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Postural Analysis of Sedentary Activities using Ergonomics Methods and VICON Motion Capture System

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ABSTRACT: The most commonly used posture in our daily life is the sitting posture. An elevated amount of time, in our daily life, is spent in a sitting position. Muscles are not actively used while sitting, as compared to running and walking, which can lead to the inactivation of corresponding muscles. In industrial countries, more than 75% of the office workers spend their time, of more than seven hours, in sedentary postures and approximately half of them are affected by back pain. Prolonged sitting is a risk factor for developing future health problems, specifically vertebral column disorders. In this research work, a comparative analysis is carried out on different sedentary postures that will expose the correct sitting position for long sitting hours. To avoid the health issues that happen due to the wrong sitting positions, one must be aware of the correct sitting position. The diagnosis and precautions can help in reducing the health issues that are caused by the wrong sitting positions. This research will help in the diagnosis of the wrong sedentary postures and analysis of the correct postures. The results showed that the fatigue levels were highest in tasks A-5 and A-6 which were reclined at the elbow and reclined above elbow postures respectively. The postural analysis through VICON motion capture systems could be helpful for biomechanics and physiotherapist to understand the comparative analysis between subjective methods and recent technology.

Keywords: work-related musculoskeletal disorders, posture, NASA TLX, VICON system.

I. INTRODUCTION

Computers and mobiles play a very important role in our lives, most adults and children spend more than half of their day using mobile phones and computer devices. Everyone is making use of these gadgets frequently and for a considerable duration of time. Such extensive use of mobile phones and computer devices can possibly have an impact on physical health, particularly in terms of discomfort and disorders of the vertebral column [1]. Discomfort in the vertebral column, in other words, back pain, is the leading cause of disability all over the world. An estimated 10% of the world's population suffers from lower back pain. Experts estimate that up to 80% of the adults experience back pain at some point in their life. In a recent survey, more than a quarter of adults have reportedly experienced pain in their lower back during the past 3 months [2-3]. Back pain is one of the most common reasons for missing the work and it accounts for more than 264 million lost workdays in one year (that's two workdays for every full-time worker) [4]. One of the reasons of back pain, during work or office hours, is wrong sedentary postures. Office hours are about 10 to 12 hours a day and most of the office work is done on computer devices. A potential pattern towards more static sitting position of the call-center workers with lower back pain is critical [14].

To reduce the back pain, the correct sitting posture is mandatory. To know what is the correct sitting posture we have compared different kinds of sitting postures with the help of and on the VICON motion capture system [13]. For pilot study, we have designed an experiment that includes NASA TLX [11], physical well-being and general well-being (these are the different questionnaires designed for the comparison purpose [12]. These questionnaires are for the assessment of the subject regarding different parameters (that could be physical, mental, etc.). The experiment showed the effect of different sedentary tasks on vertebral column and upper body at different angles. After getting the results from the pilot study, same experiment was performed on VICON motion capture system and the results of both the experiments were compared. The comparison exposed the angles that effect the vertebral column and caused the discomfort in the vertebral column while performing any sedentary task. With the help of comparative analysis we could be able to determine the correct sedentary postures for performing various tasks.

II. LITERATURE REVIEW

Ergonomics involve three fundamental fields of research and exploration: physical, intellectual and organizational ergonomics. Physical ergonomics covers the human anatomy, and part of anthropometric, physiological and biomechanical aspects as identified with physical action. Physical ergonomic standards have been broadly utilized in the structure of both buyer and modern items for enhancing execution and to reduce work related issues by decreasing the systems behind mechanically induced acute and chronic musculoskeletal disorders (or injuries). Risk factors, for example, restricted mechanical stress, force and stance or posture in a stationary office climate lead to issues attributed to a word related condition [15].

Musculoskeletal issues (MSDs) are conditions that can influence a person's muscles, bones, and joints. MSDs incorporate: tendinitis, carpal tunnel syndrome, osteoarthritis, rheumatoid arthritis (RA), fibromyalgia, and bone fractures and muscles wear and tear. Risk factors for MSDs include person's age, occupation, lifestyle and family history. Activities such as sitting in the same position at a computer every day, engaging in repetitive motions, lifting heavy weights and maintaining poor posture at work can lead to MSDs [16].

According to WHO Musculoskeletal conditions affect people across the life-course in all regions of the world. Musculoskeletal conditions were the leading cause of disability in four of the six WHO regions in 2017 (ranked second in the East Mediterranean Region and third in the African Region). While the prevalence of musculoskeletal conditions increases with age, younger people are also affected, often during their peak income-earning years.

The Global Burden of Disease (GBD) study provides evidence of the impact of musculoskeletal conditions, highlighting the significant disability burden associated with these conditions. In the 2017 GBD study, musculoskeletal conditions were the highest contributor to global disability (accounting for 16% of all years lived with disability), and lower back pain remained the single leading cause of disability since it was first measured in 1990. While the prevalence of musculoskeletal conditions varies by age and diagnosis, between 20%–33% of people across the globe live with a painful musculoskeletal condition [17, 18].

Technological Development Towards Postural Analysis. Many technologies are used for the postural analysis. Few of them are given below:

The Role of Wearable Technologies in Spinal Postures:

Many parameters such as step count, distance travelled, heart rate and sleep quantity can be measured by the wearable technologies. Wearable technologies are consist of many technologies that are worn on the body for the measurement of different parameters. Some recent technologies have been introduced that are capable of detecting the spinal posture and provide the live biofeedback when an individual suffers a poor posture. The hypothesis is given the use of these wearable technologies can improve spinal postures. Wearable technology is capable of differentiating and recognizing body positions such as sitting standing or lying. It is also capable of monitoring the postures of body other than spine [6].

Postural Evaluation by Imaging: Measurement tool that helps with the diagnostic process by providing objective data in real time is the postural imaging technique. Colored topography of the musculoskeletal system is produced with the help of this technology. This helps in determining if the body's alignment is optimal by observing postural changes. Postural imaging technique can identify the pelvic asymmetry, misalignment of spine, pelvic tilt, leg length discrepancies, inward or outward inclined knees and general posture asymmetry. Poor workplace ergonomics, trauma, injury, hereditary factors, or a new physical activity that changes person's posture can cause the pain. Pain is experienced on a daily basis by the people with these problems. Postural imaging can provide the information that a naked eye is unable to detect and it allows the doctors to see the interactions between the different parts of the body. With the help of Doctor of Podiatric Medicine (DPM) and by following the customized treatment, the quality of life becomes better [8].

Cryovizion Imaging System: It is an imaging system used for the postural analysis. It is typically used by the postural health professionals. The quality of the information provided by this system during postural analysis is scientifically validated by researchers. This system is reliable and accurate, and it is known for the quality of information provided by the system. The advantages of imaging technique is that it's accurate and it provides the highly objective results. This is one of the safe techniques for posture analysis as it does not emit any radiations. It the speedy process as it gives the instantaneous results which help the doctors to diagnose the problems instantly [9-10].

VICON Motion Capture System: It is a motion capture system that records the patterns of movements of a person or an object. VICON is a company that manufactures such systems and is a key player in manufacturing motion capture systems based on markers. It's a complete setup that has many features, which make the whole system work, including markers, cameras, templates, activation wand and different software [13].

Problem & Method: Vertebral discomfort is one of the leading health problems in the world. To reduce this, one needs to understand the reason behind this. Vertebral discomfort is often caused by the prolonged sitting or performing more sedentary tasks in comparison with any physical activity [7]. People that perform more sedentary tasks in their daily routine often complain about the vertebral discomfort. The reason behind this is the wrong postures while performing these tasks. Some medical conditions due to wrong sedentary postures include:

- Vertebral column disorders.
- Accelerated degeneration of the spine and disc protrusions.
- Muscular inactivation over a long period of time leads to the weakening of the corresponding muscles.
- Muscle clenching, nerve irritation, reduced blood circulation due to compressed veins, or the narrowing of the respiratory organs may appear.

The work was divided into three stages of experimental study. The first experimental study was designed on the computer desktop and comprised of 6 different tasks which were performed by the subjects for 20 minutes each. The second experimental study was designed on mobile phone with the same 6 tasks performed for 20 minutes. These 6 tasks were performed at 6 different postures. Each posture of these tasks was at different back angles. The first two stages were pilot studies for which three questionnaires were designed. The parameters measured were analyzed using computer software SPSS ver22. The third stage of experimental design is the combination of both the experiments and is done using VICON motion capture system [13]. 12 tasks were performed on mobile phones and computer devices combined, were then performed on the VICON motion capture system again. The experimental study was performed by five healthy subjects, four females and one male. Six tasks performed, have 6 different vertebral angles and two different arm positions.

Two tasks performed at the upright position of vertebral column that is at the angle of 90 degree. Two tasks were performed at reclined position of the vertebral that is at the angle of 110 degree. The last two tasks were performed at the normal position of the vertebral column that is active sitting. Two arm positions were at elbow and above elbow. Out of 6 tasks performed, three tasks were performed at the position of at elbow and three tasks are performed at the position of above elbow.

VICON Motion Capture System: The experiment 3 was done on the VICON motion Capture System. The room was all cleared and market in a square with a cross on the center. The subject performed the same tasks like in experiment 1 and experiment 2 but for 2 minutes only. This time the desktop computer along with the chair was placed at the center on the origin point and for the mobile phone study the subject seat was placed at the origin point. There was a computer control system with Nexus software to capture the trials and observe the kinematics. The following equipment were used in experiment 3:

Medical Weight Scale: A medical scale was used to measure the weight of the subjects. It is a professional-grade devices that measure weight and has a height rod to conveniently measure height while person is on the scale.

Desktop Computer and Mobile Phone: The Experiment involved the use of desktop computer with the display screen placed on a table of height. The keyboard and mouse were places on another small adjustable height table placed in front of it.

Fig. 1. Active wand while glowing, Vero Camera Belts.

Fig. 2. Markers.

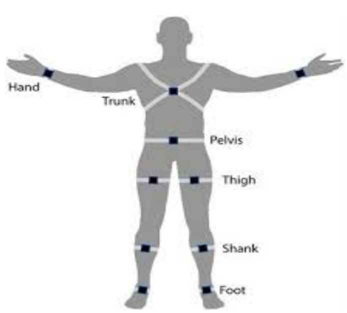

Fig. 3. Belts around the body.

Fig. 4. Medical Weight Scale.

The top of the display was at eye height, with the display located at the rear edge of the large table. A cognitive game of Solitaire was played on the desktop. The Experiment 2 and Experiment 3 were done on the mobile phone. Subject played the game Solitaire on mobile phone for 20 minutes. Any standard touch screen mobile was used.

Adjustable Seat and Table. There was a special seat made with adjustable backrest on different angles. The height of the seat was also adjusted.

Fig. 5. Desktop Computer.

Fig. 6. Using Mobile Phone.

For both tablet and desktop conditions, this seat was used. During task subjects were asked to sit with knees flexed at 90°. The keyboard and mouse was placed on an adjustable height table by the subject. The height was adjusted at elbow and above elbow of the subject.

Fig. 7. Adjustable Seat.

Fig. 8. Adjustable table.

Goniometer: A goniometer is an instrument that measures an angle or allows an object to be rotated to a precise angular position. The goniometer is used to set the backrest at the given and defined by the independent variable.

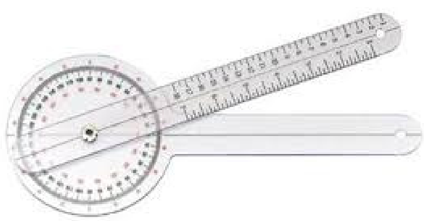

Fig. 9. Goniometer.

Following are the figures of 6 different postures in which the participant were advised to sit.

Fig. 10. Upright at elbow

Fig. 11. Recline at elbow.

Fig. 12. Recline above elbow.

Fig. 13. Normal at elbow.

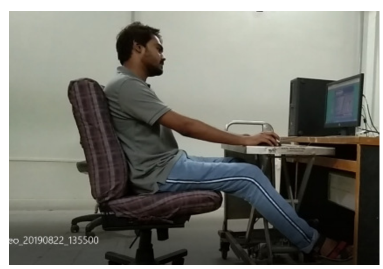

Fig. 14. Upright above elbow.

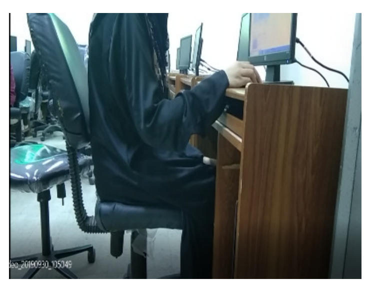

Fig. 15. Normal above elbow.

Collection of Data and Analysis: Data that has been collected from the experimental study is evaluated in the form of the tables and graphs. These tables showed the results of discomfort level, physical wellbeing and NASA

TLX. Table 1 shows the results of the discomfort level. It has four parameters (discomfort in neck, eyestrain, headache and fatigue level [12]) that are further evaluated in the form of graphs (as shown in Fig. 16 and 17). The graphs shows values for mean and standard deviation of variable.

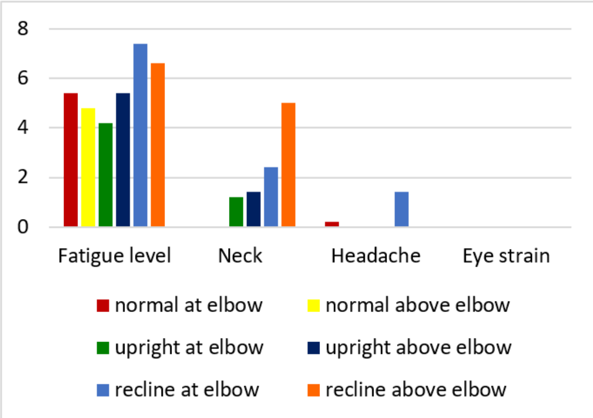

Fig. 16. Discomfort level (Mean).

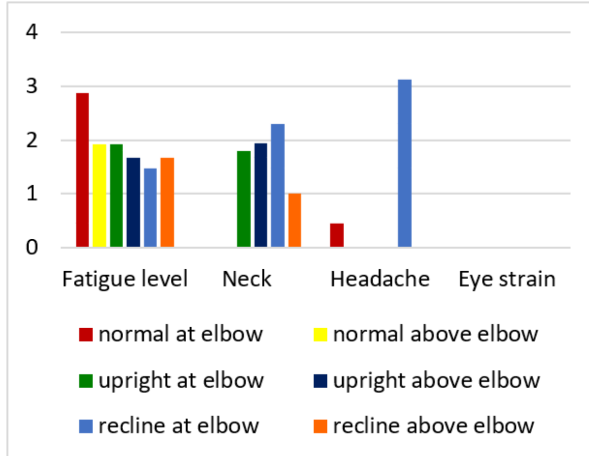

Fig. 17. Discomfort level (Standard Deviation).

Table 1: Comparative study between passive and active systems.

Dependent variables	Mean(Standard Deviation)					
	Normal		Upright @90		Recline @110	
	At elbow	Above elbow	At elbow	At elbow	Above elbow	At elbow
Eye strain	0	0	0	0	0	0
Neck	0	0	1.2 (1.789)	1.4 (1.949)	2.4 (2.302)	5 (1)
Headache	0.20 (0.447)	0	0	0	1.4 (3.130)	0
Fatigue level	5.40 (2.881)	4.80 (1.924)	4.20 (1.924)	5.40 (1.673)	7.40 (1.475)	6.60 (1.673)

Graph 1 (Fig. 16) shows the mean values of the table and graph 2 (Fig. 17) shows the values of standard deviation of each variable. The results which we got after the evaluation of the different independent variables gives the highest fatigue level in the table of discomfort level of body after the performance of task. This shows that prolonged sitting can highly cause fatigue in the human body. People that do the office jobs have to sit in the same posture for hours which results in different health problems. The fatigue level ultimately affects the efficiency of performance of the task or job which they have to perform. Increase in fatigue level will cause the increase in the effort which will decrease the efficiency of the performance of the task that has to be done. Physical discomfort increases with prolonged sitting. In these both graphs the fatigue level shows the highest values out of the four variables and discomfort in neck shows the second highest values. Headache shows a very small mean value and a little higher value of standard deviation. Whereas, the value of eye strain obtained in both the graphs is 0. Fatigue level has the highest value at the angle of 110 degree° which is reclined position of vertebral column and the position of arms is 'at elbow'. On the other hand, lowest value of the fatigue level is obtained at upright position of the vertebral column that is at the angle of 90° and the position of arms is 'at elbow'.

This shows that if an individual sits in an upright position (that is at the angle of 90°) of vertebral column, it will result in the less fatigue level as compared to other postures. Discomfort in neck is 0 while active sitting but fatigue level is extremely high. To avoid both the discomforts, one should sit in the upright position. Other than active sitting (normal body posture), the least values of discomfort in neck are obtained at the angle of 90° that is the upright position of vertebral column. The position of arms at this posture must be at elbow joint, to avoid the discomfort level.

The highest level of fatigue, headache and discomfort in neck was obtained at the reclined position of vertebral column that is at the angle of 110° and positioning of arms was at elbow. This concludes that reclined posture is the worst sitting posture while performing any kind of sedentary task as compared to other five postures. Because the reclined posture shows the worst effects on the human body when compared to the effects of other five postures. Out of all the six postures on which we have performed the experiments, the upright position of the vertebral column (at the angle of 90°) is the best posture for the sedentary activities. And the positioning of arms must be at elbow. These results are on the basis of mean and standard deviation values of all the parameters. The Table 2 shows the evaluated results of the dependent variables of physical well-being. The variables are lower back pain, upper back pain, pain in right and left arm, and pain in right and left shoulder.

Two graphs are obtained. Graph 3 (Fig. 18) shows the mean values and graph 4 (Fig. 19) shows the values of standard deviation. The Table 2 shows the highest mean values at upper back. This means, according to this study, while performing any computer task the most affected upper body part is upper back. The upper back is affected the most at the angle of 90˚ which is the upright position of vertebral column and the positioning of arm is above elbow. At this point the mean value is 2.2, which is the highest value in this table. The value of standard deviation is highest at the reclined position of the vertebral column (above elbow). The lowest mean value of upper back pain is 0, and it was obtained at the reclined position (angle 110°), above elbow. The second highest value or the second most physically affected part of upper body is lower back, according to this study. Graphs show that this dependent variable was highly affected due to prolonged sitting. The highest mean value which table shows is 2, and it was obtained at the angle of 110° (reclined position), above elbow. This means that lower back pain increases at the reclined position and to avoid the pain one should avoid sitting in this posture for a very long time. Whereas, the standard deviation value of lower back pain is highest while active sitting. The upper body part that is completely unaffected is left arm. No amount of pain was detected at this part of the upper body. The little amount of pain was detected at the right arm while sitting in upright and reclined position, and placing arms above the elbow joints. A little lesser amount of pain was also detected on both, right and, shoulders.

Table 2: Discomfort level.

Dependent variables	Mean(Standard Deviation)					
	Normal		Upright @90		Recline @110	
	At elbow	Above elbow	At elbow	At elbow	Above elbow	At elbow
Eye strain	0	0	0	0	0	0
Neck	0	0	1.2 (1.789)	1.4 (1.949)	2.4 (2.302)	5 (1)
Headache	0.20 (0.447)	0	0	0	1.4 (3.130)	0
Fatigue level	5.40 (2.881)	4.80 (1.924)	4.20 (1.924)	5.40 (1.673)	7.40 (1.475)	6.60 (1.673)

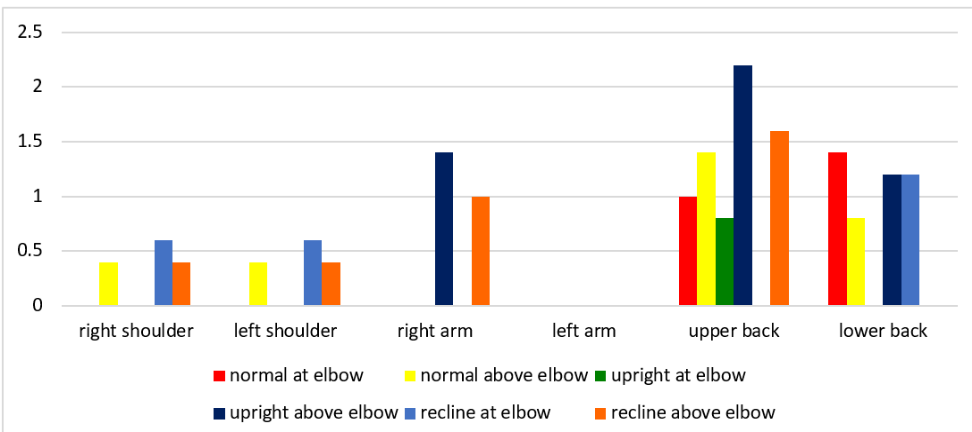

Fig. 18. Physical well-being (Mean).

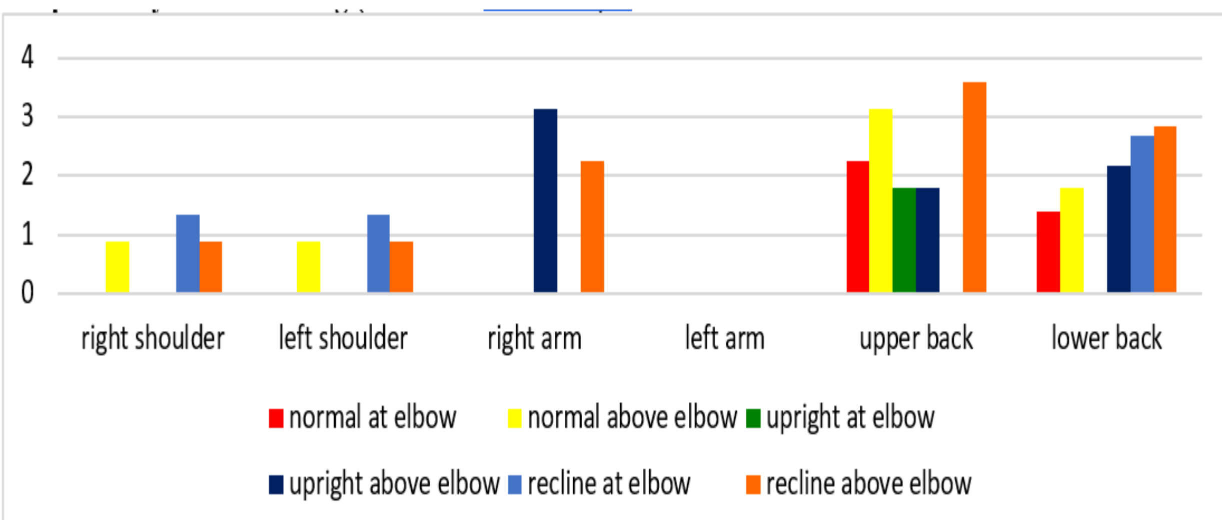

Fig. 19. Physical well-being (Standard Deviation).

The graphs show both the dependent variables, most affected and least affected. According to the graphs and table, the best sitting posture which will least affect the upper body parts is the upright position of vertebral column, and the arm positioning must be at elbow. At this position all the variables, except upper back pain, have the value 0. The upper back pain shows the mean value of 0.8 at this position, which is the second smallest value. Table 3 shows the evaluated results of the dependent variables of NASA TLX. The variables are physical demand, mental demand, temporal demand, effort, performance and frustration. The graph (Fig. 20) shows the mean values of these variables and the graph (21) shows the standard deviation values. The mean values of these variables are relatively very high as compared to other variables. These graphs and table show that these six dependent variables are highly affected while performing a task on a computer in any sitting posture. These tasks are highly demanding on mental, physical or temporal basis. The frustration level is very high while performing these tasks, as sitting in a single position for a long period of time could be frustrating for anyone. As the physical demand increases the effort to perform the task also increases. And this affects the performance of the task.

Table 3: NASA TLX .

Dependent variables	Mean(Standard Deviation)					
	Normal		Upright @90		Recline @110	
	At elbow	Above elbow	At elbow	At elbow	Above elbow	At elbow
Mental demand	66.3 (18.319)	63.3 (8.386)	51.2 (7.5548)	54.1 (11.5780)	65.1 (16.6223)	58.1 (13.1548)
Physical demand	38 (14.8324)	47.3 (21.5017)	40.1 (12.147)	68.1 (7.6191)	74 (15.1658)	72 (12.5499)
Temporal demand	38.2 (4.59)	51.2 (2.1389)	47 (9.7468)	53 (10.3682)	59.2 (12.5728)	53.1 (4.3932)
Performance	62.1 (29.4457)	62.2 (13.1937)	74 (11.9373)	62 (14.4049)	79 (15.1658)	59.1 (15.0930)
Effort	64.1 (11.36)	56.3 (24.3017)	63.1 (12.1161)	57 (17.5357)	74 (19.6361)	57.1(14.8593)
Frustration	48.2 (25.9051)	44.2 (18.0437)	40.1 (15.6541)	64.1 (16.7048)	54 (36.4692)	64 (15.1658)

Analysis on VICON Motion System: The graphs shown from Fig. 21-25 were obtained in the Experiment 3 on the VICON Motion Capture System. The graphs show the distance from origin point, angle between C-7, T-10, and Sacrum, Distance between C-7 and Sacrum, distance Between XYZ coordinates of C-7 and Sacrum, distance between Shoulder and Wrist.

The Experiment 1 and 2 showed the subjective measurement analysis of the study. The Tables (1-3) showed the mean and standard deviation of all the dependent variables (Discomfort, Physical well-being, and NASA-TLX) with respect to all the 6 posture assigned to perform the tasks on the Desktop. The results showed that the fatigue levels were highest in the tasks A-5 and A-6 which were reclined at elbow and reclined above elbow postures respectively. The reason was that the subject was very far from the desktop as he/she was reclined at 110° because of which their hands were stretched to the fullest away from the body resulting into more work done by the muscles. This resulted into fatigue. When we compare these results in the VICON Study we saw that the A-5 and A-6 showed the vertebra was more stretched and away from the desktop.

The comparison between the fatigue levels of the Experiment 1 and Experiment 2 shows that the Mobile task causes more fatigue levels in all the postures as compared to the desktop tasks. This is because of the placement of the hands very near to the body. The second reason is the load of the mobile phone in the hands while playing the game.The mobile task resulted into more discomfort in the cervical region. This is due to the bending of the head to view the mobile screen. All the postures of experiment 2 showed elevated levels of neck ache while only the reclined postures of the desktop task showed neck stain. This can be seen in the VICON trials as the labeled skeleton shows the decreased angle on the neck joint.

Posture A-1

Distance from origin

C-Seven = 1194 mm

Thoracic = 916 mm.

Sacrum = 755 mm

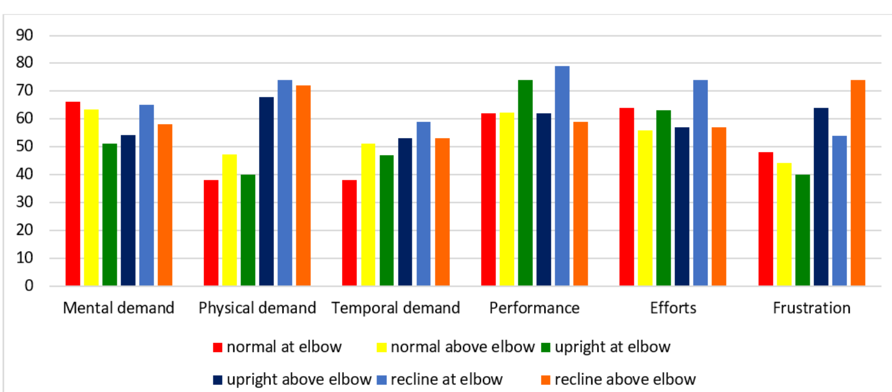

Fig. 20. NASA TLX (Mean).

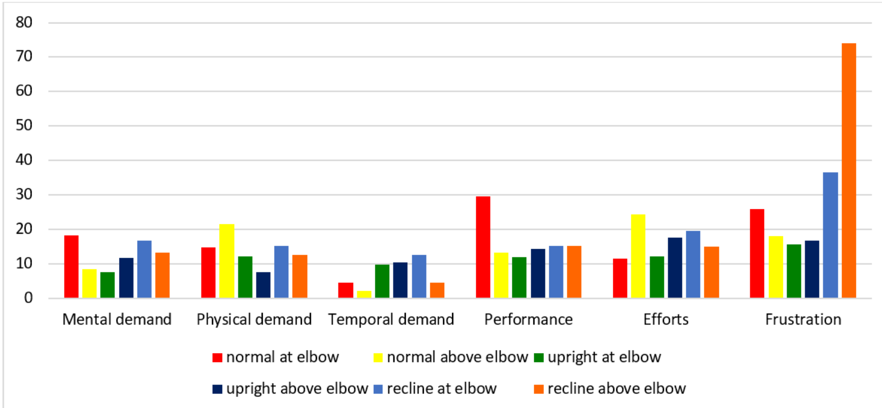

Fig. 21. NASA TLX (Standard Deviation).

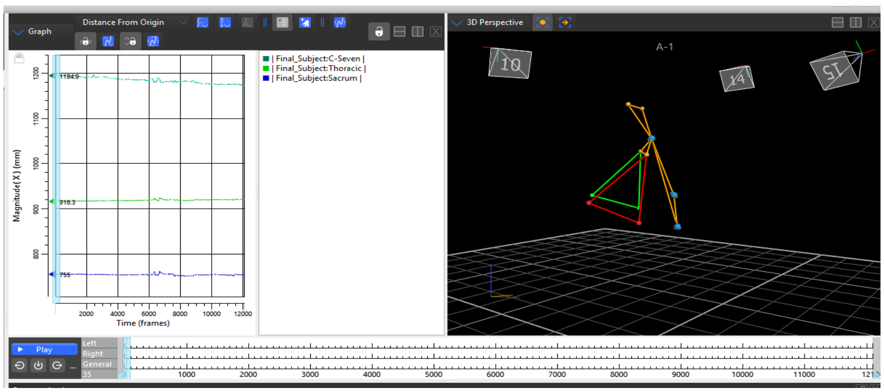

Fig. 22. Angle Between C-7, T-10, and Sacrum = 14°.

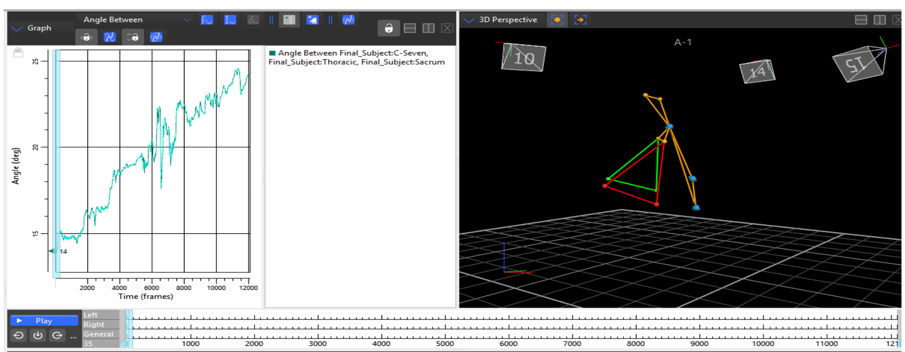

Fig. 23. Distance Between C-7 and Sacrum = 504 mm.

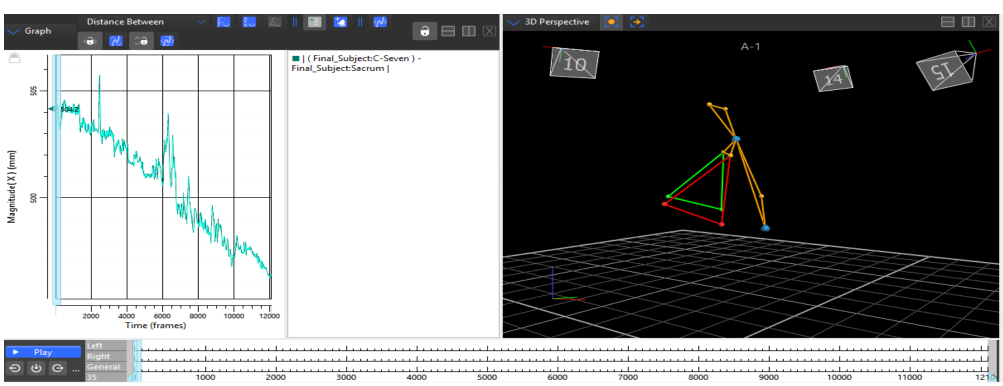

Fig. 24. Distance Between XYZ coordinates of C-7 and Sacrum.

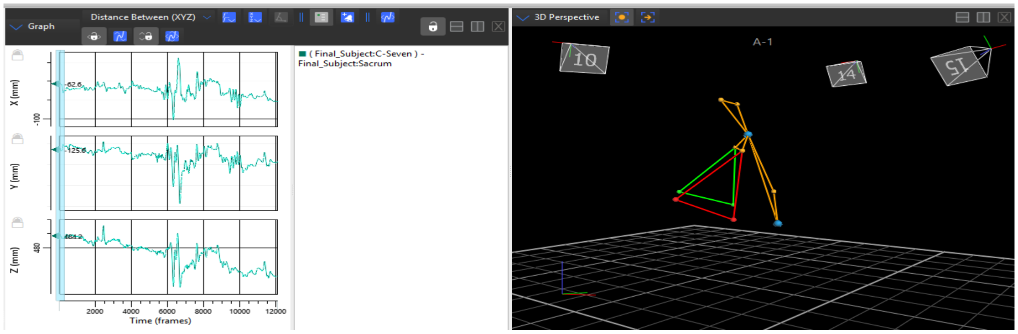

Fig. 25. Distance Between Shoulder and Wrist = 348 mm.

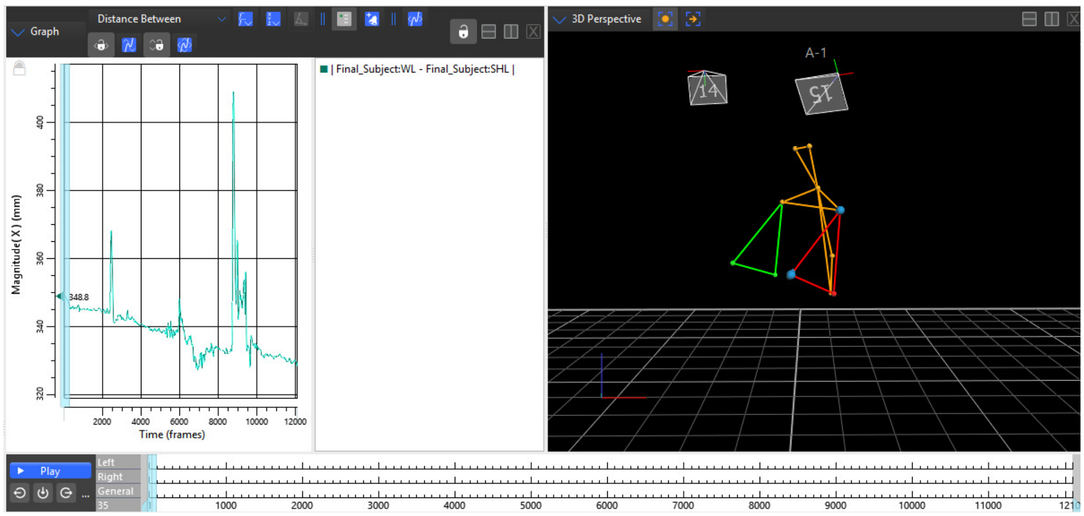

Fig. 26. Posture A-2.

Comparative Analysis of three Experimental Studies: The eye strain was only observed in the mobile phone study while no subject showed any sign of eye strain from the desktop study. The reason is that the desktop screen was farther away from the subject's eyes as compared to the mobile screen.

In the same way the Mobile study showed signs of headache while there were very minimum signs of headache in the desktop study. This is due to the neck strain as well as the eye strain which results in headache of the subject.

The desktop study shows that almost all the postures cause lower back pain. This is because the extra anterior curve of the lumbar region in the desktop tasks. This is visible in the VICON study of the desktop tasks.

The arms and shoulders are affected in the mobile phone study. The desktop study shows no such strain on the arms and shoulders of the subject. This is due to the weight of the mobile phone which the subjects lifted for 20 minutes causing stress on the arms and shoulders.

The upper back is affected in the mobile studies more than the desktop study. This is due to the more outward curve of the spine in the mobile phone study. This is clearly visible in the VICON Study.

The physical demand measured by the NASA-TLX in experiment 1 shows that the normal and upright postures are less physically demanding (near 40%), while the reclines posture shows high physical demand (near 70%). On the contrary the mobile tasks show that the normal and upright postures are more physically demanding (near 80%) as compared to the reclined posture (50%).

The performance was better at the mobile task as compared to the desktop task while playing the same game of Solitaire. This is due to less movement required to interface with the touch screen mobile phone as compared to using a mouse at the desktop.

There is high level of frustration in the mobile tasks because it has high physical demand, high fatigue level as well as a lot of strain on the arms, shoulders and the upper back. The frustration on the desktop is less as compared to the mobile phone.

The subject has to put more efforts at elbow in the desktop task as compare to above elbow indicated by the NASA-TLX graph.

III. CONCLUSION

This research work helped us in identifying the correct sitting posture while performing the sedentary tasks on mobile phone and computer desktop. The posture that can cause the least amount of pain and discomfort in the upper body while performing the sedentary task on computer desktop is the upright position of the vertebral column at elbow joint. While performing the mobile task, the position that caused the least amount of pain and discomfort in the upper body was the reclined position of vertebral column above elbow.

IV. FUTURE SCOPE

Risk related to use to upcoming technologies may increase in form of musculoskeletal disorders resulting in affecting the quality of working life. More concentration is needed in improving the working environments using ergonomics tools in order to enhance the safety.

This study may help the companies and researchers to carry out further relevant research.

Conflict of Interest: This is to certify that research with title "*postural analysis of sedentary activities using ergonomics methods and VICON motion capture system*" is being attested by authors that they have no conflict of interests, regarding financial concerns and other kind of related disagreements with any organization, institutes, research labs and educational grants.

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