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The correlation between smartphone use and musculoskeletal symptom

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Abstract

Several issues arise from using smartphones while sitting and lying down, such as poor posture and physical discomfort. Therefore, this research aims to assess the ergonomic risk level of smartphone users and determine the correlation between self-reported musculoskeletal disorders (MSDs) and ergonomic risk level. Data were collected from 90 participants, aged 18 to 24, through video recording while seated and using a smartphone. MSDs were measured using the Modified Standardised Nordic Questionnaires (SNQ) and the Numerical Rating Scale (NRS). Rapid Upper Limb Assessment (RULA) was used to evaluate ergonomic risks in the posture of smartphone users. Furthermore, the correlation between MSDs and the ergonomic risk levels was evaluated using Chi-Square and Fisher's exact tests. Most smartphone users had RULA scores between 6 and 7 for both the left and right sides, suggesting a need for immediate investigation and improvement. The results showed a strong correlation between the right sided RULA total score and MSDs in the neck and upper back. Other results showed there was a significant correlation between RULA B and RULA D scores with neck MSDs, as well as between the RULA score of the right upper arm and MSDs in the right shoulder, and between the RULA score of the neck and MSDs in the neck. The trunk RULA score also had a significant correlation with upper back MSDs. The research showed that smartphone users face significant ergonomic risks.

Keywords: *ergonomic risk; musculoskeletal disorders (MSDs); Numerical Rating Scale (NRS); Rapid Upper Limb Assessment (RULA); Smartphone; Standardised Nordic Questionnaires (SNQ).*

1. Introduction

The use of smartphones is increasing in this digital era, with 6.37 billion users reported globally by the end of 2021 (Ericsson Mobility Report, 2021). According to Turner (2018), Indonesia ranks fourth among the top twenty smartphone markets worldwide, with approximately 160.23 million users. These users base consist of employees, high school students, undergraduates, and the elderly (Awan et al., 2021). Among these users, students in their twenties use these electronic devices more frequently than those of other age groups. Smartphones are highly advanced gadgets that provide a wealth of information and communication at one's fingertips, compared to traditional mobile phones. However, compared to computers, smartphones feature a more robust operating system that enables increased computational capability and access to a vast array of software applications (Han, & Shin, 2019). These gadgets offer numerous advantages, such as the ability to send and receive emails and access the internet, which aid and facilitate everyday tasks. This has led to a dramatic increase in smartphone usage over the years (Alsiwed et al., 2021).

Musculoskeletal Disorders (MSDs) are among the most prevalent occupational diseases in many countries and The incidence of MSDs is on the rise (Samaei, Tirgar, Khanjani, Mostafaee, & Bagheri Hosseinabadi, 2017). Furthermore, the increasing use of smartphones has been found to contribute to MSDs. According to epidemiological research in the Republic of Korea involving 938 smartphone users, 18.8% (n = 185) reported symptoms of MSDs in at least one body part (Eom, Choi, & Park, 2013), particularly in the neck, upper back, and limbs. Another Korean study of 292 smartphone users found that the neck (55.8%) and shoulders (54.8%) were the most frequently reported sources of discomfort from smartphone use (Kim, & Kim, 2015). Furthermore, in Hong Kong, the prevalence of MSDs among smartphone users was found to be higher than that reported in the study by Eom et al., (2013) in Korea, which is consistent with the results of several other studies in Asia that used similar survey methods. Similarly, Namwongsa, Puntumetakul, Neubert, and Boucaut (2018) found that neck discomfort was the most prevalent type of MSD among smartphone users in Thailand. In cross-sectional studies, neck and shoulder disorders have been found to have the highest incidence rates, ranging from 26.3% to 60%, among users of mobile touch screen devices (Toh, Coenen, Howie, & Straker, 2017). To date, MSDs among Indonesian smartphone users, particularly students in their twenties, have not been studied, highlighting the need for further research in this area.

Previous research has showed that physical risk factors, such as awkward posture, are strongly correlated to neck MSDs in employees (Lallukka et al., 2017; Charles, Ma, Burchfiel, & Dong, 2017; Alhusuny, Cook, Khalil, Xie, & Johnston, 2020; van der Molen et al., 2017; Merkus et al., 2021; Roggio et al., 2021). Long-term smartphone usage may result in various MSDs (Shinde, Aa, & Bhore, 2022; Jain, Rana, Meena, & Verma, 2022; Jain, Rana, & Meena, 2021). In particular, the use of smartphones is usually associated with uncomfortable postures. An earlier investigation carried out in Thailand by Namwongsa et al., (2018) reported that majority of the smartphone users experience MSDs on their upper bodies due to neck flexion (82.74%), shoulder extension (56.61%), elbow flexion (65.16%), wrist and hand flexion (22.40%), including supination of the wrists and hands in respect to holding the device (21.64%). Furthermore, it was found that 67.50% and 43.23% of smartphone users experience upper and lower back flexion postures, respectively. This uncomfortable position may cause physical pain because it affects soft tissues by straining ligaments or muscles, irritating tendons, and compressing nerves.

The primary hypothesis proposed by this research is that there is a correlation between MSDs and the ergonomic risk levels associated with smartphone usage. Furthermore, the correlation between the ergonomic risk levels and MSDs suffered by smartphone users in Indonesia has never been evaluated in previous research. The present research used the Rapid Upper Limb Assessment (RULA) instrument to figure out the ergonomic risk level encountered by smartphone users. Additionally, the study will examine the correlation between the posture of the upper limbs during smartphone usage and the incidence of upper extremity MSDs, as previously reported by Namwongsa et al., (2018). The findings of this research will serve as recommendations for the safe usage of smartphones and aim to reduce the incidence of MSDs by applying engineering, administrative, and behavioral ergonomic concepts that are adaptable in terms of providing support, improving ability, and preventing MSDs (Kristanto, Neubert, Puntumetakul, & Sessomboon, 2019).

2. Objectives

This research aimed to investigate the relationship between Musculoskeletal Disorders (MSDs) and ergonomic risk levels. The ergonomic risk level was determined using the RULA score, and its correlation with MSDs was assessed through the modified Standard Nordic Musculoskeletal Questionnaire (SNQ) and Numeric Rating Scale (NRS) questionnaire.

3. Materials and methods

3.1 Research design

The cross-sectional approach was used by respondents to independently complete the distributed questionnaires to obtain data on smartphone usage and musculoskeletal diseases of the neck, upper and lower backs, shoulders, elbows, wrists, hips, knees, as well as ankles on both the left and right sides. The research used Dennerlein's (2015) model of mobile computing technology as its conceptual framework.

3.2 Sample size

The Slovin formula was used to determine the sample size (Yang, Lin, & Hu, 2020), with an estimated deviation (e) of 0.1 (Kaur, 2021). The calculated number of samples using the Slovin formula amounted to 90 respondents. The total sample of 90 respondents is in line with previous research where the sample size ranged from 58 to 100 respondents (Prairie, Plamondon, Hegg-Deloye, Larouche, & Corbeil, 2016; Habibillah, & Romli, 2022).

3.3 Participants

The respondents are undergraduates of the Universitas Ahmad Dahlan, and were selected through purposive sampling based on advertisements on print and social media. The selected respondents meet the following criteria: 1) in their 20s, 2) possess an Android smartphone, 3) have at least six months of smartphone experience, and 4) use their smartphone for at least two hours daily.

The respondents were eliminated from the investigation assuming they had encountered any of the following: 1) traumatic injury histories or surgical treatments to related body parts in the preceding year, for instance, whiplash injuries, 2) various medical disorders, such as abnormalities, that may have a detrimental influence on the spinal column and upper limbs, 3) chronic musculoskeletal illnesses, for example, rheumatoid arthritis, osteoarthritis, and other connective tissue disorders such as fibromyalgia, 4) neurological, orthopedic, and sensory problems, and 5) visual impairment.

All eligible participants were invited to partake in the investigation, and each was asked to fill out a permission form before the trial. This research has gotten ethical approval (Ethical permission) number 012207099 from the Universitas Ahmad Dahlan Research Ethics Committee.

3.4 Experimental procedure

The research or experimental procedure is divided into five parts. First, each participant was asked to complete an MSDs questionnaire using a smartphone. The questionnaire is divided into four segments, namely (1) respondent demographic characteristics data, (2) smartphone usage statistics, (3) the SNQ, and (4) a modified Indonesian version of the NRS questionnaire. Second, each respondent was instructed to operate their smartphones simultaneously while the footage was being recorded. Third, the relevant team reviewed each participant's video clip and agreed on which segment demonstrated the most ideal posture for analysis. Fourth, the team further evaluated the posture analysis independently and computed the overall score for each body part, resulting in one RULA assessment for the right and left sides. Fifth, statistical analysis was applied to examine the correlation between MSDs and ergonomic risks among smartphone users.

3.5 Description of the activity

The participants were instructed to use their smartphones to send a message back to the relevant team using a well-known messaging application in Indonesia, namely WhatsApp Messenger. Regarding this scenario, they sat in a standard lecture chair for 10 minutes (Chen, Chen, Cheng, & Chang, 2022; D'Anna, Schmid, & Conforto, 2021; Eitivipart, Viriyarojanakul, & Redhead, 2018; Alfaitouri, & Altaboli, 2019; Yoopat, Kladkunsaeng, Chotisutra, & Vanwonterghem, 2019). The participants were instructed to enter the text as quickly as possible without making any errors while sending messages, utilizing the "word complete" feature automatically during the texting process or using stickers or emoticons other than words. Before the data collection procedure, the respondents were permitted to spend three minutes in the laboratory to get acquainted with smartphones and texting (Xie, Szeto, Madeleine, & Tsang, 2018). Three cameras captured the participants' activities from the front view (anterior perspective), including the right and left (lateral perspectives). The cameras were situated at a distance to provide a good picture of the individuals using a smartphone. However, the camera setup point and seat position for smartphone respondents were parallel throughout the video recording.

3.6 Response measures

3.6.1 Ergonomic risk level

The three-member team examined each participant's video together, altering its speed to slow down the pace of movement to perform a more exact and precise analysis. The most persistent pose of smartphone users while composing messages was discovered within 10 minutes. A three-member research team separately assessed the extent of ergonomic risk. The ergonomic risk level was determined using RULA's total score category: "a score of one or two suggests that the posture is acceptable provided it is not practiced or repeated over an extended period." A score of three or four suggests that further research and modifications are required. Meanwhile, a score of five or six indicates that quick action is needed, while seven implies immediate action (McAtamney, & Corlett, 1993).

3.6.2 MSDs

Questionnaires are utilized to obtain data on the pain experienced at each lower extremity joint. The NRS pain measuring device has a scale of zero to 10, depicting painlessness and excruciating pain, respectively (Hawker, Mian, Kendzerska, & French, 2011). The pain categorization adopted in this research included none (score 0), mild (score 1 to 3), moderate (score 4 to 6), and severe pains (score 7 to 10). A map of body parts based on the SNQ was also presented (Kuorinka et al., 1987).

3.7 Statistical analyses

Descriptive statistics were employed to examine the respondents' characteristics and MSD-related factors. The mean and standard deviation were used to examine continuous variables such as age, weight, height, smartphone usage duration, and average smartphone use per event, day, or week (SD). Gender, BMI, hand dominance, MSD, and ergonomic risk levels are categorical variables that are provided with respect to percentage and frequency. The Chi-Square and Fisher's exact analyses were applied to examine the correlation between MSDs and ergonomic risk encountered by smartphone users. p-values less than 0.05 are deemed statistically significant. The SPSS software version 26 was used to examine the data (IBM SPSS, USA).

4. Results and discussion

4.1 Participants

The present research investigated 90 male and female students who had used smartphones for at least one year. Table 1 shows the respondents' demographic characteristics and descriptive statistics. There were 55 males (61%) and 35 women (39%) within the age range of 19 to 24 years (an average of 21.19±0.92). The most prevalent responses (62 respondents; 68.89%) had a normal BMI, while all respondents (100%) performed tasks using their right hands. The respondents reportedly used smartphones for 10.80±1.82 years, weekly 97.92±15.52 hours, and daily usage of 13.99±2.22 hours.

4.2 MSDs of the smartphone users

Figure 1 shows the data on the distribution of pain felt by the respondents based on the findings of the modified SNQ and NRS questionnaires. The neck (46.67%), right shoulder (24.22%), upper back (16.67%), left (11.11%), and right wrists (8.89%) suffered severe pains, according to the findings of the modified SNQ and NRS questionnaires. Meanwhile, moderate pain was found in the following areas: right wrist (70.00%), upper back (63.33%), left and right shoulders (58.89%), right elbow (57.78%), neck (53.33%), lower back (50.00%), right (47.78%), and left hips (45.56%), left wrist (35.56%), left elbow and right knee (27.78%), right (16.67%), and left ankle (13.33%).

Table 1 The respondents' demographic characteristics and descriptive statistics (n=90).

Characteristics	N (%)	*Mean*±SD
Sex		
Male	55 (61%)	
Female	35 (39%)	
Age (years)		21.19 ± 0.92
Height (cm)		163.92 ± 9.78
Weight (Kg)		60.44 ± 13.37
BMI (Kg/m^2)		22.43 ± 3.41
Smartphone use duration (hours/week)		97.92 ± 15.52
Smartphone use duration (hours/day)		13.99 ± 2.22
Time length of smartphone use (years)		10.80 ± 1.82

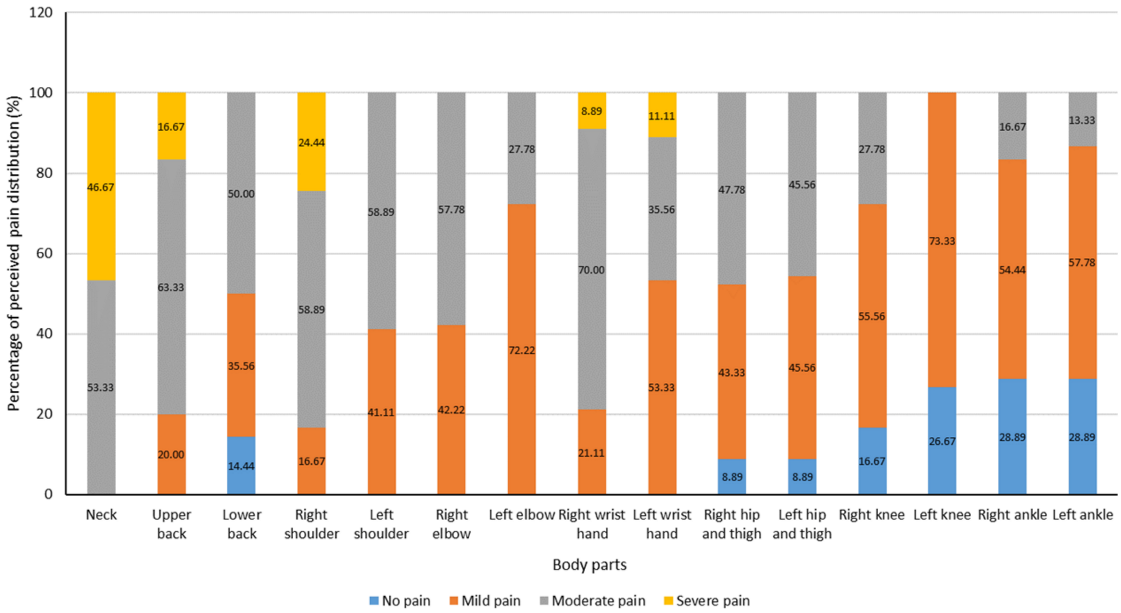

Figure 1 Percentage of perceived pain distribution

4.3 Ergonomic risk using RULA

Figure 2 shows the RULA score of smartphone user responders, and the average score for the upper arm posture is 2.49±0.98 (left side) and 2.53±0.88 (right side), whereas that of the forearm posture is 2.40±0.48 (left side) and 2.43±0.70 (right side). Wrist posture had an average RULA score of 2.19±1.18 and 1.33±0.47 for the left and right sides, respectively. Meanwhile, the wrist-twist posture had an average RULA score of 1.24±0.43 and 1.28±0.52 for the left and right sides, respectively. The average RULA scores for neck, trunk, and leg postures were 3.80±1.19, 4.21±1.21, and 1.22±0.42, respectively. The average RULA upper and lower extremity muscular scored 1.00±0.00. The upper and lower extremity's forces received an average RULA score of 0.00±0.00 on both sides.

The final total RULA score for smartphone user respondents ranged from five (n=14; 15.56%) to six and seven (n=38; 42.22%), with an average RULA score of 6.27±0.71 for the left side. Meanwhile, on the right side, the final total RULA score ranges from four (n=1; 11%), through five (n=13; 4.44%), to six (n=42; 46.67%) and seven (n=34; 37.78%), with an average RULA score of 6.21±0.72. Most smartphone users had a total RULA score of six or seven on both sides (84.44% and 84.45% on the left and right, respectively), indicating the need for further research and immediate improvements (levels three and four actions). The RULA data also indicated that none of the smartphone user respondents received an acceptable RULA score of one or two.

4.4 MSDs and ergonomic risk level among smartphone users' correlation

Table 2 shows the correlation between MSDs and the ergonomic risk level of smartphone users in the present research. There was a significant correlation between the total score of the right-side RULA and the MSDs on the neck ($\chi2$=0.244 at a p-values of 0.014) as well as the total score of the right-side RULA and MSDs on the upper back ($\chi2$=2.316 at a p-values of 0.028), in accordance with the chi-square results and Fisher's exact analysis. RULA B (an integration of neck, trunk, and leg postures) and D scores (an integration of RULA B scores, muscle use scores, and force use scores for group B) also exhibited a significant correlation with the neck MSDs (p-values=0.010 and p-values=0.003, respectively). The research also discovered a significant correlation between the RULA score of the right upper arm and MSDs on the right shoulder (p-values=0.032) and the RULA score of the neck and MSDs on the neck (p-values=0.043). The trunk RULA score also revealed a significant correlation with the upper back MSDs ($\chi2$=7.254, p-values=0.027).

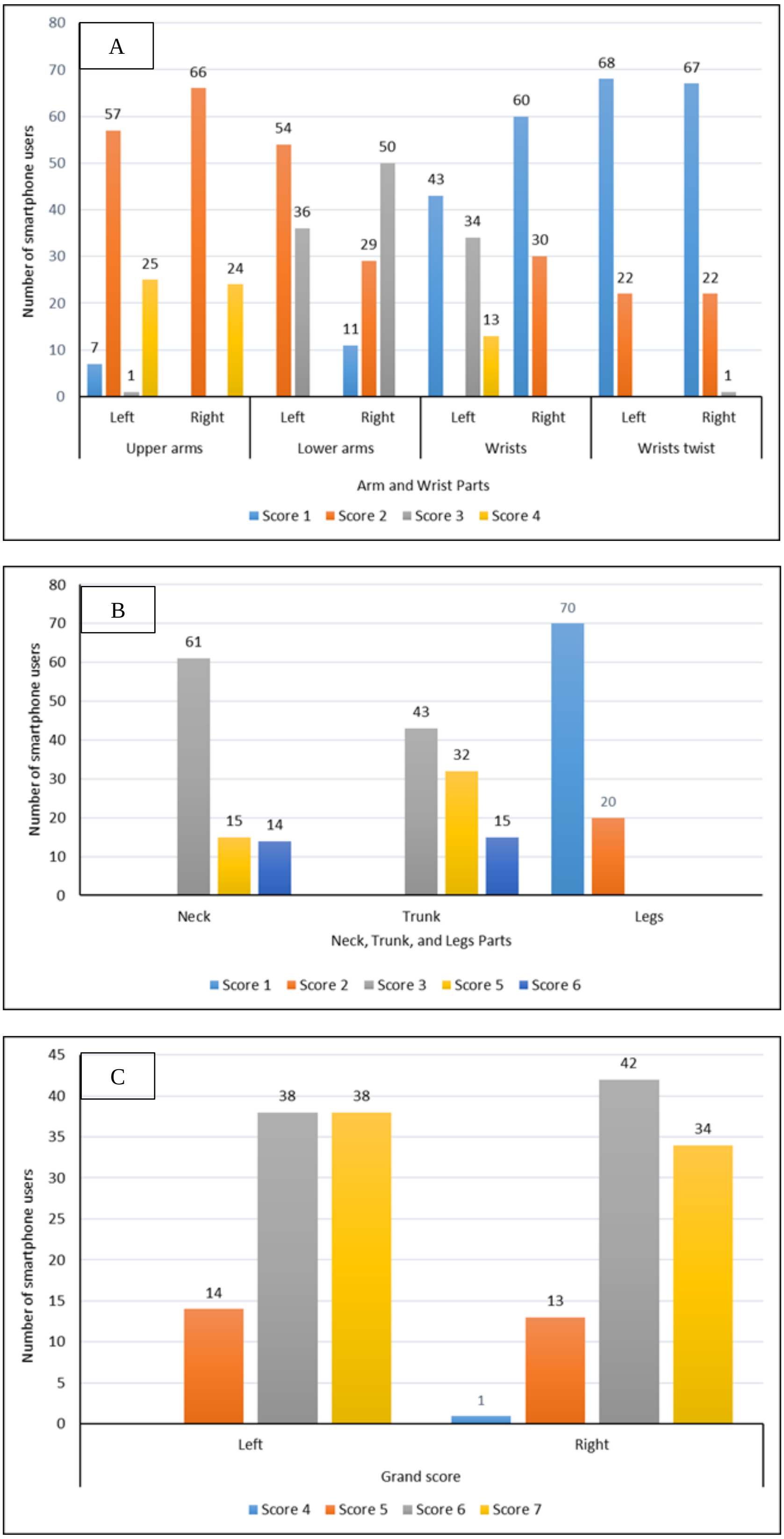

Figure 2 RULA score distribution; (A) arm and wrist parts, (B) neck, trunk, and legs parts, (C) RULA grand score

4.5 Discussion

The RULA instrument was used to determine ergonomic risk levels among smartphone users. According to the findings of RULA, none of the respondents received an appropriate RULA score (total RULA score of one or two). Relatively all smartphone users are exposed to a high level of ergonomic risk, as shown by the overall scores of RULA six and seven for both sides (left and right sides: 84.44% and 84.45%). This suggests further investigation and immediate modification (action for levels three and four). There was a significant correlation between the total score of the right-side RULA and MSDs on the neck ($\chi2$=0.244 at a p-values of 0.014) and the total score of the right-side RULA and MSDs on the upper back ($\chi2$=2.316 at a p-values of 0.028), in respect to the chi-square results and Fisher's exact analysis.

RULA B (an integration of neck, trunk, and leg postures) and D scores (an integration of RULA B scores, muscle, and force use scores for group B) also exhibited a significant correlation with MSDs on the neck (p-values=0.010 and p-values=0.003, respectively). The research also discovered a significant correlation between the RULA score of the right upper arm and MSDs on the right shoulder (p-values=0.032), including the RULA score of the neck and its MSDs (p-values=0.043). The trunk RULA score also significantly correlated with upper back MSDs ($\chi2$=7.254, p-values=0.027).

Table 2 The relationship between MSDs and ergonomic risk among smartphone users

RULA body parts	MSDs	Chi-square (p-values)	
		Left	Right
Upper arms position	Shoulder	1.193 (0.275)	6.854 (0.032)*
Lower arms position	Elbow	0.923 (0.337)	0.146 (0.703)
Wrists position	Wrist hand	3.705 (0.157)	0.239 (0.887)
Wrist twist position	Wrist hand	3.566 (0.168)	0.987 (0.611)
Score A (integration of upper arms, lower arms, and wrists position)	Shoulder	0.056 (0.813)	1.835 (0.400)
	Elbow	0,247 (0.619)	0.316 (0.574)
	Wrist hand	2.686 (0.261)	1.543 (0.199)
Neck position	Neck	4.078 (0.043)*	
Trunk position	Upper back	7.254 (0.027)*	
	Lower back	1.115 (0.573)	
Leg position	Hip and thigh	1.168 (0.558)	1.722 (0.423)
	Knee	0.037 (0.848)	1.016 (0.602)
	Ankle	2.139 (0.343)	3.377 (0.185)
Score B (combination of neck, trunk, and leg position)	Neck	9.184 (0.010)*	
	Upper back	2.328 (0.312)	
	Lower back	2.255 (0.324)	
	Hip and thigh	3.615 (0.164)	0.378 (0.539)
	Knee	0.674 (0.714)	0.247 (0.619)
	Ankle	3.290 (0.193)	0.598 (0.742)
Score C (integration of score A, muscle use, and force for group A)	Shoulder	0.175 (0.676)	0.316 (0.574)
	Elbow	0.758 (0.384)	0.316 (0.574)
	Wrist hand	5.014 (0.082)	< 0.0001 (0.985)
Score D (integration of score B, muscle use, and force for group B)	Neck	8.601 (0.003)*	
	Upper back	3.714 (0.156)	
	Lower back	1.398 (0.497)	
	Hip and thigh	3.909 (0.142)	3.724 (0.155)
	Knee	0.417 (0.518)	2.208 (0.332)
	Ankle	2.473 (2.90)	0.783 (0.676)
Grand Score	Neck	0.940 (0.332)	0.244 (0.014)*
	Shoulder	0.495 (0.482)	1.339 (0.512)
	Elbow	2.146 (0.143)	0.024 (0.876)
	Wrist hand	1.253 (0.535)	0.498 (0.480)
	Upper back	1.342 (0.511)	2.316 (0.028)*
	Lower back	2.807 (0.246)	3.353 (0.187)
	Hip and thigh	1.328 (0.249)	0.584 (0.445)
	Knee	0.299 (0.584)	8.433 (0.051)
	Ankle	2.340 (0.310)	11.073 (0.054)

* Significant correlation (p<0.05)

Smartphone users usually encounter a significant ergonomic risk while using their devices, which tends to impact various variables. This risk level is connected to three RULA assessment components: upper extremity posture, muscle usage, and force scores (McAtamney, & Corlett, 1993). In terms of posture ratings, it was observed that most participants maintained both upper arms bent between -20 and +20 degrees when using smartphones. Some individuals, however, shrugged, leaned back, or supported their upper arms, besides, both forearm postures are in flexion at a 90-degrees angle. In comparison, the posture of the wrist is usually in a flexion and extension position, with the wrist bent away from the midline, while its rotation posture is in a handshake pose (mid-range of twist). A comfortable working position needs a sagittal and frontal arm angle of less than 20 degrees (OSH, 2022).

The respondents also held the neck part at a flexion angle greater than 20 degrees and rotated or bent it to the side. A hunched position is considered the primary source of neck MSD disruption (Keown, & Tuchin, 2018). A slight forward motion of the head in the sagittal plane puts more strain on the supporting bone structures and activates the neck's cervical muscles (Lee, James, Edwards, & Snodgrass, 2022). Previous research indicated that the compressive stress on the cervical disc in the neck is 10 kg larger in the forward bending position than in the upright posture at an angle of 45 degrees for more than 25% of the working period.

There is usually an increased risk when the neck is bent for over 45 degrees from its normal posture for more than 5% of the working day. However, assuming it is flexed at a 20-degree angle for more than 40% of the workday, the risk rises dramatically with time (Øverås et al., 2020).

The trunk flexion angle of the respondents ranged from 20 to 60 degrees, and some had additionally rotated or side-bent trunks. Furthermore, a trunk that bends forward or backward falls into one of the four load zones. The best working posture zones for bending are (1) to a 20-degrees angle and (2) between 20 and 60 degrees. Musculoskeletal problems are likely to occur when the trunk is bent forward or backward by more than 60 degrees. Bending to the side (frontal plane) or rotating the top corresponding to the bottom (transverse plane) provides a 10-degrees comfort zone for the trunk. Awkward trunk posture, such as twisting or bending, is also a significant risk factor for back pain-related MSDs (OSH, 2022). The position of the user's hands and that of the responder while looking at the smartphone screen affects the posture of the neck, trunk, and shoulders (Kaya Aytutuldu, Birinci, & Tarakcı, 2022; Legan, & Zupan, 2022).

The position of the respondent's foot was unsupportive and imbalanced, during certain circumstances, the legs tend to be subjected to uncomfortable situations during work. When utilized, for example, the soles should be put at ground level to prevent an awkward posture of the feet and ankles (OSH, 2022).

Previous research stated that smartphone users maintain their neck, elbow, wrist, and hand flexion, shoulder protract, during typing activities, with wrists and hand supination to support the smartphone device. At the same time, the upper and lower backs are bent, resisting hip, thigh, knee, and ankle flexion alongside foot neutrality (Tapanya, & Puntumetakul, 2019). Each of the smartphone users' poses is found to be uncomfortable (Ratan, Parrish, Zaman, Alotaibi, & Hosseinzadeh, 2021). The more the joint moves away from the neutral part or towards one end of its range of motion, the greater the pressure placed on the muscles, tendons, and ligaments around the joint, which may also compress the nerves and irritate the tendons (OSHA, 2000). Awkward postures, such as lifting the arms, bending the head, neck, and trunk forward, cause ergonomic difficulties and influences the risk level (Habibi, Mohammadi, & Sartang, 2016). Therefore this needs to be addressed to avoid the pain of MSDs (Gałczyk, Zalewska, Białokoz-Kalinowska, & Sobolewski, 2021).

In terms of muscle use, smartphone users' posture is often static, the respondents held the smartphone for more than a minute or operated it often. The activities performed more than four times per minute raise the RULA (score 1) score (McAtamney, & Corlett, 1993). According to the poll, respondents used smartphones for 97.92±15.52 hours per week and 13.99±2.22 hours per day on average. All the respondents (100%) acknowledged taking time off while using their smartphones. Previous observational research revealed that smartphone users statically engaged their muscles (Tao, Yang, Zhang, & Qu, 2022) for lengthy periods (Cetin et al., 2022), and this tends to have an impact on the ergonomic risk level (Ratan et al., 2021; Jain, Meena, & Rana, 2022).

Concerning the force use score, the average weight of the respondent's smartphone was 172.89 grams (including the average smartphone protective case), which is still less than the 4.4 pounds or two kilograms minimum standard limit in RULA. According to the RULA instrument, the force score on the upper extremities of both the left and right sides was zero (McAtamney, & Corlett, 1993). All responders (100%) held their cell phones in a static position. The respondents actively employed the right upper body gestures to type on smartphones because they all use their right hand for most activities while holding the left side of the upper body stationary. Likewise, they kept their lower extremities in a static posture on the left and right sides. This posture caused the force use evaluation to be assigned a score of zero.

For the explanations earlier affirmed, it is obvious that their posture mostly drives the high ergonomic risk level experienced by smartphone users during usage. MSDs on the neck and upper back were shown to have a strong connection with the overall RULA score on the right. These findings are explained by recognizing that posture scores are the primary factors affecting such associations. This is consistent with Dennerlein's (2015) conceptual model that using smartphones increases the risk of ergonomic pose and muscle usage, alongside perceived discomfort and MSDs. The existence of a significant correlation between the RULA score of the right upper arm and MSDs on the right shoulder ($\chi2=6.854$ at p-values=0.032) bolstered the findings. The RULA score of the neck and trunk were associated with the MSDs on the neck ($\chi2=4.078$ at p-valued=0.043) and upper back ($\chi2=7.254$ at p-values=0.027), respectively. The neck and trunk posture has been shown to have a combined influence on musculoskeletal problems of the neck. In the present research, the posture of the neck and trunk included 1) keeping the neck in a flexion position of more than 20 degrees, extending it or bending to the side, and 2) holding the trunk in a flexion position of more than 20-degrees and bending to the side. Smartphone users must evade this combination of positions to avoid musculoskeletal neck issues.

Individual exposure to ergonomic variables are assessed rapidly and in real-time using RULA instruments such as a smartphone. This research adopted observation-based investigation techniques to determine the ergonomic risk levels of smartphone users. According to findings, neck pain is a musculoskeletal problem with the greatest frequency felt among smartphone users, and this is consistent with prior research (Kim, & Kim, 2015; Namwongsa et al., 2018; Toh et al., 2017). Smartphone users are exposed to high ergonomic risk due to their posture. The drawback of the present research is that it does not concentrate on the area of the body conducting repeated motions while engaging in typing activities, namely repetitive finger movements. Another instrument is the Occupational Repetitive Action (OCRA), used to measure repetitive activities. Future research will be more interesting, assuming direct measuring techniques are employed, for example, surface Electromyography (sEMG), to evaluate muscle usage for each position around the neck area and observation-based evaluation tools. Another limitation of the present research is that most respondents are right-handed. It may be more advantageous to include respondents who are likewise dominant in using the left hand more equally to compare prior findings.

Further research on aids to avoid upper body and neck injuries such that there is no bending posture while engaging in smartphone activities needs to be conducted. The criteria for smartphone usage, such as the duration of use, the users' age, and suggested posture, need to be considered. As a result, the risk of musculoskeletal problems tends to be reduced, thereby ensuring the body retains a healthy state.

5. Conclusion

In the present research, smartphone users are reportedly exposed to uncomfortable postures and significant ergonomic risks. The findings showed the existence of a strong correlation between the RULA score of the right upper arm and MSDs on the right shoulder, as well as the RULA score of the neck and MSDs on the neck. The RULA score of the trunk shows a significant correlation with the upper back MSDs. These findings are useful for practitioners treating patients with neck discomfort who use smartphones. Behavioral ergonomic therapies that target postural issues, especially neck posture, trunk, and upper extremities, as well as muscle usage, are beneficial in avoiding or treating musculoskeletal neck diseases among smartphone users.

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