

RECOMMENDATION

Weaknesses of research methodologies on musculoskeletal disorders associated with mobile touch-screen devices

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Abstract

The objective of the currently study is to point out the weaknesses of some recent researches, which were done about the effects or symptoms of using Touch Screen Mobile Devices on the human musculoskeletal system. In this article, we reviewed the research processes performed in recent 26 randomly selected papers about musculoskeletal disorder to clarify the common weaknesses of these published articles. The electronic database search and reference search were conducted in four different databases: Medline, PubMed, Web of Science, and Scopus. We noticed that none of the reviewed papers had performed the experimental design phase of a scientific research. Additionally they had not validated the assumptions of the statistical methods used in their researches. Therefore, their findings are doubtful. In this article, we proposed practical outlines for a reliable experimental research.

KEYWORDS

experimental scientific research, musculoskeletal disorder, smartphones, statistical analysis, symptoms, tablets

1 | INTRODUCTION

Recently, mobile phones have been introduced with less sleek designs and became increasingly popular in usage, since they can be used for many purposes (e.g., internet communication, mobile applications, and social media).¹ More importantly, the designs of mobile phones became more touch-based. Thus, Mobile Touch Screen Devices (MTSDs) refers to the mobile gadgets provided with touch screens for finger or stylus usage, such as tablets and smartphones.²

Chronic pain due to Musculoskeletal Disorders (MSDs) is generally intensified with age and morbidity factors include depression, inflammation, pain, impaired cognitive function, sleep disturbance, physical disability, and anxiety.³ These factors significantly affect the quality of life and impose intense economic burdens on health systems.⁴

In recent years, an increase in the number of research works in the field of MDSs focusing on the use of MTSD was observed. Therefore, we reviewed the research works published in the years between 2011 and 2021. As a result, we randomly selected 26 articles (as shown in Table 2). We observed that most of them failed to satisfy the requirements of a reliable scientific research hence their conclusions were not meaningful.

Design of the experiment is a useful scientific tool that contributes in planning and organizing experiments in order to achieve valid conclusions through analyzing the observed findings. It should be noted that studies that affect on MTSDs of the prevalence of musculoskeletal symptoms among the users have found different findings as risk factors for musculoskeletal symptoms and different pains of lower and upper body regions. This is why, we performed this research study,

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with an effort to help and guide scientists on how to design and conduct a reliable experimental research for finding the significant factors that contribute to MSDs due to the use of MTSD.

In this article, we have clarified the common weaknesses of the reviewed published articles. Additionally, we have presented a guideline flowchart on how to make

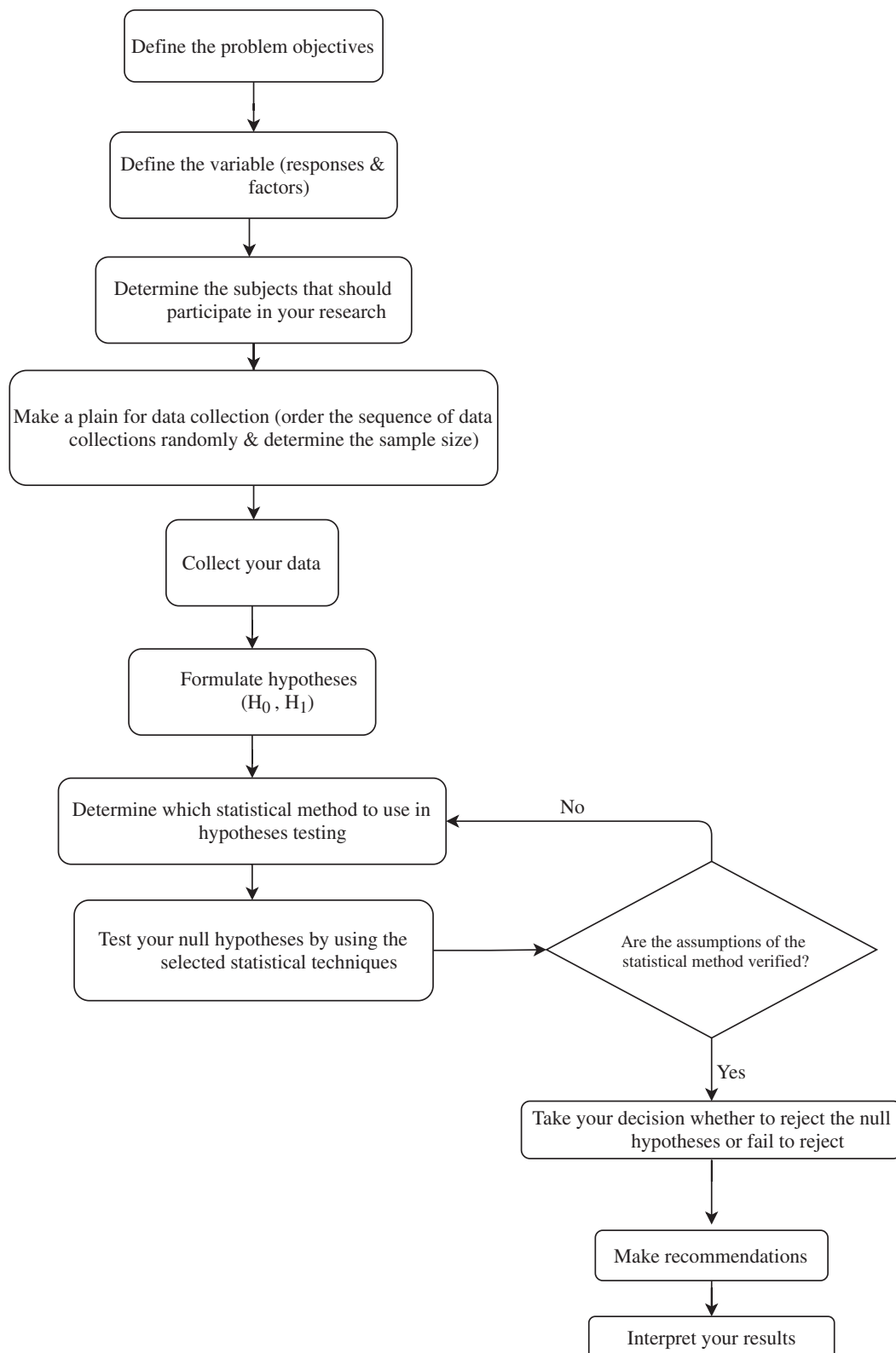


FIGURE 1 Flowchart to guidelines for reliable experimental research

a reliable scientific experimental research in the field of MDSs related to the use MTSD as shown in [Figure 1](#).

2 | SEARCH STRATEGY AND ELIGIBILITY CRITERIA

The research strategy in this article aims to help authors improve the reporting of papers. [Table 1](#) shows the electronic database searches and references search, for this recommendation paper, in four different databases mentioned as follows: Medline, PubMed, Web of Science, and Scopus. We intended to identify analyses relevant recent published studies between years 2011 and 2021 that reported any MSDs and /or the prevalence pain or discomfort among users of MTSDs. There was no date restriction; unrelated and ineligible studies were removed through

TABLE 1 Stages of searching through database for selecting relevant articles

Records identified through database searching	
From Medline database	
<i>Initial search</i>	58 152
<i>Source type (data) 2011–2021</i>	29 860
<i>Document type (Article) and Type of Language (English)</i>	3380
<i>Records screening</i>	32
From PubMed database	
<i>Initial search</i>	11 317
<i>Source type (data) 2011–2021</i>	4569
<i>Document type (Article) and Type of Language (English)</i>	4301
<i>Records screening</i>	87
From Web of Science database	
<i>Initial search</i>	28 610
<i>Source type (data) 2011–2021</i>	12 520
<i>Document type (Article) and Type of Language (English)</i>	8286
<i>Records screening</i>	81
From Scopus database	
<i>Initial search</i>	2256
<i>Source type (data) 2011–2021</i>	1479
<i>Document type (Article) and Type of Language (English)</i>	1084
<i>Records screening</i>	94
Screening and eligibility	
<i>After removal duplicates</i>	201
<i>After removal systematic review</i>	196
<i>Records screened on titles and abstract for eligibility</i>	55
<i>Full text articles</i>	52

the process of screening of the titles and abstracts of the studies. As a result from searching the database we found 52 related publications. We selected randomly 26 papers out of them as listed in [Table 2](#).

The inclusion criteria were as following: (1) Focus of the research papers should be on the effects using of MTSDs (such as smartphones, tablet device, and mobile phone device) and associated musculoskeletal outcomes such as musculoskeletal symptoms and/or exposures; (2) the research papers must use English as reporting language.

We excluded articles that focus on the musculoskeletal problems due to the use of computer. There are no specific inclusion or exclusion criteria for demographics, study design, and sample size. The study used the following search keywords: smartphone, tablet, touchscreen, mobile phone, musculoskeletal disorder, musculoskeletal symptoms, muscle activity, posture, and pain.

3 | LITERATURE REVIEW ON MUSCULOSKELETAL DISORDERS ASSOCIATED WITH MOBILE TOUCH- SCREEN DEVICES

Johnson et al.⁵ identified factors possibly related to the application of portable information and communication technology (ICT) devices. Their goal was to decrease pain and MDSs in wrist, hands, fingers, thumb, and forearm regions due to ICT tasks. Research hypothesis was that some outcome measures of simpler electro-goniometric methods could be correlated with and might be applied as a surrogate measure in more complex electromyography (EMG) method. The study population was selected from a list of mobile phone gamers and/or text message (short message service, SMS) users; consisting of 1204 high school and university students with the age range 18 to 25 years. 15 healthy subjects (seven women and eight men) with no pain in hand, wrist, arm, and shoulders were selected. Two statistical analysis methods were used: cross-correlation between EMG and goniometry signals and group correlation between EMG and goniometry parameters.

Berolo et al.⁶ conducted a preliminary study and showed the relationship between the symptoms of MDSs and application of mobile device. The distributions of seven measures of mobile device application and musculoskeletal symptoms of the neck, upper neck, and upper extremity were determined. 98% of the participants reported that they used mobile device and most of them (84%) declared to have pain in at least one part of their body. A cross-sectional design used based on internet-based questionnaire to obtain data on the daily application of mobile

TABLE 2 Summary of the selected papers on the use of MTSD on musculoskeletal disorders

Author	Type of device examined	Study design and population	Statistical analysis (methodology)	Significant factors found
Berolo et al (2011) ⁶	Mobile phones	- Cross-Section study - 104 university student - 32 staff	- Descriptive statistics - Chi-square test - Multivariable logistic regression	- Time duration of tasks
Gustafsson et al (2011) ⁷	Mobile phones	- Observational study - 60 subject	- Multicollinearity - Multiple logistic regression - T-test	- Forearms support
Johnson et al (2011) ⁵	Mobile phones	- Experimental laboratory - 18 subject	- Normalized cross-correlation functions - The Pearson Product–Moment correlation coefficient	- Time duration of tasks
Young et al (2013) ⁸	Touch-screen tablet	- Experimental laboratory - 15 adult	- A repeated measures analysis of variance (RMANOVA) - A post hoc Tukey's HSD test	- Configuration - Postures
Shin & Kim (2014) ⁹	Smartphone	- Experimental laboratory - 15 subject	- Mean and Standard Deviation (SD) - One-way analysis of variance (ANOVA) - Post hoc analysis	- No significant differences were found
Kim & Kim (2015) ¹⁰	Smartphone	- Cross-section study - 292 university student	- Pearson's correlation Coefficient was calculated - Logistic regression analysis.	- Size of device liquid crystal display (LCD) screen
Inal et al (2015) ¹¹	Smartphone	- Case–control laboratory - 102 university student	- Kolmogorov–Smirnov test - Chi-square test - T-test - Mann–Whitney U-test - One-way analysis of variance (ANOVA)	- Pain during movement
Lee et al (2015) ¹²	Smartphone	- Experimental laboratory - 10 subjects	- One-way repeated-measures ANOVA - A non-parametric Wilcoxon test	- one hand
Yang et al (2016) ¹⁴	Smartphone	- Cross-section study - 315 a junior college student	- Descriptive statistics - Stepwise regression - logistic regression	- Time duration of functions
Xie et al (2016) ¹³	Smartphone	- Case–control laboratory - 40 university student	- T- test - Chi squared analysis - Mann–Whitney U-test - A mixed-model repeated measures analysis of variance (RMANOVA) - Post hoc simple	- Discomfort scores -
Gustafsson et al (2018) ¹⁵	Touchscreen smartphone & Keypad smartphone	- A laboratory study with a cross-over design - 19 university student	- linear regression models - Univariate regression analyses - Wilcoxon signed rank test	- Hand size
Namwongsa et al (2018) ¹⁶	Smartphone	- Cross-section study - 779 university student	- Descriptive statistics - Mean and Standard Deviation (SD) - Simple logistic regression - Multiple logistic regression	- Flexed neck postures and smoking
Intolo et al (2019) ¹⁷	Touch-screen tablet	- Cross-section study - 25 participants	- Kolmogorov–Smirnov test - One-way ANOVA - Bonferroni correction	- Table with a case set

TABLE 2 (Continued)

Author	Type of device examined	Study design and population	Statistical analysis (methodology)	Significant factors found
Namwongsa et al (2019) ¹⁸	Smartphone	- Quasi-experimental study 44 participants	- Mean \pm SD and median - Shapiro–Wilk test - T-test - Mann-Whitney test - ANCOVA - Friedman test - Wilcoxon signed-rank test	- Neck flexion angles
Al-Hadidi et al (2019) ¹⁹	Mobile phone	- Cross-section study - 500 university students	- Descriptive Statistics - Tukey Post-hoc analysis - One-way ANOVA - Independent sample t-test - Regression Analysis	- Age - Duration of use
Cochrane et al (2019) ²¹	Smartphone	- Cross-section observational study - 63 university student	- Descriptive statistical - The two-sample t-test - Pearson's correlation coefficients	- Time duration of use - The neck, shoulder, trunk and pelvis
Toh et al (2019) ²⁰	Smartphone & Tablet	- Cross-section study - 1884 school student	- Median and interquartile range - Chi squared analysis - Mann–Whitney U-test - Wilcoxon signed rank or Fisher's exact tests - Binary logistic regression - Ordered logistic regression	- Time spent of use - Smartphone
Baabdullah et al (2020) ²⁴	Smartphone	- Cross-section study - 387 university student	- Median and interquartile range - Finkelstein test - Kolmogorov–Smirnov test - Chi-square test - Mann–Whitney U-test	- Heavy time of use
Merbah et al (2020a) ²²	Smartphone	- Experimental laboratory - 12 subject	- Kruskal–Wallis ANOVA	- postural strategy
Merbah et al (2020b) ²³	Smartphone	- Experimental laboratory - 12 subject	- Analyses of variance (ANOVA) - Tukey post-hoc tests - A non-parametric Mann–Whitney test	- Support
Osailan (2021) ²⁶	Smartphone	- Observational study - 100 subject	- Kolmogorov–Smirnov test - Bivariate correlation - Partial correlation - Two stepwise linear regressions	- Time of use - Weight and BMI
D'Anna et al (2021) ²⁷	Smartphone	- Experimental laboratory - 17 subject	- Two-way ANOVA - Lilliefors test - Kruskal–Wallis test	- posture - Gender
Keklik & Akbaş (2021) ²⁸	Smartphone	- Research study - 251 participants	- Kolmogorov–Smirnov test - Spearman Rank - Chi-square test	- Physical activity levels
Mustafaoglu et al (2021) ²⁵	Smartphone	- Cross-section study - 249 university student	- Kolmogorov–Smirnov test - Pearson's correlation - Point biserial correlations - T-test - Logistic regression models	- Time of usage - How long the device was owned

(Continues)

TABLE 2 (Continued)

Author	Type of device examined	Study design and population	Statistical analysis (methodology)	Significant factors found
Thorburn et al (2021) ²⁹	Smartphone & Tablet	- A retrospective study - 207 university student	- Chi-square - Mann–Whitney U tests - T-test - Spearman's correlation	- Devises (smartphone & tablet)
Walankar et al (2021) ³⁰	Smartphone	- Cross-section study - 2000 university students	- Descriptive statistical - Chi-square - Logistic regression analysis	- Size of the smartphone

hand-held devices and pain symptoms. 140 (80 female and 60 male) students, staff, and faculty members of Canadian university participated in this study. Multivariate logistic regression was applied for exploring the relation between neck, upper back and upper extremity pain and seven dichotomous variables of mobile device exposure. The results indicated a significant association between any pain in the middle of right thumb and time spent gaming on typical days and between any pain in right thumb base and the time spent internet browsing on a typical day.

Gustafsson et al.⁷ investigated differences in techniques between young adult with and without musculoskeletal symptoms when employing mobile phones for texting as well as in muscle kinematics and activity between different techniques of `texting. In this study, the authors analyzed the most controlled conditions, where participants entered a standardized SMS message on one mobile phone type. 60 young adults with daily mobile phone use for texting and playing games participated in the research and answered questions about musculoskeletal health and ICT application. Among them, 15 reported no symptoms while 45 declared musculoskeletal symptoms in upper extremities and/or neck. The analysis used a statistical program based on multiple logistic regression with the variables that showed significant relationships. Then, t-test was used to compare forearm support versus no forearm support, neck flexion $\geq 40^\circ$ versus neck flexion $< 40^\circ$, and back support versus no back support. The authors concluded that texting technique differences between asymptomatic and symptomatic participants could not be explained by the presence of symptoms but this could possibly contribute to their symptoms.

Young et al.⁸ conducted a study of 15 adults who have been using touch screen tablet device to use postures of the right and left shoulders and wrists regions and their related muscle activity. Surface electromyography, and electro-goniometry were used to measure the muscle activity, wrist postures, and shoulder postures respectively. To examine the preposition of postures and muscle, they used repeated measures analysis of variance (RMANOVA)

as activities differ among tablets, strong and weak hands, and user setting, The study found that postures and muscle activity of shoulders and wrists were highly different among configurations and across hands.

Shin & Kim⁹ measured intensity of neck pain and cervical flexion-relaxation ratio (FRR) and identified differences based on the postures adopted when working with smartphones. 15 healthy adults participated in this study. In the statistical analysis, FRR was compared through a one-factor repeated analyses of variance (ANOVA). Bonferroni correction was used to perform post hoc analysis. They found no significant FRR difference among baseline, lap posture, and desk posture although neck pain intensity was enhanced in lap posture. They claimed that it was not possible to distinguish neck pain due to performing short time tasks. Neck pain can be caused by lap posture; therefore, one should avoid working with smartphones for long time in this posture.

Kim & Kim¹⁰ studied smartphone application by university students in certain areas, their musculoskeletal symptoms, and associated hazard ratios. The authors distributed questionnaires and collected 292 completed copies of them to analyze. Pearson's correlation coefficient was obtained for the identification of relationships between subjective musculoskeletal symptoms and smartphone-related features. It was found that the most painful regions in the body after using smartphones were neck and shoulders.

Inal et al.¹¹ showed the effect of addiction to smartphone on the clinical and functional status of hands. Participants of this study were 102 students (non-users of smartphone as well as low and high smartphone users). Chi-square tests were performed for the comparison of categorical variables. The two groups were compared through student t-test and Mann–Whitney U-test for parametric and non-parametric data. One way ANOVA was applied for the comparison of parametric data. The authors used Levene test to determine the homogeneity of the variance. Tukey post hoc test evaluated homogeneity, while Tamhane T2 multiple comparison was applied

when homogeneity was not found. The results showed that median nerve cross-sectional areas were much higher in high smartphone users than non-users. They found that excessive use of smartphones cause pain in thumb, decreases pinch strength and hand function and enlarges the median nerve.

Lee et al.¹² compared the impact of smartphone using with right hand and right and left hand at same time to know whether muscle pain and activities a impacting the upper limb. The task of ten females was typing the Korean national anthem for 180 s, the age of participants was 20–22 years old. To analyze the difference between the pressure-induced pain thresholds and the numbers that are above right handed and both handed, one-way ANOVA was used. Non-parametric Wilcoxon method was applied to compare the muscle activities. Results show significance of the muscle activity on the upper trapezius pain in one-handed smartphone device use than in its two-handed use, and an induced enhanced the upper extremity muscle activity by working with right hand.

Xie et al.¹³ studied muscle activity distribution in upper limb and neck while texting on touchscreen smartphones. Forty healthy adults from local universities participated in this study. The authors used t-test on demographic features and the pattern of electronic devices. Chi-square was applied for the determination of differences among occupation proportions, phone input methods, and phone operation systems in each category. Mann–Whitney U-test was applied for the determination of group differences in using smartphone. RMANOVA was applied for the evaluation of group effect between subject factor and task within the subject factor. The results of this research revealed that discomfort scores in the case group were significantly higher than those of control group for texting with one and two hands on smartphones and two handed typing on desktop computers.

Yang et al.¹⁴ used a case study of Taiwan junior college to determine the difference between working with the smartphone and musculoskeletal discomfort among the students. The study employed logit and stepwise regression technique to analyze the factors that affect MSDs. The findings of the study shows that the duration of smartphone ancillary function use is related with upper back discomfort among students.

Gustafsson et al.¹⁵ compared thumb kinematics and the activity of upper limb muscle as well as hand size effect when texting with touchscreen and keypad smartphones. Univariate regression analysis on repeated data regarding smartphone type (touchscreen or keypad) as an independent variable was performed for the comparison of upper limb muscle activity and kinematics between smartphones. Wilcoxon signed rank test was applied for the comparison of differences between touchscreen and

keypad phones. The authors found that differences in thumb flexion were merely in participants with longer hands. The authors suggested that there were differences in musculoskeletal disorder development risk during smartphone application with different hand sizes and key activation mechanisms.

Namwongsa et al.¹⁶ investigated MDSs in smartphone users in Thailand to confirm high neck pain prevalence. The authors determined all factors possibly related to neck disorder among smartphone users. 779 university students were participated in this study. Simple logistic regression analysis was applied to introduce each independent variable into a multiple logistic regression model for the identification of related factors. It was found that the angle of head flexion was much higher while texting compared to that in other tasks and also much significantly larger when sitting than standing. The highest musculoskeletal disorder prevalence was witnessed in upper back, shoulder, neck, hand, and wrist. MDSs foot, ankle, knee, thigh, hip, lower back, and elbow were less prevalent.

Intolo et al.¹⁷ investigates the pain and muscle activity of a sample of 25 participants of age between 10 to 12 years on the neck, and upper extremities while using touch screen tablet at least 2 h a week. Twenty-five right handed dominant were recruited. In testing for normality distribution Kolmogorov–Smirnov test was used. Additionally, uni-way ANOVA and Bonferroni test correction were used to compare the levels of pain and muscle activity between workstations. Muscle activity was measured by Electromyography (EMG). The authors concluded the pain of the neck region was the least level when using the touch screen device which has a case set on a table.

Namwongsa et al.¹⁸ investigate the impact of neck flexion angles on neck muscle activities for a sample of 44 users of smartphone device age 18–25 years. The study employed Shapiro–Wilk test and t-test technique to check for normality distribution. Normally distributed data were analysed using the independent t-test. The unsymmetrical distributed data were analyzed using Mann–Whitney test, ANCOVA method, Wilcoxon signed-rank technique, and Friedman method.

The findings shows that there is a variation between muscle activities at the neck region for all flexion angles. Additionally, there is higher muscle activity for the users of smartphone with neck pains than the ones without neck pains.

A cross-sectional study was conducted by Al-Hadidi et al.¹⁹ on 500 university student from healthcare facilities (166 male and 334 female) to analyze the relationship between neck pain and the time spend using the device. This study used a regression analysis to predict factors affecting pain severity and factors affecting pain duration. The results found that age and duration of using smartphone

were highly related with the region of the neck that has pain. Additionally, only the time spent using the device is related the level of pain.

Toh et al.²⁰ described contemporary technology application, especially tablets and smartphones, and evaluated the relation between visual health and musculoskeletal symptoms among adolescents in Singapore. Thirteen school teenage students were recruited to participate. The distribution of data was not normal. Binary logistic regression was applied for the evaluation of relation between musculoskeletal symptoms and MTSDs application. Visual symptoms and musculoskeletal discomfort was commonly reported. After tuning for potential confounders, more hours/day of smartphone application increased discomfort risk in wrist/hand, arms, upper back, and neck/shoulders as well as visual symptoms, but reduced myopia.

Cochrane et al.²¹ compared the amplitudes of EMG in neck extensor muscles while performing two-handed texting and one-handed browsing while walking, standing, and sitting. 20 young users participated from university community. Posture and task effects on average kinematic and NEMG variables were explored using two way repeated measures analysis of variance (ANOVA). Pair comparison was performed using Tukey's post hoc test. The average level of muscle activation while working with phone when walking was higher than when standing and sitting when texting compared with when browsing. Non-significant difference in the flexion angle of upper back between the two tasks caused much larger neck flexion while texting.

Merbah et al.²² applied objective 3D motion analysis to examine the strategies possibly adopted by subjects while using their smartphones without particular instructions or restrictions on proceeding method under different environmental conditions. 12 healthy persons (five female and seven males) were involved in the study. Task and posture sequence was randomly generated for each of the subjects to prevent learning effect. Each condition was repeated three times. Hierarchical cluster analysis (HCA) was employed to trunk and neck angular parameters as well as telephone-face distance. Various clusters were compared by performing Kruskal–Wallis ANOVA by ranks. For each cluster, Rapid Upper Limb Assessment (RULA) table was applied for the evaluation of the ergonomics of the postures of subjects under different experimental conditions. Consequently, three different postural strategies were revealed to be adopted by subjects. The first posture involved neck without involving trunk; the second one strongly mobilized trunk flexion without involving neck; and the third postural strategy combined the above two postures.

Merbah et al.²³ evaluated the influences of the absence and presence of a support on the biomechanical characteristics of postures selected by subjects and qualified the incidence of above postures on MSD development risk in each of the two conditions explored during web browsing in seated position with a smartphone. 12 subjects performed web browsing under the above two environmental positions. ANOVA and Tukey post hoc test were conducted to examine the influence of position on postures. Non-parametric Mann–Whitney tests were also performed for the evaluation of gender effect. The results of the study were concerning the angular parameters, between the two experimental conditions, great differences were witnessed in all joints but not necessarily in all planes. While sitting in front of a table, shoulder and trunk are supported and neck is less stressed which impose less constrains for joints. Biomechanical analyses on joint angles showed great differences in some joints. Also, lack of support caused higher ulnar deviation of wrist and elbow flexion far from neutral position, resulting in high potential MSD risk in long term.

Baabdullah et al.²⁴ evaluated the relation between wrist and thumb pain and addiction to smartphone and determine pain severity. 387 undergraduate medical students participated in the study. Finkelstein test was performed on participants who reported wrist and thumb pain. Chi-square test was applied for the determination of relations among categorical variables. Mann–Whitney U-test was employed for the comparison of non-parametric data among the groups. The authors found that 257 participants were assigned as smartphone addicts and had positive Finkelstein test results. This study showed high smartphone addiction prevalence among university students and a correlation was found between hand pain and excessive application of smartphones indicating that excessive application of such devices could create subclinical effects on human hand.

Mustafaoglu et al.²⁵ investigated the level of smartphone addiction and its effect on the prevalence of musculoskeletal pain among university students. 249 university students participated in this research. Pearson's correlation test was conducted to evaluate bivariate correlations between two continuous variables and point bi serial correlations were applied to evaluate the correlation between one continuous and one dichotomous. An independent sample t-test was applied. Logistic regression models were developed for the prediction of discomfort in body parts. The obtained results revealed that the highest musculoskeletal pain prevalence occurred in wrists/hands, neck, and upper back. SAS scores were related to the duration of owning a smartphone ($P = .027$), smartphone use duration on any typical day, and musculoskeletal pain prevalence in upper back, shoulders, wrists/hands, and neck.

SAS scores were closely related to the prevalence of musculoskeletal pain in upper back, wrists/hands, and neck.

Osailan²⁶ studied the relation between smartphone application and pinch-grip and hand-grip strength among youngsters and explored factors affecting pinch-grip and hand-grip strength. 100 young males participated in the study. Variable normality was evaluated by Kolmogorov–Smirnov test. Bivariate correlation was evaluated by Pearson product-moment correlation analyses and the results were applied for evaluating the association of pinch-grip and hand-grip strength and smartphone usage. Two stepwise linear regression analyses were performed for the determination of factors related to pinch-grip and hand-grip strength. The author found that the duration of smartphone application and hand-grip pinch-grip and strength were strongly and inversely related. A strong correlation was found between BMI and weight with hand-grip strength.

D'Anna et al.²⁷ investigated the upper complex kinematics when performing prolonged texting on smartphone devices in both sitting and standing postures and quantified its association with the parameters of EMG surface of upper trapezius (UT) muscle activity and with self-reported measures of perceived discomfort. Lilliefors test was applied to verify data distribution normality. Kruskal–Wallis test was used in case normality was rejected at a certain level of significance; otherwise a two-way ANOVA was conducted. Pearson's coefficient of possible linear correlation between kinematics angles was checked. The obtained results showed the same postural strategies in both conditions which was assumed to be under the control of visual system to retain a constant viewing distance from the device, participants preferred “stiffer” neck and head postures during standing than when sitting, with direct correlation with upper trapezius muscle activity, perceived discomfort, and neck angle.

Keklik & Akbaş²⁸ studied the relationship between physical activity level, smartphone overuse, low back, and the neck health in participants aged 18–65 during Covid-19 pandemic. 251 (179 female and 72 male) were sampled in the study. A Questionnaire-Short Form was applied for examining the physical activity levels. Oswestry Disability Index (ODI) and the Neck Bournemouth Questionnaire was applied for the evaluation of back and neck pain. The questionnaire of Smartphone Addiction Scale (SAS-SV) was applied to evaluate of smartphone usage. 53% of participants had low physical activity and 14% had sufficient physical activity. Kolmogorov–Smirnov test was applied to examine the stand of the data. Spearman Rank Correlation Coefficient was applied to determine the relationship among physical activity levels, smartphone use, and low back and neck health. The data obtained by counting was

evaluated with Chi-square test. A weak correlation was observed between neck pain and features of smartphone use while the relationship between physical activity and low back and neck health could not be demonstrated.

Thorburn et al.²⁹ studied the patterns and prevalence of musculoskeletal symptoms among tablet and smartphone users, and compared the users of these devices with regard to the variables. In an online survey in eastern states of Australia, 207 participants retrospectively reported device usage and symptoms in the preceding two weeks. Chi-square analysis was performed to reveal relationships among categorical variables; Mann–Whitney U-test for the comparison of two groups with ordinal dependent variables; independent samples t-test if dependent variables were continuous and approximated a normal distribution; and Spearman's correlation analysis to assess the relationships between pairs of continuous or ordinal variables. The authors found no statistically significant difference between smartphone-only and tablet device users reporting symptoms during using their devices.

Walankar et al.³⁰ applied a cross-sectional study to examine the risk determinants that are correlated to MSD and assess the prevalence of musculoskeletal pain among university students of smartphone users. In their analysis, they used descriptive statistics and Chi-square method to reveal the relationship among prevalence of musculoskeletal pain and demographic and smartphone usage characteristics. In addition, the logistic regression was applied to check the risk determinants. It was found that the neck, thumb, lower back, and elbow are the regions with high level of pain. The outcome of the Logistic regression revealed that the size of the smartphone was a significant factor of musculoskeletal pain.

4 | CRITICISM AND DISCUSSION

To perform a scientific research most efficiently, we should use a scientific method for planning the experiments. Statistical design of experiment means the process of planning experiments to collect appropriate data capable of being analyzed by statistical methods to give objective and valid conclusions. A statistical method is necessary for experimental design to draw meaningful conclusions from the obtained data. Any experimental research problem should have the following two phases: (1) experiment design and (2) statistical analysis of data. Analysis method directly depends on the employed experimental design.³¹

As we have been observed, most of the scientific research works published in 2011–2021 years in the field of MSDs related with the usage of MTSDs as shown in Table (2), failed to satisfy the requirements of a reliable scientific research; hence, their conclusions were doubtful.

4.1 | As related with the design of experiment

All of the papers in Table 2 did not show/make an experimental design for the research. Additionally, none of them selected a correct target population for their experimental research. The subjects should only include people with musculoskeletal disorder symptoms identified by a specialized physician such as orthopedic. In this way, it can be found whether the use of MTSDs could cause any MDSs or something else.

Among the weaknesses we observed was that, the selection of factors was not performed properly. Physicians orthopedic had to participate in determining factors to be included in such research. We observed that authors considered specific questionnaires contenting unrealistic factors (e.g. smoking, alcohol, etc.) as potential cause of MDSs.

In all of the reviewed articles, the randomization of data collection was not reported or planned. This means that both, the order in which the individual runs or trials of the experiment and the experimental material allocations, were not scheduled randomly. By proper randomization of experiments, we averaged out the influences of possible extraneous factors. Statistical methods need observations (or errors) to be independently distributed random variables. Randomization generally validates this assumption.

4.2 | As related with the statistical method

Subjectively comparing questionnaire answer frequency is not a correct approach for decision-making. Statistical approaches have to be applied for data analysis to obtain objective, rather than judgmental, results and conclusions.

In analyzing the data collected from any experimental research, actually, we formulate and test the hypotheses (H_0 and H_1). Therefore, two kinds of errors could occur:

$$\text{Type I Error: } \alpha = P(\text{Type I Error}) = P(\text{Reject } H_0 | H_0: \text{True})$$

$$\text{Type II Error: } \beta = P(\text{Type II Error}) = P(\text{Fail to Reject } H_0 | H_0: \text{False})$$

As we observed, most researches in this field used some statistical methods randomly without validating the assumptions necessary for such methods and without showing corresponding null hypotheses (i.e. H_0 's). Very frequently, researches use two samples *t*-test without showing their null hypotheses. *T*-test is suitable only when you compare two different samples (i.e., treatments). Otherwise, when you have more than two treatments of

a factor, then ANOVA should be applied in order not to increase Type I error. However, ANOVA analysis has two important assumptions that should be validated: (1) observations are adequately described by ANOVA model and, (2) errors are independently and normally distributed with mean zero and constant but unknown variance σ^2 .³¹ When these assumptions are not valid, we should select different statistical method (e.g., non-parametric methods) to test null hypotheses.

Additionally, most selected researches, in Table 2 did not scientifically determine sample size. They had to estimate required sample size and decide if more replications are needed, they had to collect more observations and repeat the analysis.

Finally, a multiple comparison test (such as LSD, Tukey test, etc.) had to be conducted to determine which treatment of each significant factor contribute more to the symptoms of MDSs. In this way, decisions could be made regarding which factors significantly affect each musculoskeletal disorder symptom.

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AUTHOR CONTRIBUTIONS

Design of the study: A.M.; Database searches: A. LEG. and T. B.; Writing—original draft: A.M., A. ELG., and T. B.; Writing—review and editing: A.M., A. ELG., and T. B.; Supervised this study: A. M. All authors read and approved this article.

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REFERENCES

1. Alsalamah AM, Harisi MJ, Alduayji MA, et al. Evaluating the relationship between smartphone addiction/overuse and musculoskeletal pain among medical students at Qassim University. *J Family Med Prim Care*. 2019;8(9):2953.
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(8):e0181220.
3. Weiner DK, Ernst E. Complementary and alternative approaches to the treatment of persistent musculoskeletal pain. *Clin J Pain*. 2004;20(4):244-255.

4. World Health Organization. The burden of musculoskeletal conditions at the start of the new millennium: report of a WHO Scientific Group. World Health Organization. 2003.
5. Jonsson P, Johnson PW, Hagberg M, Forsman M. Thumb joint movement and muscular activity during mobile phone texting - A methodological study. *J Electromyogr Kinesiol*. 2011;21(2):363-370.
6. 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(2):371-378.
7. Gustafsson E, Johnson PW, Lindegård A, et al. Technique, muscle activity and kinematic differences in young adults texting on mobile phones. *Ergonomics*. 2011;54(5):477-487.
8. 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(1):59-71.
9. Shin H, Kim KM. Effects of cervical flexion on the flexion-relaxation ratio during smartphone use. *J Phys Therapy Sci*. 2014;26(12):1899-1901.
10. Kim H-J, Kim J-S. The relationship between smartphone use and subjective musculoskeletal symptoms and university students. *J Phys Therapy Sci*. 2015;27(3):575-579.
11. İnal EE, Demirci K, Çetintürk A, et al. Effects of smartphone overuse on hand function, pinch strength, and the median nerve. *Muscle Nerve*. 2015;52(2):183-188.
12. Lee M, Hong Y, Lee S, et al. The effects of smartphone use on upper extremity muscle activity and pain threshold. *J Phys Therapy Sci*. 2015;27(6):1743-1745.
13. Xie Y, Szeto GPY, Dai J, et al. A comparison of muscle activity in using touchscreen smartphone among young people with and without chronic neck-shoulder pain. *Ergonomics*. 2016;59(1):61-72.
14. Yang S-Y, Chen M-D, Huang Y-C, et al. Association between smartphone use and musculoskeletal discomfort in adolescent students. *J Community Health*. 2017;42(3):423-430.
15. Gustafsson E, Coenen P, Campbell A, et al. Texting with touchscreen and keypad phones - A comparison of thumb kinematics, upper limb muscle activity, exertion, discomfort, and performance. *Appl Ergon*. 2018;70:232-239.
16. Namwongsa S, Puntumetakul R, Neubert MS, et al. Factors associated with neck disorders among university student smartphone users. *Work*. 2018;61(3):367-378.
17. Intolo P, Prasongsansuk N, Srilabutr P, et al. Pain and muscle activity of neck, shoulder, upper back, and forearm during touch screen tablet use by children. *Work*. 2019;64(1):85-91.
18. Namwongsa S, Puntumetakul R, Neubert MS, et al. Effect of neck flexion angles on neck muscle activity among smartphone users with and without neck pain. *Ergonomics*. 2019;62(12):1524-1533.
19. Al-Hadidi F, Bsisu I, AlRyalat SA, et al. Association between mobile phone use and neck pain in university students: a cross-sectional study using numeric rating scale for evaluation of neck pain. *PLoS One*. 2019;14(5):e0217231.
20. Toh SH, Coenen P, Howie EK, et al. Mobile touch screen device use and associations with musculoskeletal symptoms and visual health in a nationally representative sample of Singaporean adolescents. *Ergonomics*. 2019;62(6):778-793.
21. Cochrane ME, Tshabalala MD, Hlatswayo NC, et al. The short-term effect of smartphone usage on the upper-back postures of university students. *Cogent Eng*. 2019;6(1):1627752.
22. Merbah J, Gorce P, Jacquier-Bret J. Interaction with a smartphone under different task and environmental conditions: emergence of users' postural strategies. *Int J Ind Ergon*. 2020;77:102956.
23. Merbah J, Jacquier-Bret J, Gorce P. Effect of the presence or absence of upper limb support on posture when a smartphone user is in a seated position under ambient light conditions. *Int J Ind Ergon*. 2020;80.
24. Baabdullah A, Bokhary D, Kabli Y, et al. The association between smartphone addiction and thumb/wrist pain: a cross-sectional study. *Medicine (Baltimore)*. 2020;99(10):e19124.
25. Mustafaoglu R, Yasaci Z, Zirek E, et al. The relationship between smartphone addiction and musculoskeletal pain prevalence among young population: a cross-sectional study. *Korean J Pain*. 2021;34(1):72-81.
26. Osailan A. The relationship between smartphone usage duration (using smartphone's ability to monitor screen time) with hand-grip and pinch-grip strength among young people: an observational study. *BMC Musculoskelet Disord*. 2021;22(1):186.
27. D'Anna C, Schmid M, Conforto S. Linking head and neck posture with muscular activity and perceived discomfort during prolonged smartphone texting. *Int J Ind Ergon*. 2021;83:103134.
28. Suner-Keklik S, Akbaş AN. Effects of Covid-19 pandemic in Turkey: physical activity, smartphone usage, musculoskeletal system. *J Exp Clin Med*. 2021;38(4):550-556.
29. Thorburn E, Pope R, Wang S. Musculoskeletal symptoms among adult smartphone and tablet device users: a retrospective study. *Arch Physiother*. 2021;11(1):1.
30. Walankar PP, Kemkar M, Govekar A, et al. Musculoskeletal pain and risk factors associated with smartphone use in university students. *Indian J Occ Env Med*. 2021;25(4):220.
31. Montgomery DCJI. *New York, Design and analysis of experiments*. John Wiley & Sons. 2001;1997:200-201.

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