Study of Text Neck Syndrome Among Smartphone Users Via JACK Software

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Abstract

This paper focuses on examining the risk factors associated with Text Neck syndrome (TN) among individuals using smartphones. TN syndrome has many side effects that may harm the users' health by causing musculoskeletal disorders (MSD) to be the riskiest among anything else. This paper experimented with all possible scenarios that an individual would use their smartphones. As it was applied for both genders, three different percentiles, three possible postures, and three possible levels of usages using digital human modeling. JACK software was used for modeling all possible postures to analyze the effect of texting on the neck area. In addition, a survey was done with 722 respondents in order to measure and analyze the pain level associated with the main factors of TN occurrence. Also, Minitab software was used to analyze both the survey's data and RULA scores to show the most significant factors affecting the neck pain. Solutions and recommendations were given in order to reduce the pain level and ergonomic risks on the neck.

Keywords

Text Neck Syndrome, Cervical Spine, Digital Human Modeling, Musculoskeletal Disorders, JACK software.

1. Introduction

Text Neck syndrome (TN) is a present-day term that combines the symptoms of repeated neck and head pain caused by prolonged texting or gazing down at the cell phone or any other portable electronic device. In addition, (Ali et al., 2017) in a recent study stated that "79% of the population between the ages of 18-44 have their cell phones with them almost all the time, with only 2 hours of their working day spend without their cell on hand". Any abnormal curvature in the cervical spine influences the head, neck, and entire spinal cord is known as TN. It is derived from musculoskeletal disorders (MSDs) that affects the physical health of an individual. MSDs are associated with the unusual behavior of the muscles, bones, joints, tendons, ligaments, and nerves that are connected to form the physical system of the human being. Prolonged exposure to Forward Head Posture (FHP) is a result of TN that can lead to degeneration in the structure of the cervical spine because the head exerts extra weight on the shoulders and neck obligating them to carry the extra load. (Ali et al., 2017) The wrong position will lead ligaments holding the vertebrae and muscles to be tensioned and consequently loosening on the long run. Increasing the pressure could lead to disks, inflammation, injuries, and severe pain. Repeated performance of texting on a smartphone causes from tolerable to severe neck pain experienced by a user while bending their neck. Users often adjust their physical posture based on the smartphone to be able to use it easily and not vice versa. (Anna et al., 2018) showed that 66.7% of people who used the smartphone for 3 hours or more while seating or standing experienced neck pain.

Digital Human Modeling (DHM) is a reliable method to visualize and analyze the major concern of this paper which is the TN syndrome. JACK software will assist in measuring the effort exerted on the neck in different postures by DHM. It has several assessment tools that will help in measuring outcomes like Rapid Upper Limbs Assessment (RULA) and Comfort Assessment tool. Identify Critical factors affecting the neck

Billions of people in the world have access and use smart devices on a regular basis; therefore, this paper will help to raise awareness of the importance of correcting smartphone usage postures. As the critical factors affecting the neck will be identified. This paper will also focus on reducing the neck pain caused by the prolonged usage of smartphones.

It will be done by presenting the effect of smartphone usage on neck pain and investigating its factors. Lastly, a few alternative solutions will be recommended.

2. Literature Review

Many ergonomic risk assessment tools, such as Rapid Upper Limb Assessment (RULA), Movement and Assistance of Hospital Patients (MAPO), National Institute of Occupational Safety and Health (NIOSH) lifting equation were used to measure the risk associated with the work procedures. They were also used to improve the protocol to avoid several injuries in the workplace. Digital human modeling, especially JACK software facilitates the measurements of risk. It provides the ability to do experiments and scenarios that cannot be done in real-life. Commonly, the usage of smart devices is associated with musculoskeletal pain in the upper extremities and neck which is the focus of this paper. Due to the rising problem of prolonged usage of smartphones that result in MSDs, many types of researches and approaches were conducted in order to solve and prevent awkward postures.

Several studies focused on measuring the muscle activity and nerve cells that control them by the use of Electromyography. (Douglas & Gallagher, 2017) studied the inclination effects on the head and neck posture, and (Hu et al., 2015) studied poor posture results from the overuse of smartphones. Both of them measured the neck flexion angle. Moreover, (Chan et al., 2014) studied the effects of using 1 display screen Vs. 2 display screens on cervical muscle and measured head and neck angles. Also, (Reeves & Werth, 2014) studied ergonomic risk when using portable device measured head angle and trunk angles.

Another approach is a biofeedback system was applied to correct the posture by alerting the user when a bad posture has occurred. Both (Elallam & Elnaffer, 2018) and (Breen et al., 2009) studied correcting head and neck postures and measured the carnio-cervical angle. In addition, the cervical range of motion is an approach that measures cervical rotation, lateral flexion, forward head measurements, and extension. Two studies were conducted on this approach, (Ali & Moawd, 2015) studied the effect of over-usage of smart device on the user and (Han et al., 2016) studied posture and duration effect on neck flexion by smartphone users, both measured neck flexion angle.

To the best of the knowledge obtained from the literature review, DHM hasn't been used to study and analyze TN syndrome.

3. Methodology

The flowchart of the methodology is shown below in Figure 1 which illustrates the followed procedures in this paper. In the beginning, the TN problem clearly defined with its consequences. Then, a relevant literature was checked, and factors related to the TN problem were analyzed. After that, a survey was conducted to collect reliable data. Also, a survey was developed including three factors which are gender, posture and smartphone usage level that were maintained from the conducted literature review. A general linear model was developed using Minitab software based on the results of the survey. Moreover, digital human models were created using JACK software with different postures and smartphone usage levels. Some alternatives were developed in order to improve the model and evaluated to know its efficiency and selecting the best solution.

A survey was designed and conducted in one-on-one interviews with people in public places on 722 respondents who claimed to use smart devices regularly. 69% of respondents claimed to experience neck pain regardless of the posture and or level of usage which is almost 500 respondents from all ages' groups and genders questioned. As a result, 54 different scenarios were modeled on JACK software based on 2 different genders, 3 postures (standing, sitting and walking), 3 levels of usage (eye, chest and lap) and 3 different height percentiles to measure and analyze the economic effect on the neck due to texting on males and females at three different height percentiles (5th, 50th, & 95th) with three different postures and three level of usages. There is a significant risk on the neck even if people claimed not to experience neck pain; therefore, it was a matter of concern to study this problem. As shown below in Figure 2, several models of the postures and level of usages experimented on JACK software. The analysis and measurements were to show the riskiness, and to show the riskiest scenarios in order to recommend and suggest a solution. In addition, Table 1 below shows clearly the design matrix that was the scope of the experiment

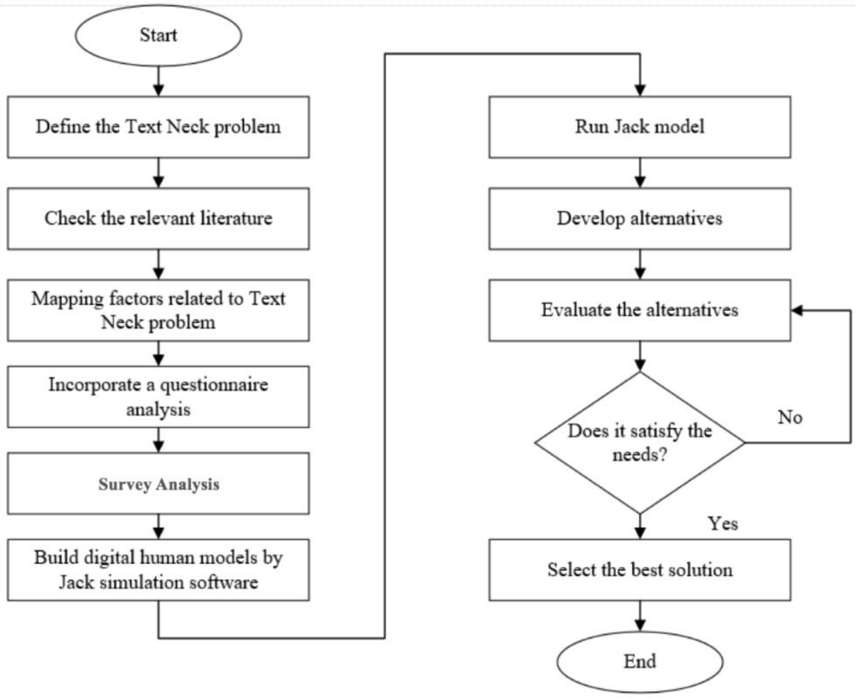

Figure 1: Logical flow

Table 1: Factors and levels matrix

Factors and Levels Matrix		
Factor	**Level**	**Values**
Gender	2	Males & females
Posture	3	Standing, sitting, & walking
Level of usage	3	Eye, chest & lap
Height percentiles	3	5^{th}, 50^{th} & 95^{th}

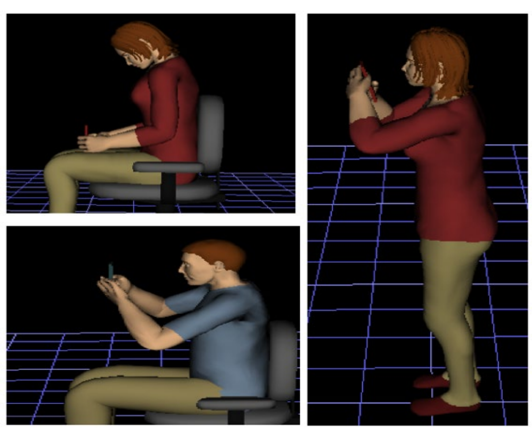

Figure 2: Digital human models

4. Results

Numerical results were obtained from Minitab software analysis, in addition to analysis of real-life scenarios are obtained from JACK software.

4.1 Survey Analysis

A survey was conducted to assess people's perspective about smartphones usage including four factors which are gender (Chen et al., 2016), postures (Anna et al., 2018) smartphone usage level and height percentiles (Ailneni et al., 2018) that were maintained from the conducted literature review. This survey yielded 722 responses as 65.1 % of the respondents were females and the other 34.9 % were males. Moreover, 91.7% of people use their smartphones while sitting more than standing which scored 5.7% and walking scored the minimal percentage. One important thing is that 52.9% of people use their phones more than 5 hours a day which is expected to continue to increase more and more.
Minitab software was used to perform the whole statistical analyses. A general linear model was used to analyze the most significant factors affecting the neck pain level as all results were considered statistically significant at alpha 0.1. Results of ANOVA have illustrated in Figure 3 that the duration factor has a significant effect on the neck pain since the P-value is equal to 0.000 being less than 0.1. This is compatible with the findings of (Ali & Moawd, 2015) that duration has an impact on the prevalence of neck pain for smartphone users. Moreover, age was statistically significant that the P-value was 0.071 being less 0.1. In addition, the interaction between duration and using smartphones at sitting posture was significant as the P-value 0.073 being less 0.1 which matches with what (Anna et al., 2018) showed that 66.7% of the participants who used the smartphone for 3 hours or more while seating or standing experienced neck pain.
Main effects plots were obtained for only the significant factors (i.e. Age and Hours Spent). It was found that the age group (38- 48) years old are the most affected group. Also, the main effects plot shows that neck pain is increasing gradually when the duration using the smartphone increases as using the smartphone for more than five hours has the highest effect on neck pain. This compatible with the findings of (Hu et al., 2015) that the longer usage of smartphones, the deeper neck flexion which contributes to increasing neck pain.
The interaction plot was done to show the significant effect of the interaction between duration and smartphones' usage at sitting posture factors. The effect of sitting posture on the neck pain level which depends on the hours spent on smartphones as represented in Figure 4. There is an incremental impact on the pain level by using smartphones for a longer time and especially at the eye level while sitting as (Gustafsson et al., 2011) proved that texting while sitting with the head bent forward was more common among with musculoskeletal symptoms.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Gender	1	0.016	0.01616	0.01	0.909
Age	3	8.671	2.89029	2.35	0.071
hours used	3	22.725	7.57510	6.17	0.000
Most posture	2	0.787	0.39347	0.32	0.726
sitting level	2	0.219	0.10951	0.09	0.915
Gender*Age	3	2.583	0.86090	0.70	0.551
Gender*hours used	3	7.618	2.53940	2.07	0.103
Gender*Most posture	2	5.233	2.61642	2.13	0.119
Gender*sitting level	2	1.126	0.56287	0.46	0.632
Age*sitting level	6	5.493	0.91556	0.75	0.613
hours used*sitting level	6	14.273	2.37880	1.94	0.073
Most posture*sitting level	4	3.137	0.78417	0.64	0.635
Gender*Age*sitting level	6	11.376	1.89601	1.54	0.161
Gender*hours used*sitting level	6	8.174	1.36228	1.11	0.355
Age*hours used*Most posture	18	18.686	1.03812	0.85	0.646
Error	654	802.740	1.22743		
Lack-of-Fit	39	36.983	0.94828	0.76	0.853

Figure 3: ANOVA outcomes

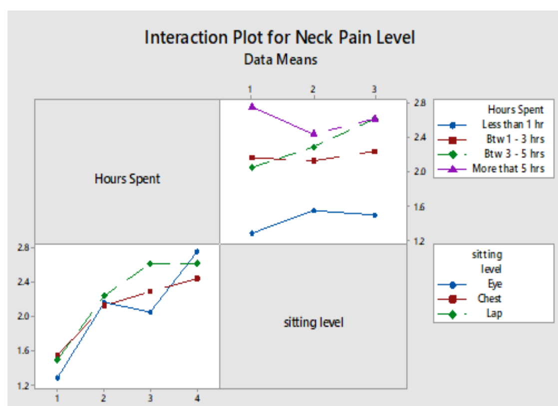

Figure 4: Interaction plot between hours spent and sitting

4.1 JACK software Analysis

Different Key Performance indicators were used to analyze the risk factors of the TN problem which are the RULA tool and the Comfort Assessment tool that are mentioned in the improvement part. In addition to the analysis obtained by the survey data from Minitab software, the below outcomes showed significant factors in different scenarios.

Results of RULA outcomes of different scenarios based on the factors' combinations that are shown in Table 2 below. Two-body groups A and B were measured by using RULA tool. Body group A measures upper arm, lower arm, wrist, and wrist twist. On the other hand, body group B takes measurements of the neck and the trunk. The measurements for each posture vary between 1 and 7, If the score is between (1-2) it means that the risk is negligible. If the score is between (3-4) low risk, (5-6) medium risk and changes are required and if the score above 7 so the risk is very high, and changes should be done as soon as possible.
Males with a height percentile of 95th mostly showed medium MSD risks in all postures and levels so the changes must be done. In addition, chest level showed the medium risks for all percentiles at all postures. However, sitting posture maintained the highest RULA scores for males as indicated by red color. Besides, the findings for females showed that the highest score was 7 in standing and sitting postures at different levels especially for 50th and 95th percentiles that due to their physical structure. Both males' and females' outcomes are shown in Table 2. As stated, there is a significant difference between how both genders bear the mechanism of pain that females suffer from pain more than males (Mogil, 2018).

Table 2: Males & females RULA outcomes

Gender	Posture	Levels of Usage	5th %	50th %	95th %	Gender	Posture	Levels of Usage	5th %	50th %	95th %
Males	**Standing**	**Eye**	4	3	5	**Females**	**Standing**	**Eye**	3	4	5
		Chest	5	6	6			**Chest**	6	7	7
		Lap	4	4	5			**Lap**	6	7	7
	Sitting	**Eye**	5	5	5		**Sitting**	**Eye**	7	7	7
		Chest	5	5	5			**Chest**	6	6	6
		Lap	4	4	4			**Lap**	5	5	5
	Walking	**Eye**	3	5	5		**Walking**	**Eye**	4	4	4
		Chest	5	5	5			**Chest**	4	4	4
		Lap	4	4	4			**Lap**	3	4	6

Another general linear model was developed to analyze only RULA scores as the sitting posture was the worst posture used to get their results. Figure 5 illustrates the statistically significant factors which are gender, postures, level of usage and height percentiles. In addition, the following 2-way interactions were significant too at (gender & posture), (gender & level of usage), (posture & level of usage) and (posture & height percentiles). One interaction out of the 3-way interactions was significant which is (gender, postures & level of usage). R-squared was very high as it indicates that approximately 98% of data fit the model. All the results match with the outcomes of the survey's analysis that have been done previously.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	45	81.6296	1.81399	8.52	0.002
Linear	7	38.7407	5.53439	25.99	0.000
Gender	1	8.9630	8.96296	42.09	0.000
Posutres	2	16.4444	8.22222	38.61	0.000
Level of Usage	2	7.0000	3.50000	16.43	0.001
Height Percentiles	2	6.3333	3.16667	14.87	0.002
2-Way Interactions	18	30.5556	1.69753	7.97	0.003
Gender*Posutres	2	4.5926	2.29630	10.78	0.005
Gender*Level of Usage	2	3.8148	1.90741	8.96	0.009
Gender*Height Percentiles	2	0.0370	0.01852	0.09	0.918
Posutres*Level of Usage	4	16.8889	4.22222	19.83	0.000
Posutres*Height Percentiles	4	3.5556	0.88889	4.17	0.041
Level of Usage*Height Percentiles	4	1.6667	0.41667	1.96	0.194
3-Way Interactions	20	12.3333	0.61667	2.90	0.063
Gender*Posutres*Level of Usage	4	5.6296	1.40741	6.61	0.012
Gender*Posutres*Height Percentiles	4	2.0741	0.51852	2.43	0.132
Gender*Level of Usage*Height Percentiles	4	0.1852	0.04630	0.22	0.921
Posutres*Level of Usage*Height Percentiles	8	4.4444	0.55556	2.61	0.098
Error	8	1.7037	0.21296		
Total	53	83.3333			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.461479	97.96%	86.46%	6.85%

Figure 5: General linear model for RULA results

Figure 6 below shows the main effects plot of the most significant factors affecting the neck as females are the most affected than males. Moreover, using the smartphone in chest level while sitting have the highest effect on the neck. Also, the more height percentile, the more effect on the neck as 95th is the most affected percentile.

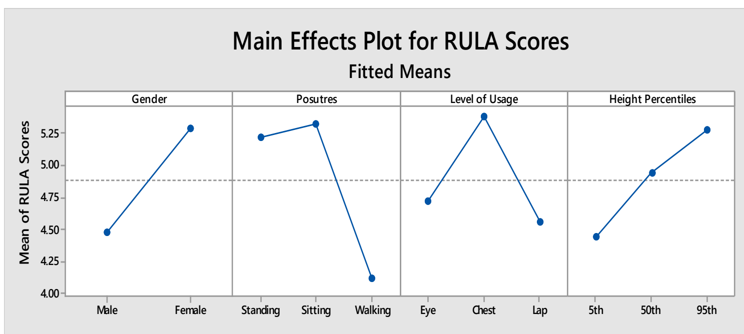

Figure 6: Main effects plot for RULA results

As shown in Figure 7, the effect of gender on the neck depends on the height percentile that the higher height percentile, the more effect on the neck pain level, especially on females with 95th percentile in comparison with males who are less affected. This is compatible with the results of the survey mentioned above. The interaction between postures and level of usage illustrates that using smartphone while standing at the chest level is the worst posture. However, walking posture has the lowest effect on the neck pain level as the neck is not fixed for a long time. The effect of level of usage depends on the height percentile as people with 5th percentile are less affected than other percentiles while people with 95th percentile who are using their smartphones at the chest level are the most affected. All these results don't match with survey analysis as RULA scores take into consideration both upper and lower extremities.

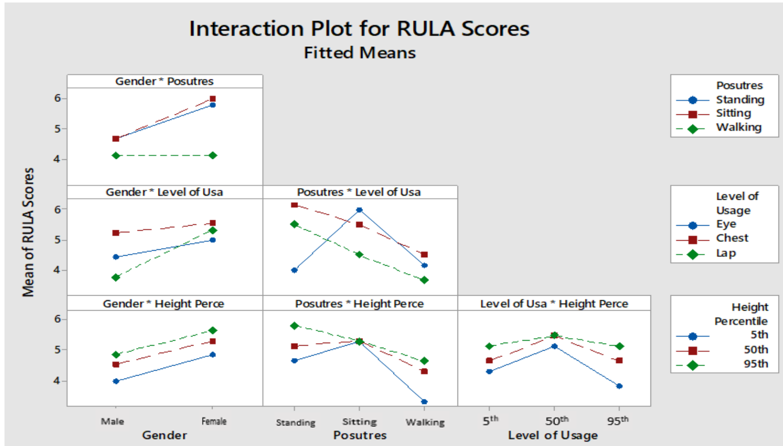

Figure 7: Interaction plot for RULA results

As the main focus is neck pain the below Table 3 illustrates the neck scores that are independently extracted from RULA tool. The sitting posture was chosen to extract neck scores as it was the most frequent posture as per the survey analysis where 91.7% of respondents have stated that they use their smartphones the most while sitting. RULA gave the highest neck scores at chest and lap levels since both genders need to bend their neck forward to reach the smartphone level. However, the highest neck score was 4 for females while sitting for 95th percentile at lap level. Nevertheless, the lowest score was at the eye level for both genders in sitting posture as the bending of the neck is the minimal at that level.

Table 3: Neck scores comparison between males & females

Neck scores – Males		**Levels**			**Neck scores – Females**		**Levels**		
Posture	**Percentile**	**Eye**	**Chest**	**Lap**	**Posture**	**Percentile**	**Eye**	**Chest**	**Lap**
Sitting	**5th**	1	3	3	**Sitting**	**5th**	2	3	3
	50th	1	3	3		**50th**	2	3	3
	95th	1	3	3		**95th**	2	3	4

5. Improvements

After searching and conducting the literature review, many types of research have tried to solve the TN problem in several ways. However, in this paper, JACK simulation software was used in order to solve and minimize the TN syndrome. Therefore, the suggested chair arm support and prism glasses were applied in JACK software in order to compare RULA scores and head flexion angle results before and after applying the selected solutions. Tables from 4 to 6 below illustrate the results of RULA scores, neck scores and head flexion angles for both genders with different percentiles and postures. It is obvious that RULA scores decreased from high and medium risk to low risk for both genders. Neck scores were decreased from 3 to 1 and 2 which is much better. Moreover, the head flexion angle for males became within the range; however, females were still out of the range but the angles decreased.

Table 4: RULA scores comparison between males and females – Chair support

RULA Chair Support															
Male	RULA – Chair support		Levels (before)			Levels (after)			Female	RULA – Chair support		Levels (before)			Levels (after)		
	Posture	Percentile	Eye	Chest	Lap	Eye	Chest	Lap		Posture	Percentile	Eye	Chest	Lap	Eye	Chest	Lap
	Sitting	5th	5	5	4	4	3	3		Sitting	5th	7	6	5	4	4	4
		50th	5	5	4	4	3	3			50th	7	6	5	4	4	4
		95th	5	5	4	4	3	3			95th	7	6	5	4	4	4

Table 5: Neck scores comparison between males and females – Chair support

Neck scores Chair support																
Male	Neck – Chair support		Levels (before)			Levels (after)			Female	Neck – Chair support		Levels (before)			Levels (after)		
	Posture	Percentile	Eye	Chest	Lap	Eye	Chest	Lap		Posture	Percentile	Eye	Chest	Lap	Eye	Chest	Lap
	Sitting	5th	1	3	3	1	2	2		Sitting	5th	2	3	3	2	2	3
		50th	1	3	3	1	2	2			50th	2	3	3	1	2	2
		95th	1	3	3	1	2	2			95th	2	3	4	1	2	2

Table 6: Head flexion scores comparison between males and females – Chair support

Head flexion – Chair support																
Male	HFA – Chair support		Levels (before)			Levels (after)			Female	HFA– Chair support		Levels (before)			Levels (after)		
	Posture	Percentile	Eye	Chest	Lap	Eye	Chest	Lap		Posture	Percentile	Eye	Chest	Lap	Eye	Chest	Lap
	Sitting	5th	10.5	17.8	20	10.5	17.8	13		Sitting	5th	6.3	20.1	28.5	6.3	17	21.5
		50th	6.9	17.1	18	6.9	17.1	13			50th	8.1	19.7	37.1	8.1	15	28.3
		95th	6.9	17.1	18	6.9	17.1	13			95th	11.5	18.5	41.8	11.5	16	26

Table 7: RULA scores comparison between males and females - Prism glasses

RULA – Prism glasses													
Male	RULA–Prism glasses		Levels (before)		Levels (after)		Female	RULA–Prism glasses		Levels (before)		Levels (after)	
	Posture	Percentile	Chest	Lap	Chest	Lap		Posture	Percentile	Chest	Lap	Chest	Lap
	Sitting	5th	5	4	4	3		Sitting	5th	6	5	4	4
		50th	5	4	4	3			50th	6	5	4	4
		95th	5	4	4	3			95th	6	5	4	4

Table 8: Neck scores comparison between males and females – Prism glasses

RULA – Prism glasses													
Male	**RULA–Prism glasses**		**Levels (before)**		**Levels (after)**		**Female**	**RULA–Prism glasses**		**Levels (before)**		**Levels (after)**	
	Posture	**Percentile**	**Chest**	**Lap**	**Chest**	**Lap**		**Posture**	**Percentile**	**Chest**	**Lap**	**Chest**	**Lap**
	Sitting	**5th**	3	3	1	1		**Sitting**	**5th**	3	3	1	2
		50th	3	3	1	1			**50th**	3	3	1	2
		95th	3	3	2	2			**95th**	3	4	1	2

6. Conclusion

To conclude, this paper focused on the ergonomic risk and neck pain due to the TN syndrome problem that affects people that is based on gender, postures, level of usage and height percentiles. The TN is associated with exponential growth and development of technology that has many side effects on people. Other than that, the head flexion angle was a matter of concern that was measured. Based on the survey that was developed, hours spent using a smartphone and people ages have a significant effect on the neck pain level. Digital Human Models with different scenarios were built using JACK software to show the risk associated with the prolonged usage of a smartphone. The results proved that both genders' outcomes showed a riskiness level that needs further investigation and other high risky levels outcomes that required immediate changes. Therefore, alternative solutions were suggested such as chair arm support and prism glasses. Based on all outcomes, prism glasses were the optimum solution as RULA and neck scores decreased and the head flexion was zero, this means that the neck will not be bent that minimizes the vulnerability to experience/ get text neck.

On the other hand, some recommendations might help in reducing neck pain due to the usage of smartphones such as: using the correct texting techniques by raising the smartphone closer to eye level with a straight back while sitting or standing. For tall people from (50^{th} to 95^{th}) percentiles, it is preferred to use the smartphone in sitting posture, it is necessary to make sure that both arm and hand are well supported by anything like a chair, table, briefcase or others supporting arm techniques. One important thing is to avoid using the smartphone while walking; however, in case of something urgent it is preferable to take care of the usage level and neck posture. Lastly, it is important to have frequent breaks with stretching and do some exercises that will help in easing muscle pain.

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