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RESEARCH ARTICLE

EFFECT OF USING TABLET COMPUTER ON MYOELECTRIC ACTIVITY OF WRIST AND NECK MUSCLES IN CHILDREN

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ABSTRACT

Tablet computer games widely increased among children. The impact of this technology on children should be studied. The purpose of this study was to investigate wrist and neck extensors muscle activity in children during tablet playing and to investigate playing effect on pain threshold in shoulder region. Thirty right-handed healthy children (15 boys and 15 girls) with age ranged 5-7 years participated in this study. Electromyography data were collected from cervical erector spinae, upper trapezius, and right wrist extensors. Pressure pain threshold over trapezius muscles were measured. Data was collected during two gaming sessions, 10 and 20 minutes. Mixed design MANOVA was conducted to investigate the effect of playing duration and gender on muscle activity and the effect of playing, playing duration, and gender on pain threshold. Results revealed that muscle activity significantly increased with increasing playing duration for boys and girls (p <. 0.001). Pressure pain threshold was significantly decreased after playing in both playing duration, and significantly decreased with increasing playing duration for boys and girls (p <. 0.001). In conclusion, Tablet computer playing is associated with increased neck and wrist muscle activity and with decreased pain threshold. Playing duration is a critical factor in determining effects of playing.

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INTRODUCTION

The invention of smart phones and the replacement of desktop computers with digital tablets promote young children to use this new technology anytime and anywhere (Strader, 2011). A tablet PC is a type of portable computer, larger than a smart phone, with an integrated tactile screen to interact with fingers, with no need for a physical keyboard or mouse. These are replaced by a virtual keyboard; they have been described as being halfway between a smart phone and a notebook (Santamarta *et al.,* 2015). The number of tablet computer users has increased significantly in recent years with introduction of many new applications (Vasavada *et al.,* 2015). Young children are highly attracted to portable handheld game devices as these devices can be played anywhere and the games are designed specifically for their age groups (Ramos *et al.,* 2005). Computer and electronic games has gradually become an important part of leisure and social activities for people of all ages (Zapata *et al.,* 2006). A study in the United States showed that 65% of children aged 4-11 had high screen time of over 2 hours per day while 37% had low levels of active play, less than 1 hour per day (Anderson *et al.,* 2008). New technology may be negatively affected children development in physical, psychological, and social aspects. Preschool children with increasing use of digital technology tend to be less physically active, increasing the risks of obesity and musculoskeletal problems (Bremer, 2005). The incidence of musculoskeletal disorders increase with computer usage (Cook *et al.,* 2000). The high incidence of musculoskeletal disorders in the neck and shoulder region, as well as in the upper extremities, has been shown to be associated with factors such as constrained posture (Vieira and Kumar, 2004), inappropriate ergonomic design, and use of input devices (Kadefors and Laubli, 2002). Posterior neck pain suggested to be the result of faulty posture, poor ergonomics, stress and chronic muscle fatigue (Fichground, 2004). Holding a sustained posture for a prolonged period of time (1-2 hours) was also identified as an important physical risk factor for neck pain (Andersen *et al.,* 2003).

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Head and neck flexion angles during tablet use were greater than angles previously reported for desktop and notebook computing (Young *et al.,* 2012). Gold *et al.,* (2012) evaluated kinematics of the cervical spine during the operation of a touch screen tablet and a smart phone in college-aged individuals. The majority of users maintained flexed neck postures and typing-side non-neutral wrist during the use of mobile devices. Research into postures of office administration staff describes working in a bent or twisted posture for prolonged periods of time as the most important physical risk factor for neck pain (De Loose *et al.,* 2008).

Children are using computers more frequently and for longer durations, and may use them differently from adults, hence it is important to specifically address the effects of this use for this population. A reported association between computer use and discomfort in children has prompted concerns about the musculoskeletal stresses associated with computer use (Straker *et al.,* 2009). With the increasing use of portable handheld electronic devices such as touch screen tablets and smart phones, concerns are raised regarding the poor neck posture that users may employ and its potentials of causing neck and shoulder strain. There is still a lack of research that has quantitatively investigated the neck postures and neck muscle activities during the use of different mobile devices with various screen sizes (Ning *et al.,* 2015).

The objectives of this study were to investigate the muscle activity of wrist and neck extensors in children during tablet playing and to investigate playing effect on pain threshold in shoulder region.

MATERIALS AND METHODS

Participants

Thirty right-handed children (15 boys and 15 girls) with age ranged from 5 to 7 years were recruited from primary schools in Najran, KSA for data collection in this study. All the participants were free from any musculoskeletal disorders and had no history of neck injury or notable neck pain. The children regularly used tablet computers. Children were excluded if there was previous hand or neck injuries or deformities. Before data collection, all participants and their parents were given an explanation of the purpose, procedures and benefits of the study. This work is carried out in accordance with the code of ethics of the world medical association (Declaration of Helsinki) for experiments involving humans. All parents of the children signed a consent form prior to participation. In addition, acceptance of the ethical committee of the University was taken.

Instrumentation

Tablet

Portable tablet computers (Lenovo A3500-HV, Bratislava, Slovakia) were used in the current study to represent a touch screen tablet. The tablet was 7 inches' touch screen, 198 mm height, 121.2 mm width, 9.9 mm thickness, and weight 320 grams. The font sizes of the devices were set to system default.

Electromyography (EMG)

Myoelectric activity was recorded using AMT-8 EMG cable telemetry system (Bortec Biomedical, Alberta, Canada) with analogue differential amplifiers (common mode rejection ratio: 115 dB). Disposable, self-adhesive Ag/AgCl snap electrodes were used for the signal collection. The bipolar electrodes were pregelled with 1.2 cm in diameter and an inter-electrode distance of 2.5 cm. The frequency of EMG data acquisition was set at 1000 Hz.

Algometry

A digital algometer (DD-200, Instrutherm™) was used to evaluate pressure pain threshold (PPT) through the application of pressure. PPT, the minimal pressure that induces pain, was assessed. The measuring capacity of the algometry was 5 kg. The apparatus consists of a rubber disk 1cm in diameter attached to the plunger of a pressure gauge. Hand held pressure algometry has previously been validated and clinically applied (Geber *et al.,* 2011; Staahl *et al.,* 2006).

Protocol

Subjects participated in two gaming sessions, one for 10 minutes and another for 20 minutes. The two sessions were separated by 3 days and the order of sessions were random. The child sat comfortably on a chair with back support with the chair adjusted to permit horizontal thighs and right knee angles. Children were allowed to assume self-selected posture.

Measurement of muscle activity

EMG data were recorded from right and left cervical erector spinae, right and left upper trapezius, and right wrist extensors. To record the surface EMG data, the skin over the anatomical landmarks was shaved (if needed), abraded, and cleaned with 70% alcohol, prior to the placement of the EMG electrodes.
Electrode placement for right and left cervical erector spinae were at midpoint between the external occipital protuberance and C7. Electrodes were placed lateral to the cervical spinal processes on the erector spinae muscle bulk bilaterally. Electrode placement for right and left upper trapezius were just lateral to the midpoint between C7 spinous process and acromion. Electrode placement for right wrist extensors were 1/3 distance between the right lateral humeral epicondyle and radial styloid process. Common ground electrode was placed at mid clavicle (Straker *et al.,* 2009).

In order to permit amplitude normalization of surface EMG data, the subjects performed several maximum voluntary isometric contractions (MVI) for five seconds for each of the monitored muscles following electrode application (Frost *et al.,* 2012). For the cervical erector spinae, the child attempted to push the head back against the examiner hand as strongly as possible. For the upper trapezius, the child asked to lift the shoulders towards their ears as strongly as possible with motion resisted by examiner hands. For the right wrist extensors, the child asked to perform wrist extension against examiner hand. Verbal encouragement was provided by the examiner to elicit a maximal contraction.

For the gaming task, participants played the gaming application “subway”. This is a generic gaming application, and it is primarily played using the right forefinger. Children support the tablet using left hand during playing. EMG data were filtered using a 10 Hz high-pass filter and a low-pass filter of 500 Hz. The processed EMG data were then fully rectified and further smoothed using a 1/8 s moving data window. For each muscle EMG data collected during over the final 2 min during experimental trials were normalized to the corresponding maximum EMG values recorded during the MVI trials and presented as a percentage of the maximum.

Measurement of pressure pain threshold (PPT)

Measurements of PPT were applied over two muscles, right and left trapezius muscles. Measurement was carried two times in each playing sessions, one before practicing game prior application of EMG electrodes and following the playing sessions. Two points were measured over each muscle, and the mean of the two points measurements was calculated to obtain the mean PPT values. All points were localized by palpation and marked with a felt-tipped pen. Prior to the readings, the algometer would be applied to the child arm to be familiarized with the procedure.

The child was in the sitting comfortable and relaxed position. The sequence of measurement was randomly assigned. The round rubber end of the algometer was in full contact with the skin and the force transmission rod was perpendicular to skin surface. The compression pressure was increased gradually at a rate of approximately 0.2 kg/sec. The child was asked to raise hand when felt pain. At that point, the examiner stopped the compression and read the scale on the algometer (kg/cm²), indicating the PPT value at that site.

Statistical analysis

Mixed design MANOVA was conducted to investigate the effect of playing duration and gender on EMG activity of right and left cervical erector spinae, right and left upper trapezius, and right wrist extensors, and to investigate the effect of playing, playing duration, and gender on PPT of right and left upper trapezius. The level of significance for all statistical tests was set at $p < 0.05$. All statistical analysis was conducted through the statistical package for social studies (SPSS) version 19 for windows. (IBM SPSS, Chicago, IL, USA).

RESULTS

Subject characteristics

Table 1, showed the mean ± SD age, weight, and height of the study group.

Table 1. Mean age, weight, and height of the study group

	Study group	Boys	Girls
	$\bar{X}$±SD	$\bar{X}$±SD	$\bar{X}$±SD
Age (years)	6.16 ± 0.83	6.2 ± 0.77	6.13 ± 0.91
Weight (kg)	21.16 ± 2.64	21.8 ± 2.81	20.52 ± 2.38
Height (cm)	115.61 ± 5.67	115.07 ± 5.26	116.16 ± 6.19

$\bar{X}$, Mean; SD, standard deviation.

Effect of playing duration and gender on EMG activity

Results of the mixed model MANOVA revealed significant interaction effect of playing duration x gender ($F = 2.93$, $p = 0.03$), significant main effect of playing duration ($F = 88.86$, $p = 0.0001$), while there was no significant effect of gender ($F = 0.79$, $p = 0.56$) on EMG activity.

Muscle activity significantly increased with increasing playing duration from 10 to 20 minutes for boys and girls ($p < 0.001$). Both right and left cervical erector spinae and upper trapezius significantly increased its activity with increased playing duration ($p < 0.001$), with the right sided muscles showed relatively higher activity than left one. The right upper trapezius muscle in girls showed highest increase in activity (6.94%) with increased playing duration from 10 to 20 minutes. The right wrist extensors muscles increased its activity with increasing playing duration by 3.78 and 3.61% in boys and girls respectively. There was no significant difference between boys and girls in muscles activity in both playing durations ($p > 0.05$). Table (2) and Figure (1) showed the mean values of normalized EMG of muscles of boys and girls during 10 and 20 minutes playing duration.

Table 2. Mean normalized EMG (% MVI) of neck and wrist muscles of boys and girls during 10 and 20 minutes playing duration

	% MVI				
	10 min $\bar{X}$±SD	20 min $\bar{X}$±SD	MD	% of change	P- value
Boys					
Right cervical erector spinae	12.76 ± 1.88	13.35 ± 1.67	-0.59	4.62	0.008*
Left cervical erector spinae	12.2 ± 1.61	12.54 ± 1.59	-0.34	2.78	0.0001*
Right upper trapezius	13.1 ± 0.87	13.46 ± 0.93	-0.36	2.74	0.0001*
Left upper trapezius	10.83 ± 1.01	11.26 ± 1.02	-0.43	3.97	0.0001*
Right wrist extensors	9.77 ± 0.62	10.14 ± 0.65	-0.37	3.78	0.0001*
Girls					
Right cervical erector spinae	12.68 ± 1.31	13.56 ± 1.37	-0.88	6.94	0.0001*
Left cervical erector spinae	12.23 ± 1.14	12.66 ± 1.11	-0.43	3.51	0.0001*
Right upper trapezius	13.32 ± 0.82	13.76 ± 0.77	-0.44	3.3	0.0001*
Left upper trapezius	11.18 ± 1.04	11.48 ± 1	-0.3	2.68	0.001*
Right wrist extensors	9.97 ± 0.51	10.33 ± 0.49	-0.36	3.61	0.0001*

$\bar{X}$, Mean; SD, standard deviation; MD, mean difference; p-value, level of significance; * Significant.

Effect of playing, playing duration, and gender on PPT

Results of the mixed model MANOVA showed no significant interaction effect of playing duration x gender x time ($F = 0.24$, $p = 0.78$), no significant interaction effect of playing duration x gender ($F = 0.02$, $p = 0.97$), a significant interaction effect of playing duration x time ($F = 44.74$, $p = 0.0001$), no significant interaction effect of gender x time ($F = 0.11$, $p =$

0.89), a significant main effect of time ($F = 207.04$, $p = 0.0001$), a significant main effect of playing duration ($F = 12.84$, $p = 0.0001$), while there was no significant effect of gender ($F = 0.21$, $p = 0.8$) on PPT. Right and left trapezius PPT in boys and girls was significantly decreased post playing when compared with that pre playing in both playing duration ($p < 0.001$). PPT of right and left trapezius significantly decreased with increasing playing duration from 10 to 20 minutes for boys and girls ($p < 0.001$). The right sided muscles showed relatively greater decrease in PPT than left one in 20 minutes playing duration.

Table 3. Mean PPT (kg/cm²) of right and left upper trapezius of boys and girls pre and post 10 and 20 minutes playing sessions

	PPT (kg/cm²)							
	10 min			20 min			10 Vs 20	
	Pre	Post		Pre	Post		Pre	Post
	$\bar{X}$±SD	$\bar{X}$±SD	p value	$\bar{X}$±SD	$\bar{X}$±SD	p value	p value	p value
Boys								
Right upper trapezius	1.03 ± 0.16	0.93 ± 0.15	0.0001*	1.04 ± 0.17	0.84 ± 0.18	0.0001*	0.78**	0.0001*
Left upper trapezius	1.04 ± 0.15	0.94 ± 0.14	0.0001*	1.04 ± 0.17	0.86 ± 0.15	0.0001*	0.1**	0.001*
Girls								
Right upper trapezius	1.02 ± 0.17	0.92 ± 0.16	0.0001*	1.02 ± 0.13	0.82 ± 0.12	0.0001*	1**	0.0001*
Left upper trapezius	1.03 ± 0.16	0.94 ± 0.15	0.0001*	1.04 ± 0.18	0.85 ± 0.16	0.0001*	0.26**	0.001*

$\bar{X}$, Mean; SD, standard deviation; p-value, level of significance; * Significant; ** Non-significant.

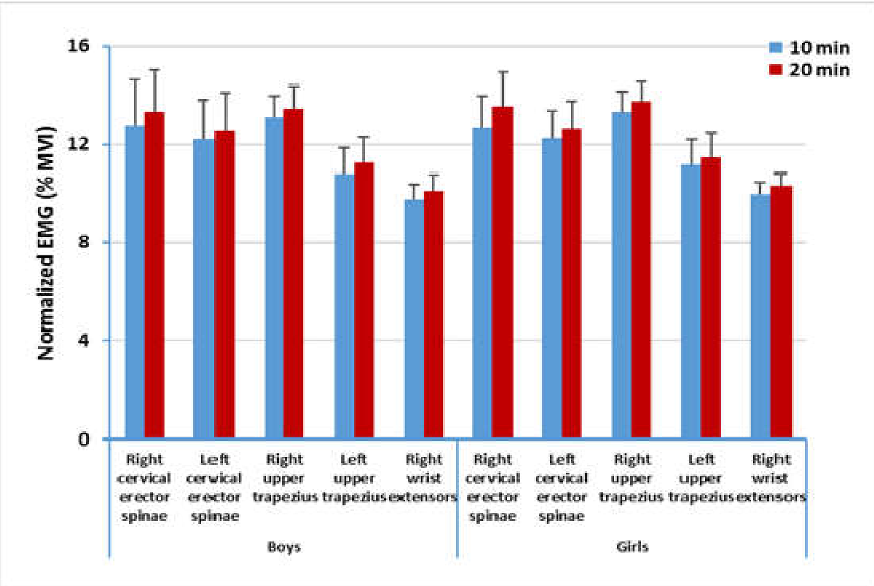

Figure 1. Mean normalized EMG (% MVI) of neck and wrist muscles of boys and girls during 10 and 20 minutes playing duration

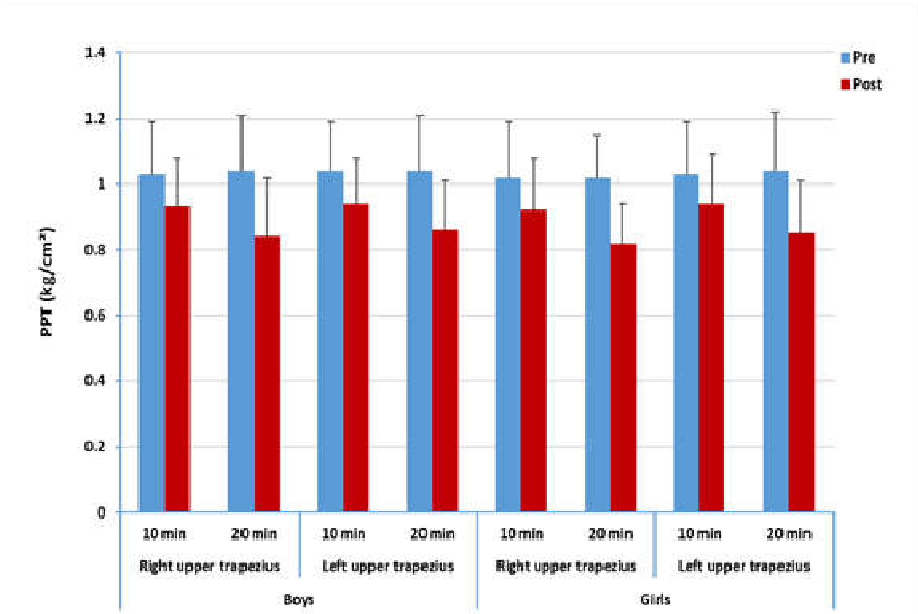

Figure 2. Mean PPT (kg/cm²) of right and left upper trapezius of boys and girls during 10 and 20 minutes playing duration

There was no significant difference between boys and girls in PPT in both playing durations ($p > 0.05$). Table (3) and Figure (2) showed the mean values of PPT of right and left upper trapezius muscles of boys and girls during 10 and 20 minutes playing duration.

DISCUSSION

Increased and wide spread use of tablet computer among children draw researchers' attention about the impact of this technology on children from different aspects. Children spent many hours daily playing with tablet games and assuming unnatural posture during this time. Those children may be exposed to musculoskeletal problems. This study pointed out the impact of relatively short duration of tablet computer playing games on myoelectric activity of neck muscles and wrist extensors and on pain threshold over shoulder region in children.

The results of this study showed significant effect of playing duration on myoelectric activity of neck muscles, right and left cervical erector spinae, right and left upper trapezius, as well as right wrist extensors. These muscles had considerable myoelectric activities (9.77-13.76 %MVI) during 10 and 20 minutes playing duration. Both right and left sided muscles were active, with the right sided muscles showed relatively higher activity than left one. The myoelectric activity significantly increased with increased playing duration.

Considerable activation of neck muscles on both sides may be attributed to the flexed neck posture assumed by children during playing that apply increased gravitational demand on neck. Large muscle force is needed to counterbalance the increased gravitational moment. This requires greater activation of neck extensor muscles compared to that in neutral posture (Caneiro *et al.,* 2010). Also the nature of game that requires immediate response may have increased muscle activation (Ning *et al.,* 2015).

Increased neck muscle activity reported in this study is in agreement with Straker *et al.* (2008) who investigated the posture and muscle activity of children using a tablet computer. They compared posture and muscle activity of children using a tablet computer to that while using a desktop computer and paper technology in a coloring task. Compared with a desktop computer, tablet computer use by young children is associated with more flexed and asymmetrical trunk and more flexed and elevated shoulders and greater muscle activity around the neck. Also, the finding agreed with Young *et al.* (2013) who assessed postures of the shoulders and wrists and their associated muscle activity during touch-screen tablet use in adults. Wrist extension was high and particularly for the dominant hand when a tablet was placed on the lap and higher activity levels of wrist radial deviation were observed for the non-dominant hand when it was used to tilt and hold the tablet. Tablet use often involved head and neck flexion angles far from neutral angles reported in the literature (Young *et al.,* 2012). Users of hand held devices may adapt more neck flexion angle as a compensatory strategy of reducing eye-screen distance and to increase the clarity of vision (Ning *et al.,* 2015). The head and neck postures during tablet computer usage have been found greater than in desktop or notebook computer usage (Straker *et al.,* 2008, Young *et al.,* 2012, Werth and Babski-Reeves 2014). Neck extensor muscle activation levels while holding the head in 20˚ or greater flexed postures were approximately 10-15% of maximum voluntary contraction values (Finsen, 1999).

Playing electronic games may involve long periods of static body posture and highly repetitive finger movements (Greig *et al.,* 2005). The input mechanisms of all these game devices require high repetition of finger movements mainly tapping and pressing buttons that would affect the fingertip forces, tendon excursion and muscular efforts. If repetitive finger movement performed for long durations with high speeds may cause musculoskeletal strain (Lui *et al.,* 2011). The tablet computer was found to result in more non neutral wrist, elbow and neck postures and reduced performance (Werth *et al.,* 2014). There is coupling between the trapezius and the finger muscles as co-activity, Schnoz *et al.,* (2000) found low to high activity constantly present in the upper arm and trapezius muscles during finger tapping in a simple computer task that requires little mental demand. Fast tapping and a forward-leaning body posture caused considerable increases in upper arm and trapezius muscles activity.

Bilateral activation of neck and shoulder muscles is well observed in gaming task. The relative higher activity of the right sided muscles is due to that all children in this study are right handed. Frequent use of right hand motion to operate the tablet and interact with the game may increase the activation of neck and shoulder muscles on the same side. Left side muscle activation may be attributed to the unnatural head posture assumed as most children maintained a slight leftward head bending posture, this posture could generate higher muscle activities on the contralateral side of cervical extensors (Ning *et al.,* 2015).

There was a significant effect of playing and playing duration on PPT. Decreased pain threshold level and sensation of discomfort following playing is attributed to higher muscle activation level especially on the right side. Operation of tablet games with the right hand could cause the right side muscles to reach fatigue sooner than the left side (Ning *et al.,* 2015). This finding is consistent with Sommerich *et al.* (2007) who reported that 60% of a group of 16-18 years old students with unlimited access to tablet computers at school and home reported associated neck discomfort. Hakala *et al.* (2012) conducted a survey study of 436 school children aged 12-16 years, A dose–response relationship was reported for computer use and neck and shoulder pain. Daily computer use of 2 hours or more increases the risk for pain at most anatomic sites. Children's use of these portable computers has been associated with musculoskeletal discomfort (Harris and Straker 2000; Sommerich *et al.,* 2007).

Breen *et al.,* (2007) investigated discomfort and posture while using computers in 68 schoolchildren with mean age 9.5 years, computer session lasts 15-25 minutes, finding that 16% of the children reported pain evaluated by visual analogue scale, mostly in the neck or back region, at the beginning and end of a computer session. Pain intensity increased during the session.

Posture became worse over time. Poor posture was associated with discomfort. Also Ramos *et al.* (2005) suggested that children adopt different postures to adults when using computers and confirmed that children experience discomfort, particularly in the neck region, as a result of computer use. Head rotation away from the midline was found to be related to more severe pain and stiffness in the upper torso amongst computer operators (Faucett and Rempel, 1994). Upper limb postures during tablet use may also pose a risk to the musculoskeletal system. Shoulder flexion greater than 25˚ has been shown to be a risk factor for neck and shoulder symptoms in adults (Marcus *et al.,* 2002).

Straker *et al.* (1997) study postures assumed for laptop and desktop computers and demonstrated that after twenty minutes all participants reported some areas of discomfort, pain, headaches and muscle fatigue, mainly in the neck and upper back. Also, Shan *et al.* (2013) reported that in over 3600 high school students, 44% of the students who owned a tablet computer reported neck and/or shoulder discomfort. The risk of developing musculoskeletal pain increases with an increase in the amount of time spent on the computer. Computer use exceeding 2 hours/day is a threshold for neck and shoulder pain, and exceeding 5 hours/day for low back pain, and digital gaming exceeding 5 hours/day is a threshold for low back pain (Hakala *et al.,* 2006).

The static posture and increased muscle activity associated with tablet use may be the etiology of pain associated with tablet use. The 'Cinderella hypothesis' proposed by Hagg, (1991) postulates the continuous activity of specific motor units during low level muscle contraction. These motor units may become metabolically overloaded, with the subject developing muscle pain and strain. This hypothesis is applied to muscles that are active for a time long enough to actually damage muscle fibers. Zennaro *et al.* (2003) investigated motor unit activity in the trapezius muscle during a 30 minutes' experimental computer task. The results provide evidence of continuously active muscles throughout the 30-minutes dynamic long-term measurements while working with a computer mouse. They observed three Cinderella motor units that were active during almost a complete experimental session. The development of trigger points has been shown to occur during computer work, suggesting that even low level static muscular exertions can damage muscle (Treaster *et al.,* 2006). Gosselin *et al.* (2004) found that sustained low-level contractions of 25% maximum voluntary contraction for neck extensor muscles in the neutral posture cause muscle fatigue that present in the electromyographic signal at 10 minutes.

Also, Blangsted *et al.* (2005) found that sustained low-level contractions 10% MVC cause muscle fatigue in wrist muscles. The most common musculoskeletal symptoms associated with computer use are pain and tenderness in the trapezius muscle. Factors such as visual load, concentration, repetitive finger movements, high demands on precision and fatigue may be linked to increased trapezius activity (Maeda *et al.,* 1977). Task engaging the hand and arm evokes activity in the trapezius muscle. It seems probable that computer work induces low threshold motor units, which are continuously active in such a working task. Continuous trapezius muscle activity could explain the development of pain in the neck region (Zennaro *et al.,* 2003). Increased muscle activity and development of discomfort and pain associated with playing are well demonstrated in this study. This impact confirms the general idea of association between electronic computer games and musculoskeletal disorders.

This study is limited by small sample size and short duration of task. Future studies are required to investigate larger population and longer playing duration. Also factors such as different screen size and tablet weight should be considered. Guidelines for safe use of tablet should be developed to avoid risk of musculoskeletal disorders on children.

Conclusion

Tablet computer playing is associated with increased neck and wrist muscle activity and with decreased PPT over shoulder region. Playing duration is a critical factor in determining effects of playing. Uncontrolled tablet use may place children at risk of developing musculoskeletal disorder.

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Conflict of Interest

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