain only 4% of 16–24 year olds have never used the internet [14] and young adults consistently comprise the highest usage age group amongst adult populations [1,6].

Concern about the physical impacts of computer use has led to the development of guidelines for adult use, including international and national standards such as the international ISO-9241 [12] and USA

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BSR/HFES100 [11]. However guidelines for children's use are immature, because only a limited body of evidence is derived specifically from children. School computer workstation set-up has been shown to be poor across a number of countries (e.g. [29]). The majority of children in several studies were shown to be working in postures that could not be categorised as acceptable using tests such as the Rapid Upper Limb Assessment [2,13,15]. Children are also likely to use computers differently from adults, for example with two or more children sharing a single computer and workstation [2,21].

A limited number of experimental studies of children's information technology and workstation design has been conducted. Straker et al. [22] compared posture and muscle activity during work with an individually adjusted workstation to that obtained with a typical computer workstation for 4–17 year old children. The children's posture when using the adjusted workstation was closer to resting alignment. Posture and muscle activity whilst using a desktop computer, laptop computer and book were assessed for the same children [3,8]. However the task for the study was limited to reading only, with no keyboard, mouse or pen input.

It is important to understand the physical ramifications of computer use by children. Physical discomfort during desktop, laptop and notebook computer use has been described by several authors [9,10,17,20], with a small proportion of children as young as five years experiencing computer-related discomfort [28]. In addition, computer use by young children has been reported to displace physical activity [28] which may be of developmental significance.

The aim of this study was to compare for the first time the posture and muscle activity loads of children and young adults interacting manually with computers.

2. Methods

A series of three laboratory experiments was conducted evaluating aspects of workstation design and electronic and paper based information technology tasks. This paper compares the postures and muscles activities across the three studies. Detailed methods for the adult study [24], middle school aged children study [25] and younger children study [27] have been reported, therefore only a brief description of methods will be given here.

2.1. Participants

Thirty six adults aged 18–25 years, 24 children aged 10–12 years and 18 children aged 5–6 years were recruited through personal contact and advertisements in local community newspapers. Each group was balanced for gender. All participants were right-hand dominant, had no history of musculoskeletal disorders or pain and had normal or normal corrected vision. The older two groups used computers at least twice per week, for a total of at least two hours per week and the 5–6 year olds had been using computers for more than a year.

2.2. Workstation setup

The work reported here was part of a larger series of studies addressing many parameters of workstation setup. In consequence, slightly different workstation configurations were employed for each age group, however all configurations were adjusted to suit individual anthropometry of the participant. A 38 cm display was used for all computer conditions. The chair/stool was adjusted to popliteal height, using a foot rest if required. For the adults the desk surface was 3 cm below the seated participant's elbow height and an adjustable height display arm was positioned such that the top of the display was at eye level. The desk surface was at seated elbow height for the 10–12 year old group, with the bottom of the electronic display 100 mm above the desk surface. Desk height for the youngest group was also at seated elbow height, and the top of the display was at eye level. Figure 1 shows the setup for each age group.

2.2.1. Experimental tasks

The computer task for the adults and older children comprised 10 minutes of reading and keyboard/mouse data entry using an electronic version of a history encyclopaedia. Worksheet topics were balanced across genders. This task was considered developmentally unsuitable for the youngest children and a more age-appropriate colouring task was designed for that group. Although this is a limitation of the study, the use of a realistic form of IT work for each age was considered to be important. The colouring task required selection of colours and colouring using a mouse-driven software 'paintbrush'. No keyboard input was required and the keyboard was set away for this group. Task duration for the 5–6 year old group was five minutes. Participants also performed paper based tasks, but the data are not reported here.

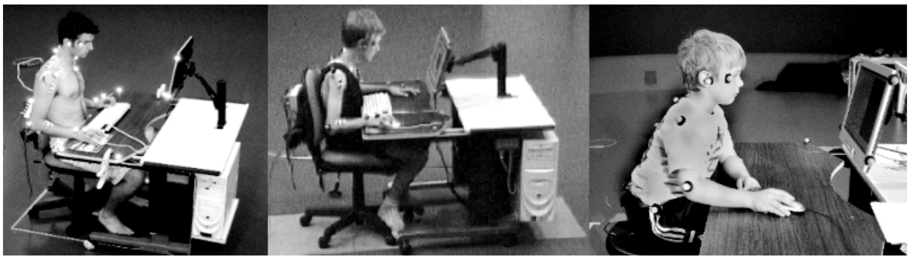

Fig. 1. Photographs of experimental setups for adults, 10–12 year olds and 5–6 year olds.

2.2.2. Postural variables

Three-dimensional posture of the head, neck, trunk and upper limbs was assessed using an eight-camera, infra-red motion analysis system (Peak Motus v8. Peak Performance Technologies, CO, USA). Specific landmarks and procedures employed have been detailed elsewhere [24,25]. The location of the acromial marker did change slightly between studies. For the adult participants this marker was on the anterior aspect of the acromial shelf whereas it was on the posterior aspect for the two younger groups. Output from the postural analysis comprised gaze angle (from eye level to the centre of the display, with respect to the horizontal), spinal flexion, spinal asymmetry variables (head, neck, trunk lateral bending and rotation), scapula elevation and protraction and arm flexion and abduction.

2.3. Muscle activity

Surface myoelectric activity (sEMG) was collected from bilateral cervical erector spinae (CES) and upper trapezius (UT) according to standard procedures [26]. Disposable Ag-AgCl electrodes were applied to cleaned and lightly abraded sites with a 25 mm centre-to-centre distance. The electrodes remained on the skin throughout both normalisation and task periods. Impedances were checked after electrode attachment and only accepted if the value was <5 kΩ. Participants performed three repetitions of maximum voluntary isometric exertions (MVEs) to enable amplitude normalisation. MVEs had good inter-trial reliability for all age groups, with intraclass correlation coefficients within the range 0.718–0.933.

2.4. Data processing

Posture and sEMG were collected during the last 2 minutes of each trial. Mean amplitude measures included the mean posture and amplitude-normalised sEMG RMS. Asymmetry variables were also calculated as 'absolute' asymmetry, defined as the magnitude of asymmetry regardless of direction. Posture and sEMG variation was characterised using the difference between the 90th and 10th percentiles of the Amplitude Probability Distribution Function (APDF$_{90-10}$) and the standard deviation of the Exposure Variation Analysis (EVA$_{sd}$) [23].

2.5. Statistical analysis

There was no significant effect of gender for any of the age groups so data were pooled across genders. Differences between young adults, 10–12 year olds and 5–6 year olds were examined using analysis of variance with Tukey's HSD post hoc comparisons identifying pairwise differences. A critical alpha probability of 0.01 was used to balance family-wise error and power. Trends were identified if the alpha probability was between 0.01 and 0.05 – these are not indicated in the tables but are described in the text.

3. Results

Mean postural and muscle activity results for each age group are presented in Table 1, with exposure variability data presented in Table 2 (APDF$_{90-10}$) and Table 3 (EVA$_{sd}$).

3.1. Mean Postures

3.1.1. Mean gaze angle and spinal flexion

Gaze angle was the same for the adults and the youngest children, but slightly (approximately 6°) lower for the 10–12 year olds (Table 1). This limitation was a result of slight differences in workstation setup between studies, as described in the methods section. The adults generally worked with slightly less spinal flexion than children: head flexion was less compared to that of the youngest children and there was a trend

Table 1
Mean (standard deviation) posture (°) and muscle activity (% maximum voluntary exertion) during computer use by adults and children

	Adults	10–12 years	5–6 years	F	p
Gaze angle	99.0 (2.5)[a]	105.7 (3.7)[b]	100.4 (3.0)[a]	35.0	< 0.001
Head flexion	75.4 (7.3)[a]	80.3 (7.4)[a,b]	86.1 (5.9)[b]	13.7	< 0.001
Neck flexion	55.3 (5.4)[a]	52.2 (7.4)[a]	61.9 (7.7)[b]	10.7	< 0.001
Trunk flexion	26.3 (8.3)	21.6 (10.8)	29.9 (7.4)	4.5	0.014
Cranio-cervical angle	160.0 (6.4)[a]	151.8 (10.0)[b]	155.6 (8.3)[a,b]	7.1	0.002
Cervico-thoracic angle	151.4 (7.9)	149.0 (7.6)	147.7 (8.4)	1.4	0.251
Head lateral bending	−0.7 (4.5)	−0.1 (4.7)	−2.3 (4.8)	1.1	0.334
abs. lat. bending	3.4 (3.0)	3.5 (3.0)	3.8 (3.7)	0.1	0.911
rotation	−3.1 (5.5)[a]	1.7 (4.4)[b]	−4.0 (7.1)[a]	6.5	0.003
abs. rotation	4.8 (4.0)	3.8 (2.8)	6.8 (4.3)	3.1	0.053
Neck lateral bending	−0.4 (3.6)	0.4 (3.7)	−0.1 (5.7)	0.3	0.776
abs. lat. bending	2.9 (2.2)	3.0 (2.2)	4.5 (3.4)	2.6	0.083
Trunk rotation	−1.0 (4.1)[a]	1.7 (4.1)[a,b]	3.6 (6.7)[b]	5.4	0.007
abs. rotation	3.3 (2.5)[a]	3.6 (2.6)[a,b]	6.2 (4.2)[b]	5.5	0.006
Head rel. to trunk	−2.0 (5.7)[a]	0.1 (5.2)[a]	−7.5 (6.4)[b]	8.4	0.001
abs. rel. to trunk	4.6 (3.7)[a]	4.2 (2.9)[a]	8.5 (4.9)[b]	7.2	0.001
Scapula elevation R	70.6 (4.4)[a]	83.3 (5.8)[b]	77.5 (6.6)[c]	40.1	< 0.001
elevation L	70.0 (5.6)[a]	83.3 (5.7)[b]	76.6 (4.8)[c]	41.8	< 0.001
protraction R	25.1 (5.1)[a]	11.5 (4.9)[b]	13.3 (7.8)[b]	47.0	< 0.001
protraction L	22.0 (6.9)[a]	14.1 (6.9)[b]	19.2 (9.0)[a,b]	8.0	0.001
Arm flexion R	−11.9 (8.9)[a]	1.0 (10.1)[b]	1.8 (12.8)[b]	15.8	< 0.001
flexion L	−8.0 (14.5)[a]	4.1 (10.9)[b]	20.1 (15.5)[c]	25.2	< 0.001
abduction R	21.5 (5.3)[a]	28.0 (6.5)[b]	25.2 (6.8)[a,b]	8.5	< 0.001
abduction L	20.9 (6.2)[a]	22.9 (14.6)[a]	7.8 (11.8)[b]	11.8	< 0.001
Cerv. Erector Spinae R	13.5 (7.7)	12.7 (6.9)	22.4 (18.7)	4.9	0.010
Cerv. Erector Spinae L	13.4 (9.0)	12.8 (5.4)	23.4 (21.8)	4.6	0.013
Upper Trapezius R	11.2 (6.2)	12.0 (6.7)	14.8 (9.8)	1.5	0.240
Upper Trapezius L	10.7 (7.8)	10.6 (6.1)	7.7 (6.5)	1.1	0.351

Superscript symbols show results of Tukey's HSD post hoc analysis: different letter superscripts denote a difference with $p < 0.01$, eg adult and child data which was not significantly different share the same letter.

for less head flexion in comparison to the 10–12 year olds. Neck flexion was also less than for the youngest children however trunk flexion did not differ across age groups. A straighter craniocervical angle in comparison to the 10–12 year olds also reflected a less flexed posture in adults. There were no differences in trunk flexion between groups.

3.1.2. Mean spinal asymmetry

The youngest children tended to adopt more asymmetric postures than adults and older children for rotational but not lateral bending variables (Table 1). The 10–12 year olds had a mean head rotation which was in the opposite direction to the other two groups, however the head rotation for all three groups was only a few degrees in magnitude and the group difference disappeared when 'absolute' rotations (magnitude of the rotation regardless of direction) were considered. A more consistent difference was evident for the trunk, with the 5–6 year olds more rotated than the adults for both directional and absolute trunk rotation (see Fig. 2). The youngest children also tended to have more rotation of the head in relation to the trunk (Table 1) than the older groups.

3.1.3. Mean upper limb posture

Upper limb posture differed substantially across the age groups. Scapula elevation was different for all three groups on both right and left sides (Table 1) with least elevation for the adults. The children also had less scapula protraction – both groups of children had less right (dominant side) protraction and the 10–12 year olds had less left scapula protraction than adults. Arm flexion also differed substantially between groups. For adults the mean arm position was in extension, whilst the children had fairly neutral arm flexion positions for the right side and were in flexion for the left arm. The youngest children had significantly greater left arm flexion than the older children. The 10–12 year olds also had a more abducted right arm than the adults and the 5–6 year olds adopted significantly less left arm abduction than both the older groups.

Table 2
Variability (APDFrange$_{(90-10)}$) of posture (°) and muscle activity (% maximum voluntary exertion) during computer use by adults and children: mean (standard deviation)

	Adults	10–12 years	5–6 years	F	p
Gaze angle	2.4 (2.0)	3.2 (3.1)	4.7 (4.4)	3.5	0.034
Head flexion	18.5 (13.2)	16.9 (8.9)	12.0 (3.3)	2.2	0.113
Neck flexion	9.4 (7.2)	10.9 (5.8)	12.0 (7.4)	0.8	0.431
Trunk flexion	4.3 (2.5)^{a}	10.3 (9.2)^{b}	9.9 (7.5)^{a,b}	7.8	0.001
Cranio-cervical angle	12.4 (7.4)	14.6 (10.4)	10.9 (6.3)	1.0	0.360
Cervico-thoracic angle	8.7 (6.9)	11.5 (7.1)	7.4 (3.3)	2.2	0.118
Head lateral bending	5.2 (2.8)^{a}	8.9 (6.0)^{a,b}	11.6 (6.9)^{b}	10.3	< 0.001
rotation	8.1 (4.2)^{a}	11.7 (3.7)^{a,b}	14.5 (5.5)^{b}	13.3	< 0.001
Neck lateral bending	5.2 (2.4)^{a}	7.8 (4.5)^{b}	8.3 (2.5)^{b}	7.3	< 0.001
Trunk rotation	3.2 (1.7)^{a}	10.1 (5.8)^{b}	9.8 (4.6)^{b}	26.6	< 0.001
Head rel. to trunk	8.4 (3.9)^{a}	11.8 (6.0)^{a,b}	15.2 (6.2)^{b}	10.3	< 0.001
Scapula elevation R	2.9 (1.6)^{a}	6.0 (2.6)^{b}	6.7 (3.8)^{b}	16.9	< 0.001
elevation L	3.3 (1.9)^{a}	6.0 (2.5)^{b}	5.6 (3.4)^{b}	9.7	< 0.001
protraction R	3.4 (1.8)^{a}	8.3 (4.6)^{b}	8.9 (4.7)^{b}	19.8	< 0.001
protraction L	5.0 (3.5)^{a}	10.3 (6.9)^{b}	9.7 (6.2)^{a,b}	8.4	< 0.001
Arm flexion R	7.9 (5.3)^{a}	14.5 (7.6)^{b}	16.9 (10.2)^{b}	10.4	< 0.001
flexion L	12.8 (14.2)	21.5 (14.2)	14.1 (13.2)	2.8	0.064
abduction R	5.7 (3.8)^{a}	10.6 (5.4)^{b}	9.3 (4.5)^{a,b}	9.3	< 0.001
abduction L	3.7 (2.8)^{a}	10.4 (7.7)^{b}	11.5 (7.7)^{b}	13.9	< 0.001
Cerv. Erector Spinae R	5.9 (4.8)	9.0 (10.0)	7.2 (5.6)	1.4	0.245
Cerv. Erector Spinae L	6.0 (5.1)	6.0 (3.0)	11.0 (11.8)	3.3	0.042
Upper Trapezius R	8.8 (6.0)	12.3 (8.6)	9.3 (5.7)	1.9	0.156
Upper Trapezius L	7.3 (7.0)	9.7 (6.4)	5.9 (9.3)	1.3	0.268

Superscript symbols show results of Tukey's HSD post hoc analysis: different letter superscripts denote a difference with $p < 0.01$.

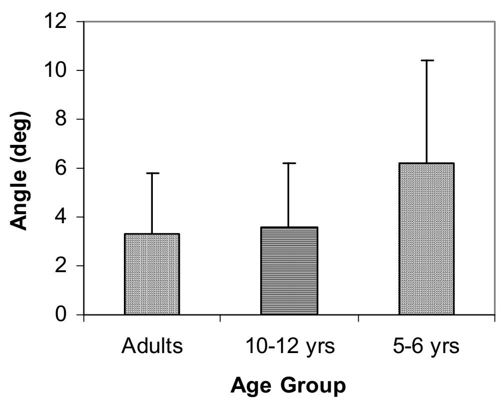

Fig. 2. Mean absolute trunk rotation.

3.2. Mean muscle activity

Adults and the older children did not differ in normalised mean muscle activity amplitudes for either CES or UT. There was a trend for the youngest group to have higher CES activity than older children and adults ($p = 0.017$–0.023). There was no difference across age groups for UT activity.

3.3. Amplitude range

A higher $APDF_{90-10}$ value denotes a greater range of movement or muscle activity amplitude, and therefore greater exposure variation. Adults had lower values than one or both groups of children for many postural $APDF_{90-10}$s (Table 2) indicating a smaller range of movement and a more static posture. The exception to this pattern was spinal flexion, which showed similar monotony across age groups apart from the trunk segment. Adults had approximately half the amplitude range of the children for the trunk. Although the children tended to have less postural fixity than adults, there was no difference for any of the postural variables for the 5–6 year olds compared to the older children.

Muscle activity amplitude ranges were similar across age groups except for a trend for younger children to have a greater range than adults for left CES ($p = 0.040$).

3.4. Exposure variation analysis

Larger values of EVA_{sd} reflect a more concentrated grouping within a duration/intensity class, hence a more monotonous posture. EVA_{sd} encompasses both variation in intensity and variation in duration of movement

Table 3
Variability (EVA_{sd}) of posture (°) and muscle activity (% maximum voluntary exertion) during computer use by adults and children

	Adults	10–12 years	5–6 years	F	p
Gaze angle	8.2 (2.6)	8.6 (1.9)	9.9 (2.1)	3.3	0.041
Head flexion	4.5 (1.8)	3.7 (0.9)	4.9 (0.6)	2.8	0.070
Neck flexion	5.5 (2.0)	4.7 (1.3)	5.6 (1.2)	1.7	0.195
Trunk flexion	8.0 (2.3)^{a}	5.7 (2.3)^{b}	7.4 (2.7)^{a,b}	6.7	0.002
Cranio-cervical angle	4.1 (2.0)	4.1 (1.7)	4.2 (0.9)	0.1	0.920
Cervico-thoracic angle	5.9 (2.2)^{a,b}	4.6 (1.6)^{a}	6.6 (1.3)^{b}	6.1	0.004
Head lateral bending	6.1 (2.0)^{a}	4.5 (0.8)^{b}	5.3 (1.4)^{a,b}	6.8	0.002
rotation	4.9 (1.7)	3.9 (0.5)	4.5 (0.6)	4.0	0.023
Neck lateral bending	5.7 (1.9)	4.6 (0.8)	5.7 (1.0)	4.8	0.011
Trunk rotation	7.7 (2.3)^{a}	4.7 (1.7)^{b}	5.8 (1.9)^{b}	15.2	< 0.001
Head rel. to trunk	4.8 (1.3)^{a}	3.8 (0.4)^{b}	4.6 (1.4)^{a,b}	5.2	0.008
Scapula elevation R	7.4 (2.1)^{a}	5.4 (1.1)^{b}	6.9 (1.5)^{a,b}	10.2	< 0.001
elevation L	7.2 (2.2)	5.9 (1.7)	7.3 (2.1)	3.2	0.047
protraction R	7.3 (2.3)^{a}	5.2 (1.0)^{b}	7.1 (2.3)^{a}	8.2	0.001
protraction L	6.5 (2.4)^{a}	4.8 (1.4)^{b}	6.5 (1.7)^{a,b}	5.4	0.006
Arm flexion R	6.2 (2.1)	5.0 (2.0)	5.8 (1.8)	2.2	0.123
flexion L	6.6 (2.4)^{a,b}	5.2 (1.7)^{a}	7.5 (2.0)^{b}	5.9	0.004
abduction R	6.6 (2.2)^{a}	4.6 (1.2)^{b}	6.1 (2.2)^{a,b}	7.8	0.001
abduction L	7.3 (2.8)^{a}	5.4 (1.6)^{b}	7.7 (2.1)^{a}	6.3	0.003
Cerv. Erector Spinae R	7.9 (2.2)^{a}	5.7 (1.1)^{b}	8.4 (2.6)^{a}	10.8	< 0.001
Cerv. Erector Spinae L	8.0 (2.6)^{a}	6.1 (1.3)^{b}	8.0 (2.1)^{a,b}	6.0	0.004
Upper Trapezius R	6.2 (2.2)^{a,b}	5.0 (1.0)^{a}	7.0 (1.3)^{b}	6.9	0.002
Upper Trapezius L	5.9 (1.5)^{a}	5.2 (1.0)^{a}	8.2 (2.7)^{b}	14.7	< 0.001

Superscript symbols show results of Tukey's HSD post hoc analysis: different letter superscripts denote a difference with $p < 0.01$.

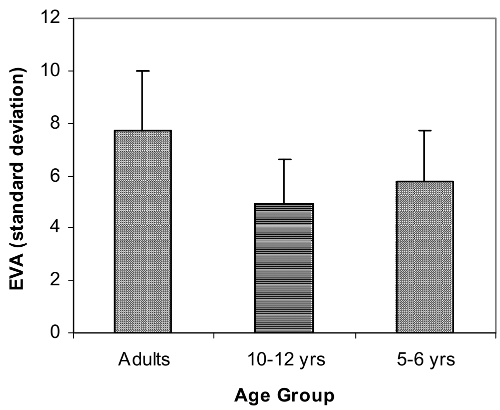

Fig. 3. Trunk rotation variation (EVA_{sd}).

or muscle activity. The 10–12 year olds tended to show less monotonous postures compared to adults, younger children or both groups across a range of postural variables, particularly those describing the upper limb (Table 3). EVA_{sd} did not differ between age groups for head and neck flexion, however the 10–12 year olds had less monotonous trunk flexion than adults and a more variable cervico-thoracic angle than 5–6 year olds, with a trend for this also to be less static than adults ($p = 0.032$). Adults had a more monotonous trunk rotation when compared to both groups of children (See Fig. 3 and Table 3). Upper limb postures also tended to be more monotonous for adults than 10–12 year olds, with significantly higher EVA_{sd} values for right scapula elevation and protraction, left scapula protraction, bilateral arm abduction and left arm flexion. The upper limb postural monotony was more similar for the two younger groups, however the 10–12 year olds had less static postures for left arm abduction and flexion and right scapula protraction than that of the 5–6 year olds.

Adults had greater muscle activity EVA_{sd} values than the 10–12 year old children for left and right CES and a trend for greater RUT monotony ($p = 0.029$). The youngest children had more monotonous activity of the LUT than both older groups. Muscle activity monotony for the other muscle groups was similar to that of adults but more monotonous compared to that of the 10–12 year olds (significant for RCES and RUT and a trend for LCES with $p = 0.025$).

4. Discussion

4.1. Mean posture

4.1.1. Gaze angle and spinal flexion

The gaze angle for the 10–12 year olds was slightly lower than for the other two groups as a result of minor method differences in the series of studies, however all of the mean gaze angles were in the 'preferred range' for visual preference as determined from previous research [16]. The 10–12 year olds sat with 5° more head flexion as expected from the 6° lower display angle. However the 8° change in craniocervical angle reflected not only more head flexion but 3° less neck flexion (Table 1). There was no difference in trunk flexion or cervico-thoracic angle. In contrast the youngest children sat with both more head and neck flexion than was expected in comparison to the older children and adults. Because their task involved only mousing and looking at the display it was expected that their posture would be more upright as they did not need to look down at a keyboard. Furthermore, whilst they sat on a stool without a back rest (to avoid back rest obstruction of trunk markers on small torso) it was expected they may have had more trunk flexion, but this was not the case.

Many of the differences in spinal flexion are likely to reflect individual differences in which part of the body accommodates changes in visual target. Adjustment of both spinal posture and eye orientation occurs in response to changes in visual target height [4,16,19].

4.1.2. Mean spinal asymmetry

There was a tendency for very young children to exhibit greater mean spinal rotation during computer work than adults. The tasks for the 10–12 year olds and adults were identical and similar postural rotations were adopted. For the youngest children the task was different, and was solely mouse driven rather than requiring keyboard and mouse. The greater rotation of the trunk and the head in relation to trunk position which was evident for this group may be related to this task difference, or there may be a developmental tendency to adopt less rotation with age and/or years of computer work.

4.1.3. Mean upper limb posture

Differences in upper limb posture are probably multifactorial, with experimental conditions, developmental stage and physical parameters all possible contributors. A slightly lower desk and a lower acromial marker location may have contributed to the less elevated scapula in adults. The adult acromial marker was also slightly more anterior than for the children and this may also have contributed to the more protracted scapula for the adults. However other factors must also have been influential because the group difference was not significant for the left side scapula.

Arm flexion was markedly different between adults and children, with the adults extending their arms during the computer work but the children in flexed postures. The lower desk and acromial marker location may both be contributors to this but the magnitude of the postural difference was substantial hence other factors may also be influential. Differences in arm flexion for the youngest children were probably task related – this group used mouse input only whilst the two older groups used both keyboard and mouse. The left arm abduction differences for this group compared to the older groups may also be associated with the task, due to 'resting' on the left elbow whilst operating the mouse with the right hand.

4.2. Mean muscle activity

The youngest children had a trend for greater bilateral CES activity than the other two groups. This is in line with the greater head and neck flexion which was evident for this group, and may also be related to the greater relative head mass of young children. There may also have been some contribution from normalisation effects: less than maximal contractions during normalisation trials would result in inflated MVE values. However verbal and visual encouragement was provided during normalisation procedures and sEMG trials showed good inter-trial reliability for the youngest group. In addition, the age-related difference in muscle activity was specific to the CES muscle group, hence it is likely to be an actual phenomenon rather than a normalisation difference.

4.3. Amplitude range

A greater degree of postural fixity was evident for adults in comparison to one or both groups of children for many postures involving the head, neck, trunk and upper limb (Table 2). This pattern may be related to absolute size – the same sized keyboard and computer display were used for adults and children so the distance between individual keyboard key targets (for example, movement between the 'b' and 'p' keys) was the same for both populations. Given a longer limb segment in adults, this same target sequence could be achieved with a smaller angular rotation of the segment. With larger hands, reaching between keys could be achieved with less rotation of the arm. Similarly, the same absolute movement of the mouse would be required to move between two targets on the display for adults and children, but would be accomplished with smaller postural angular displacements for larger bodies.

A further contributor to the greater postural fixity could be a learning or habituation effect – the adults had been using computers for an average of 10 years and the older children for about half of that time. The adults were also more proficient at typing, with an average speed of 40 words per minute compared to 17 words per minute for the 10–12 year olds. Although hours of use per day were not recorded this pattern suggests significantly greater exposure to computers in the adult sample. The increased exposure and proficiency with computer use could be associated with a more efficient movement pattern having been developed, with less extraneous movement and hence a smaller amplitude range.

In contrast to most of the spinal asymmetry and upper limb postural variables, amplitude ranges for head and neck flexion were similar across age groups. In spite of some differences in mean flexion angles, movement away from this mean position tended to be similar for the different age groups and, in the case of the youngest children, different computer task. Trunk flexion monotony was however, different across age groups, with the children having an amplitude range which was more than twice that of the adults.

Whilst the difference in postural amplitude ranges for the youngest children in comparison to adults could be associated with differences in absolute size and the learning effect described earlier, the similarity between 5–6 year olds and 10–12 year olds is more difficult to explain. The youngest children did not use a keyboard, and therefore it could be expected that the alteration of upper limb postures would be less of a requirement. Fewer visual targets (mouse and computer only, compared to mouse, computer and keyboard for the older groups) could also be expected to decrease spinal flexion and rotation variation compared to the older children. Offsetting these factors however, are the smaller segment lengths of the younger children, which would necessitate greater amplitude ranges to achieve the same absolute movement of, for example, the mouse cursor. These children also had less experience using computers and this may also have been a factor in the postural accommodation to their computing task.

Adults and children performed the computing tasks with similar ranges of relative muscle activity amplitude for CES and UT. The EVA_{sd} statistic seemed to be more sensitive than $APDF_{90-10}$ for identifying differences in muscle activity variation, as described in the next section.

4.4. EVA_{sd}

A comparison of the adults and 10–12 year old children reveals that children performed the same computing task with significantly greater postural and muscle activity variation (Table 3). Postural variation for head and neck flexion was similar across all groups, in line with the $APDF_{90-10}$ indices. A more monotonous trunk posture was evident in adults compared to the 10–12 year olds and this was again in accordance with the APDF results. Similarly, the more monotonous adult spinal asymmetry and upper limb postures were also detected in the amplitude variation analysis. As described for the APDF index, more static postures for adults could be related to both greater size and years of computer use.

The tendency for more monotonous upper trapezius muscle activity pattern in the youngest children is probably task-related: the mouse was operated with the right hand and no keyboard was used by this group.

In addition to the greater postural fixity, adults also had lower muscle activity variation than the 10–12 year olds for bilateral CES. The greater variation exhibited by the children is likely to be beneficial as it has been shown that low level static postures occurring during computer work can be associated with continuously active motor units and therefore the potential for overload [30].

4.5. Clinical implications

Children may adopt slightly different, less neutral, postures to adults when working with computers. However the increase in biomechanical and physiological loads with less neutral postures is likely to be similar for both adults and children. Clinicians working with children experiencing musculoskeletal pain related to computer use, and providing primary prevention information, should therefore encourage neutral postures for children as they would for adults.

The more varied postures adopted by children during computer use should also be encouraged by clinicians. Parents and teachers should be discouraged from reprimanding children for ‘fidgetting’ during computer use. Adults should be encouraged to be more like children in the amount of movement during computer use. Children should still be encouraged to move away from the computer at regular intervals to create even greater posture variety.

5. Conclusion

Children and young adults are now the most frequent users of computers, however computer-related posture and muscle activity differences between children and adults have not been previously examined. This study found children tended to use more spinal flexion and young children had greater spinal asymmetry when interacting with computers. The potential for these posture differences to result in greater risk of musculoskeletal discomfort and disorder may be offset by the tendency for children to have greater variation of posture and muscle activity. Despite these differences, similar prevention messages may be appropriate for children and adults including the encouragement of appropriate postures and appropriate task variation.

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