SUBJECTIVE ASSESMENT TO DETERMINE AN IMPROVED HAND ARM POSTURE OF OPERATOR DURING HAND DRILLING

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By

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ABSTRACT

Use of Powered hand tools have the potential to create reaction forces that may be related with upper extremity musculoskeletal disorders. In the present work the aim of the study is to compare elbow angle with subjective rating to improve the hand-arm posture during hand drilling operation. Eleven male and four female participants operated hand drill at three locations: overhead level, eye level and chest level in horizontal position. The corresponding subjective responses were collected to predict most comfortable posture for drilling. The results indicate that most comfortable posture for drilling is the eye level and chest level, while overhead level is found to be uncomfortable .

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CHAPTER 1

1. Introduction

1.1 Background of the work

Work-related Musculoskeletal disorders (WMSDs) are principal causes of work-related disabilities and loss of output. In industrialized nations MSDs are frequently allied with revelation to work-related physical threat factors such as force-ful efforts, extremely monotonous motions, continued stationary postures, difficult postures and muscle exhaustion. Absence costs cure, and reimbursement costs are frequently the leading focus in financial ergonomics pronouncement creation around MSD interventions. Kumar and Kumar (2008) initiate that where jobs were bodily challenging and little ergonomics interferences were in area, operators were not capable to complete tasks in the allocated time because of pain and discomfort. Several work-related physical factors have been recognised as the major source of increasing the risks of musculoskeletal discomfort or pain between workers.

The use of powered hand tools is related through several cumulative trauma disorders (CTDs) of the upper extreme joint of body; specifically those of the hand and wrist (Chaffin et al., 2006). Nevertheless, hand tool use may also produce pain in the proximal areas of the upper extremity .

It is significant to know that operator of hand tools frequently express comfort and discomfort in the field of working environments and powered hand tools. The significant issue in ergonomics is to recognise important issues of comfort and discomfort in order to improve working situations and hand tools to diminution the work related musculoskeletal disorder.

The persistence of the present study was to investigation comfort-discomfort posture of hand for intermittent iso-metric shoulder, arm and hand exertion during drilling operation, at various position overhead level, eye level and chest height level.

1.2 Objectives

- To perform subjective evaluation of an operator’s hand-arm posture during powered hand drilling.
- To propose range of angles of elbow joints for comfortable posture during hand drilling operation.

1.3 Methedology

- Fifteen healthy adults participated in this study .
- On fixture three different position overhead level, eye level and chest height level is marked for drilling.
- Subjective analysis is carried out for this study.
- The 3D motion capture camera is used for capturing the posture of hand-arm.
- Standard approach is follow for placing marker on hand-arm and wrist joint.
- The value of elbow joint angle is collected by 3D motion capture camera.
- Subjective rating is collected simultaneously during drilling.
- Subjective rating is compared with elbow joint angle to found out comfortable posture.

CHAPTER 2

2. Literature review

2.1 Overview

In the area of postural analysis various reseach had been done. significant reseach are are tabularised in the table 2.1. further work is categorized as per various arrangements of method used. Major methods deliberated are subjective rating, Electromyo graphy(EMG),CAD modelling,strain gauge,hand dynamometer

2.2 Major works done so far on hand-arm posture analysis

Table 2.1:Key works done in the field of postural analysis

Sl. No.	Title	Author	Source	Equipment / Software used	Remark
1	Comparison of comfort, discomfort, and continuum ratings of force levels and hand regions during gripping exertions	Yong-Ku Kong	Applied Ergonomics	Multi-finger force measureme nt, SolidWorks 2008, 3D Printer, LABVIEW	Evaluate discomfort and comfort of hand tool to analyse the affect on palm and finger.
2	Handle displacement and operator responses to pneumatic nutrunner torque buildup	Jia-Hua Lin	Applied Ergonomics	Pneumatic nutrunners	Investigated the responses of operator while using powered hand tools and effects impulsive reaction forces for the upper extremity musculoskeletal disorders .
3	Spatial and temporal postural analysis: a developmental study in healthy children	Nathalie Gouleme	Int. J. Devl Neuroscience	Multitest Equilibre	Investigate the development of postural control in healthy children.

4	Effects of handle orientation and between-handle distance on bi-manual isometric push strength	Jia-Hua Lin	Applied Ergonomics	Isokinetic muscle testing apparatus	Investigated the effects of different condition like handle revolution and tilt of operator manual push ability For hand-handle interface design
5	Multi-objective optimisation method for posture prediction and analysis With consideration of fatigue effect and its application case	Liang Ma	Computers & Industrial Engineering	CATIA	Preposed a novel method to predict and analysis the posture of operator under fatigue and non- fatigue condition
6	Predicting subjective perceptions of powered tool torque reactions	Jia-Hua Lin	Applied Ergonomics	Pneumatic nut runners	Analyse the factors associated with the work place, grip force and tool handle movement with the help of subjective ratings .
7	Variability and misclassification of worker estimated hand force	A.M. Dale	Applied Ergonomics	Hydraulic Hand Dynamo-meter	Estimate hand strength of worker to verify misclassification of hand force using direct measurement of the forces.

2.3 Major work done using EMG

Rebecca L et al., Proposed work in posture analysis of the upper limb with hand drilling task for the evaluation of muscle activation using EMG.

Abid Ali Khan et al., Studied the mutual effects of forearm rotation, radial eccentricity and flexion on a discomfort scale.

Chih-Hung Chang et al., investigated Hand-arm stress with the help of force applied on the finger ,using EMG and hand transmitted pilsation .

Mohd Farooq et al., Investigated the effects of shoulder flexion/extension combined with an elbow flexion angle on discomfort score for repetitive gripping task. It was found that 45˚ shoulder extension combined with 45˚elbow flexion angle was the most discomforting posture for repetitive gripping task.

Yong-Ku Kong et al., Analyze the effects of operator's gender ,diameter of handle and direction of handle (horizontal and vertical) on the supposed comfort, torque and total force applied on finger with respect to activity of muscle for the effectiveness of flexor and extensor in a maximum torque task .

Larry Fennigkoh et al., Developed a power hand tool simulator for experimenting the effort of wrist reaction to the toque applied and along with this measure the griping force directly.

2.4 Major work done using Strain gauge

Gunnar Bj. Oring et al., Investigate the effect of different operating conditions on surface pressure of hand while performing drilling tasks. It is found that total pressure level augmented with increasing feed force .

Chih-Hong Chang et al., Analyze the magnitude and ratios of the contribution of triggering force by the finger while operating electrically-powered tools.

Jia-Hua Lin et al., Develop a model of human operator for a single degree of freedom dynamic mechanical system to predict the reaction of impulsive reaction forces produced by power hand tools.

Jae Young Kim., Investigate the specification of handle design for to find out the controller area in a manual control double tasks to improve the hand grip .

2.5 Major work done in design of power hand tool

Yung-Hui Lee et al. said the isometric and long term contraction including tools which can support the arms and tripping a trigger can be seen when tools having electric power are operated. The objective of their study was to focus on the analysis of the rations and magnitude of contribution of triggering force by some fingers and also analyse the holding force contribution for selected fingers. They analysed the contribution of forces according to grip span and centre mass of the tool methodology. The study appreciate the idea related to the index finger, which says when the task is performed forcefully for tripping a trigger then the index finger should not be used as the digit only. When the flexion strength of the isometric finger is high then the triggering force will be double from the middle finger.

Gregor Harih et al. said that the hand tools are still used in the most of manual work. So a correct design is needed to prevent the problems like musculoskeletal disorders, upper-extremity, hand arm vibration syndrome etc. When they focused on the ergonomics behind the design of the tool they found the important part for the tool is tool handle. In most of the studied a cylindrical handle design is considered and guidelines are given for use and the mathematical model also introduced. The aim of the study was to develop an optimize model for the handle design.

Seoungyeon et al. said the better understanding of the muscle activities and handle kinematics is required for the tool design and development. Target torque and the joint hardness are the considerable parameters for the study of the reaction force. Apart from this the orientation and distance of operator from the tool are the considerable parameters for the workstation. They studied the various parameters like handle velocity and displacement, power used for working, EMG activities for the arm muscles and introduced the relationship among them.

Gunnar et al.introduced the parameters which influence the pressure on the hand during the performing the drilling operation by an ordinary drilling machine. They measured pressure on the hand by considering 16 reference points on the hand. They conducted the test in different handle designs and finally conclude that the force on index finger and on the thumb is highest in all designs. When handle size increased, the pressure on the hand will also increase.

2.6 Major work done in operating difficulties of powered hand tools

Gregor Harih et al. found that the in large area of work, the operations is performing manually and they required powered tool for the task. In order to brighten user performance and lower the risk of disorder related the muscle activities several studied have been done till the date. They focused on the shape and size of the hand tool to reduce the trauma and disorders. In this study the authors developed the finite element analysis for grasping the tool handle and simulate human fingertip.

Yuh-Chuan et al. Researched on the “Psychophysical evaluation of diameter and angle of container handles” they focused to develop an efficient method to assess the optimal handle angle and diameter in the perception of heaviness. On another hand they evaluate power grip of one hand on different designs of handles.

A. Naddeo et al. said for the designing in the Humane Machine Interface (HMI), huge parameters are studied in order to introduce high level of safety in work and develop an user friendly design to avoid health related problems.

CHAPTER 3

3. Subjective assessment during Hand drilling

3.1 Overview

For subjective analysis a experimental setup is developed which consist of 3D motion capture camera from Qulisys, Qualisys track manager, Hand drilling machine from BOSCH and a wall mounting fixture is designed which is made of wooden material is used.

3.2 Experimental setup

Fifteen healthy person age between 23 and 28 years , without any existing musculoskeletal disorder participated in the study after giving the informed consent. There were four female and eleven male participants. The average age, body mass, and height for the female candidate was 23.5 years, 47.75 kg, and 163.85 cm respectively and for the males 26.8 years, 65.9 kg, and 174.56 cm, respectively.

For the analysis of posture of the operator throughout the hand drilling operation, A fixture is used which enclose vertical position. The fixture having four holes at the four corners, and this hole is provided to sit on the four screws coming toward the wall for screwing purpose.

A task of hand drilling in three different position is overhead leve ,eye level and chest height level is given to each participant. In the present study repetitive drilling task was considered for investigation. The task was captured using 3D motion capture camera.

3D motion capture camera is calibrated to capture the experimental task, and to record discomfort score set of questionnaire asked and noted down in tabular form .

The 3D motion capture camera is placed in such way that postion of hand-arm is clearly visible.The operation is explained to the candidates . Which consist of drilling a hole with all safety precaution .Then ask them to perform drilling operation in three different postion which is overhed level ,eye level and chest height level. While perfoming drilling operations simultaneously subjective rating is collected by asking sets of questionnaires. The motion of drilling is captured from the camera.

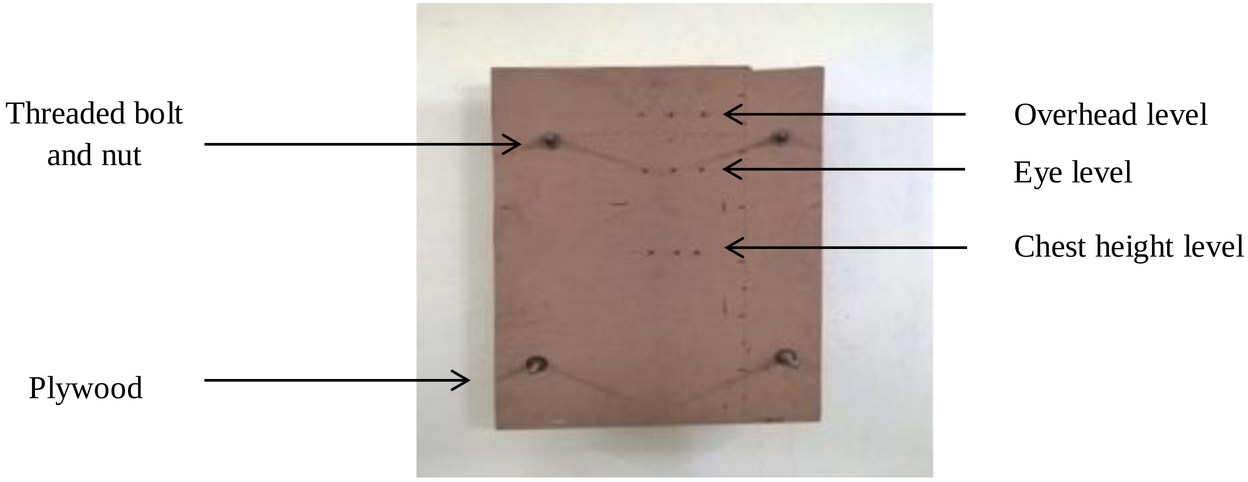

Fig.3.1 Wall mounting fixture

Fixture used here is mounted on the wall ,it consisting of four threaded screw in four corner . The work piece used is a plywood which is sit on threaded bolt coming toward the wall and screwed in the fixture with the help of nut.

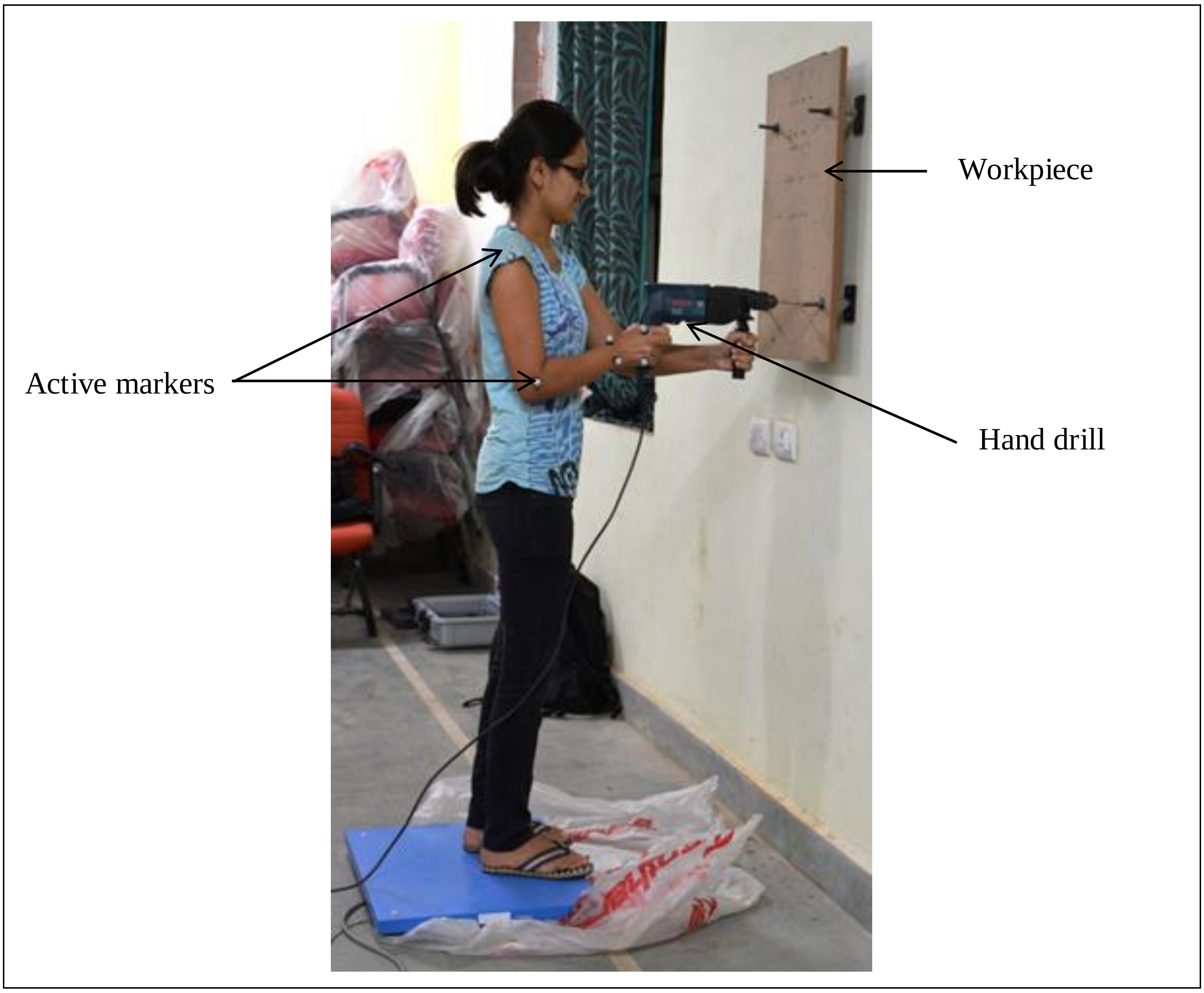

Fig.3.2 Experimental setup

3.3 Performing drilling operation

Before starting the experiment the participants were informed about the procedure and the possible risks involved in the experiment and the consents of all the participants were taken. The participants were advised to quit the experimentation at any stage if they felt any type of unbearable pain or any other problem. The experimental task was explained to the participants. The participants who performed the trial run were made aware about the cycle time for exertion duration and rest durations. The trials for gripping at given postures were also taken for all the participants before starting the experiment.

(a) (b) (c)

Figure 3.3 Drilling at (a)Overhead level, (b) Eye level and (c) Chest level

(a) (b) (c)

Figure 3.4 Drilling at (a)Overhead level, (b) Eye level and (c) Chest level

(a) (b) (c)

Figure 3.5 Drilling at (a)Overhead level, (b) Eye level and (c) Chest level

(a) (b) (c)

Figure 3.6 Drilling at (a)Overhead level, (b) Eye level and (c) Chest level

(a) (b) (c)

Figure 3.7 Drilling at (a)Overhead level, (b) Eye level and (c) Chest level

(a) (b) (c)

Figure 3.8 Drilling at (a)Overhead level, (b) Eye level and (c) Chest level

3.4 Subjective evaluation during hand drilling

Subjective analysis is carried out during hand drilling. The set of questionnaire were asked from all the fifteen participants in each postion and the rating is simultaneously noted down. The set of questionnaire is in tabular form which is as follows-

At overhead level	Totally disagree	Disagree somewhat	Cannot say	Agree somewhat	Totally Agree
Does Posture is uncomfortable for drilling?					
Dows drilling is difficult to Perform?					
Does drilling Causes peak pressure in hand?					
Do you feel numbness?					
Does your muscles is getting cramped?					
Does you feel Stiff(Difficult to bend or fold)?					
Do you feel Recurrent pain					
Do you feel Swelling?					

Table 3.1 Questionnaire for overhead level

At eye level	Totally disagree	Disagree Somewhat	Cannot say	Agree somewhat	Totally Agree
Does Posture is uncomfortable for drilling?					
Dows drilling is difficult to Perform?					
Does drilling Causes peak pressure in hand?					
Do you feel numbness?					
Does your muscles is getting cramped?					
Do you feel Stiff (Difficult to bend or fold)?					
Do you feel Recurrent pain					
Do you feel Swelling?					

Table 3.2 Questionnaire for eye level

At chest level	Totally Disagree	Disagree somewhat	Cannot say	Agree somewhat	Totally Agree
Does Posture is uncomfortable for drilling?					
Dows drilling is difficult to Perform?					
Does drilling Causes peak pressure in hand?					
Do you feel numbness?					
Does your muscles is getting cramped?					
Do you feel Stiff (Difficult to bend or fold)?					
Do you feel Recurrent pain					
Do you feel Swelling?					

Table 3.3 Questionnaire for chest height level

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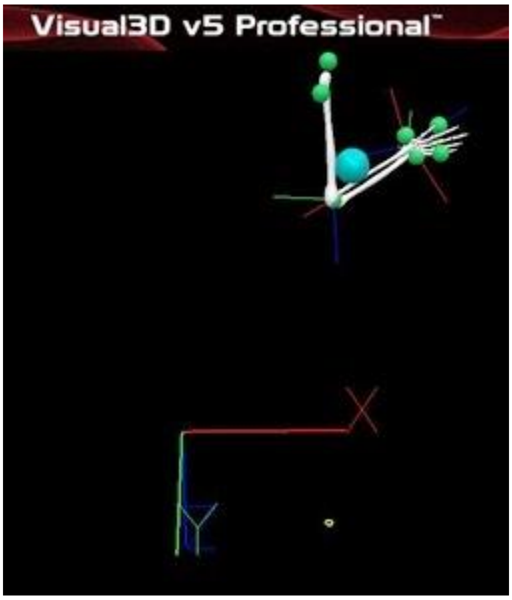
Response	Rating
Totally Disagree	1
Disagree somewhat	2
Cannot say	3
Agree somewhat	4
Totally Agree	5

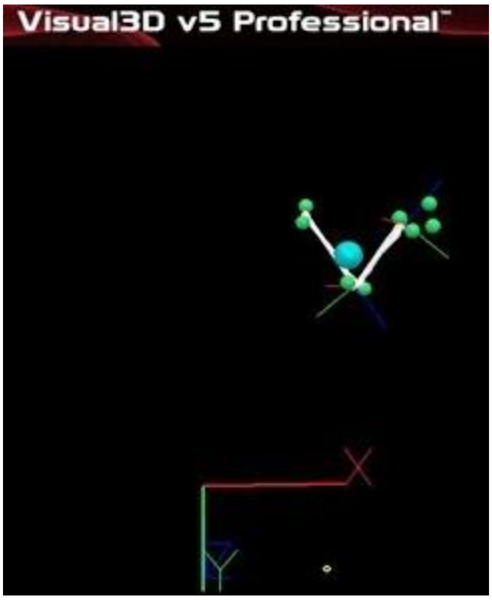
Table 3.4 Subjective response and rating

For the response of discomfort the subjective rating 1 to 5 is used, where 1 stand for totally disagree, 2 stand for disagree somewhat, 3 stand for cannot say, 4 stand for agree somewhat and 5 stand for totally agree.

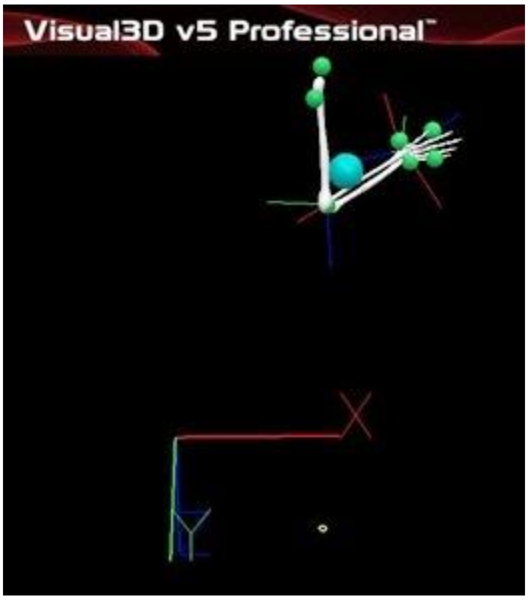
Bone model of all fifteen participant's hand-arm is obtain by VISUAL 3D after performing the operation .Which give the angle of the elbow joint of each postion .



(a)



(b)



(c)

Fig.3.9 Bone model of hand while Drilling at (a)Overhead level, (b) Eye level and (c) Chest level

3.5 Elbow angle recorded at different position

These are the following angles are obtained from the experiment at three different levels

For female candidate

Sl.NO	Overhead level (in deg)
1	81.68
2	82.10
3	82.33
4	85.60

Table 3.5 Angle of elbow for female candidate in overhead level

Sl.NO	Eye level (in deg)
1	75.46
2	60.12
3	53.82
4	73.05

Table 3.6 Angle of elbow for female candidate in eye level

Sl.NO	Chest level (in deg)
1	56.05
2	54.89
3	53.20
4	72.54

Table 3.7 Angle of elbow for female candidate in chest height level

For male candidate

Sl.NO	Overhead level (in deg)
1	80.35
2	84.50
3	75.80
4	82.78
5	74.16
6	82.43
7	76.82
8	90.30
9	77.10
10	93.70
11	88.10

Table 3.8 Angle of elbow for male candidate in overhead level

Sl.NO	**Eye level (in deg)**
1	76.24
2	51.25
3	77.52
4	72.74
5	53.20
6	73.00
7	68.50
8	79.70
9	77.30
10	90.05
11	89.00

Table 3.9 Angle of elbow for female candidate in eye level

Sl.NO	Chest level (in deg)
1	71.36
2	52.51
3	62.25
4	65.20
5	60.03
6	73.85
7	65.30
8	84.17
9	70.30
10	96.60
11	79.10

Table 3.10 Angle of elbow for female candidate in chest height level

3.6 Comfort Analysis

The angle obtained is compared with corresponding subjective rating of each position-

For female-

Sl.No.	Elbow angle for overhead level(deg)	Subjective rating for overhead (1-5)
1	81.68	3.5
2	82.10	4.2
3	82.33	4.0
4	85.60	3.6
Mean	**82.92**	**3.8**

Table 3.11 Elbow angle at overhead with subjective rating

Sl.No.	Elbow angle eye level (deg)	Subjective rating mean eye level (1-5)
1	75.46	2.4
2	60.12	2.5
3	53.82	2.25
4	73.05	2.2
Mean	**65.62**	**2.34**

Table 3.12 Elbow angle at eye level with subjective rating

Sl.No.	Elbow angle chest level (deg)	Subjective rating mean chest level (1-5)
1	56.05	1.2
2	54.89	1.4
3	53.20	1.2
4	72.54	1.5
Mean	**59.17**	**1.33**

Table 3.13 Elbow angle at chest level with subjective rating

The mean elbow angle for overhead position for four female participants is 82.92˚, mean subjective discomfort rating for corresponding overhead level is 3.8.The mean elbow angle for eye level position for four female participants is 65.62˚; mean subjective discomfort rating for eye level is 2.34.The mean elbow angle for chest level position for four female participants is 59.17˚; mean subjective discomfort rating for chest height level is 1.33.As the discomfort rating for chest level is least when compared with the other two positions it is the most comfortable position for drilling .The average elbow angle for four female participants for chest level position is 59.17˚.

For male candidate

Sl.No.	Elbow angle overhead level(deg)	Subjective rating overhead (1-5)
1	80.35	4.2
2	84.50	4.5
3	75.80	4.2
4	82.78	4.7
5	74.16	4.4
6	82.43	4
7	76.82	4.3
8	90.30	4.4
9	77.10	4.5
10	93.70	4.6
11	88.10	4.4
Mean	**82.36**	**4.3**

Table 3.14 Elbow angle at overhead level with subjective rating

Sl.No.	Elbow angle at eye level(deg)	Subjective rating for eye level (1-5)
1	76.24	2.2
2	51.25	2.3
3	77.52	2.5
4	72.74	2.4
5	53.20	2.2
6	73.00	2.1
7	68.50	2.2
8	79.70	2.3
9	77.30	2.2
10	90.05	2.7
11	89.00	2.3
Mean	**73.5**	**2.31**

Table 3.15 Elbow angle at eye level with subjective rating

Sl.No.	Elbow angle chest level(deg)	Subjective rating mean chest (1-5)
1	71.36	1.1
2	52.51	1.1
3	62.25	1.4
4	65.20	1.1
5	60.03	1.2
6	73.85	1
7	65.30	1.3
8	84.17	1
9	70.30	1.2
10	96.60	1
11	79.10	1.1
Mean	**70.97**	**1.2**

Table 3.16 Elbow angle at chest level with subjective rating

The mean elbow angle for overhead position for eleven male participants is 82.36˚, subjective discomfort rating for overhead level is 4.3.The mean elbow angle for eye level position for eleven male participants is 73.50˚; subjective discomfort rating for eye level is 2.31.The mean elbow angle for chest level position for eleven male participants is 70.97˚; subjective discomfort rating for chest height level is 1.2

As the discomfort rating for chest level is least when compared with the other two positions it is the most comfortable position for drilling .The eye level is the second most comfortable position for drilling and overhead level is the most discomfortable position.The average elbow angle for eleven male participants for chest level position is 70.97˚.

The graph below represent relation between three different posture and subjective comfort rating

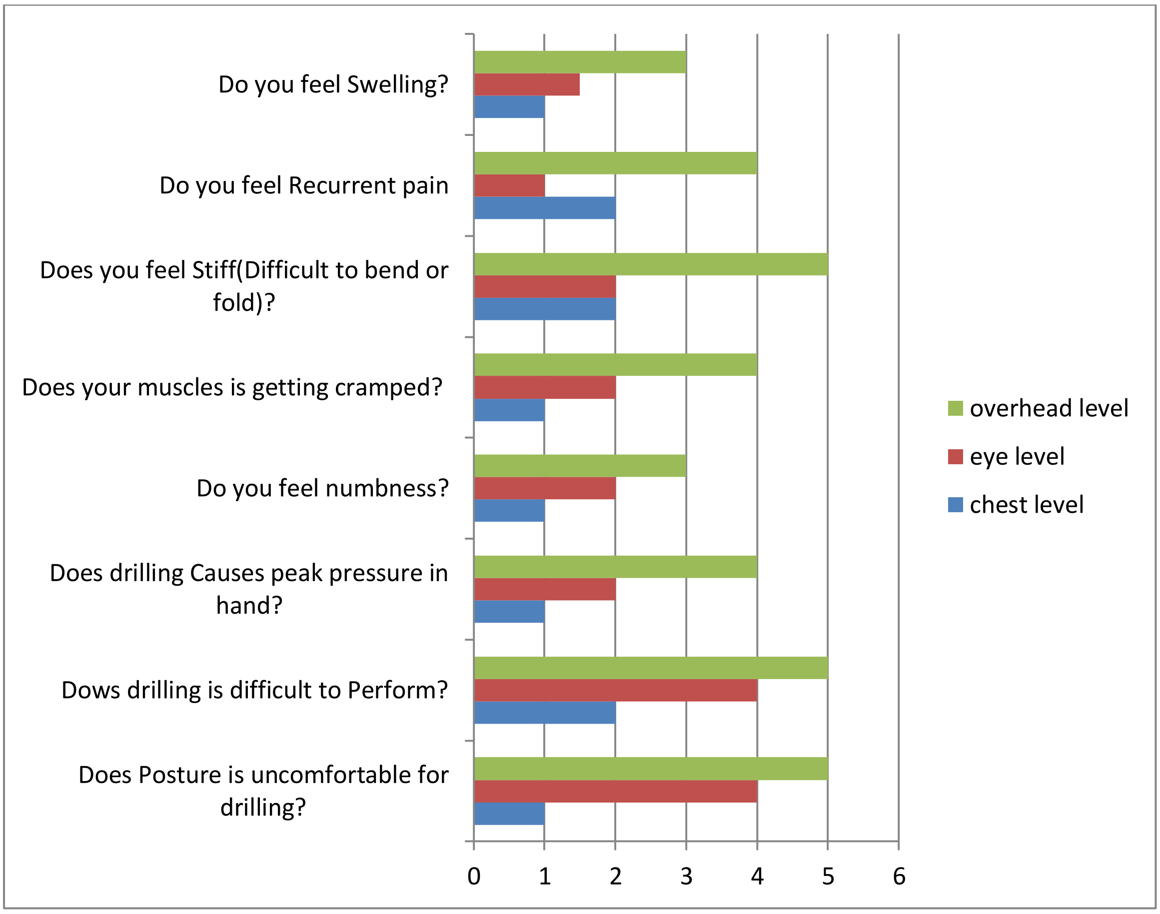


Fig. 3.10. Overall subjective discomfort -ratings.

Fig. 3.10 Depict the relation between three different postures and subjective comfort rating in which first level is overhead ,second level is eye and last one is chest level.

From the graph it is concluded that the most comfortable posture for drilling is at chest level and then eye level. It is also concluded that the most uncomfortable for drlling is at the overhead level .Subjective rating is given during the hand drilling operation .For the rating scale between 1-5 is used,where 1 is given for comfortable posture and 5 is given for most uncomfortable posture .

3.7 Range of elbow angle for comfortable position

For female

Position	**Comfortable range of elbow angle (deg)**
Eye level	53.82 to 75.46
Chest height level	53.20 to 72.54

Table 3.17 Range of comfortable angle for female

For male

Position	**Comfortable range of elbow angle (deg)**
Eye level	51.25 to 90.05
Chest height level	52.51 to 96.60

Table 3.18 Range of comfortable angle for male

For female participants the range of comfortable elbow angle at eye level is 53.82 to 75.46, and the range of comfortable elbow angle at the chest height level is 53.20 to 72.54.

For male participants the range of comfortable elbow angle at eye level is 51.25 to 90.05, and the range of comfortable elbow angle at the chest height level is 52.51 to 96.60.

CHAPTER 4

4. Conclusions and Future Scopes

4.1 Average subjective rating of position

	Overhead level	**Eye level**	**Chest height level**
Female	3.8	2.34	1.33
Male	4.3	2.31	1.2

Table 4.1 Average subjective rating for male and female

It is concluded that for drilling operation the chest and eye level for both male and female candidates was found in the most comfortable position as per the rating. Which can help to minimize the musculoskeletal disorder associated with hand ,arm and shoulder joints.

Where as at the overhead level is found to be most uncomfortable for drilling operations. So it should be avoided to drilling in the overhead level because it can cause musculoskeletal disorder in the hand, arm and shoulder.

The average elbow angle for four female participants for chest level position is 59.17˚ and eye level is 65.62˚ having mean subjective rating 1.33 and 2.34 respectively. As the discomfort rating for chest level is least when compared with the other positions it is the most comfortable position for the female participants.

The average elbow angle for eleven male participants for chest level position is 70.97˚and eye level is 73.5˚ having mean subjective rating 1.2 and 2.31 respectively. As the discomfort rating for chest level is least when compared with the other two positions it is the most comfortable position for the male participants. The eye level is the second most comfortable position for drilling.

The mean elbow angle for overhead position for four female participants is 82.92˚ having mean subjective rating 3.8 and the mean elbow angle for overhead position for eleven male participants is 82.36˚ having mean subjective rating 4.3. As the discomfort rating for overhead level is highest when compared with the other two positions for both male and female participants it found to be the most uncomfortable position for drilling.

The range of comfortable elbow angle for female participants at eye level is 53.82 to 75.46, and the range of comfortable elbow angle at the chest height level is 53.20 to 72.54.

The range of comfortable elbow angle for male participants at eye level is 51.25 to 90.05, and the range of comfortable elbow angle at the chest height level is 52.51 to 96.60.

The overhead level is found to be most uncomfortable position; the range of elbow angle for overhead level is 81.98 to 85.60 for female participants and 74.16 to 93.70 for male participants

In the future work the can experiment can be carried out for more than three drilling position.

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