Influence On Physical Work While Working With Segmental Vibration Inducing Hand Operated Power Tools

Sudhir Vinayakrao. Deshmukh [#1], Suresh Gulabrao Patil [*2]
[#] Mechanical Engineering Department,
Government Polytechnic,
Amravati (M S.) India-444603
sudhirvdeshmukh27@rediff.com
* IBSS College of Engineering,
Ghatkhed, University Mardi Road,
Amravati (M.S.) India-444602
sgpatil33@rediffmail.com

Abstract

Study evaluates and assesses the work done by vibrating equipments. It includes the assessment of influence of various independent variables associated with hand tools, operators, work & environmental factors on various dependent variables.

Three tools selected for study include Rock drill (Dry type) (Tool-1), Concrete breaker (Tool-2), Hand grinder (Tool-3). The impact of vibration exposure on health of operators is assessed by the help of survey.

It is found that the human energy expenditure is more in the subjects having low grip strength whereas it is less in the subjects of more grip strength. The subjects having more grip strength show less change in touch sensation. The human energy expenditure of subjects of hand grinder is significantly less than the subjects of rock drill and concrete breaker. The presence of hand arm vibration Syndrome (HAVS) in the subjects under heavy work, like rock drill and concrete breaker found very high.

Keywords: Segmental vibration, Grip strength, Human energy expenditure, Hand arm vibration syndrome, Touch sensation

I. INTRODUCTION

Power driven hand tools are used in variety of industries (e.g. agricultural, construction, logging and manufacturing). These tools are also used in dental and medical work. During the operation with power tools the workers directly come in contact with it. Due to this physical contact, the vibration induced by these tools passed in the body of worker through palm and finger this type of vibration influencing part body of worker is called as segmental vibration [1], [2], [3]

The most important sources of hand arm vibration (HAV) are pneumatic tools (air compressed and electrical), for example, grinders, sanders, drills, fettling tools, impact wrenches, jack hammers, and riveting guns. Users of chainsaws, brush saws, hedge cutters, and grass trimmers are also at risk [4].

Hand-arm vibration syndrome is a condition associated with the use of hand-held vibrating tools. Vibration can cause changes in tendons, muscles, bones and joints as well as affecting nerves. Collectively, these effects are known as Hand-Arm Vibration Syndrome (HAVS) [5]. HAVS is also called as Raynaud's phenomenon of occupational origin, vibration-induced white finger (VWF), dead finger, traumatic vasospastic disease and vibration syndrome [6]. HAVS is a complex syndrome caused by the constriction of blood vessels in the fingers, and involves circulatory, sensory, motor and musculoskeletal disturbances [6].

Some of the presenting complaints are attacks of whitening (blanching) of one or more fingers when exposed to cold often associated with pain, tingling and numbness in the affected finger, loss of sensation, tactile discrimination & manipulative dexterity, pain and stiffness in the hands and wrists, loss of grip strength, and bone cysts in the fingers & wrists [5]. The development of HAVS is gradual and increases in severity with time, often taking a few months to several years for the symptoms of HAVS to be noticeable depending on the vibration exposure dose [5]. Histological changes in blood vessel walls and nervous tissues are irreversible, resulting in the long-term circulatory and nervous dysfunction [7].

At low frequency the perception is transmitted to the arm therefore the perception is high. The perception greatly decreases with frequency with the reduction of vibration transmissibility throughout the hand arm system [8].

When the organs are subjected to vibration at their specific resonance frequencies, the energy transfer from the source to the exposed part will be maximum and adverse effects will be more [9].

The existence of sensory and vascular components in HAVS lead to the adoption of the Stockholm grading based on the subjective history supported by the results of clinical tests [4]. Muscle weakness, particularly affecting the long finger flexors and affecting grip strength, may occur in association with long-term vibration exposure from hand-held tools [10].

Progression through the stages is most likely with all components if there is no reduction in vibration exposure. However, there is a good deal of physiological evidence that while the dose response relationships are fairly linear, the actual pathophysiological response has something of an all or none quality [4].

The international standard for assessing exposure to hand- transmitted vibration, ISO 5349-1 (2001) indicates that hand coupling forces influence the vibration energy transmitted to the hand [11].

In most of the research work, done previously either survey or experimentation is done, there is very little research work on segmental vibration where both experimentation as well as survey is conducted.

The objective of the study is to evaluate and assess the work done by vibrating equipments. It includes the assessment of influence of type of hand tools and associated variables. It is also well known that the amount of vibration actually transmitted to the hand–arm system is dependent on the coupling forces at the hand–handle interface [11]. Any vibration-induced injuries or disorders must be associated with vibration actually transmitted to the hand- arm system. Therefore, it is important to understand the transmission of vibration from a tool handle to the hands in interaction with the tool. [12]

How hard a person grips a tool, affects the amount of energy entering the hands, hence hand grip force is another important factor in the exposure assessment. The relationship in between grip strength to human energy expenditure, along with changes in touch sensation, if any is discussed.

The impact of vibration exposure on health of worker is assessed by the help of survey. The questionnaire was framed to understand various Hand arm vibration syndrome (HAVS). It is again classified as per Stockholm workshop scale.

II. MATERIALS AND METHODS

A. *Subjects*

Seven subjects each for three occupations were selected (Rock drilling, Concrete breaking and Hand grinding) for the purpose of structured interview. The purpose was to assess the various symptoms associated with hand arm vibration syndrome (HAVS). Out of these seven, three each were selected randomly for the purpose of experimentation. The anthropometric data of subject is shown in table I. The subjects labeled as A1 to A21 were interviewed for HAVS, touch sensation and investigation of various related consequences. Subject A1 to A9 were used for experimentation along with survey.

B. *Type of hand held power tools:*

The tools those were selected for study include

1) Rock drill (Dry type) (Tool-1)
2) Concrete breaker (Tool-2)
3) Hand grinder (Tool-3)

The specifications of these tools are shown in table II, III, IV respectively.

C. *Questionnaire symptom survey*

The questionnaire is circulated among the subjects to access the vibration syndrome. The questionnaire is made to assess preliminary physical disorders and to classify the hand arm vibration syndrome (HAVS) according to Stockholm workshop scale [13],[9], [16].

Preliminary questions are asked pertaining to the neurological and vascular disorder of fingers and hand, The questions like " Do your fingers suffer from whiteness?", "Do your fingers get white in cold?" , etc. are asked to access vascular symptoms. To identify neurological symptoms, the questions are asked, "Do you have numbness in finger?", and "Do you find difficulty in handling small objects?" Similarly questions to assess musculoskeletal symptoms are also asked to subjects. The questionnaire is designed in such a way that symptoms can be classified on the basis of Stockholm workshop scale. For example, the questions about white fingers are based on the Stockholm scale for the classification of cold-induced Raynaud's phenomenon [14], [6], [16], [15] ,[17], [4]. A positive answer to the question "Do you suffer from infrequent attacks of whitening of the fingers?" is understood as demonstrating the presence of symptoms of vibration induced white fingers (VWF). The workers are also asked to designate the area where they had symptoms of white fingers on the sketch of fingers & palm. The number and type of affected phalanges on each hand, resultant from the drawing, are used to define three stages of symptoms of white fingers. When no attack on any finger and palm are recognized then it is considered as stage 0. When only the tips of one or more fingers are infected it is classified as stage1. When tip distal and/or middle phalanges of one or more fingers are infected, it is put in stage 2 class. When the tips, distal and/or middle phalanges of one or more fingers and 12 or more phases are infected, it is classified as stage 3.When a severe attacks with deteriorate skin changes in the finger tips are noticed, it is termed as stage 4 .

Data on the presence of numbness are derived by the questions like: “Do you suffer from occasional numbness in the fingers?” Subjects who gave a positive response and who had no other complaints are classified as stage 1SN. Those who showed notice of increased thresholds of perception of temperature and pain are defined as stage 2SN. If they said that they had difficulty in discovering small objects on a fat surface and experienced reduced manual agility in precision tasks, classified as stage 3SN.

D. Experimentation Procedure

Run of five minute for each tool for different three subject (morning, afternoon, evening) was carried on. Hence nine run for each tool and total twenty seven runs**.** The plan of experimentation is shown in table V

The various independent variables associated includes

1) Variables of tools (G)
2) Variables of operator (A)
3) Environmental variables (E)
4) Work sample variable (M)

The dependent variable are

· Work output
· Human energy consumed

E. Equipment and instruments

1) Heart rate monitor

This is an instrument used of the measurement of the heart rate monitor during the test the heart rate is an important indicator of the human energy consumed. The human energy consumed during the work can be estimated from the heart rate. The ‘polar’ make heart rate monitor is used for this purpose. It has following components.

i) Transmitter

It is fitted with a built in lithium cell having average life of about 25000 hours. It is made out of polyurethane and is operable in a temperature range -10 ^{0} C to 50 ^{0} C

ii) Elastic strap

The fabric material of the strap is nylon, polyester and natural rubber including a small amount of latex. The buckle is made out of polyurethane.

ii) Wrist receiver

A CR2025 battery having an average life of two years (2 hr/day, 7days/week) powers it. Operable in temperature range of -10^{0}C to 50^{0}C, attached with polyurethane wrist strap. The accuracy of this equipment is +/- 1% or +/-1 bpm, which ever is larger under steady state condition. The total working time is 9h 59 min. For less than 1hour, the display indicates mm:ss, for than 1hours the display indicates hh: mm. The minimum duration of recorded time is one minute. During the run the transmitter is positioned on the chest just below the chest muscles with elastic strap. The wrist receiver can be attached to wrist or kept at suitable position within 1-meter distance from the transmitter. (Fig. 1)

2) Calculation of Human Energy Input From Heart Beats

The human energy ‘HE” consumed by the person performing the task is measured in KJ. The human energy can be estimated by many methods. But the heart rate measurement is the simplest and most suitable in the context of this research method for estimation of the human energy. It is calculated by using scheme of the relationship between energy expenditure and heart rate. [18]

3) Hand Grip Dynamometer

Hand grip of subjects is measured by using hand grip dynamometer. The dynamometer used for this purpose is known as Lafayette or Stoelting dynamometer (Figure2). The subject to be tested holds the dynamometer in the hand to be tested, with the arm at right angles and the elbow by the side of the body. The base rest on the heel of palm, while the handle rest on middle of four fingers. The hand grip of each hand is measured and added to get aggregate hand grip it is measured in Kg.

4) Hygrometer

Hygrometer is an instrument for measuring the degree of moisture of the atmosphere. The instrument used for the measurement is shown in photograph (Figure 3)

5) Thermometer

Analog mercury thermometer is used to measure the ambient temperature during three run, it shown in photograph (Figure 4)

III RESULT & DISCUSSION

Table VI, VII, & VIII shows the relationship of grip strength with heart beats and energy consumed. Table also shows how touch sensation varies with grip strength. The effect of environmental factor is also shown on output variables like heart beats, energy consumed and touch sensation.

A. Grip strength

1) Grip Strength and Energy Expenditure

Figure 4 to 6 shows how grip strength is related with human energy expenditure for three tools. It can be observed that the human energy expenditure is more in the subjects having low grip strength whereas it is less in the subjects of more grip strength. This is revealed in all three cases i.e. rock drill, concrete breaker and hand grinder.

2) Grip Strength and Touch Sensation

Figure 7 to 9 shows how the touch sensation of subjects varies with grip strength. The subjects of less grip strength demonstrate maximum effect on touch sensation, after five minute run on respective tool. The subjects having more grip strength shows less change in touch sensation.

B. Effect of Environmental Factors

Figure 10 to 12 shows how the average heart rate varies with ambient temperature. In the afternoon, the average heart rate of subject is more whereas in morning and evening it is quite equal. This could be observed in all three tools. The humidity does not show any significant effect on the performance of subjects

C. Comparative Analysis of Three Tools

The performance of first three subjects out of seven in each batch is compared while working with three different tools. It has been observed that the human energy expenditure for rock drill (tool-1) is maximum followed by concrete breaker (tool-2) and hand grinder (tool -3), respectively.

The material on which the rock drills work was hardest amongst the material on which the other two tools worked. The work of rock drill was continuous. The subjects did not take pauses until one hole was drilled. The impact rate and stroke of rock drill was more than concrete breaker. Among the three tools, the weight and speed (rpm) of hand grinder was least. Therefore, the human energy expenditure of subjects of hand grinder was significantly less than the subjects of rock drill and concrete breaker. The performance on the hand grinder was under roof. This is another reason of less human energy expenditure. Figure 13 shows the comparisons of the human energy expenditure during the use of three different tools.

D. Presence of Hand Arm Vibration Symptoms (HAVS)

The workers were interviewed to assess the presence of hand arm vibration symptoms. Seven subjects working on each tool were asked different questions. The presence of hand arm vibration symptoms in the subjects under heavy work, like rock drill and concrete breaker found very high. It is comparatively less in case of light work like hand grinder. The Hand arm vibration was also classified according to Stockholm workshop scale. Figure 14 shows the stages of vascular symptoms among the subjects. The subjects are at stage I or at higher stage in case of rock drill and concrete breaker. The subjects of hand grinder are mostly at stage 0. No subject is identified in stage 4.

Figure 15 described how the neurological symptoms identified in subjects. Similar to vascular symptoms, it is more in rock drill and concrete breaker but less in case of hand grinder. Figure 16 to 19 shows the presence of Numbness, Blanching, Tingling, Musculoskeletal (Presence of pain stiffness) in subjects of different occupations. It is evident that HAVS shows more existence in subjects of occupations with heavy work tools.

E. Quantitative Analysis

Table IX shows the relationship between percent increases in grip strength to percent decrease in energy expenditure. Though subjects of more grip strength consume less energy, the reduction in energy expenditure is not in exact proportion to increase in grip strength. This is applicable for all three tools & for all runs.

IV. CONCLUSION

The conclusions drawn are as follows-

1) The rock drill consumes maximum human energy as compare to concrete breaker and hand grinder
2) Ambient temperature influences the performance of worker. Where as there is no significant influence of humidity, on the performance.
3) Appearance of hand arm vibration syndrome is more in occupations like rock drilling and concrete breaking while it is minimum in case of hand grinding.

4) The appearance of musculoskeletal syndrome found in large number of subjects as compared to blanching, numbness and tingling.
5) There is a relationship between grip strengths and human energy expenditure. Yet energy expenditure does not change with exact proportion as change in grip strength.
6) Influences on the touch sensation vary with grip strength.

REFERENCES

[1] Halender Martin 1981. Human factors: Ergonomic for building and construction. Jhon Willy and sons, New York.
[2] Murrel K. H. F., 1969. Ergonomics. Capman and Hall, London.
[3] Sonya H. Bylund, Lage burstrom, Anders Knutsson, 2002. A descriptive study of women injured by hand –arm vibration. Ann. Occup. hyg, 46 (3), 299-307.
[4] Peter L. Pelmear, David leong, 2000. Review of occupational standards and guidelines for hand- arm (segmental) vibration syndrome (HAVS). Appl. occup. and environ. hyg., 15(3), 291-302.
[5] B Dias & E Sampson, 2005. Hand arm vibration syndrome: health effects and mitigation. Int. Occup. Hyg. Assoc., B1-4.
[6] Colleen E Hill, Wendy J Langis, John E Petherick, Donna M Campbell, Ted Haines, Joel Andersen, Kevin K Conley, Jason White, Nancy E Lightfoot, Randy J Bissett, 2001. Assessment of Hand-Arm Vibration Syndrome in a Northern Ontario Base Metal Mine. Chronic Dis. In Can., 22, (3/4), 88-92.
[7] Shina Ymada, Hisataka Sakakibara, 1998, Prevention strategy for vibration hazards by portable power tools national forest model of comprehensive prevention system in Japan. Ind. health, 36, 143-153.
[8] P Donati, 2001.Evaluation of occupational exposures to hand-transmitted vibration: frequency weighting and exposure duration. Vibration injury network, Appendix H4A to final report.
[9] Mandal B. B., Srivastava A.K., 2006. Risk from vibration in Indian miners. Indian J. of Occup. and Environ. Med. 10 (2), 53-57.
[10] Mirta Widia, Siti Zawiah Md Dawal, 2010. Investigation on Upper limb Muscle Activity and Grip Strength During Drilling Task. Proceedings of international conf. on engineers and computer scientist,(III), 17-19.
[11] T. W. Mc Dowell, S.F. Wiker, R.G. Dong, D. E. Welcome, 2007. Effects of vibration on grip and push force-recall performance, Int. J. Ind. Ergon, 37, 257-266.
[12] Ren G. Dong , Thomas W. Mcdowell , Daniel E. Welcome, 2005. Biodynamic Response at the Palm of the Human Hand Subjected to a Random Vibration, Ind. Health 2005, 43, 241- 255.
[13] I. J. Lawson, D. A. Nevell, 1997. Review of objective tests for the hand-arm vibration syndrome, Occup. Med, 47(1), 15-20.
[14] Michael j. Griffin, Massimo Bovenzi, 2001.The diagnosis of disorders caused by hand- transmitted vibration: Southampton Workshop 2000, Vibration injury network, Appendix X5B to Final Report May EC Biomed II concerted action BMH4-CT98- 3291.
[15] Busi Nyantumu, Chris M. Barber, Marry Ross, Andrew D. Curran, David Fishwick, Belindo Dias, Spo Kgalamono, James I. Phillips, 2007. Hand-arm vibration syndrome in south African gold miners. Occup. Med., 57, 25-29.
[16] Kenneth L. Mcgeoch, W. Harper Gimour, 2000. Cross sectional studyof workforce exposed to hand-arm vibration: with objective tests and the Stockholm workshop scales. Occup.Environ. Med., 57, 35-42.
[17] Keith T Palmer, Barbara Haword, Michael j Griffin, Holly Bendall, David Coggaon, 2000. Validity of self reported occupational exposures to hand transmitted and whole body vibration. Occup. Environ. Med., 57, 237-241.
[18] Kroemer Karl, Henrike Kroemer, Katrin Kroemer Elbert 1994. Ergonomics, How to design for ease of efficiency. Prentice Hall, International series in industrial & System engg.

Table I. Anthropometric Data Of Subjects

Tools	Subjects No.	Age (Yrs)	Weight (kg)	Height (cm)	Functional overhead reach (cm)	Knuckle height (cm)	Elbow height (cm)	Grip Strength (Kg)		Aggregate grip strength
								Left	Right	
1	A1*	29	47	162	205	56	101	40	38	78
	A2	25	50	160	202	54	100	48	48	96
	A3	23	75	170	214	68	106	75	70	145
	A10	35	60	174	218	72	108	55	56	111
	A11	41	58	165	208	58	103	56	58	114
	A12	45	59	169	212	61	106	60	62	122
	A13	34	66	171	216	69	107	61	68	121
	Mean	33	59	167	211	63	104	56	59	115
	SD	7	9	5	6	7	3	11	11	11
2	A4	30	50	160	211	68	104	48	45	93
	A5	22	55	168	215	70	104	60	55	115
	A6	44	72	178	224	74	114	67	68	135
	A14	44	57	166	213	67	102	62	69	131
	A15	35	59	163	214	70	104	50	54	104
	A16	37	64	167	214	70	103	65	68	133
	A17	39	48	160	210	67	100	48	52	100
	Mean	36	58	166	214	69	104	57	59	116
	SD	7	8	6	5	2	5	8	10	9
3	A7	30	50	163	206	58	101	49	47	96
	A8	29	68	164	214	59	104	58	62	120
	A9	35	72	176	216	70	110	71	76	147
	A18	34	65	162	212	56	101	58	64	122
	A19	38	67	165	214	61	107	66	60	126
	A20	49	48	160	202	55	99	39	40	79
	A21	36	70	170	211	65	105	63	69	132
	Mean	36	63	166	211	61	104	56	56	112
	SD	6	10	5	5	5	4	10	11	11

Note:
1 Subject A1 to A9 are subjected to experimentation.
2 Subject A1 to A21 all are interviewed for HAVS and investigation of various related consequences.

Table II. Specifications Of Tool 1 (Rock Drill)

Model	HAVA RH-658-5L
Weight	25 kg
Air requirement at 6 bar	3.4 m3/min
Piston diameter	65 mm
Piston stroke	60 mm
Impact rate	2000 blows/min
Drilling rate	425 mm/min
Hose connection (Air)	19 mm
Rotation speed	215 rpm

Table III. Specifications Of Tool 2 (Concrete breaker)

Model	Drillman DM221
Weight	35 kg
Length	740 mm
Shank size	32*160 mm
Stroke	165 mm
Frequency	1200 blows/min
Piston diameter	57.15 mm
Air consumption	2.5 m^3/min
Hose connection for air	ϕ 19mm

Table IV. Specifications Of Tool 3 (Hand Grinder)

Model	KPT 57-91
Weight	6.9 kg
Rated voltage	110-240
Frequency	50-60 Hz
Speed	8200 rpm
Input power	2.0 kw
Grinding wheel diameter	180mm

Table V Plan Of Experimentation

Run	Level G	A	E	M
O1	a	A	A	a
02	a	B	B	a
03	a	C	C	a
04	a	A	A	a
05	a	B	B	a
06	a	C	C	a
07	a	A	A	a
08	a	B	B	a
09	a	C	C	A

Table VI. Observations During The Three Runs Of Tool 1 For Five Minutes Each

Run	Subjects	Aggregate grip strength	Hearts Beats			Energy consumed KJ	Environmental Variables		Touch Sensation Nail test			
			Start	Max.	Avg.		Temp. ^0C	Humidity %	High	Moderate	Low	No. effect
Morning	A1	96	135	235	190	300					y	
	A2	78	178	238	219	375	34	38		y		
	A3	145	127	235	179	275					y	
Afternoon	A1	96	100	240	220	380				y		
	A2	78	176	240	233	425	40	32	y			
	A3	145	129	239	195	310				y		
Evening	A1	96	101	235	200	325				y		
	A2	78	174	236	215	370	35	38	y			
	A3	145	125	234	185	290				y		

Table VII. Observations During The Three Runs Of Tool 2 Of Five Minutes Each

Run	Subjects	Aggregate grip strength	Hearts Beats			Energy consumed KJ	Environmental Variables		Touch Sensation Nail test			
			Start	Max.	Avg.		Temp. ^0C	Humidity %	High	Moderate	Low	No. effect
Morning	A4	135	96	208	112	85	33	38				y
	A5	115	107	202	145	175					y	
	A6	93	110	210	180	280				y		
Afternoon	A4	135	170	230	165	230	39	42			y	
	A5	115	130	210	170	240				y		
	A6	93	150	215	192	305			Y			
Evening	A4	135	100	210	125	125	34	40		y		
	A5	115	102	215	168	230				y		
	A6	93	108	202	190	300			Y			

Table VIII. Observations During The Three Runs Of Tool 3 Of Five Minutes Each

Run	Subjects	Aggregate grip strength	Hearts Beats			Energy consumed KJ	Environmental Variables		Touch Sensation Nail test			
			Start	Max.	Avg.		Temp. ^0C	Humidity %	High	Moderate	Low	No. effect
Morning	A7	96	97	107	126	125	32	38			y	
	A8	147	98	110	99	50						y
	A9	120	88	102	110	80						y
Afternoon	A7	96	101	140	140	160	37	32		y		
	A8	147	99	117	115	90						y
	A9	120	94	136	118	100					y	
Evening	A7	96	97	130	134	145	34	38			y	
	A8	147	97	112	101	55						y
	A9	120	92	113	112	60					y	

Table IX. Relation Of Percent Change In Grip Strength To Percent Change In Energy Expenditure.

	Tool-1				Tool-2				Tool-3			
Run	Aggregate grip strength in kg	Energy consumed in KJ	% increase in grip strength	% reduction in energy expenditure	Aggregate grip strength in kg	Energy consumed in KJ	% increase in grip strength	% reduction in energy expenditure	Aggregate grip strength in kg	Energy consumed in KJ	% increase in grip strength	% reduction in energy expenditure
Morning	78	375	--	--	93	280	--	--	96	125	-	-
	96	300	23	20	115	175	19	38	120	80	20	36
	145	275	51	8	135	85	15	51	147	50	18	38
Afternoon	78	425	--	--	93	305	--	--	96	160	--	--
	96	380	23	11	115	240	19	21	120	100	20	38
	145	310	52	19	135	230	15	4	147	90	18	10
Evening	78	370	--	--	93	300	--	--	96	145	--	--
	96	325	23	12	115	230	19	23	120	60	20	59
	145	290	51	11	135	125	15	45	147	55	18	18

Fig. 1 Polar Heart Rate Monitor

Fig. 2 Hand Grip Dynamometer

Fig. 3 Hygrometer

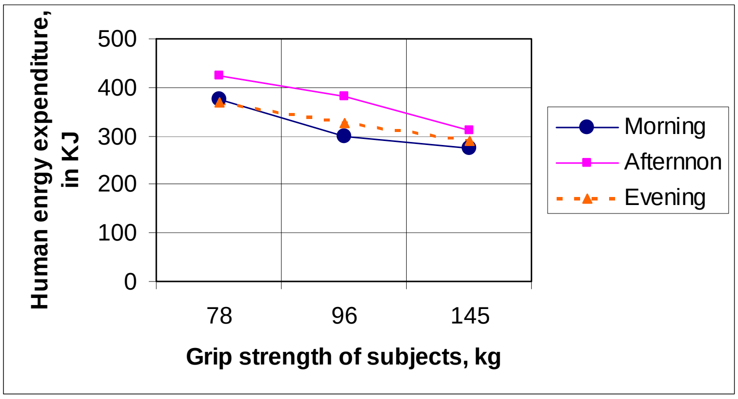

Fig 4. Relationship Of Human Energy Expenditure With Grip Strengths Of Subjects For Tool 1

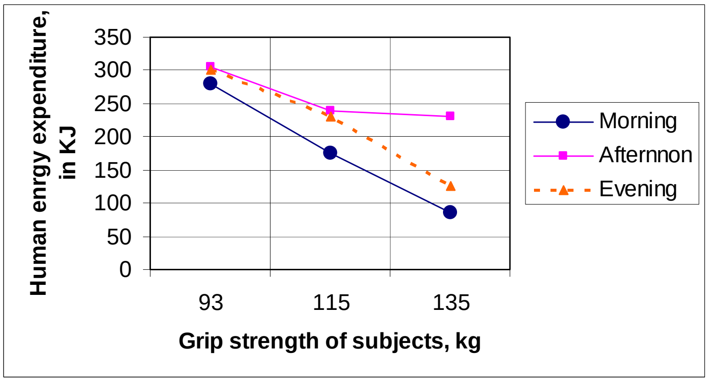

Fig 5. Relationship Of Human Energy Expenditure With Grip Strengths Of Subjects For Tool 2

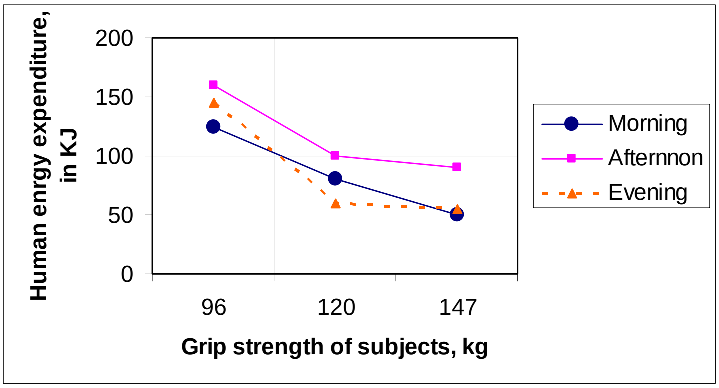

Fig 6 .Relationship Of Human Energy Expenditure With Grip Strengths Of Subjects For Tool 3

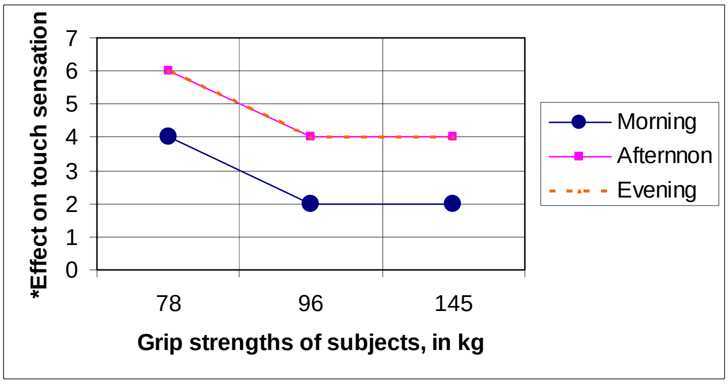

Fig 7 . Effect On Touch Sensation Due To Grip Strengths Of Subjects For Tool 1
(0- No effect, 2- Low effect, 4- Moderate effect, 6 – High effect)

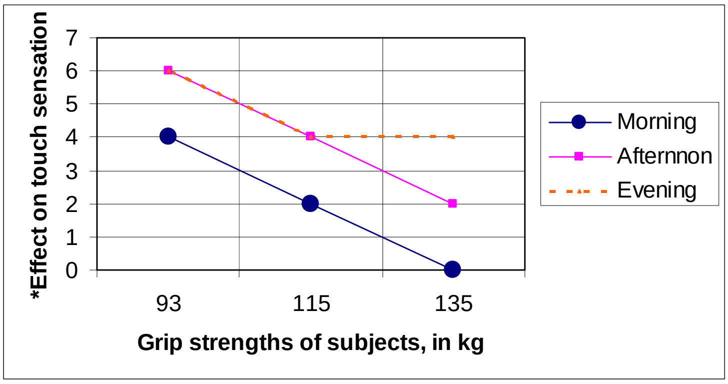

Fig 8. Effect On Touch Sensation Due To Grip Strengths Of Subjects For Tool 2
(0- No effect, 2- Low effect, 4- Moderate effect, 6 – High effect)

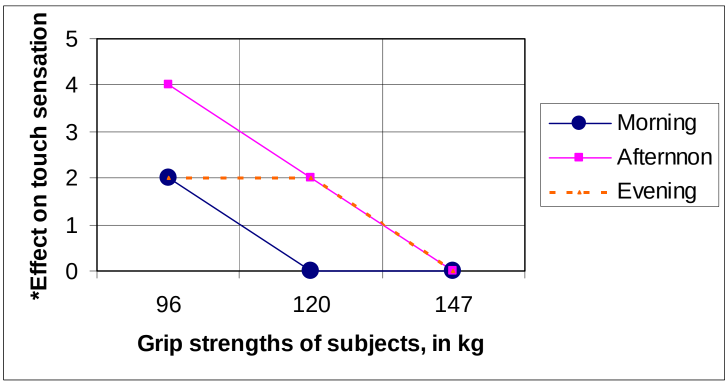

Fig 9. Effect On Touch Sensation Due To Grip Strengths Of Subjects For Tool 3
(0- No effect, 2- Low effect, 4- Moderate effect, 6 – High effect)

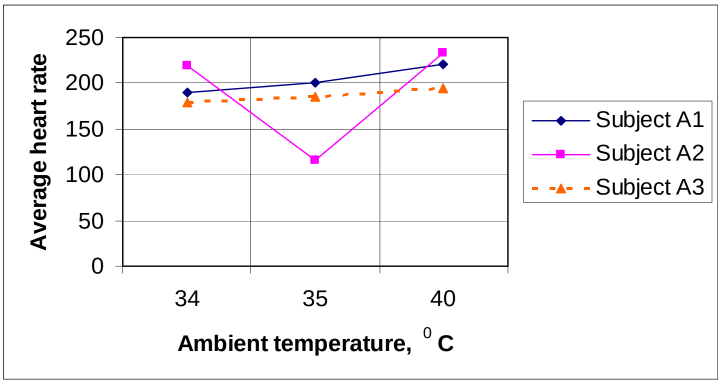

Fig 10. Effect Of Ambient Temperature On Average Heart Beats Of Subjects For Tool 1

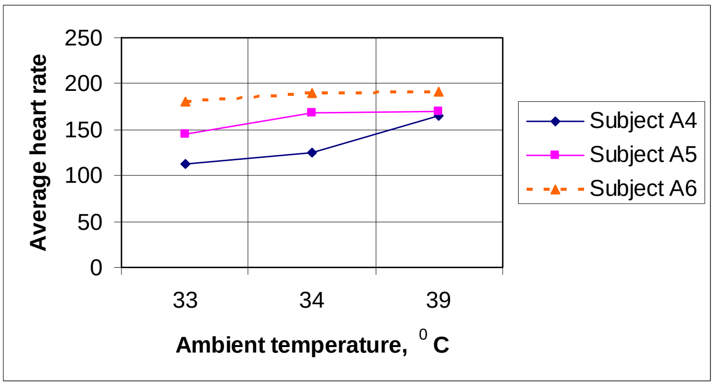

Fig 11. Effect Of Ambient Temperature On Average Heart Beats Of Subjects For Tool 2

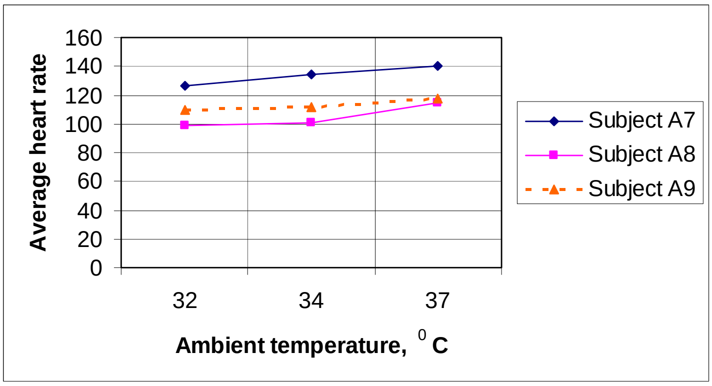

Fig 12. Effect Of Ambient Temperature On Average Heart Beats Of Subjects For Tool 3

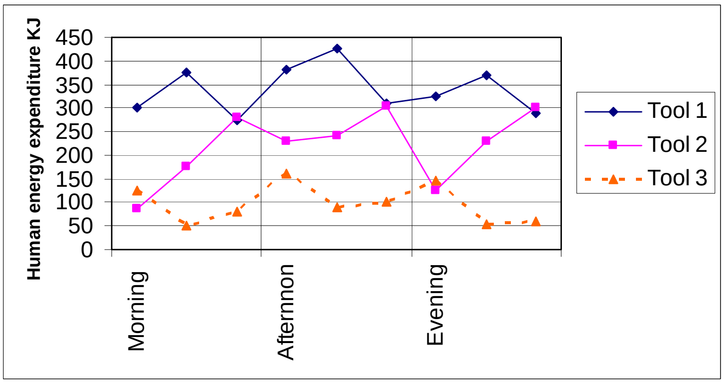

Fig 13. Comparison Of Human Energy Expenditure Of Three Tools

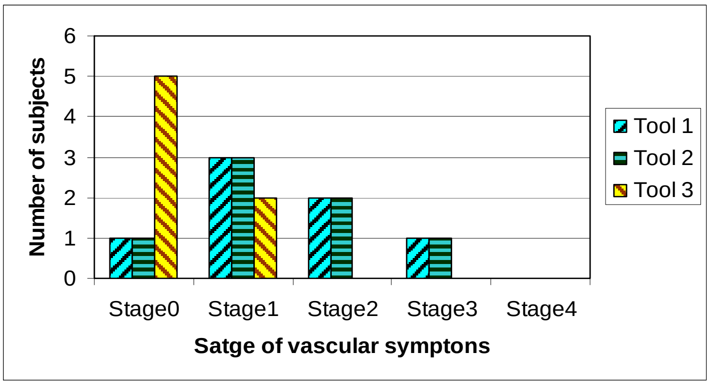

Fig 14. Classification Of Symptoms As Per Stockholm Work Shop Scale (Vascular Symptoms)

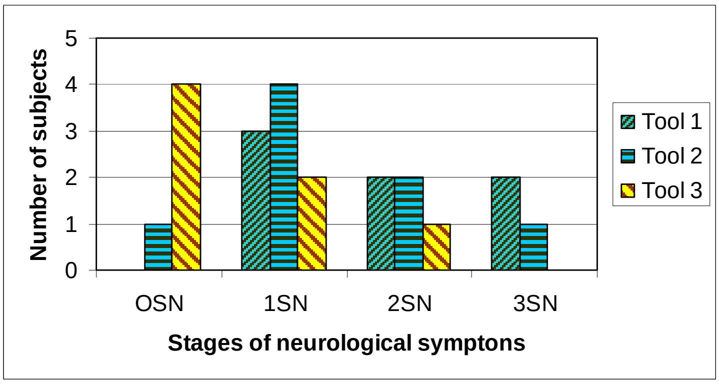

Fig 15.. Classification Of Symptoms As Per Stockholm Work Shop Scale (Neurological Symptoms)

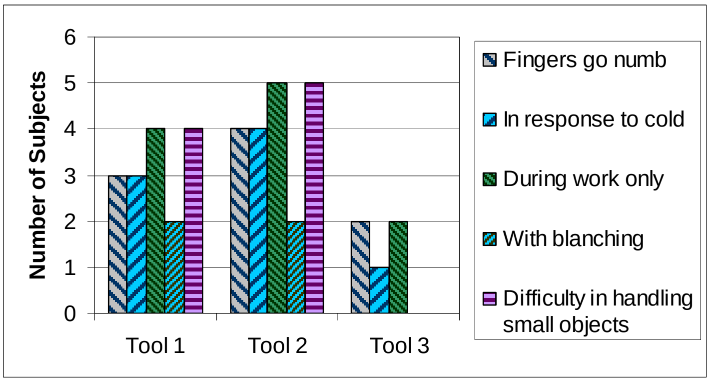

Fig 16. Numbness

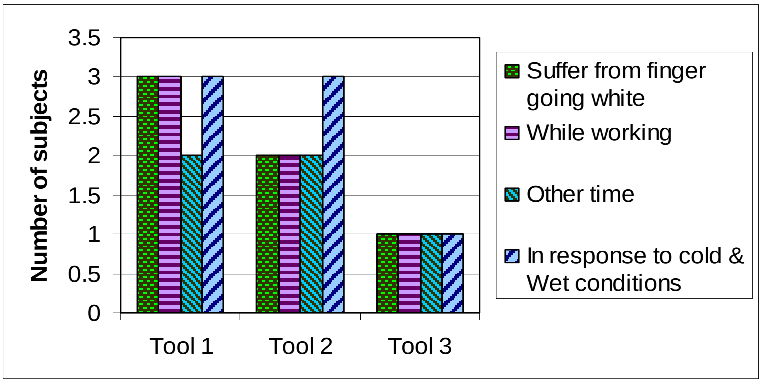

Fig 17.. Blanching

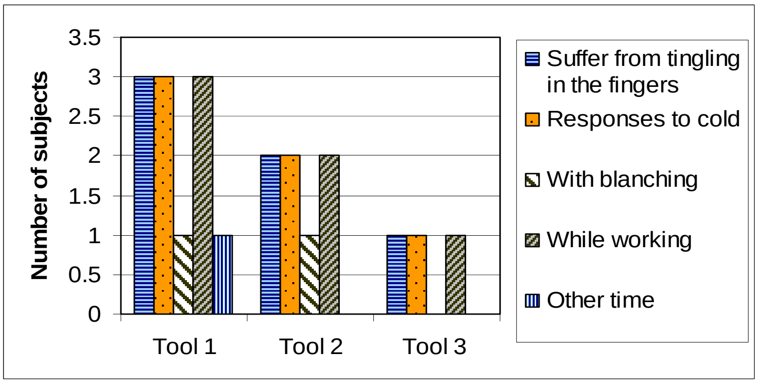

Fig. 18.. Tingling

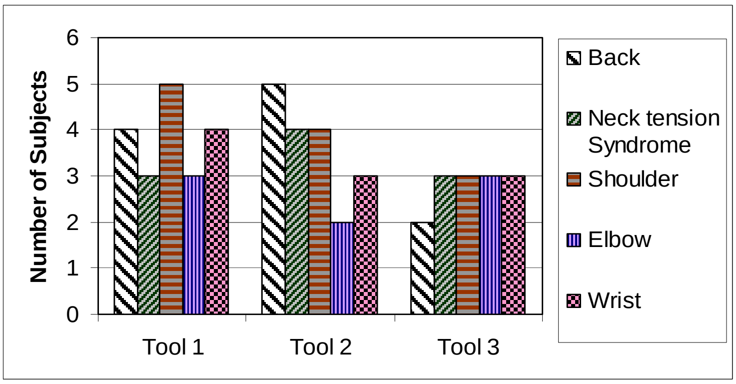

Fig 19.. Musculoskeletal (Presence Of Pain Stiffness)