J. Phys. Ther. Sci. 30: 1293–1300, 2018

The Journal of Physical Therapy Science

Original Article

A comparison of upper body and limb postures across technology and handheld device use in college students

Kimberly A. Szucs, PhD, OTR/L[1)*], Kara Cicuto, MS, OTR/L[2)], Marissa Rakow, MS, OTR/L[3)]

[1)] *Department of Occupational Therapy, Duquesne University: 600 Forbes Avenue, Pittsburgh, Pennsylvania 15282, USA*
[2)] *Mahoning County Educational Service Center, USA*
[3)] *Physical Disabilities Programs of Montgomery County Public Schools, USA*

Abstract. [Purpose] People using technology and handheld devices adopt postures of the upper limb and neck that could result in musculoskeletal pathology. Previous research has explored the postures assumed during isolated use of technology devices, such as a smartphone, however a comparison of posture assumed between multiple devices has not been completed. The purpose of this study was to compare the posture of the upper body and limb between handheld devices and technology. [Participants and Methods] Twenty one healthy college students completed this study. Pictures of participants were taken in a neutral posture and as they performed standard tasks with 3 devices (mobile phone, tablet, laptop). A mobile application calculated sagittal and coronal plane posture variables, which were compared between device conditions with an ANOVA and post-hoc tests. [Results] Head translation and angulation and shoulder angulation varied significantly between conditions in both planes. Shoulder translation varied significantly between conditions in the sagittal plane. Rib translation varied significantly between conditions in the coronal plane. Tablet use produced postures that were statistically different than the other devices. [Conclusion] Use of each device altered posture however, frequent, regular use of a tablet may produce greater deleterious effects than regular use of other handheld devices/technology.

Key words: Ergonomics, Technology, Posture

(This article was submitted Jun. 5, 2018, and was accepted Jul. 26, 2018)

INTRODUCTION

The use of handheld mobile devices, such as tablets and smartphones, has increased significantly in recent years[1, 2)]. Media access, which can include cell phones, laptops, and tablets, has increased significantly over the past couple years due to the number of individuals who own devices[2, 3)]. Mobile broadband subscriptions, which allow users to access the internet with a phone, tablet or other mobile device, have grown 20% annually in the last five years[4)]. It was projected that by the end of 2016, 360 million tablets will be sold[3)], significantly increasing from 60 million in 2011. In addition, individuals aged 8–18, who own cell phones has grown from 39% to 66%. This number is higher for adults with 92–95% of persons aged 18–34 owning a smartphone[2)], which they use an average of three to three and a half hours per day for various activities, such as texting, app use, and internet searching[1, 5)].

As mobile device use has drastically increased in the recent years, the health implications associated with device use needs to be explored. It has been established that computer use, whether desktop or laptop, is associated with increased sleep disturbances, mental health issues[6)], decreased attention, headaches[7)] and musculoskeletal symptoms[2)]. Cell phones have

*Corresponding author. Kimberly A. Szucs (E-mail: szucsk@duq.edu)

also been found to cause sleep disturbances, a depressed mood, headaches and sore thumbs from texting[8]. Device use is also linked to an increase in neck and upper extremity pain[9–11]. Previous research has indicated that children who use devices, such as tablets or computers, express discomfort and adopt varying non-neutral postures when using the devices[9, 11]. In 2013, 40.8% of students reported neck shoulder pain and 33.1% reported low back pain out of 3,600 students from high schools in Shanghai[11]. The musculoskeletal pain reported from these students was hypothesized to be caused from a variety of factors including tablet use, mobile phones, and computers.

A common observation of people using handheld mobile devices reveals that they frequently adopt postures of the upper limb and neck that when done repeatedly could result in musculoskeletal pathology[2, 12, 13]. Since many individuals are utilizing handheld devices starting in adolescence[2], abnormal postures and musculoskeletal pathology have started to affect individuals at a younger age than ever before. A study conducted by Straker et al. [14], concluded that children who used tablets had increased trunk flexion and more flexed and elevated shoulders compared to when they were using a desktop computer. By the time students enter university, they likely have been using mobile devices and technology for many years and are already experiencing musculoskeletal pain. Woo et al. [15], found almost 50% of university students who regularly use electronic devices experience musculoskeletal symptoms.

Additionally, several studies have determined that the placement of these devices and technology affects posture[2, 3, 11]. Whether a device is supported on a table, held in one or two hands impacts both posture and muscle activity[2]. The tablet does not have a strong support stand, like a PC, and therefore, the position of this device depends on the user's preference[3]. When the tablet is placed on a flat table, shoulder postures have varied by configuration with the greatest amount of shoulder flexion and elevation[3]. Frequent tablet users have also reported increases in neck/ shoulder pain, which could be related to the position of the tablet[11].

The purpose of this study was to explore the patterns of mobile device and technology use in college-aged students and how use of these devices impacts postural alignment. The purpose of this study is novel as we compared posture during device use not only to a baseline posture but also between devices. We hypothesized that use of all tested devices/technology would produce postures that differ significantly from baseline posture. We also postulated that handheld mobile devices would alter posture to a greater extent than a supported laptop computer.

PARTICIPANTS AND METHODS

A convenience sample of 21 healthy, college students completed this study. Eighteen participants were female and all participants were right hand dominant. Mean age and standard deviation for participants was 21.1 ± 1.5 years. This study was approved by the University's Institutional Review Board (Protocol No. 2015-08-2), and all participants provided informed consent prior to participation. Once informed consent was given, participants underwent a screening protocol to determine eligibility. Exclusion criteria included an inability to achieve full cervical range of motion or ≥120° of shoulder flexion or abduction pain-free, arthritis, and a BMI greater than or equal to 25 as excess skin and adipose tissues limit the ability to accurately palpate and track anatomical landmarks.

The PostureScreen Mobile® Application (PostureCo; http://postureanalysis.com/mobile/) was used to calculate the variables of interest (Table 1) for baseline posture analysis and posture analysis during device use. This app calculates angular and translation posture variables in the coronal and sagittal planes, using digitized landmarks on pictures taken with a device camera[16–18], such as an Apple iPad®. The app directs the user on how to digitize each specified landmark. Previous research[16–19] has explored the reliability and validity of this mobile application with good outcomes. A full description of the app, its properties, and the participant set up for this study has recently been published[18].

Once eligibility was established, participants completed a five-minute questionnaire adapted from Berolo et al. [1], to gain a better understanding of their daily technology use. As part of this survey, participants indicated what devices and technology they use in a typical day, how many hours they use each device in a typical day, how many years they have been using each device, and the three primary activities for which they use the device. The device choices included in the survey were: desktop computer, laptop computer, tablet, cell phone and other (to be indicated by the participant).

After completion of the survey, participants were set up for the postural assessment. Reflective tape was placed over various anatomical landmarks to assist with digitization of the skeleton in the app[18]. Participants stood on a marked X while looking straight ahead to assess their baseline postural alignment. The researcher stood 8 ft from the participant in the anterior (coronal plane) and right lateral directions (sagittal plane). The researcher took a picture in each of these directions while the participant stood with a neutral posture. The right lateral direction was chosen as all participants were right hand dominant and used that extremity to complete the technology/device tasks on the device interface. Following the baseline pictures, participants used different handheld devices and technology to complete various tasks as described in Table 2. The order of these conditions was randomized. Participants completed the tasks at a table, which was adjusted per participant to ensure correct ergonomic set-up. Two pictures were taken as the participant was completing each task—one in each plane/direction. The researcher did not start taking the pictures until approximately 30 seconds after the task was initiated to assure that the participant assumed a natural posture for that task.

One rater then digitized each picture of the participant (total of 12 pictures per participant—6 in each plane). The mobile app calculated the posture variables, which were provided in a pdf document. Values for the variables of interest were entered

Table 1. Posture variables of interest

Posture variables	
Coronal plane	Head translation (relative to sternum)
	Head angular displacement
	Shoulder translation (relative to ribs)
	Shoulder angular displacement
	Ribcage translation (relative to hip ASIS)
Sagittal plane	Head translation (relative to sternum)
	Head angular displacement
	Shoulder translation (relative to hip)
	Shoulder angular displacement

Angular displacements were calculated with two points and either the vertical or horizontal plane. Translations were calculated relative to the inferior segment.

Table 2. Conditions and device use protocol

Condition	Device	Activity	Positioning	Task
1	None	Baseline assessment	Standing	None
2	Cell phone	Texting	Standing	Participant types a text message in response to the question "Why did you choose to attend X University?"
3	Cell phone	Phone conversation	Standing	Participant is asked a series of multi-step math questions.
4	Tablet	Typing, selecting objects on the screen	Seated with the device supported on a table	Participant opens maze application and completes it.
5	Tablet	Typing, selecting objects on the screen	Seated, device handheld	Participant opens maze application and completes it.
6	Laptop	Typing, selecting objects on the screen	Seated with the device supported on a table	Participant opens personality test and completes it.

manually into an Excel spreadsheet. In the pdf document, postural measures were indicated as either to the Right or Left of center and Flexion or Extension. For data analysis, values that were to the left of center or extended were transformed to the negative (i.e., 4.8° Left became −4.8°).

Descriptive statistics were compiled from the survey data. For the quantitative postural assessment, all data were normally distributed and there was homogeneity of variances. A repeated measures ANOVA was conducted to compare the effect of device use (Condition) on each posture variable. The alpha level for statistical significance was set at 0.05. Post-hoc comparisons were completed with the Tukey-Kramer test for statistically significant differences from the repeated measures ANOVA. The alpha level for statistical significance was adjusted with a Bonferroni correction due to the multiple comparisons and set at 0.003[20].

RESULTS

All participants included in this study were free of upper body and limb pathology. Mean height and standard deviation for participants was 66.2 ± 2.6 inches and average weight and standard deviation was 137.2 ± 17.4 pounds.

One-hundred percent of participants reported daily use of a cell phone and 95.2% of participants reported daily use of a laptop. Only 33.3% and 28.6% of participants regularly use a desktop computer or tablet, respectively.

One third (33.3%) of participants reported using their cell phone between 7 and 10 hours daily, though 42.9% of participants only use their cell phone between 1 and 3 hours daily. The large majority of participants (85.7%) use their cell phone primarily for texting. Other common uses include talking on the phone, searching the internet, and taking pictures. Of regular laptop users, 28.6% report using the device between 7 and 10 hours daily and 33.3% report using the device between 1 and 3 hours daily, with the remaining third using their laptop for approximately 4 to 6 hours daily. The primary use for laptops was school related activities, followed by emailing and internet searching.

In terms of years of use, 23.8% of participants reported using a cell phone for over 10 years, with another 23.8% using one for 8–10 years. The remaining participants have been using a cell phone for 5–8 years. While fewer participants report still currently using a desktop computer, this technology has been used the longest, with most regular users (83.3%) reporting over

Table 3. Results from the Tukey-Kramer analysis for the coronal plane

Head Angular Displacement						
Means ± SE	1 −Baseline 0.64° ± 0.80	5 −3.71° ± 1.16	2 −0.61° ± 0.69	4 −0.52° ± 1.08	6 0.06° ± 0.88	3 4.49° ± 1.37
1 −Baseline 0.64°	–	−4.35	−1.25	−1.16	−0.58	3.85
5 −3.71°	–	–	3.1	3.19	3.77	8.2*
2 −0.61°	–	–	–	0.09	0.67	5.1*
4 −0.52°	–	–	–	–	0.58	5.01*
6 0.06°	–	–	–	–	–	4.43*
Head Translation						
Means ± SE	1 −Baseline 0.29" ± 0.07	4 −0.75" ± 0.21	5 −0.44" ± 0.22	2 −0.02" ± 0.14	6 0.10" ± 0.14	3 0.90" ± 0.17
1 −Baseline 0.29"	–	−1.04*	−0.73	−0.31	−0.19	0.61
4 −0.75"	–	–	0.31	0.73*	0.85*	1.65*
5 −0.44"	–	–	–	0.42	0.54	1.34*
2 −0.02"	–	–	–	–	0.12	0.92*
6 0.10"	–	–	–	–	–	0.8*

Values represent the differences between condition pairs.
*Indicates the difference is statistically significant at p≤0.003.

10 years of use, while tablets have been used the shortest amount of time, with over half of regular users (54.5%) reporting just 1–3 years of use.

For the quantitative assessment of posture, the main effect of Condition was statistically significant for Head Translation ($p<0.001$) and Head Angular Displacement ($p<0.001$) in the Coronal plane. In the Sagittal plane, Condition was also statistically significant for Head Translation ($p<0.001$) and Head Angular Displacement ($p<0.001$). Condition was statistically significant for Shoulder Angular Displacement in both the Coronal ($p=0.04$) and Sagittal ($p<0.001$) planes, while Condition was statistically significant for Shoulder Translation in the Sagittal plane only ($p<0.001$). Condition was statistically significant for Ribcage Translation in the Coronal plane ($p=0.005$).

The results of the Tukey-Kramer post-hoc analysis are presented in Tables 3 and 4. Statistically significant differences among pairs of Conditions were found for Head Angular Displacement (both planes), Head Translation (both planes) and Shoulder Translation (sagittal plane only). In the coronal plane, the only Condition to differ statistically from baseline was table supported tablet use (Condition 4) for Head Translation. For both Head Translation and Angular Displacement in the Coronal Plane, making a phone call (Condition 3) demonstrated statistically significant differences from the other device conditions. Additionally, Head Translation during table supported tablet use (Condition 4) differed compared to texting and laptop use.

Head Translation and Angular Displacement in the sagittal plane differed for several device conditions compared to baseline (Table 4). Exceptions include Head Translation while making a phone call (Condition 3) and Head Angular Displacement during laptop use (Condition 6). Handheld tablet use (Condition 5) was the only condition to differ from baseline for Shoulder Translation. Head Translation during tablet use, both table supported (Condition 5) and handheld (Condition 4), differed significantly from the other device conditions. Head Angular Displacement for both of these tablet conditions also differed from the other devices, with the exception of table supported tablet use compared to texting. Shoulder translation during laptop (Condition 6) and handheld tablet (Condition 5) use differed significantly from both phone conditions (Conditions 2 and 3). Shoulder translation also significantly differed between tablet conditions (Conditions 4 and 5).

Table 4. Results from the Tukey-Kramer analysis for the sagittal plane

Head Angular Displacement						
Means ± SE	1 −Baseline 13.75° ± 1.76	6 21.82° ± 2.34	3 24.26° ± 2.52	2 28.57° ± 2.17	5 35.56° ± 3.35	4 38.55° ± 2.91
1 −Baseline 13.75°	–	8.1	10.51*	14.82*	21.81*	24.8*
6 21.82°	–	–	2.44	6.75	13.74*	16.73*
3 24.26°	–	–	–	4.31	11.3*	14.29*
2 28.57°	–	–	–	–	6.99	9.98*
5 35.56°	–	–	–	–	–	2.99
Head Translation						
Means ± SE	1 −Baseline 1.79” ± 0.23	3 2.89” ± 0.32	2 3.38” ± 0.25	6 3.43” ± 0.34	5 5.22” ± 0.42	4 5.76” ± 0.33
1 −Baseline 1.79”	–	1.1	1.59*	1.64*	3.43*	3.97*
3 2.89”	–	–	0.49	0.54	2.33*	2.86*
2 3.38”	–	–	–	0.05	1.84*	2.38*
6 3.43”	–	–	–	–	1.79*	2.33*
5 5.22”	–	–	–	–	–	0.54
Shoulder Translation						
Means ± SE	1 −Baseline −0.19” ± 0.35	3 −2.24” ± 0.42	2 −1.42” ± 0.41	4 0.36” ± 0.56	6 1.86” ± 0.84	5 2.85” ± 0.69
1 −Baseline −0.19”	–	−2.05	−1.23	0.55	2.05	3.04*
3 −2.24”	–	–	0.82	2.60	4.10*	5.09*
2 −1.42”	–	–	–	1.78	3.28*	4.27*
4 0.36”	–	–	–	–	1.50	2.49*
6 1.86”	–	–	–	–	–	0.99

Values represent the differences between condition pairs.
*Iindicates the difference is statistically significant at $p \leq 0.003$.

DISCUSSION

While previous research studies have explored the postures used for individual mobile devices and technology, in this study, we were able to develop generalized pictures of the postures assumed during use of each technology device and compare between them. Based on our results, using a tablet, whether supported on a table or held in the hands, produced the greatest amount of forward head shift and neck flexion. Also, tablet use produced postures that were statistically different than many other devices and technology. This suggests that frequent, regular use of this device may produce greater deleterious effects than regular use of other handheld devices/technology.

We assumed that postures assumed during technology use would differ from baseline posture. This was true for Head Translation and Angulation in the sagittal plane for most conditions, the exception being cell phone conversation and laptop use. Surprisingly, head position in the coronal plane during technology use varied little from baseline for all conditions, with a statistically significant increase in head translation to the left during handheld tablet use.

At baseline, posture variables in the coronal plane were near neutral, with less than an inch translation in either direction (right or left). The shoulder exhibited slight flexion away from the body. Larger deviations from neutral were observed for baseline head posture in the sagittal plane, as the head was shifted and flexed forward, while the shoulders maintained a fairly neutral position. This large anterior shift and angulation of the head is consistent with previous research[2, 21)] demonstrating changes in baseline head/neck posture in persons who regularly use handheld devices and technology. Given the fact that 100% of participants use a cell phone daily and 95% use a laptop daily, and have been doing so for many years, this head shift and angular deviation is not unexpected.

In the sagittal plane, texting produced significant anterior head shift and flexion. These variables were statistically greater than baseline, producing over an inch and a half more anterior shift, and almost 15° greater flexion. This change in head position was coupled with a slight posterior shift and extension in the shoulders. While we initially expected greater shoulder flexion during this task, this was not the case and was confirmed by visual inspection of the pictures taken during device use. More shoulder flexion during this activity would bring the phone up higher in the visual field, potentially reducing the need for increased forward positioning of the head. However, repeated shoulder flexion for this task would likely present further issues at the shoulder joint, so this may not be a reasonable solution for this maladaptive head posture. As the screen and user interface of a typical cell phone are small and closely associated, it would be hard to separate out the head and shoulder postures. Producing a better joint posture at the head may directly impact the posture of the shoulder.

When using the phone for a call, participants maintained a fairly neutral position in the coronal plane. The head was angled slightly to the right (4.5°), the side in which the phone was being held, though this did not differ statistically from baseline. In the sagittal plane, the head assumed statistically more flexion, compared to baseline. This finding was unexpected as the task does not seem to necessitate increased head flexion. It might be suggested that movement of the upper extremity to bring the phone to the ear would be the primary movement requirements, however this was not observed as the shoulders were only slightly more extended and posteriorly shifted when compared to baseline.

Tablet use, both table supported and handheld, produced posture variables that were relatively neutral in the coronal plane, the exception being head translation when using the tablet handheld. This variable demonstrated a shift to the left that was statistically significant from baseline. It is possible to suggest that this head positioning allows the user to see the screen around the right (dominant) hand as it is manipulating objects on the screen. Interestingly, a similar head position was not observed in the table supported tablet condition. Both tablet conditions demonstrated large increases in head anterior shift and angulation in the sagittal plane, statistically significant when compared to baseline. While shoulder positioning did not differ much from baseline when using the tablet handheld, table supported tablet use produced an anterior shift in the shoulders, accompanied by shoulder flexion, both of which were statistically significant from baseline. It is interesting to note that supporting the device on a table did not result in less head anterior shift or flexion as might be expected. This is likely due to the positioning of the tablet relatively flat on the table. This position was chosen by all of the participants despite options to prop it with the cover.

Laptop use produced a posture that was similar to baseline in both the coronal and sagittal planes. Any changes from baseline in the coronal plane were small and not significant. In the sagittal plane, there was statistically greater head anterior shift, though this was not coupled with a significant increase in head flexion, as observed in other conditions. The shoulders demonstrated greater anterior positioning and flexion though not statistically larger than baseline. This finding differed from our expectations and a visual inspection of the pictures was undertaken to discover why. While it may appear that the shoulders had greater flexion than baseline, the forward positioning of the trunk (not quantified in this study), offset this as shoulder angulation was a measure of humerothoracic position. This trunk position may also reduce the amount of head flexion required, though this does not necessarily reduce risk of injury development, instead moving risk of injury to the back/vertebral column.

While previous research[2, 3, 12, 14, 22)] has shown postural positions associated with specific devices, the goal of this study was to explore postures across multiple devices as daily multi-device use may further increase risk of injury and cumulative trauma. The vast majority of participants in this study regularly use both a cell phone and laptop. When considering the postures assumed while using both of these devices, the head is shifted and angled anteriorly, significantly more than baseline. Regularly using two devices that put the head in this position increases the cumulative trauma and the risk of developing these issues.

Though tablets are not used as frequently as laptops by participants in this study, we anticipate an increase use of this device as people become more familiar and comfortable with this technology. It is reasonable to suggest that regular tablet users will use the device in both a supported and handheld position, given their environment and context of the task. Therefore we had an interest in determining whether this impacted postural positioning. Interestingly there were no differences in head position, either translations or angulations, between these two tablet conditions. Supporting the tablet on the table resulted in shoulder positioning that was shifted more anteriorly and flexed, whereas holding the tablet positioned the shoulder more posteriorly and with slight extension. Essentially, the device was held closer to the body. Table supported tablet use produced shoulder positions that were similar in direction and magnitude to using a laptop.

Few participants in this study reported regularly using a tablet for their schoolwork, however this is a device that is emerging in general use[5)]. Those who do decide to use it for schoolwork may use an attachable, physical keyboard. It would be an interesting comparison between the postures assumed during traditional keyboarding with a laptop and the postures assumed when using a tablet with an attachable keyboard. Given the smaller size of the tablet and associated virtual keyboard, one might anticipate differences in posture, though this was not explored in this study. As it was, in this study we found statistically significant differences when using the laptop versus using the tablet in several key postural variables. Using the tablet both supported and unsupported resulted in a head that was more anterior shifted and angled than when using the laptop. This difference was not coupled with any significant differences in shoulder position. This likely has to do with the positioning of the screen angle, which with the tablet was near horizontal for most participants, as discussed above[2].

As part of the study design, we attempted to capture pictures of participant using these devices in their natural postures. However, given that these activities were being done in a lab with standardized methods, participants may not have been fully comfortable and able to achieve a truly natural position. Also, we collected data not long after they began completing the task. Participants may have assumed different postures the longer the task went on. The investigators provided the laptop and tablet used in this study so participants may not have been familiar or comfortable using them, potentially affecting their posture during use. Another limitation to this study is that we did not compare postures during technology use with posture during reading a typical book or completing a pencil and paper writing task. Posture during reading and writing will likely differ from baseline and also potentially device use and should be further explored. Participants were all right-hand dominant, healthy college students therefore the results of this study may not be generalizable to other populations. We were specifically interested in this population as we anticipate these young healthy adults may already be showing signs of musculoskeletal discomfort and altered posture due to years of device use. In conclusion, results from this study demonstrate that using a tablet positions the head in a more anterior and flexed position compared to other devices. This is a potential risk factor for developing cumulative trauma and the implications of regular tablet use should be further explored.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflicts of interest

The authors declare no conflicts of interest.

REFERENCES

1) Berolo S, Wells RP, Amick BC 3rd: Musculoskeletal symptoms among mobile hand-held device users and their relationship to device use: a preliminary study in a Canadian university population. Appl Ergon, 2011, 42: 371–378. [Medline] [CrossRef]
2) Toh SH, Coenen P, Howie EK, et al.: The associations of mobile touch screen device use with musculoskeletal symptoms and exposures: a systematic review. PLoS One, 2017, 12: e0181220. [Medline] [CrossRef]
3) Young JG, Trudeau MB, Odell D, et al.: Wrist and shoulder posture and muscle activity during touch-screen tablet use: effects of usage configuration, tablet type, and interacting hand. Work, 2013, 45: 59–71. [Medline]
4) Telecommunications I: ICT facts and figures 2017. https://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2017.pdf. (Accessed May 15, 2018)
5) eMarketer: Growth of time spent on mobile devices slows. https://www.emarketer.com/Article/Growth-of-Time-Spent-on-Mobile-Devices-Slows/1013072. (Accessed May 15, 2018)
6) Thomée S, Härenstam A, Hagberg M: Computer use and stress, sleep disturbances, and symptoms of depression among young adults–a prospective cohort study. BMC Psychiatry, 2012, 12: 176. [Medline] [CrossRef]
7) Jomoah IM: Work-related health disorders among Saudi computer users. Sci World J, 2014, 2014: 723280. [Medline] [CrossRef]
8) Redmayne M, Smith E, Abramson MJ: The relationship between adolescents' well-being and their wireless phone use: a cross-sectional study. Environ Health, 2013, 12: 90. [Medline] [CrossRef]
9) Harris C, Straker L: Survey of physical ergonomics issues associated with school childrens' use of laptop computers. Int J Ind Ergon, 2000, 26: 337–346. [CrossRef]
10) Nejati P, Lotfian S, Moezy A, et al.: The relationship of forward head posture and rounded shoulders with neck pain in Iranian office workers. Med J Islam Repub Iran, 2014, 28: 26. [Medline]
11) Shan Z, Deng G, Li J, et al.: Correlational analysis of neck/shoulder pain and low back pain with the use of digital products, physical activity and psychological status among adolescents in Shanghai. PLoS One, 2013, 8: e78109. [Medline] [CrossRef]
12) Binboğa E, Korhan O: Posture, musculoskeletal activities, and possible musculoskeletal discomfort among children using laptops or tablet computers for educational purposes: a literature review. J Sci Educ Technol, 2014, 23: 605–616. [CrossRef]
13) Xie Y, Szeto G, Dai J: Prevalence and risk factors associated with musculoskeletal complaints among users of mobile handheld devices: a systematic review. Appl Ergon, 2017, 59: 132–142. [Medline] [CrossRef]
14) Straker LM, Coleman J, Skoss R, et al.: A comparison of posture and muscle activity during tablet computer, desktop computer and paper use by young children. Ergonomics, 2008, 51: 540–555. [Medline] [CrossRef]
15) Woo EH, White P, Lai CW: Musculoskeletal impact of the use of various types of electronic devices on university students in Hong Kong: an evaluation by means of self-reported questionnaire. Man Ther, 2016, 26: 47–53. [Medline] [CrossRef]
16) Boland DM, Neufeld EV, Ruddell J, et al.: Inter- and intra-rater agreement of static posture analysis using a mobile application. J Phys Ther Sci, 2016, 28: 3398–3402. [Medline] [CrossRef]

17) Hopkins BC: Validity of posturescreen mobile® in the measurement of standing posture. In: Department of Exercise Sciences. Provo: Brigham Young University, 2014, p 41.
18) Szucs KA, Brown EV: Rater reliability and construct validity of a mobile application for posture analysis. J Phys Ther Sci, 2018, 30: 31–36. [Medline] [CrossRef]
19) Kan S, Fortuna J, Nur S, et al.: Can a mobile application be used to assess postural alignment in clinic? In: Canadian Society for Biomechanics. Hamilton, ON. 2016.
20) Portney LG, Watkins MP: Foundations of clinical research: applications to practice. New Jersey: Pearson Prentice Hall, 2015.
21) Jung SI, Lee NK, Kang KW, et al.: The effect of smartphone usage time on posture and respiratory function. J Phys Ther Sci, 2016, 28: 186–189. [Medline] [CrossRef]
22) Maslen B, Straker L: A comparison of posture and muscle activity means and variation amongst young children, older children and young adults whilst working with computers. Work, 2009, 32: 311–320. [Medline]