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REVİEW ARTICLE

The Effect of Digital Gaming Duration on Musculoskeletal System Symptoms: A Systematic Study

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Abstract
The aim of this study is to review the existing literature on the musculoskeletal system symptoms associated with digital gaming. Literature related to the subject was searched in Web of Knowledge, PubMed, Medline, PsycINFO, Proquest, Google Scholar, and Sport Discuss databases. Articles published from 2010 to 2022 were scanned using keywords describing digital gaming-related postural disturbances, and musculoskeletal system exposure (pain, muscle activity). The articles were independently scanned by three authors, the relevant data were extracted, and the methodological quality of the included studies was evaluated. A total of 1252 articles were scanned for eligibility. Eleven articles are included in the study. Systematic reviews and meta-analysis studies were not included in our study. A wide range of prevalence rates of musculoskeletal complaints in different body regions has been reported, with the highest prevalence commonly found in neck complaints. This review has only found some evidence showing that a neck flexion posture as well as the frequency of digital gaming are associated with musculoskeletal disorders and pain, postural disorders among users of digital devices. The findings were presented and discussed in relation to the effects of digital games on posture and the musculoskeletal system. There is limited evidence that digital gaming and its various aspects (occupancy and properties) are associated with musculoskeletal system symptoms and exposures. Therefore, it is considered that evidence-based guidelines should be presented by experts for the wise use of digital games.

Keywords
Digital Gaming, Posture, Musculoskeletal System, Health.

INTRODUCTION

Smartphone access and possession among children and adolescents have notably increased nowadays. Adverse health outcomes associated with excessive use of the device have also emerged with the increasing use of smartphones by children and adolescents (Sohn et al., 2019). Excessive phone use has been reported to have negative effects on sleep quality, physical activity, obesity, headaches, and eye strain among children (Domoff et al., 2019). In another study, a relationship has been identified between the smartphone exposure time of adolescents and musculoskeletal system problems. It is noted that the symptoms of the neck, shoulder area, and

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musculoskeletal system (Toh et al., 2019). and forward head posture, and hunchback posture (Peter et al., 2019) have the highest prevalence rates. Some studies have shown that the neck flexion posture, the most common posture among smartphone users, potentially pose risks of pain in the musculoskeletal and discomfort in the back of the neck area. As a result of the forward head flexion, the posture generates excessive external flexion force, which in turn causes a greater load on the neck extensors and adjacent connective tissue of the neck in order to balance the increase in the external flexion moment caused by the forward moment (Eitivipart et al., 2018; Xie et al., 2017). The use of smartphones increases the muscular activity of the neck muscles, especially the cervical erector spinae (CES) and upper trapezius (UT), as well as the forward shift of the head (Hanphitakphong et al., 2021). It is argued that prolonged and continuous contraction of the neck muscles will cause an increase in neck muscle fatigue. The longer duration of the device use, the greater the severity of the awkward position of the neck and head. During prolonged static postures, overloading of the neck muscles due to the use of smart devices contributes to discomfort and fatigue (Eitivipart et al., 2018; Xie et al., 2017). When it is compared to the standing position, it is stated that the shift in the head-neck angle when using a smartphone occurs more than in a sitting position (Lee, 2014; Ning, 2015).

In recent years, some experimental studies have been conducted to determine the effectiveness of guideline practice strategies to reduce the risk of pain in the neck area and posture caused by smartphone use (Park, 2017). Smartphone usage time, such as playing games with digital devices, is known as an important risk factor affecting the musculoskeletal system. There is evidence that helps guide the practice recommendations for the prevention of the risk of developing musculoskeletal problems in the neck area among smartphone users. Likewise, there is evidence reporting that children and adolescents are at a higher risk of injury compared to adults (Hanphitakphong et al., 2021). In addition, musculoskeletal problems that occur in childhood lead to problems that persist into adulthood (Jones et al., 2007). Therefore, the related smartphone (Morley and Thomas, 2017). The primary search was based on title, abstract, and keywords, using Boolean logic for the combination of terms.

activities that lead to symptoms of musculoskeletal pain in children and adolescents should not be ignored.

In the studies that are the subject of our review, there are common negative points such as posture, musculoskeletal system symptoms, pains, and forward head posture of digital gaming duration and digital device use. Especially as the digital gaming duration increases, muscle fatigue and pain occur in the posterior neck area. In addition, existing studies suggest that postures in digital device use and digital gaming duration may be associated with musculoskeletal problems that are common in the neck, shoulder, and back areas, and awkward postures (Hanphitakphong et al., 2021; Park et al., 2017; Alfaitouri and Altaboli, 2018; Lui et al., 2012). Limitations of the current studies include the use of measurements of the digital gaming duration and musculoskeletal system symptoms without the reliability and validity of the measurement methods indicated by the authors.

Assessment of the quality of the study, systematic it is an indication of the strength of the evidence provided by the review and informs the standards required for future research. It is thought that our study will benefit researchers who will investigate the postural effects of digital game addiction in the future.

Since the widespread use of smartphones is increasing, there is a need for guidelines that can reduce musculoskeletal problems. In conclusion, the objectives of this study are: (i) to examine the changes in the upper body postures of smartphone users, (ii) to examine the fatigue that occurs in the muscles depending on the duration of smartphone use.

MATERIALS AND METHODS

Study Strategy and Eligibility Criteria A systematic literature review was conducted in 2022 using Web of Science, PubMed, Google Scholar, and Sport Discus databases. This study was conducted as an observational study with publicly available data. The study data were obtained from the official websites open to the public. Since the study data are not collected through experiments, there is no ethical concern

Two authors (PA and AB) have scanned all the possible titles (abstracts, full-text articles) for eligibility. The disputes that arose about inclusion

were resolved in consultation with the third author (IB). The search terms were determined based on previous reviews and agreements between authors. These are concepts such as digital game, digital gaming duration, posture, and musculoskeletal system. Some limitations have been imposed on the study of comprehensive literature. In addition, searches in databases are conducted in the following sequence (digital gaming & posture* digital gaming & neck pain* digital gaming & pain* digital gaming & joint pain* digital gaming & fatigue*, digital game duration & musculoskeletal system).

The components of the PICOS question, including population, intervention, comparison, outcomes, and study design, were answered to define eligibility criteria (Methley et al., 2014). The study covers only articles published between 2010 and 2022 in English-language peer-reviewed journals.

Table 1. Study selection criteria

PICOS	Eligibility Criteria
Population	Children and adults
Interventions	Any physical activity conducted in nature
Comparators	Comparison group not determined
Outcomes	Physiological consequences: changes due to stimulus response
Study Designs	No limitations with the study design

Scanning and Study Selection

The reference results of the database search were transferred to the Mendeley reference program. The studies were scanned in terms of inclusion criteria according to the title in the first stage, followed by abstract and full-text scans. The scanning process was conducted independently by the authors. The authors discussed the results, and the full texts were included in the analysis based on mutual agreement. In this review article, authors, year, participants and sample group, objectives and hypotheses, findings, and results are included in the analysis table.

The "Effective Public Health Practice Project" (EPHPP) was used to evaluate the bias risk of the included studies (Thomas et al., 2014). EPHPP is used for observational, cross-sectional, cohort, and randomized controlled trial designs (Armijo-Olivo et al., 2012). The EPHPP tool has six equiponderant categories that are included in an overall rating to assess the quality of work. These are selection bias, study design, confounders, blinding, data collection practices, and withdrawal. The category of withdrawals and dropouts was also applied to cross-sectional studies since it contains information about the percentage of participants who completed the study. Each category received a strong (Sohn et al., 2019), medium (Domoff al., 2019) or weak (Toh et al., 2019), rating, which is the basis for the overall rating of the work. In addition, systematic reviews and meta-analysis studies were not included in the study.

RESULTS

After the duplications were extracted from the database search, 1252 references were taken. These have been scanned for eligibility according to their titles (Figure 1). Then, 192 abstracts and 64 full-text articles were evaluated for eligibility.

Articles on posture correction or musculoskeletal system improving digital games are excluded from the study. In addition, articles conducted on adults have not been evaluated. A total of 11 articles were included in this study.

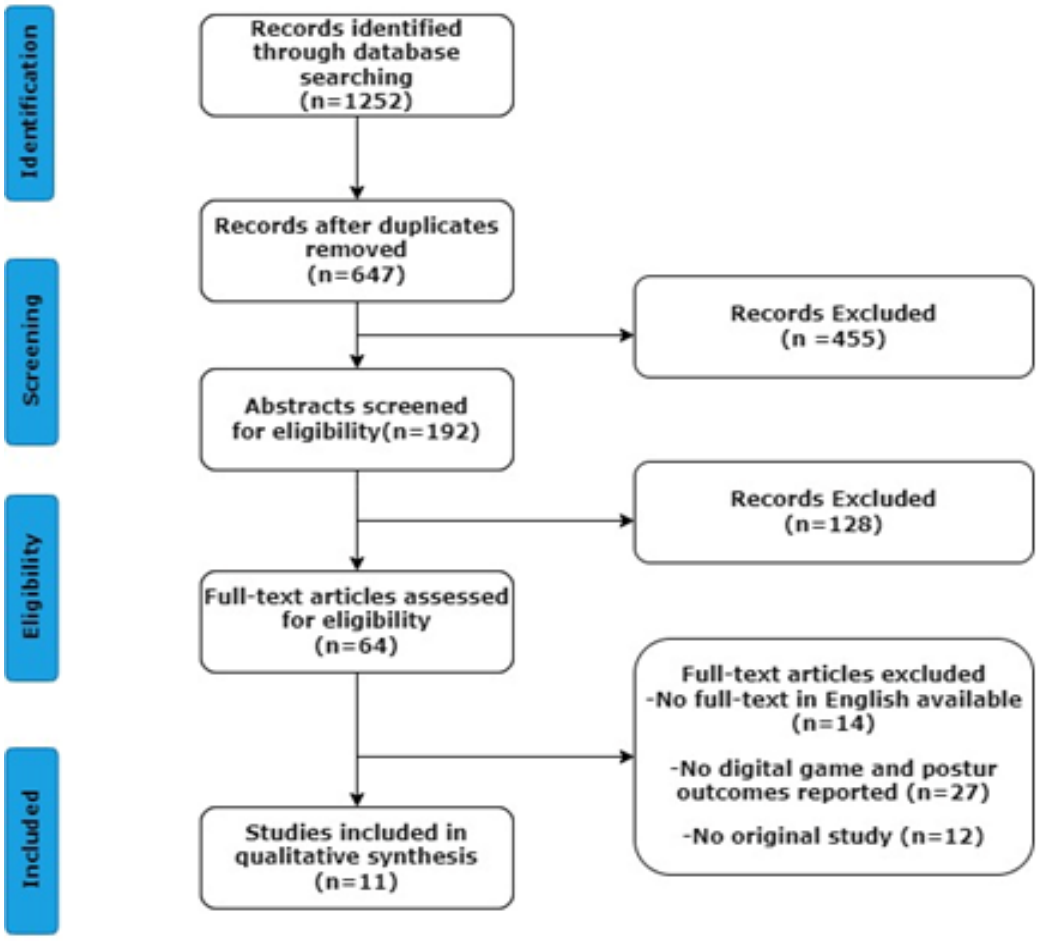

Figure 1. PRISMA flowchart for selecting relevant articles.

The Quality of the Reviewed Articles

It was identified that five articles are of high quality (Hanphitakphong et al., 2021, Young et al., 2013; Kim and Koo 2020), and four articles are acceptable (Park JHM, et al., 2017, Ashok et al., 2020; Lam et al., 2022) and two articles are of low quality (Cankurtaran et al., 2022; Lui et al., 2012). In more than half of the included studies, smartphone usage conditions were simulated so that participants could apply them in a laboratory environment. Accordingly, it is seen in Table 2 that the data do not fully represent smartphone use in real life and therefore the external validity of the studies is low.

Table 2. Methodological quality scores of studies

Included studies	External validity criteria				Internal validity criteria						Overall quality
	1	2	3	4	5	6	7	8	9	10	11
(Kim & Koo, 2016)	N	N	N	Y	Y	Y	Y	Y	N	Y	++
(Hanphitakphong et al., 2021b)	N	N	Y	Y	Y	Y	N	Y	Y	N	++
(Park et al., 2017b)	N	N	N	N	Y	Y	N	Y	Y	Y	+
(Young et al., 2013)	N	N	Y	Y	N	Y	N	Y	Y	Y	++
(Anna et al., 2018)	N	N	N	Y	Y	Y	N	Y	Y	Y	++
(Alfaitouri & Altaboli, 2019)	Y	N	Y	N	Y	Y	N	Y	Y	N	++
(Cochrane et al., 2019)	N	N	N	Y	Y	Y	N	Y	Y	N	+
(Lui et al., 2011)	N	N	N	N	N	Y	N	Y	Y	Y	-
(Lam et al., 2022)	N	N	Y	Y	Y	Y	N	Y	Y	N	+
(Ashok et al., 2020)	N	Y	N	Y	Y	N	N	Y	N	Y	+
(Cankurtaran et al., 2022)	N	N	N	N	Y	Y	N	Y	N	Y	-

Note; N=No; Y=Yes; ++=high quality (low risk of bias); +=acceptable (moderate risk of bias); -=low quality (high risk of bias); 1 – Was the study's target population a close representation of the national population in relation to relevant variables, e.g. age, sex, occupation? 2 – Was the sampling frame a true or close representation of the target population? 3 – Was some form of random selection used to select the sample, OR, was a census undertaken? 4 – Was the likelihood of non-response bias minimal? 5 – Were data collected directly from the subjects (as opposed to a proxy)? 6 – Was an acceptable case definition used in the study? 7 – Was the study instrument that measured the parameter of interest (e. g. prevalence of low back pain) shown to have reliability and validity (if necessary)? 8 – Was the same mode of data collection used for all subjects? 9 – Was the length of the shortest prevalence period for the parameter of interest appropriate? 10 – Were the numerator(s) and denominator(s) for the parameter of interest appropriate? 11 – Summary item on the overall risk of bias (Hoy et al., 2022).

Musculoskeletal system symptoms, posture, and body areas reported in pain complaints that occur along with the duration of digital gaming are the neck, upper extremity areas, and upper and lower back. The common point revealed in the studies examined is that phone use for a long time usually causes pain fin the shoulder and neck area (Kim and Koo 2020), In the studies, it has been reported that pain occurs after 16 minutes of phone use, 20 minutes of playing digital games cause muscle fatigue and pain, feeling pain in the neck during phone use, and suffering from neck pain in children who are exposed to digital games for more than 2 hours, and there is a positive relationship between electronic device use and neck pain.

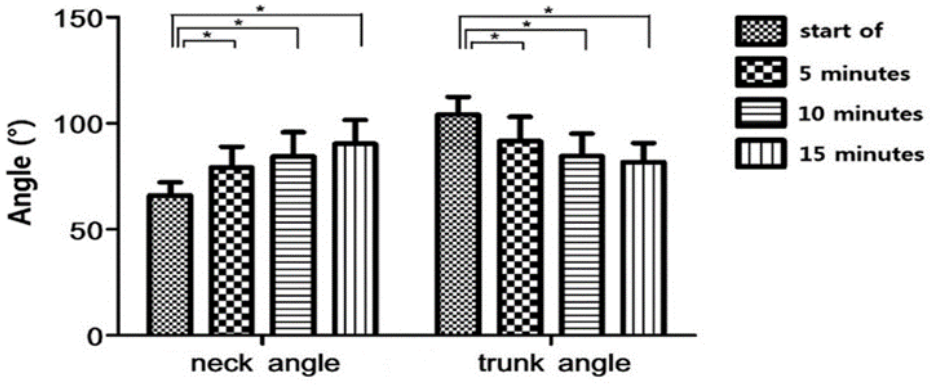

Figure 2. Pain rate associated with phone use time (Park et al., 2017).

In the figure above, the rate of pain that occurs along with the duration is shown. As time extends, muscle fatigue and discomfort occur in the posterior neck area. However, a situation arises that is unsuitable for posture (Park et al., 2017). The neck flexion angle increased significantly in all postural positions (standing, arms-free sitting, and sitting with arms resting on a table) as the time spent on the phone progressed (Alfaitouri and Altaboli 2019). The flexion of the neck is considerably high during digital gaming. And this is a potential risk factor for the development of neck pain, musculoskeletal system fatigue and disorders (Anna et al., 2018). Increased shoulder protraction along with neck flexion causes scapula dysfunction during upper extremity movement. For this reason, it has been stated that the use of smartphones negatively affects the supine posture (Cochrane et al., 2019). Individuals who spend a long time with electronic devices have a high risk of developing a forward head posture due to static load acting on the cervical spine (Ashok et., al. 2020). It is also noted that esports players have significantly poor spinal posture compared to the normal reference range (Lam et al., 2022).

Risk Factors and Evidence

In general, the risk factors identified in the reviewed studies can be grouped into two main categories. These are (i) the postures adopted when using digital devices (ii) and the time spent. Besides neck flexion, there is evidence that the frequency of playing games causes musculoskeletal system complaints among digital device users. The selected studies reflected consistent results with each other. It is seen in the studies which we have included in our study, that playing digital games causes pain, forward head posture, musculoskeletal system symptoms, and posture impairments as time spent.

Table 3. Studies on musculoskeletal symptoms associated with digital games

	Author, Year	Participants	Intervention	Finding	Conclusion
1	(Lui et al., 2011)	-Age range 8-13 -N=464 children	-Questions about frequency, duration, and pain have been directed to children who have been playing games with technological devices in the last 8 months.	- About 1/3 of the participants (28.9%) reported discomfort in different parts of the body associated with playing e-games. The vast majority of 20% stated that the pain was in the shoulders.	Exposure to digital devices, especially for more than 2 hours daily was significantly associated with neck and upper limb discomfort. Long durations of play would increase the cumulative muscle loading and contribute to musculoskeletal symptoms.
2	(Young et al., 2013)	-N=15 - tablet users	Participants were asked to complete tasks by holding the tablet with one hand, two hands, on a desk, and on their knees.	There was a difference between the postures for the wrist ($p<0.05$). Wrist extension was especially high for the dominant hand when a tablet was placed on the lap. Differences were observed in the posture and muscle activity of the shoulder according to the position of the tablet.	Users of touchscreen tablets are exposed to excessive wrist postures, which may put them at a higher risk of developing musculoskeletal symptoms.
3	(Kim & Koo, 2016)	-N=34 -young individuals	The participants were divided into 3 groups. The first group was 10 minutes, the second group was 20 minutes, and the third group used 30 minutes of smartphones.	In the second group, a significant difference was found in the degree of fatigue in the left upper trapezius muscles whereas, in the third group, a significant difference was found in the left cervical erector spinae and bilateral upper trapezius muscles. A significant difference was found in terms of fatigue in the left trapezius muscles in the first and third groups.	Pain has occurred with fatigue after using a smartphone for a long time.
4	(Park et al., 2017b)	-N=18 male -smartphone users	Muscle activation and angular changes in the neck and torso of the participants were examined during 16 minutes of smartphone use. EMG and digital camera were used.	Neck and trunk flexion increased significantly at the 5th, 10th, and 15th minute ($p<0.05$) onwards the beginning of smartphone use.	Smartphone use has changed posture and muscle activation in a relatively short period of time (5 min), and pain occurred after 16 minutes of use.
5	(Anna et al., 2018)	-N=15 healthy young individuals -Age range 21-25	Four activities were performed with the smartphone (gaming, messaging, video watching) in two different postures (standing and sitting).	Differences were found for neck and torso angles in both postures ($p<0.05$). It showed that significant changes in neck and torso posture occurred when the activities were performed in a sitting position.	The flexion-extension of the neck is greater during digital gaming than compared to watching a video. It has been stated that posture during smartphone use is a potential risk factor for the development of neck pain, musculoskeletal fatigue and disorders.
6	(Alfaitouri & Altaboli, 2019)	-N=20 young individuals	The participants stood against a scaled board and for 20 minutes (0, 5, 10,15, and 20th minutes) photos were taken. The procedure was performed in three different postures (standing, sitting with arms free, and sitting with arms on the table).	Statistically significant results ($p<0.05$) were found in both posture and smartphone use time.	The neck flexion angle increased significantly as time progressed in all postures. Neck flexion is significantly less in the standing posture than in the sitting posture.
7	(Cochrane et al., 2019)	-N=63 students -Age mean 22.7	Photographic posture analysis was performed on the participants. Photos of the students were taken before using the smartphone and 5 minutes after using it.	-A significant increase in the amount of shoulder protraction ($p<0.001$) was found in the non-dominant hands of the students. Significant ($p<0.001$) results were found in pelvic curvature after smartphone use.	Increased shoulder protraction causes scapula dysfunction during upper extremity movement, and this causes students to be unable to use the arm well. It is clearly seen that smartphone use negatively affects the upper back posture of university students.
8	(Ashok et al., 2020)	-N=160 participants -Age mean 22.8	Forward head posture angles were measured using the photogrammetry method.	A total of 97 participants had a forward head posture and an association was found between the duration of game playing and forward head posture.	It has been reported that individuals who spend a long time on electronic gaming devices have a high risk of developing a forward head posture due to static loading affecting the cervical spine.
9	(Hanphitakphong et al., 2021a)	-Age range 10-18 --N=44 students	Participants were instructed to play digital games continuously for 20 minutes in a sitting position during the dynamic posture analysis. Wireless EMG was used to collect data from CES and UT.	Neck, trunk, left shoulder and bilateral elbow flexion angles increased significantly at the 10th and 20th minute ($p<0.05$) compared to baseline. Bilateral CES has been associated with fatigue increased significantly at the 20th minute. After the completion of the game, the neck discomfort increased significantly.	As a result, it has been concluded that continuous (20 minutes) smartphone gaming causes a posture that is not suitable for posture to a significant extent and causes muscle fatigue and discomfort, especially in the back neck area.
10	(Lam et al., 2022)	-N=48 e-Sports players -Age mean 20.1	- Spine evaluation was performed via SpinalMouse after e-sports.	The spinal posture, mobility, and stability of e-Sports players were found to be significantly worse.	It was determined that e-Sports players have significantly weaker spinal posture, mobility, and stability compared to the normal reference range.
11	(Cankurtaran et al., 2022)	-N=1000 children -age mean 11.95	Pain assessment has been performed to detect musculoskeletal problems.	When the pain complaints of children were examined, 93 people reported headache, 69 children reported shoulder pain, 48 children reported elbow pain, 50 children reported hand pain and 128 children reported back pain.	A positive relationship has been found between the duration of electronic device use and neck pain. In addition, it has been reported that there is a positive relationship between neck pain and headache.

DISCUSSION

Our study is a review that systematically describes the available evidence on postural symptoms associated with digital game use. In the studies included in this review, the findings in three specific body regions were examined. In the studies that are the subject of our review, there are common negative points such as posture, musculoskeletal system symptoms, pains, and forward head posture of digital gaming duration and digital device use. Especially as the digital gaming duration increases, muscle fatigue and pain occur in the posterior neck area. In addition, existing studies suggest that postures in digital device use and digital gaming duration may be associated with musculoskeletal problems that are common in the neck, shoulder, and back areas, and awkward postures (Hanphitakphong et al., 2021; Park et al., 2017; Alfaitouri and Altaboli,. 2018; Lui et al., 2012). Limitations of the current studies

include the use of measurements of the digital gaming duration and musculoskeletal system symptoms without the reliability and validity of the measurement methods indicated by the authors.

The objectives of our review (i and ii) are supported in detail below. In case-control and experimental laboratory studies, there is consistent evidence that musculoskeletal system symptoms were associated with digital gaming duration (Hanphitakphong et al., 2021; Park et al., 2017; Kim et al., 2022) and its use in different positions (16–18) may have an impact on the symptoms experienced.Neck flexion occurs very quickly among individuals who play games with digital devices. The increase in neck flexion occurs within five minutes (Park et al., 2017). It has been reported that neck flexion begins after typing on a desktop for ten minutes while crossing legs (Lee et al., 2011). In another study, participants played a digital game for twenty minutes in a sitting position during a dynamic posture analysis. The neck flexion angles increased in the 20th minute compared to the initial one. This condition has been associated with increased fatigue and an inappropriate posture has emerged (Hanphitakphong et al., 2021). It is in line with current findings that longer smartphone use can lead to poor posture and progressive muscle loading in the posterior of the neck. It has been pointed out that significant fatigue of UT and CES muscles was noticed after 20-30 minutes of smartphone use (Kim and Koo, 2020). An adult's neck can typically lift about 10 to 12 pounds of force in the neutral position (Hansraj, 2014). Another issue that is worth noting is that children's heads are larger compared to adults according to their body size. As the digital gaming duration increases, the extensor muscles are activated to resist the flexion moment of the neck, and the load on the CES and UT muscles increases (Eitivipart et al., 2018). In addition, the size of muscle fibers in children is less compared to adults. When the head stays in the forward flexion position for a long time, the onset of fatigue begins earlier than in adults (Hanphitakphong et al., 2021). Digital device use in relation to different body positions has a higher risk of developing musculoskeletal system symptoms (Young et al., 2013). It is stated that using a smartphone while sitting or standing without a support surface can cause more physical stress on the neck muscles compared to using a desktop or laptop computer (Lee et al., 2014). In addition, it has been stated that different activities such as gaming, texting, and watching videos in two different postures such as sitting and standing cause more changes in neck and torso posture in a sitting position compared to standing posture. As a piece of interesting information, the flexion extension of the neck during digital gaming is more significant than when watching videos (Alfaitouri et al., 2014; Anna et al., 2018). In different postures (standing, arms-free sitting, and sitting with arms resting on a table), the angle of flexion of the neck increased significantly as time progressed (Alfaitouri et al., 2014). In one study, photographic postures were taken from participants before and after using a smartphone. A significant increase in the amount of shoulder protraction was found in the non-dominant hands of the participants, and significant results were found in pelvic curvature after using a smartphone. In addition, increased shoulder protraction causes scapula dysfunction during upper extremity movement, which causes participants to be unable to use the arm well. In summary, it has been reported that smartphone use negatively affects supine postures (Cochrane et al., 2019). In the study in which spinal posture and mobility were evaluated, the spinal posture, mobility, and stability of e-sports players were found to be significantly poor (Lam et al., 202). In individuals with a forward head posture, a relationship was found between the duration of playing games and the forward head posture (Ashok et al., 2020; Hakala et al., 2006). It has been reported that individuals who spend a long time on digital gaming devices have a high risk of developing a forward head posture due to static loading affecting the cervical spine (Ashok et al., 2020).

Further Research

Since the current studies are mostly cross-sectional, case-control and experimental laboratory designs with low methodological quality, the findings obtained in our study should be interpreted carefully. Therefore, high-quality epidemiological studies are needed to strengthen the evidence, including longitudinal studies that study the duration of smartphone use in natural environments. In addition, the right methods are available to accurately measure the duration of smartphone use in everyday life. Accurate measurement methods should be used for the symptoms and exposures of the forward head posture, postural disorder, musculoskeletal system,

and laboratory studies. Anatomical angle definitions should be clearly remarked and preferably harmonized between studies.

Due to the heterogeneity of the study designs, methods, results, and data presented, narrative synthesis was used in the review rather than meta-analysis. The systematic approach used to scan articles, extract data and evaluate the meteorological quality of the included studies has helped us to minimize biases. In our review, studies examining gait and balance parameters during smartphone use were excluded.

Limitations of this review

There are some limitations in this systematic review. A lack of effort to identify unpublished peer-reviewed studies and non-English written articles as well as the exclusion of laboratory studies may introduce bias in this review. In addition, some studies have probably been missed out although an extensive literature search was performed.

Conclusion

Five articles of high quality, four articles of acceptable quality and two articles of low quality were evaluated in this systematic review. A wide range of prevalence rates of musculoskeletal complaints in different body regions has been reported, with the highest prevalence commonly found in neck complaints. This review has only found some evidence showing that a neck flexion posture as well as the frequency of digital gaming are associated with musculoskeletal disorders and pain, postural disorders among users of digital devices. Interpretation of the results of risk factors in this review should be treated with caution since many risk factors have been examined by only eleven studies. More high-quality and prospective studies are needed to reveal the correlation between musculoskeletal disorders, postural disorders and pain stemmed from digital games.

Conflict of interest

No conflict of interest is declared by the authors. In addition, no financial support was received.

Ethics Statement (Prospero ID)

Permissions for the study named The Effect of Digital Gaming Duration on Musculoskeletal System Symptoms (A Systematic Study) were obtained from York University National Institute for Health Research on April 28, 2023 with ID number 422287.

Author Contributions

Study Design, MS; Data Collection, MS, AB, IB; Statistical Analysis, AB, GK, NS, PA; Data Interpretation, MS, PA, IB, GK Manuscript Preparation, MS, NS, NS, IB; Literature Search, NS, GK, PA, AB. All authors have read and agreed to the published version of the manuscript.

REFERENCES

Alfaitouri, S., & Altaboli, A. (2019, November). The effect of posture and duration of smartphone usage on neck flexion angle. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 63, No. 1, pp. 962-966). Sage CA: Los Angeles, CA: SAGE Publications.

Anna CD', Varrecchia T, Bibbo D, Orsini F, Schmid M, Conforto S. (2018). Effect of different smartphone uses on posture while seating and standing; Effect of different smartphone uses on posture while seating and standing. 2018 IEEE International Symposium on Medical Measurements and Applications (MeMeA).

Armijo- Olivo, S., Stiles, C. R., Hagen, N. A., Biondo, P. D., & Cummings, G. G. (2012). Assessment of study quality for systematic reviews: a comparison of the Cochrane Collaboration Risk of Bias Tool and the Effective Public Health Practice Project Quality Assessment Tool: methodological research. *Journal of evaluation in clinical practice*, *18*(1), 12-18.

Ashok, K., Purushothaman, V. K., & Muniandy, Y. (2020). Prevalence of forward head posture in electronic gamers and associated factors. *International Journal of Aging Health and Movement*, *2*(2), 19-27.

Brandt, L. P. A., Andersen, J. H., Lassen, C. F., Kryger, A., Overgaard, E., Vilstrup, I., & Mikkelsen, S. (2004). Neck and shoulder symptoms and disorders among Danish computer workers. *Scandinavian journal of work, environment & health*, 399-409.

Cankurtaran, F., Menevşe, Ö., Namlı, A., Kızıltoprak, H. Ş., Altay, S., Duran, M., ... & Ekşi, C. (2022). The impact of digital game addiction on musculoskeletal system of secondary school children. *Nigerian Journal of Clinical Practice*, *25*(2), 153-159.

Cochrane, M. E., Tshabalala, M. D., Hlatswayo, N. C., Modipana, R. M., Makibelo, P. P., Mashale, E. P., & Pete, L. C. (2019). The short-term effect of smartphone usage on the upper-back postures of university students. *Cogent Engineering*, *6*(1), 1627752.

Domoff SE, Borgen AL, Foley RP, Maffett A, Sarah Domoff CE. Excessive use of mobile devices and children's physical health. 2019.

Eitivipart, A. C., Viriyarojanakul, S., & Redhead, L. (2018). Musculoskeletal disorder and pain associated with smartphone use: A systematic review of biomechanical evidence. *Hong Kong Physiotherapy Journal*, *38*(02), 77-90.

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. *The European Journal of Public Health*, *16*(5), 536-541.

Hanphitakphong, P., Thawinchai, N., & Poomsalood, S. (2021). Effect of prolonged continuous smartphone gaming on upper body postures and fatigue of the neck muscles in school students aged between 10-18 years. *Cogent Engineering*, *8*(1), 1890368.

Hansraj, K. K. (2014). Assessment of stresses in the cervical spine caused by posture and position of the head. *Surg Technol Int*, *25*(25), 277-9.

Hoy, D., Brooks, P., Woolf, A., Blyth, F., March, L., Bain, C., ... & Buchbinder, R. (2012). Assessing risk of bias in prevalence studies: modification of an existing tool and evidence of interrater agreement. *Journal of clinical epidemiology*, *65*(9), 934-939.

Jones, G. T., Silman, A. J., Power, C., & Macfarlane, G. J. (2007). Are common symptoms in childhood associated with chronic widespread body pain in adulthood? Results from the 1958 british birth cohort study. *Arthritis & Rheumatism*, *56*(5), 1669-1675.

Kim, S. Y., & Koo, S. J. (2016). Effect of duration of smartphone use on muscle fatigue and pain caused by forward head posture in adults. *Journal of physical therapy science*, *28*(6), 1669-1672.

Lam, W. K., Chen, B., Liu, R. T., Cheung, J. C. W., & Wong, D. W. C. (2022). Spine Posture, Mobility, and Stability of Top Mobile Esports Athletes: A Case Series. *Biology*, *11*(5), 737.

Lee, J. H., Park, S. Y., & Yoo, W. G. (2011). Changes in Craniocervical and Trunk Flexion Angles and Gluteal Pressure during VDT Work with Continuous Cross- legged Sitting. *Journal of occupational health*, *53*(5), 350-355.

Lee, S., Kang, H., & Shin, G. (2015). Head flexion angle while usingsmartphone. Ergonomics, *58*(2), 220-226.

Lui, D. P., Szeto, G. P., & Jones, A. Y. (2011). The pattern of electronic game use and related bodily discomfort in Hong Kong primary school children. *Computers & Education*, *57*(2), 1665-1674.

Methley, A. M., Campbell, S., Chew-Graham, C., McNally, R., & Cheraghi-Sohi, S. (2014). PICO, PICOS and SPIDER: a comparison study of specificity and sensitivity in three search tools for qualitative systematic reviews. *BMC health services research*, *14*(1), 1-10.

Morley, B., & Thomas, D. (2005). An investigation of home advantage and other factors affecting outcomes in English one-day cricket matches. *Journal of sports sciences*, *23*(3), 261-268.

Ning, X., Huang, Y., Hu, B., & Nimbarte, A. D. (2015). Neck kinematics and muscle activity during mobile device operations. *International Journal of Industrial Ergonomics*, *48*, 10-15.

Park, J. H., Kang, S. Y., Lee, S. G., & Jeon, H. S. (2017). The effects of smart phone gaming duration on muscle activation and spinal posture: Pilot study. *Physiotherapy theory and practice*, *33*(8), 661-669.

Sohn, S. Y., Rees, P., Wildridge, B., Kalk, N. J., & Carter, B. (2019). Prevalence of problematic smartphone usage and associated mental health outcomes amongst children and young people: a systematic review, meta-analysis and GRADE of the evidence. *BMC psychiatry*, *19*(1), 1-10.

Thomas, B. H., Ciliska, D., Dobbins, M., & Micucci, S. (2004). A process for systematically reviewing the literature: providing the research evidence for public

health nursing interventions. *Worldviews on Evidence‐Based Nursing*, *1*(3), 176-184.

Toh, S. H., Coenen, P., Howie, E. K., Mukherjee, S., Mackey, D. A., & Straker, L. M. (2019). Mobile touch screen device use and associations with musculoskeletal symptoms and visual health in a nationally representative sample of Singaporean adolescents. Ergonomics, 62(6), 778-793.

Xie, Y., Szeto, G., & Dai, J. (2017). Prevalence and risk factors associated with musculoskeletal complaints among users of mobile handheld devices: A systematic review. *Applied ergonomics*, *59*, 132-142.

Young, J. G., Trudeau, M. B., Odell, D., Marinelli, K., & Dennerlein, J. T. (2013). Wrist and shoulder posture and muscle activity during touch-screen tablet use: effects of usage configuration, tablet type, and interacting hand. *Work*, *45*(1), 59-71.