Title: Managing children's postural risk when using mobile technology at home: Challenges and strategies

Author names:

Marina Ciccarelli[a], Janice D. Chen[b], Torbjörn Falkmer[a, c], Sharmila Vaz [a], Reinie Cordier [a]

[a] School of Occupational Therapy and Social Work, Faculty of Health Sciences, Curtin University, GPO Box U1987 Perth, 6845 Australia.

[b] Rehabilitation Department, National University Hospital, Singapore 119074

[c] Rehabilitation Medicine, Department of Medicine and Health Sciences (IMH), Faculty of Health Sciences, Linköping University & Pain and Rehabilitation Centre, UHL, County Council, Linköping, SE 581 85 Sweden

***Corresponding author:**

Associate Professor Marina Ciccarelli

School of Occupational Therapy and Social Work

Curtin University,

GPO Box U1987

Perth, Australia, 6845.

Email: M.Ciccarelli@curtin.edu.au

Tel: +61 8 9266 3692

Fax: +61 8 9266 3636

1.0 Introduction

Information and communication technologies (ICTs) are an indispensable part of modern day society. School-aged children in Australia use a variety of ICT for educational, leisure and social purposes (Australian Bureau of Statistics (ABS), 2006, 2009a, 2009b). Several studies report associations between ICT use in children and adolescents and musculoskeletal discomfort (Bélanger, Akre, Berchtold, & Michaud, 2011; Hakala, Rimpelä, Saarni, & Salminen, 2006; Jacobs & Baker, 2002; Straker et al., 2008; Straker, Smith, Bear, O' Sullivan, & de Klerk, 2011), which are similar to those observed among adult computer users in vocational settings (Gerr, Marcus, & Monteilh, 2004). Given that children are still developing physically, there is reasonable concern regarding the long term impact of such exposure on their musculoskeletal health (Bélanger, et al., 2011; Jacobs & Baker, 2002; Straker, Pollock, & Maslen, 2009).

Recent technological advances have inspired a genre of portable, compact and personalised ICT devices, such as laptop computers, touch screen tablets and smart phones. These mobile devices can be used in a wide range of physical environments while adopting a range of postures (Harris & Straker, 2000; Sommerich, Ward, Sikdar, Payne, & Herman, 2007). In other words, nowadays, *anywhere* can be considered an ICT workstation.

Studies into the postures adopted by school-aged children while using an ICT workstation have predominantly been within school environments (Breen, Pyper, Rusk, & Dockrell, 2007; Geldhof, et al., 2007; Kelly, Dockrell, & Galvin, 2009; Murphy, Buckle, & Stubbs, 2004). Mismatches between the dimensions of school furniture and body anthropometrics are regarded as the most observed contributors of reported discomfort and musculoskeletal complaints in various parts of children’s bodies (Barrero & Hedge, 2002; Ciccarelli, Straker, Mathiassen, & Pollock, 2011b; Saarni, Nygård, Rimpelä, Nummi, & Kaukiainen, 2007). Limited research exists on the postural risks associated with children’s ICT use in the home environment (Jacobs & Baker, 2002; Kimmerly & Odell, 2009).

When at home, children are likely to use their mobile ICT devices for unsupervised leisure and social pursuits (Rideout, Foehr, & Roberts, 2010); have longer durations of use for completing educational tasks than when at school (Ciccarelli, Straker, Mathiassen, & Pollock, 2011a; Kent & Facer, 2004; Kerawalla & Crook, 2002); and adopt a range of postures across different locations in the home (Harris & Straker, 2000; Sommerich, et al., 2007). With increasing numbers of children using mobile ICT devices at home, it is important to assess their impact on children's posture, so that appropriate guidelines for the healthy use of these mobile technologies can be developed (Young, Trudeau, Odell, Marinelli, & Dennerlein, 2012).

1.1 Measuring postural risk in children

School-aged children's use of mobile technologies in and out of classroom environments may be categorised as sedentary work (US Department of Labor, 1993), wherein postural exposures can vary widely based on factors including: (i) the design and layout of furniture in the school and home; (ii) whether tasks involving mobile technologies are individual or group tasks; and (iii) the natural postural preferences of children. When determining individuals' postures in field studies, the use of job titles and descriptions of workplace characteristics are the least valid and reliable; direct monitoring using electro-goniometers limits the body segments that can be simultaneously measured (Bao, Howard, Spielholz, & Silverstein, 2007); and time-stamping postures to specific tasks requires high observer burden (Ciccarelli, et al., 2011b). The use of videorecorded work tasks performed in natural environments can allow for the impact of environmental, task, and personal factors on postures to be considered in later analysis.

The Rapid Upper Limb Assessment (RULA) is an observation-based postural screening tool originally developed for use in ergonomic investigations of workplaces, to assess individual worker's exposure to load factors due to posture, muscle function and related forces (McAtamney & Corlett, 1993). RULA was designed to be carried out quickly, with minimal equipment or change to the working environment and with minimal disruption to the person under observation. It is reportedly easy to learn, and requires no previous skills in observation techniques (McAtamney & Corlett, 1993).

RULA can be used to observe and rate postures in situ, or from video recordings. RULA uses a series of illustrations of different body segments, and allocates a numerical score to each body segment based on the degree of deviation from a neutral position. Additional ratings are assigned to factors that place strain on the musculoskeletal system, including repetitive actions, static loading, and force. RULA provides ratings for individual body segments and converts these ratings to a Grand Score. The Grand Score is used to assign the observed posture into an Action Level that indicates the level of intervention required to reduce the musculoskeletal risks of injury on the individual (see Table 1). For example, an Action Level of 3 or 4 signifies that further investigation and changes in how the task is performed are required, so as to reduce postural risk (McAtamney & Corlett, 1993).

Table 1. *RULA Grand scores, action levels and implications*

Grand Score	**Action Level**	**Implications**
1 or 2	1	Posture is acceptable if not maintained or repeated for long periods.
3 or 4	2	Further investigation needed, changes may be required.
5 or 6	3	Investigation and changes are required soon.
7	4	Investigation and changes are required immediately.

Originally developed through evaluation of workers in a range of manufacturing industries, including the garment manufacturing industry, and among computer operators (McAtamney & Corlett, 1993), researchers have since used RULA to assess postural risks among adults in a wide range of occupational groups including light and medium manufacturing workers (Bao, et al., 2007; Chiasson, Imbeau, Aubry, & Delisle, 2012; Kee & Karwowski, 2007), automotive assembly operators

(Drinkaus et al., 2003; Kee & Karwowski, 2007); healthcare workers (Bao, et al., 2007; Kee & Karwowski, 2007); office workers (Cook, Burgess-Limerick, & Chang, 2000; Cook & Kothiyal, 1998; Sen & Richardson, 2007); simulated surgical tasks (Lee, Rafiq, Merrell, Ackerman, & Dennerlein, 2005); saw mill filers (Jones & Kumar, 2007); food processing workers (Chiasson, et al., 2012); truck drivers (Massaccesi et al., 2003); and tree nursery workers (Chiasson, et al., 2012). The RULA rating scale is reported to have good reliability when used by physiotherapists, and industrial and safety engineers to assess adults; although the exact values of the reliability calculation are not documented (McAtamney & Corlett, 1993).

Several researchers have use RULA to assess postures among children in school environments (Breen, et al., 2007; Dockrell, Earle, & Galvin, 2010; Kelly, et al., 2009; Laeser, Maxwell, & Hedge, 1998; Oates, Evans, & Hedge, 1998); with a few alluding to its reliability when used to rate children's postural risk (Breen, et al., 2007; Laeser, et al., 1998; Oates, et al., 1998). A recent study compared the inter-rater and intra-rater reliability of the RULA to assess postures adopted by 12 year old students (n = 24) as they used computers in school during school hours (Dockrell et al., 2012). Using Intra Class Correlation Coefficient as an index of reliability, the study found moderate agreement between trained physiotherapists (n = 3) and undergraduate physiotherapy students' (n = 3) Grand Score and Action Level ratings; with scores in all cases to be more reliable on re-test. Inter-rater reliability varied depending on the summary score used; with the RULA Grand Score of the "trunk and legs" subscale (RULA - D score) found better than that of the "arms" subscale (RULA - C score). The authors did not present each rater's raw scores. Thus, one cannot rule out the influence of dispersion in raters' scores as a potential cause for the lower inter-rater ICC values (Bland & Altman, 2003).

An earlier study by Chen et al., (2014), investigated if experience in postural risk assessment contributed to differences in outcome scores obtained by experienced and novice occupational therapists while using RULA to rate video recordings of self-selected postures adopted by a 12-year old child using mobile ICT in the home environment. The study found no significant group differences in the Grand Score and the Action Level ratings for each video. Furthermore, the authors did not discuss the raw scores ratings of each video, or the postures that presented the greatest risk to the child's musculoskeletal system while using ICT at home. Thus, further research is needed to not only substantiate inter-rater agreement of the RULA in assessing postural risk in children at home, but to also identify the nature of high risk postures that children may adopt while using mobile ICT devices at home. The current study intended to bridge these gaps.

2.0 Study purpose

The purpose of this study was to:

a) test the agreement between an expert rater and experienced and novice raters' scores (Grand scores and Action Levels) on the RULA, whilst undertaking a postural risk assessments of a child using mobile ICT devices in the home environment;
b) identify the postures of a child using mobile ICT in the home environment that are rated as requiring further investigation and/or change; and
c) provide suggestions on how to translate ergonomics principles for healthy ICT among children into practical solutions for families to manage postural risks.

3.0 Methods

3.1 Study design

An experimental laboratory study was conducted under controlled, standardised conditions.

3.2 Sample size

Pilot data from 19 participants were used to estimate the study's power. With an estimated standard deviation of 0.5 – which is just above half a scale step on the RULA Action level, the desired effect size was Cohen's d of 1 or more. In order to obtain 80% confidence in the study's results (critical α-value of 0.05 and 1 - β of 0.2), a minimum of 16 participants in each group was needed to detect the desired effect size.

3.3 Participants

3.3.1. Student occupational therapists

A convenience sample of 14 female and two male occupational therapy students (Mean age (MA) = 24.7 years, standard deviation, SD = 8.1 years) participated in the study. Students with prior work experience in vocational rehabilitation and ergonomics were excluded from the study. None had prior knowledge about the RULA as a postural risk assessment tool.

3.3.2. Experienced occupational therapists

Occupational therapists with a minimum qualification of a Bachelor of Science degree recognised by the World Federation of Occupational Therapists, and more than four years of experience in the field of ergonomics and/or vocational rehabilitation were invited to participate in the study. These participants were purposively selected for inclusion because of their specific industry experience in conducting workplace and ergonomics assessments. Eleven female and five male occupational therapists (MA= 40.7 years, SD = 9.9 years), with relevant work experience ranging from 4-35 years (mean length of experience = 15.3 years, SD= 9.0 years) participated in the study. None reported to have previously have RULA in their professional practice. All participants across groups had normal or corrected-to-normal vision, which enabled them to clearly view the visual images presented during the experiment.

3.3.3. Expert rater

The 'expert rater' was the first author, who is a doctoral qualified ergonomist with 24 years of experience. The expert rater had prior knowledge of RULA as a postural screening tool.

3.4 Procedures

Data collection was conducted in a laboratory at Curtin University, Perth, Western Australia by the second author. Prior to data collection, participants reviewed the study protocol and RULA training was provided by the second author. The study was approved by the Human Research Ethics Committee at Curtin University, Perth in Western Australia (Approval #: OTSW-17-2011), and all participants provided informed consent prior to data collection.

3.5 RULA: Training video and rating scale

Training occurred in a laboratory setting. Each participant independently viewed a nine minute training video specifically developed for this study (Chen, et al., 2014). This video provided an overview of the RULA screening tool, instructions on its rating system, practice video scenario with a female working on a laptop in a home environment, and the correct answers for the practice exercise. While watching the training video, each participant was provided with printed paper copies of the RULA scoring sheet (Osmond Ergonomics).

Participants were given the option to pause and replay the training video as often as required. Training sessions ranged in duration from 10-20 minutes. The same researcher (second author) was present to answer queries and to ensure consistency across training sessions. At the end of their training session, all participants verbally reported being confident in independently using the RULA scoring sheet (Osmond Ergonomics) to rate postures viewed on a videorecording.

3.6 Video scenarios

Participants viewed videotaped images of a 12-year old child using either a laptop computer or a tablet in the home. Locations included the bedroom, and communal living areas, such as the dining room and lounge room. These locations were selected for inclusion based on child, adolescent, and expert panel advice on household locations in which children and adolescents use mobile ICT devices (Chen, et al., 2014). Postures represented in each scenario were videotaped mid-task to allow the child to settle into her typical self-selected postures in these locations. Each scenario was filmed from a minimum of two different stationary viewing angles to provide a comprehensive view of the child’s posture. Raw video data were edited to produce a single video clip for each scenario that was between 140 s and 165s duration. Details about the development of the video scenarios used in the study can be accessed from Chen et al., (2014).

Participants in each group (novice and experienced raters) were presented with 11 video scenarios (representative still images are shown in Table 2) in a counter-balanced rotated random order to minimise possible learning effects. Participants used a paper version of the RULA to assess the right and left side postures of the child in each video scenario – thus rating a total of 22 videos.

Each video scenario was presented only once; however, participants were allowed to take as much time as they needed to complete the RULA score sheet. After each data collection session, the second author scored the participant's RULA scoring sheet for each video scenario. Participants were not provided with any feedback about the accuracy of their responses during data collection. The expert rater was blind to the ratings of the novice and experienced participants until she had viewed the video scenarios and completed a RULA score sheet for each scenario.

4.0 Statistical analyses

Data were analysed using the Statistical Analysis Software Version 9.2 (SAS Institute, Cary, NC) and MedCal software packages. Percentage agreement values at individual video level were calculated to determine the percentage of novice and experienced therapists that had the *"same rating"* on each video as the expert. Quadratic weighted Kappa statistics at group level were also run to assess the overall agreement between novice and experienced therapists and expert, across all videos.

5.0 Results

5.1 Novice and experienced therapists' ratings compared to the expert rater

To address the first study aim, the Grand Scores (GS) and associated Actions Levels (AL) pertaining to the right and left side postures of the child in the 11 video scenarios were compared among the novice therapists, experienced therapists and the expert rater. Table 2 presents the percentage of novice and experienced therapists that had the same GS as the expert rater for each video scenario, and Table 3 presents the percentage of novices/experienced therapists who agreed with the expert rater's corresponding Action Levels for each video.

At an individual video level, 87.5% of novice and 93.75% of experienced therapists agreed with the expert rater's left side GS of 7 for Video 7 –side side-lying in bed. However, only 12.5% of novice and 25% of experienced therapists agreed with the expert rater's right side GS of 6 for Video 7. Over half the novices and nearly two-thirds of the experienced therapists gave a less conservative, higher score of 7. Similar disparity among the raters between right side and left side GS was seen for Video

4 – side-sitting on the floor. Almost 88% of novice and experienced therapists agreed with the expert rater's right side GS of 7; but only about half of the novices and experienced therapists agreed with the expert rater's left side GS of 6. One quarter of the novices and 43.75% of the experienced therapists gave the higher GS of 7 for the child's left side posture in Video 4.

Video 5 –using a laptop at bedside also had low agreement between the novice/experienced and expert rater. There was inconsistency among the novices with how they rated the child's left side posture. About 31% agreed with the expert rater's left side GS of 5; 6.25% novices gave a lower GS of 3; 25% gave a lower GS of 4, and 37.5% gave a higher GS of 6. Similar inconsistency was seen among the experienced therapists' left side GS ratings. For the right side GS, about 44% of novices agreed with the expert's GS of 5, with about 18% giving a lower GS and about 38% giving a higher GS. None of the experienced therapists agreed with the expert rater for the right side postures in Video 5; instead half gave a higher GS of 6, and one quarter gave a GS of 7. Agreement for the other videos between novice/experienced therapists and the expert rater ranged from 6.25% to 68.75%.

Given that the Action Levels were calculated based on the Grand Scores, similar patterns of agreement between the novice/experienced therapists and the expert rater on the Action Levels were seen in Table 3, as the Grand Scores in Table 2.

Table 2. Percentage of novice and experienced therapists who had the same grand score (GS) as the expert rater for each video. Data in the table are presented in order of severity of score.

Video No	ICT device/ location	Image	Type of Score	Expert GS n=1	Novice n=16	Experienced n=16
Video 1	Laptop - coffee table		Left GS	7	62.5%	68.75%
Video 7	Laptop - bed (side-lying)		Left GS	7	87.5%	93.75%
Video 1	Laptop - coffee table		Right GS	7	56.25%	68.75%
Video 4	iPad - floor (side)		Right GS	7	87.5%	87.5%
Video 7	Laptop - bed (side-lying)		Right GS	6	12.5%	25%
Video 2	iPad - dining table		Left GS	6	31.25 %	56.25 %
Video 2	iPad - dining table		Right GS	6	25%	43.75%

Video 4	iPad - floor (side)		Left GS	6	56.25%	50%
Video 6	iPad - couch (sitting hunched)		Left GS	6	18.75%	31.25%
Video 6	iPad - couch (sitting hunched)		Right GS	6	18.75%	31.25%
Video 8	iPad - couch (reclining)		Left GS	6	43.75%	25%
Video 8	iPad - couch (reclining)		Right GS	6	43.75%	50%
Video 9	Laptop - dining table		Left GS	6	18.75%	18.75%
Video 9	Laptop - dining table		Right GS	6	18.75%	18.75%
Video 11	iPad - floor (front)		Left GS	6	18.75%	25%
Video 11	iPad - floor (front)		Right GS	6	43.75%	25%

Video 3	Laptop - bed (reclining)		Left GS	5	12.5%	25%
Video 3	Laptop - bed (reclining)		Right GS	4	31.25%	25%
Video 5	Laptop - bedside		Left GS	5	31.25%	12.5%
Video 5	Laptop - bedside		Right GS	5	43.75%	0%
Video 10	Laptop - couch with breakfast table		Left GS	5	6.25%	25%
Video 10	Laptop - couch with breakfast table		Right GS	5	6.25%	6.25%

Table 3. Percentage of novice and experienced therapists who had the same action level (AL) rating as the expert rater for each video. Data in the table are presented in order of severity of score.

Video No	ICT device/ location	Image	Type of Score	Expert AL n=1	Novice n=16	Experienced n=16
Video 1	Laptop - coffee table		Left AL	4	62.5%	68.75%
Video 7	Laptop - bed (side-lying)		Left AL	4	87.5%	93.75%
Video 1	Laptop - coffee table		Right AL	4	56.25%	68.75%
Video 4	iPad - floor (side)		Right AL	4	87.5%	87.5%
Video 7	Laptop - bed (side-lying)		Right AL	3	43.75%	31.25%
Video 2	iPad - dining table		Left AL	3	50%	68.75 %
Video 2	iPad - dining table		Right AL	3	43.75%	68.75%

Video 4	iPad - floor (side)		Left AL	3	75%	50%
Video 6	iPad - couch (sitting hunched)		Left AL	3	37.5%	50%
Video 6	iPad - couch (sitting hunched)		Right AL	3	37.5%	43.75%
Video 8	iPad - couch (reclining)		Left AL	3	56.25%	43.75%
Video 8	iPad - couch (reclining)		Right AL	3	62.5%	62.5%
Video 9	Laptop - dining table		Left AL	3	31.25%	43.75%
Video 9	Laptop - dining table		Right AL	3	31.25%	43.75%
Video 11	iPad - floor (front)		Left AL	3	31.25%	37.5%
Video 11	iPad - floor (front)		Right AL	3	43.75%	37.5%

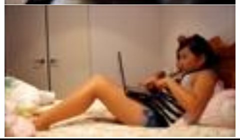
Video 3	Laptop - bed (reclining)		Left AL	3	37.5%	37.5%
Video 5	Laptop - bedside		Left AL	3	75%	50%
Video 5	Laptop - bedside		Right AL	3	75%	50%
Video 10	Laptop - couch with breakfast table		Left AL	3	25%	50%
Video 10	Laptop - couch with breakfast table		Right AL	3	25%	43.75%
Video 3	Laptop - bed (reclining)		Right AL	2	50%	31.25%

Table 4 shows the poor agreement between the expert rater and the novice and experienced therapists, respectively with regard to all left and right Grand Scores and all Action Levels.

Table 4. Weighted kappa agreements between rater groups and the expert therapist across all videos

	Groups of raters (95% CI)	
Type of rating	Novice vs. Expert rater	Experienced vs. Expert rater
Left Grand Score (GS)	0.343 (0.251, 0.433)	0.329 (0.219, 0.439)
Right Grand Score	0.329 (0.215, 0.443)	0.333 (0.210, 0.456)
Left Action Level (AL)	0.362 (0.272, 0.451)	0.292 (0.189, 0.396)
Right Action Level	0.354 (0.233, 0.474)	0.313 (0.194, 0.431)

5.2 Postural risk ratings

We aimed to determine which of the child's postures were rated as requiring further investigation or change. Using RULA, all participants in our study rated the child's postures in each of the 11 video scenarios at or above an Action Level of 2 (further investigation required; AL 3 timely intervention needed, or AL 4 immediate intervention required). None of the postures were rated at an AL 1(posture is acceptable if not maintained or repeated for long periods). Laptop use while seated at the coffee table (Video 1); side-lying on the bed (Video 7); and tablet use while side-sitting on the floor (Video 4) involved postures deemed most risky (AL 4) and warranted immediate remedial action. The high risk rating was based on the degree of trunk rotation; asymmetry of the legs and head flexion; and maintenance of the posture for longer than one minute durations while performing the task. Force taken through the supporting forearm (Video 1) and wrist and shoulder (Videos 4 and 7) also contributed to the high risk ratings.

Postures adopted while using the laptop and tablet in all other positions, both in the bedroom and communal living areas (i.e. dining and lounge room) placed the child at AL 3, warranting further investigation and/or changes that were required soon. Holding postures for greater than one minute durations; head flexion (Videos 2, 3 and 10); trunk flexion and rotation (Videos 2, 6, 8 and 11), and asymmetrical sustained postures of the lower extremities (Videos 5, 8, 9 and 11) all contributed to the high risk ratings.

The child used a laptop and tablet with, and without, a table or other supporting work surface. Use of the tablet resulted in sustained neck flexion of the child, more so than when using a laptop computer, as shown in the still images in Table 2. A back support was used during sitting in five of the 11 scenarios, but there were other concurrent postural concerns that contributed to increased postural risk including: sustained neck flexion, asymmetrical positioning of the lower extremities, and holding awkward and non-neutral postures for periods greater than one minute.

6. 0 Discussion

The current study was aimed to determine the agreement between an expert therapist, and experienced and novice therapists' scores on RULA, while undertaking a postural risk assessment of a child using mobile ICT devices in the home; and identify self-selected postures adopted by the child that require further investigation and/or change.

The study found that for two of the 22 video scenarios (Videos 4 and 7), 87.5% or more experienced and novice therapists had the same GS rating as the expert therapist. On each of these videos however, there was maximum disparity in GS ratings between the right and left sides of the body. The poor to fair agreements between the expert and the others' ratings across most of the other videos, both at and individual video and group level may be due to the reliance of RULA on visual estimation of force and static, repeated or intermittent loads whilst adopting complex postures. For example, flexion of the child's head and neck observed in Videos 2, 4 and 11 would result in increased static force to maintain position of the head against gravity held for durations longer than one minute, but the force estimates were made only through visual inspection of the posture. While joint angles can easily be estimated visually for the purpose of allocating a risk rating, estimation of force is likely to be more difficult. The usefulness of the RULA as a screening for postural risks among children using ICT at home while adopting various positions including side-lying (Video 7) or on the floor (Videos 1, 4 and 11) is questionable because these postures do not necessarily represent the working postures of the occupational groups on which the tool was developed.

When using RULA as a postural screening tool, we identified that the majority of the self-selected postures adopted by the child in the home environment presented some postural risk to musculoskeletal health, and warranted immediate or timely action. We did not assess the relationship among the postures adopted by the child, any discomfort experienced by the child, and risk ratings given by study participants, and thus were not able to validate the RULA scores with this child's postures.

6.1 Implications for future research

From a methodological standpoint, our findings highlight the poor to fair agreement between and expert and novice/experienced therapists' ratings of the child's postural risk using mobile ICT in the home. Of concern, is that irrespective of rater experience, all postures adopted by the child while using ICT at home, were rated as having a postural risk that warranted either further investigation and/or immediate or timely intervention. This finding questions the existence of a possible ceiling effect in the RULA; a concern raised by other studies that used RULA to assess musculoskeletal risk in an adult population (Chiasson, Imbeau, Aubry, & Delisle, 2012). Moreover, more than three quarters of the postures adopted in the video scenarios involved the child seated in asymmetrical postures, including side sitting on the floor and side-lying in bed. Questions regarding the validity of the RULA for assessing similar postures among children have been previously raised by other researchers (Breen, et al., 2007). Given that the RULA was originally developed as a postural screening of the predominantly seated and standing postures of adult workers, it may be that RULA is not sufficiently sensitive to accurately rate the unique and very different postures adopted by the child in the home. More research is needed to either validate the use of RULA with a paediatric population, or to determine other suitable postural risk measures for children using mobile ICT in a variety of physical environments.

Past studies on children's use of desktop computers in the home or school setting have reported associations between self-reported musculoskeletal discomfort and ergonomic mismatches in technology and technology specific furniture use (Harris & Straker, 2000; Jacobs & Baker, 2002; Jacobs, Hudak, & Mc Giffert, 2009; Szeto et al., 2013; Williams & Jacobs, 2002). For example, in one study sixth grade students who used desktop computers without computer-specific furniture were 1.89 times more likely to report musculoskeletal discomfort (Jacobs & Baker, 2002). The two ICT devices included in the video scenarios in this study are reportedly commonly used by school-aged children for study and leisure purposes (Rideout, Foehr, & Roberts, 2010). Children also use a variety of other small ICT devices in the home including smartphones, videogame consoles, and handheld gaming devices (Rideout, et al., 2010). We recommend future research that investigates the relationships among frequency, duration, type of mobile technologies used at home, and musculoskeletal discomfort among children, with a view to developing strategies for minimising postural risk when working at unconventional ICT 'workstations'.

6.2 Challenges to managing postural risks among children using ICT in the home

There is an urgent need to better understand how children use ICT in environments other than school, as there is growing evidence that greater ICT exposure occurs within the home (ABS, 2012; Rideout, et al., 2010). What is evident from the present study is that the majority of the postures adopted by the child in the home environment had an Action Level rating of 3 or 4, indicating a postural risk to musculoskeletal health requiring intervention to mediate it. Identifying suitable interventions relevant to the home context presents a challenge for a number of reasons.

First, children using ICT devices are likely more autonomous in the home than school with regard to the postures they use (Ciccarelli, et al., 2011b), and the length of time on task (Ciccarelli, et al., 2011a). Furthermore, a child's level of autonomy over areas of personal life increases with age (Smetana & Asquith, 1994). Recommendations need to be targeted to increasing children's awareness of the postural risks and framed in a way they perceive as being relevant to themselves as individuals and to the way in which they use ICT.

Second, recommendations arising from school-based ergonomics interventions may not be relevant to the home context due to fundamental differences in the size, shape and function of seating and furniture between the two environments. For example, RULA was used by Dockrell, et al., (2010) as part of a school-based ergonomics intervention for 23 grade four students (aged 9-10 years). Pre-intervention postural assessment of the children at their classroom workstations identified a mean Action Level of 3±0.5, and a post-intervention Action Level of 2.1±0.3. Although there was a significant reduction in scores post-intervention and an improvement in posture, none of the children's postures were considered to be in the acceptable Action Level (1). Recommendations for reducing risk in that study included strategies such as the use of adjustable height seating, and peripheral equipment including document holders, footrest and mouse. Given that the portability and small size of mobile technologies are characteristics that make them attractive for young people to use, restricting where these devices are used in the home (e.g. at a set workstation with peripheral equipment) may create challenges with adoption of these interventions among children and adolescents.

A third challenge is the biomechanical impact of using small mobile ICT devices such as laptop computers, tablets, and smartphones. Tablet devices were initially designed with a small screen interface to be used with a stylus pen. An increase in the size of the display using finger input was evident from around 2007 onwards until about 2012, at which time ICT manufacturers reduced the screen size to about 14-18 cm and created a smartphone-tablet hybrid (phablet) that increased functionality and portability of the devices. Recent consumer trend data suggest that in 2015, global sales of these smaller screen phablets will exceed sales of traditional tablets and laptop computers (Bolkan 2014). The limited number of studies investigating the biomechanical impact of mobile versus fixed ICT types have found that using tablet devices resulted in greater non-neutral postures of the head and neck, than laptop and desktop computers in adults (Young et al 2012) and children (Straker, Coleman, Skoss, Maslen, Burgess-Limerick, Pollock, 2008; Straker et al 2011). The child in our study demonstrated greater head and neck flexion during tablet use than during laptop use, consistent with these prior findings. With the trend for smaller screen size of tablets/phablets, there is a potential that children's head and neck postures will continue to be negatively impacted.

6.3 Strategies for families to manage children's postural risks

The third aim of the study was to present some suggestions to children and their families about strategies for managing postural risk. There is no one-size-fits-all approach to healthy use of mobile technologies by children in the home. It requires children and their parents to determine the risk specific to the situation. Guidelines for principles of healthy use of technologies among children have been published in recent years (Straker, et al., 2009), but it is necessary to translate these ergonomics principles into accessible language that families can apply to their own situations. The first author has, at the request of school administrators, presented a series of workshops for teachers, school children and their parents that have focussed on how to identify risky postures and strategies to minimise postural discomfort. A four-point approach to risk identification and management, in which both children and parents took active roles, was used:

1. *Who do you turn into?* – This first point is related to identification of postural risks. The child and the parent are asked to use candid photographic images (that can be captured on camera or smartphone by the parent or siblings) of the child's posture when using the technology, in order to identify postures that might be a concern. The child is shown the image of their posture, which is then compared to a range of visual images representing different postural risks. Examples of images include the "Hunchback" (i.e. extreme head/neck flexion, hunch shoulders and rounded unsupported low back); the "Vulture" (i.e. neck flexion with an extended chin); the "Tornado (or Twister)" (i.e. asymmetrical postures of the head, trunk and lower limbs); and the "Seal", (lying in prone, propped up on the forearms and holding the head against gravity; see Fig.1.). The use of easily identifiable images provides the children and parents with simple and common language to describe postures of concern, and that some action needs to be taken to change the posture.

Figure 1. Comparison of a child's prone posture during laptop use to the 'Who do you turn into?' image of the 'Seal'

2. *Match it up* – This point focuses on the impact of the physical environment on postures. Families are asked to consider where the child is going to use their technology. Does the physical environment provide support to the low back, the legs and the arms? Is the lack of suitable physical supports turning the child's posture into one of the images identified in 'Who do you turn into'? Suggestions are provided for how to best utilise the home environment when using technology. For example, use of a bean bag or gamers' chair can provide reclined back and leg support, while allowing for the mobile device to be supported on the lap without extreme neck flexion; or that long-legged sitting in bed provides more support for the head/neck and low back than lying in prone on the bed.
3. *Change it up* – This point addresses the need for postures and task variation to minimise postural discomfort (Ciccarelli, et al., (20011b), by explaining to children and their parents that any posture, no matter how 'good', when held for a long time can result in musculoskeletal discomfort. Furthermore, the physical environment influences the child's gross posture; i.e., sitting, standing or lying. By changing where the mobile devices are used around the home can help to vary the postures used. Making time for a total of 60 minutes of moderate to vigorous (.i.e. 'huff and puff') physical activity (Commonwealth of Australia, 2014) ; taking mini-breaks to stretch and shake; and including activities that are

not screen-based are some ways to create postural variation over the course of a day (Ciccarelli, et al., 2011).

4. *Listen to your body* – This last point highlights the importance of promptly responding to discomfort by changing postures, or taking a short break from using the device. Persistent discomfort that is not addressed may be a precursor to future pain. Prior research suggests that children may work through discomfort when using ICT (Royster, 2002) rather than respond to the discomfort. Children may be reluctant to tell their parents about any discomfort related to ICT use, for fear the technology will be taken away. Developing open communication between the child and the parent is important so that reasonable and relevant strategies to manage postural risk can be agreed upon and implemented.

6.4 Study limitations

A limitation of this study was the limited training in the use of RULA provided to the participants prior to data collection. Although participants were provided with feedback about their ratings on the practice video scenario and had the opportunity to ask questions about the RULA and use of the rating form, only one practice video scenario was utilised. Even though RULA is reportedly easy to learn, the participants were likely to have gained a higher level of proficiency with repeated use of the measure prior to data collection. Furthermore we were unable to validate the participants' ratings against a gold standard, and so the accuracy of ratings by the novice therapists, experienced therapists and the expert rater were not empirically determined.

A further limitation is that the power calculation was based on data on the standard deviation (SD) from 19 of the 32 participants, which may have biased the calculation, causing a possible Type II error. However, the final SD for the total sample was consistent with the SD used for the sample calculation.

7.0 Conclusion

Children who use mobile ICT in various locations in the home environment may be exposed to risks to their musculoskeletal health. RULA was used to assess the postural risk of a 12 year old child in self-selected postures when using a tablet and a laptop device around her home. Postural risk ratings were made by novice (student) occupational therapists, experienced therapists and an expert rater (ergonomist with experience in postural assessment). Poor agreement between the expert and the other raters was found and highlights possible concerns with how forces and loads contributing to risk are determined using RULA. All raters, irrespective of their experience, assessed nearly all postures adopted by the child as requiring further investigation and/or immediate or timely action to reduce risk. The study was limited in that the accuracy of any of the raters' scores was not validated against a gold standard measure. More research is required on the assessment of postural risk among children using unconventional ICT workstations in the home environment, in order to develop suitable strategies for reducing associated musculoskeletal risk. Strategies for postural risk management should target children and parents using accessible language and be flexible enough to allow for application within their own home environments.

Acknowledgements

We would like to thank the study participants, and the children and their families involved in the development of the video scenarios. We would also acknowledge the assistance with data processing by Mr Tim Parkin and Mr Gal Rose from AIM Employment, Autism Association of WA.

References

Australian Bureau of Statistics [ABS]. (2006). *4901.0- Children's participation in cultural and leisure activities, Australia*. Accessed 14 August 2014 from http://www.ausstats.abs.gov.au/ausstats/subscriber.nsf/0/4767CFCBCB66F4DECA2572440078021A/$File/49010_apr%202006.pdf.

Australian Bureau of Statistics [ABS]. (2009a). *4901.0- Children's participation in cultural and leisure activities, Australia.* Accessed 14 August from http://www.ausstats.abs.gov.au/ausstats/subscriber.nsf/0/691D5CEBE88905BCCA25765C0019E8D2/$File/49010_Apr%202009.pdf.

Australian Bureau of Statistics [ABS]. (2009b). *8146.0- Household use of information technology, Australia*. Accessed 14 August 2014 from http://www.ausstats.abs.gov.au/ausstats/subscriber.nsf/0/9B44779BD8AF6A9CCA25768D0021EEC3/$File/81460_2008-09.pdf.

Bao, S., Howard, N., Spielholz, P., & Silverstein, B. (2007). Two posture analysis approaches and their application in a modified Rapid Upper Limb Assessment evaluation. *Ergonomics, 50*, 2118-2136. doi: http://dx.doi.org/10.1080/00140130701458230

Barrero, M., & Hedge, A. (2002). Computer environments for children: a review of design issues. *Work, 18*, 227-237.

Bélanger, R. E., Akre, C., Berchtold, A., & Michaud, P.-A. (2011). A U-shaped association between intensity of internet use and adolescent health. *Pediatrics, 127*, e330-e335. doi: http://dx.doi.org/10.1542/peds.2010-1235

Bland, J. M., & Altman, D. G. (2003). Applying the right statistics: Analyses of measurement studies. *Ultrasound Obst Gyn, 22*, 85-93.

Bolkan, J. (2014). Phablet sales to top laptops this year, Tablets in 2015. *Technological Horizons in Education, , 41*, 3. Accessed 10 March 2015 from http://www.questia.com

Breen, R., Pyper, S., Rusk, Y., & Dockrell, S. (2007). An investigation of children's posture and discomfort during computer use. *Ergonomics, 50*, 1582-1592. http://dx.doi.org/10.1080/00140130701584944

Chen, J. D., Falkmer, T., Parsons, R., Buzzard, J., & Ciccarelli, M. (2014). Impact of experience when using the Rapid Upper Limb Assessment to assess postural risk in children using information and communication technologies. *Appl Ergon, 45*, 398-405. doi: http://dx.doi.org/10.1016/j.apergo.2013.05.004

Chiasson, M.-È., Imbeau, D., Aubry, K., & Delisle, A. (2012). Comparing the results of eight methods used to evaluate risk factors associated with musculoskeletal disorders. *Int J Ind Ergonom, 42*, 478-488. doi: http://dx.doi.org/10.1016/j.ergon.2012.07.003

Ciccarelli, M., Straker, L., Mathiassen, S., & Pollock, C. (2011a). ITKids Part I: Children's occupations and use of information and communication technologies. *Work, 38*, 401-412. doi: http://dx.doi.org/10.3233/WOR20111167

Ciccarelli, M., Straker, L., Mathiassen, S., & Pollock, C. (2011b). ITKids Part II: Postural and muscle activity diversity among different information and communication technologies used by children in school and away-from-school locations. *Work, 38*, 413-428. doi: http://dx.doi.org/10.3233/WOR20111168

Commonwealth of Australia. (2014). Australian physical activity and sedentary behaviour guidelines for children. Retrieved 10 March 2015, from http://www.health.gov.au/internet/main/publishing.nsf/content/health-pubhlth-strateg-phys-act-guidelines

Cook, C., Burgess-Limerick, R., & Chang, S. (2000). The prevalence of neck and upper extremity musculoskeletal symptoms in computer mouse users. International Journal of Industrial *Ergonomics, 26,* 347-356. doi: http://dx.doi.org/10.1016/s0169-8141(00)00010-x

Cook, C., & Kothiyal, K. (1998). Influence of mouse position on muscular activity in the neck, shoulder and arm in computer users. *Appl Ergon, 29,* 439-443. doi: http://dx.doi.org/10.1016/s0003-6870(98)00008-8

Dockrell, S., Earle, D., & Galvin, R. (2010). Computer-related posture and discomfort in primary school children: The effects of a school-based ergonomic intervention. *Comput Educ, 55*, 276-284. doi: http://dx.doi.org/10.1016/j.compedu.2010.01.013

Dockrell, S., O'Grady, E., Bennett, K., Mullarkey, C., Mc Connell, R., Ruddy, R., . . . Flannery, C. (2012). An investigation of the reliability of Rapid Upper Limb Assessment (RULA) as a method of assessment of children's computing posture. *Appl Ergon, 43*, 632-636. doi: http://dx.doi.org/10.1016/j.apergo.2011.09.009

Drinkaus, P., Sesek, R., Bloswick, D., Bernard, T., Walton, B., Joseph, B., . . . Counts, H. J. (2003). Comparison of ergonomic risk assessment outputs from Rapid Upper Limb Assessment and the Strain Index for tasks in automotive assembly plants. *Work, 21*, 165-172.

Geldhof, E., Cardon, G., Bourdeaudhuij, I., Danneels, L., Coorevits, P., Vanderstraeten, G., & Clercq, D. (2007). Effects of back posture education on elementary schoolchildren's back function. *Eur Spine J, 16*, 829-839. doi: http://dx.doi.org/10.1007/s00586-006-0199-4

Gerr, F., Marcus, M., & Monteilh, C. (2004). Epidemiology of musculoskeletal disorders among computer users: lesson learned from the role of posture and keyboard use. *J Electromyogr Kines, 14*, 25-31. doi: http://dx.doi.org/10.1016/j.jelekin.2003.09.014

Hakala, P. T., Rimpelä, A. H., Saarni, L. A., & Salminen, J. J. (2006). Frequent computer-related activities increase the risk of neck–shoulder and low back pain in adolescents. *Eur J Public Health, 16*, 536-541. doi: http://dx.doi.org/10.1093/eurpub/ckl025

Harris, C., & Straker, L. (2000). Survey of physical ergonomics issues associated with school children's use of laptop computers. *Int J Ind Ergonom, 26*, 337-347. doi: http://dx.doi.org/10.1016/S0169-8141(00)00009-3

Jacobs, K., & Baker, N. (2002). The association between children's computer use and musculoskeletal discomfort. *Work, 18*, 221-226.

Jacobs, K., Hudak, S., & Mc Giffert, J. (2009). Computer-related posture and musculoskeletal discomfort in middle school students. *Work, 32*, 275-283. doi: http://dx.doi.org/10.3233/WOR-2009-0826

Jones, T., & Kumar, S. (2007). Comparison of ergonomic risk assessments in a repetitive high-risk sawmill occupation: Saw-filer. *Int J Ind Ergon, 37*, 744-753. doi: http://dx.doi.org/10.1016/j.ergon.2007.05.005

Kee, D., & Karwowski, W. (2007). A comparison of three observational techniques for assessing postural loads in industry. *Int J Occup Saf Ergon, 13*, 3-14. doi: http://dx.doi.org/10.1080/10803548.2007.11076704

Kelly, G., Dockrell, S., & Galvin, R. (2009). Computer use in school: Its effect on posture and discomfort in school children. *Work, 32*, 321-328. doi: http://dx.doi.org/10.3233/WOR-2009-0830

Kent, N., & Facer, K. (2004). Different worlds? A comparison of young people's home and school ICT use. *J. Comput Assist Lear, 20*, 440-455. doi: http://dx.doi.org/10.1111/j.1365-2729.2004.00102.x

Kerawalla, L., & Crook, C. (2002). Children's computer use at home and at school: Context and continuity. *Br Educ Res J, 28*, 751-771. doi: http://dx.doi.org/10.1080/0141192022000019044

Kimmerly, L., & Odell, D. (2009). Children and computer use in the home: Workstations, behaviors, and parental attitudes. *Work, 32*, 299-310. doi: http://dx.doi.org/10.3233/WOR-2009-0828

Laeser, K. L., Maxwell, L. E., & Hedge, A. (1998). The effect of computer workstation design on student posture. *J. Res Comput Educ, 31*, 173.

Lee, E. C., Rafiq, A., Merrell, R., Ackerman, R., & Dennerlein, J. T. (2005). Ergonomics and human factors in endoscopic surgery: a comparison of manual vs telerobotic simulation systems. *Surgical Endoscopy And Other Interventional Techniques, 19,* 1064-1070. doi: http://dx.doi.org/10.1007/s00464-004-8213-6

Massaccesi, M., Pagnotta, A., Soccetti, A., Masali, M., Masiero, C., & Greco, F. (2003). Investigation of work-related disorders in truck drivers using RULA method. *Appl Ergon, 34*, 303-307. doi: http://dx.doi.org/10.1016/S0003-6870(03)00052-8

McAtamney, L., & Nigel Corlett, E. (1993). RULA: A survey method for the investigation of work-related upper limb disorders. *Appl Ergon, 24*, 91-99. doi: http://dx.doi.org/10.1016/0003-6870(93)90080-S

Murphy, S., Buckle, P., & Stubbs, D. (2004). Classroom posture and self-reported back and neck pain in schoolchildren. *Appl Ergon, 35*, 113-120. doi: http://dx.doi.org/10.1016/j.apergo.2004.01.001

Oates, S., Evans, G. W., & Hedge, A. (1998). An anthropometric and postural risk assessment of children's school computer work environments. *Computers in the Schools, 14*, 55-63. doi: http://dx.doi.org/10.1300/J025v14n03_06

Osmond Ergonomics (Producer). (20 March 2012). RULA Assessment Sheet. Osmond Ergonomics, Wimborne,UK. Accessed 14 August 2014 from http://www.rula.co.uk/offline.html

Rideout, V. J., Foehr, U. G., & Roberts, D. F. (2010). *Generation M2: Media in the lives of 8- to 18-year olds.* Henry J. Kaiser Family Foundation: Menlo Park, CA.

Royster, B. (2002). A healthy approach to classroom computers: Preventing a generation of students from developing repetitive strain injuries. *North Carolina Law Review, 80*, 275-314.

Saarni, L., Nygård, C.-H., Rimpelä, A., Nummi, T., & Kaukiainen, A. (2007). The working postures among schoolchildren—a controlled intervention study on the effects of newly designed workstations. *J School Health, 77*, 240-247. doi: http://dx.doi.org/10.1111/j.1746-1561.2007.00199.x

Sen, A., & Richardson, S. (2007). A study of computer-related upper limb discomfort and computer vision syndrome. *J Hum Ergol, 36,* 45-50. doi: http://dx.doi.org/10.11183/jhe1972.36.2_45

Smetana, J., & Asquith, P. (1994). Adolescents' and parents' conceptions of parental authority and personal autonomy. *Child Development, 65*, 1147-1162.

Sommerich, C. M., Ward, R., Sikdar, K., Payne, J., & Herman, L. (2007). A survey of high school students with ubiquitous access to tablet PCs. *Ergonomics, 50*, 706-727 doi: http://dx.doi.org/10.1080/00140130701194793

Straker, L., Coleman, J., Skoss, R., Maslen, B., Burgess-Limerick, R., & Pollock, C. (2008). A comparison of posture and muscle activity during tablet, desktop computer and paper use by young children. *Ergonomics, 51*, 540-555. doi: http://dx.doi.org/10.1080/00140130701711000

Straker, L., Pollock, C., & Maslen, B. (2009). Principles for the wise use of computers by children. *Ergonomics, 52*, 1386-1401. doi: http://dx.doi.org/10.1080/00140130903556344

Straker, L., Smith, A. J., Bear, N., O' Sullivan, P. B., & de Klerk, N. H. (2011). Neck/shoulder pain, habitual spinal posture and computer use in adolescents: the importance of gender. *Ergonomics, 54*, 539-546. doi: http://dx.doi.org/10.1080/00140139.2011.576777

Szeto, G. P., Tsui, M. M. S., Sze, W. W. Y., Chan, I. S. T., Chung, C. C. F., & Lee, F. W. K. (2013). Issues about home computer workstations and primary school children in Hong Kong: A pilot study. *Work,* doi: http://dx.doi.org/10.3233/wor-131810

US Department of Labor. (1993). *Selected characteristics of occupations defined in the Revised Dictionary of Occupational Titles*. Washington, DC: Employment and Training Administration.

Williams, C. D., & Jacobs, K. (2002). The effectiveness of a home-based ergonomics intervention on the proper use of computers by middle school children. *Work, 18*, 261-268.

Young, J. G., Trudeau, M., Odell, D., Marinelli, K., & Dennerlein, J. T. (2012). Touch-screen tablet user configurations and case-supported tilt affect head and neck flexion angles. *Work, 41*, 81-91. doi: http://dx.doi.org/10.3233/wor-2012-1337