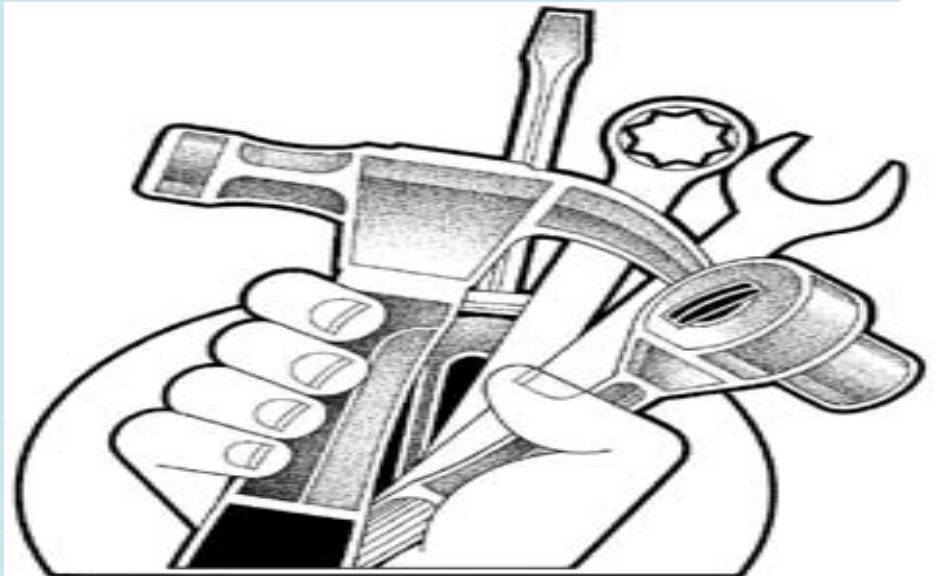


## CHAPTER 12

# HAND TOOLS AND DEVICES



# **Hand Tools**

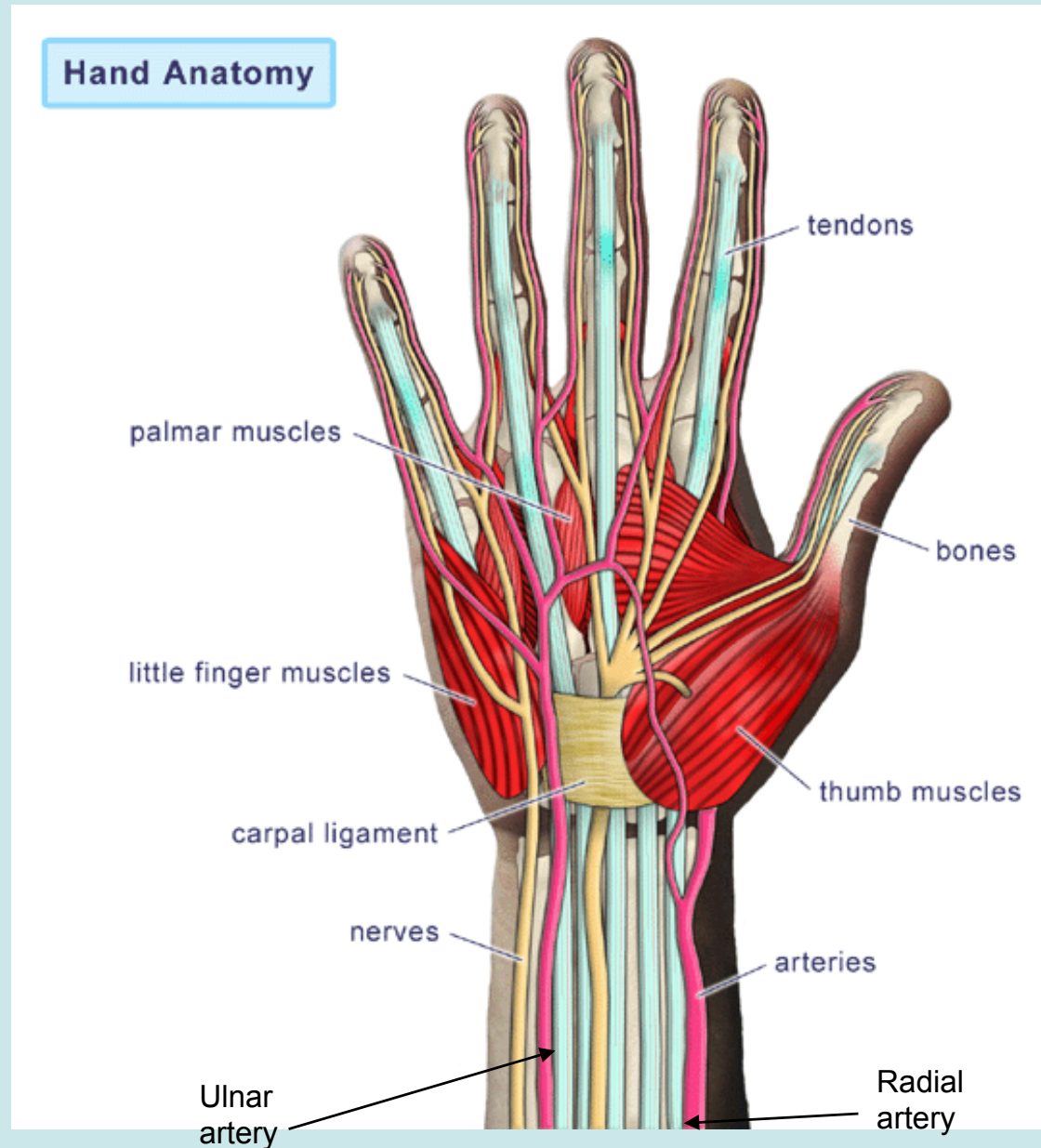
- 1. Drill machine**
- 2. Arc-welding Gun**
- 3. Hack saw**
- 4. Pliers**
- 5. Hammer**
- 6. Wrench**

- Hand Tool Related Injuries-

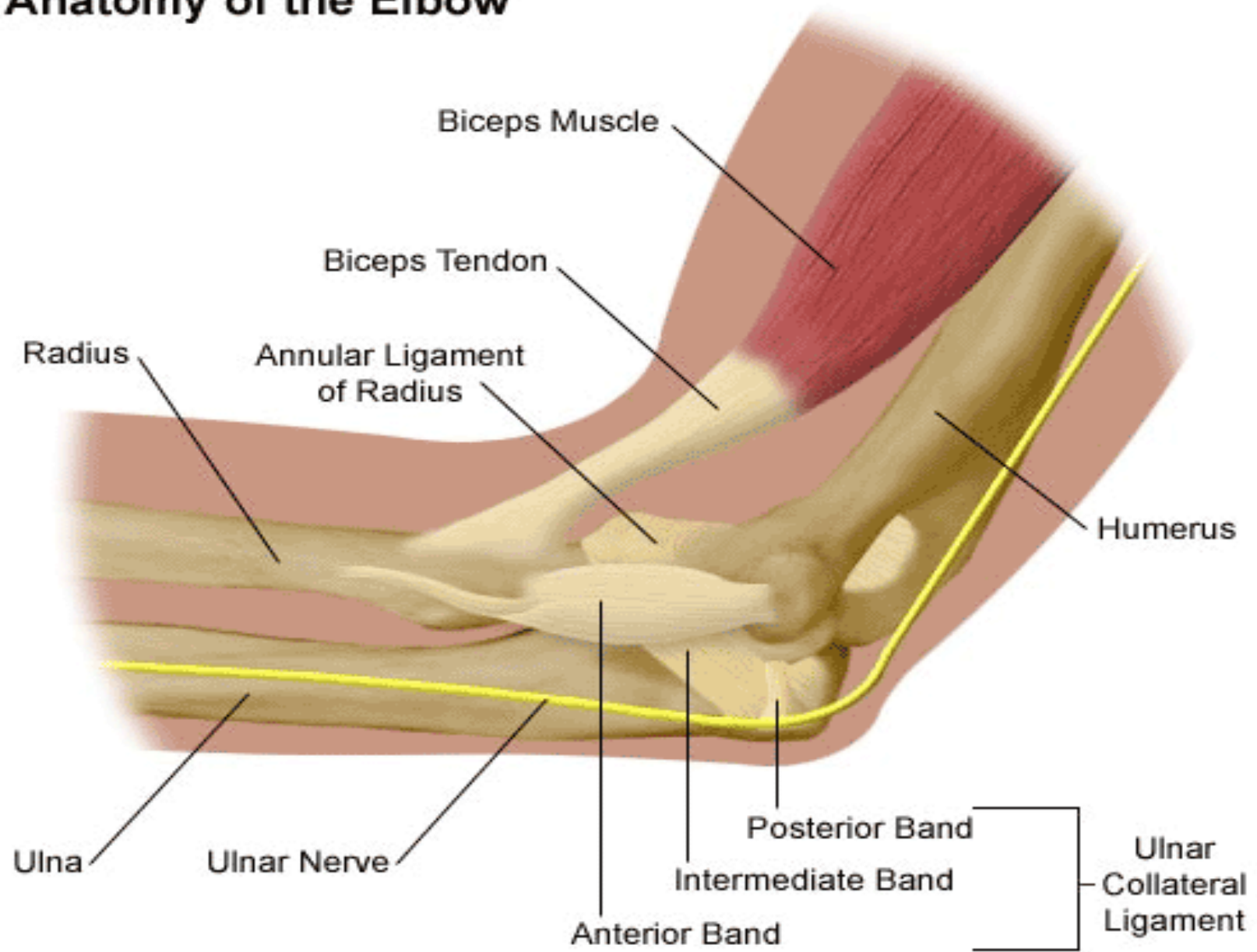
- Comprises 9 percent of all work related injuries.
- Aghazadeh and Mital estimate that there are over 260,000 hand tool related injuries in the USA each year.
- Power tools account for only about 21 percent of all hand tool related injuries.
- According to Bureau of Labor Statistics, 480 of every 10,000 meatpacking workers suffered from cumulative trauma disorder.
- Cumulative traumas account for only 1.8 % of all industrial illness and injuries.

- The proper design requires application of
- Technical
- Mechanical
- Kinesiological
- Anthropometric
- Physiological
- Hygienic considerations.

# Structure of Hand



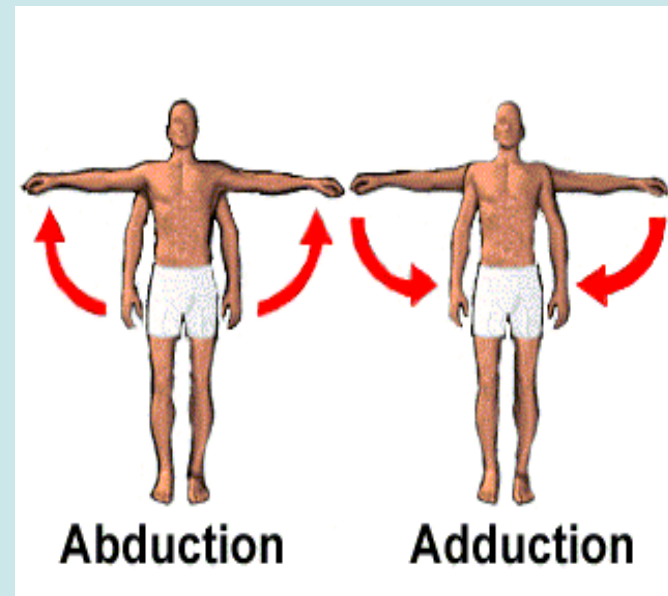
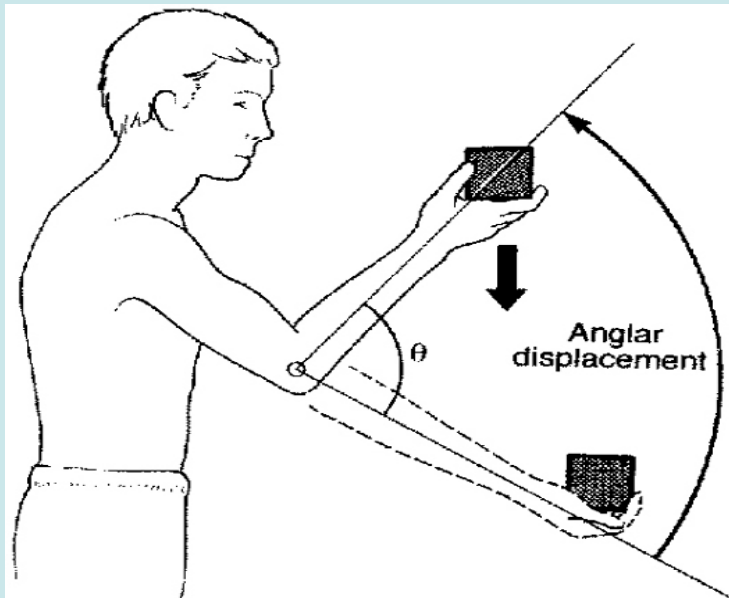
## Anatomy of the Elbow



# Motion of Hand

There 4 different motions of hands

1. Flexion
2. Extension
3. Abduction
7. Adduction



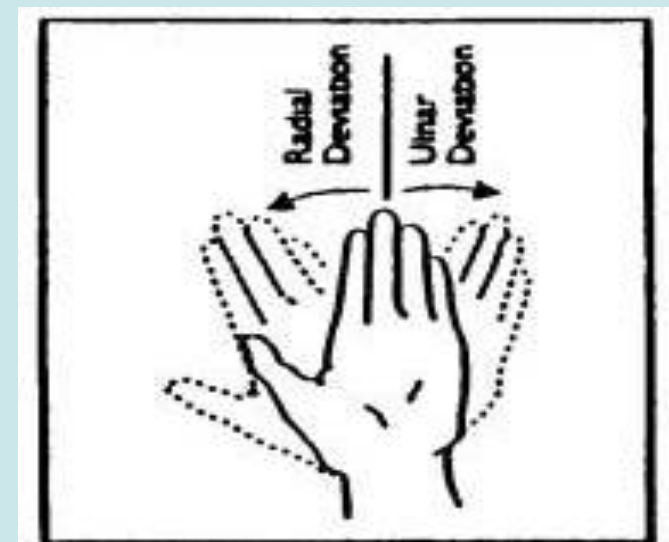
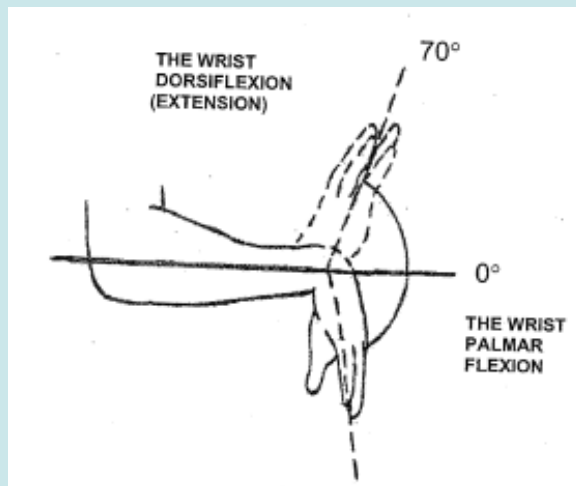
## Motion of forearm

1. Supination and
2. Pronation



## Motion of Wrist joint

1. Dorsiflexion and 2. Palmar Flexion
3. Ulnar Derivation and 4.Radial Deviation



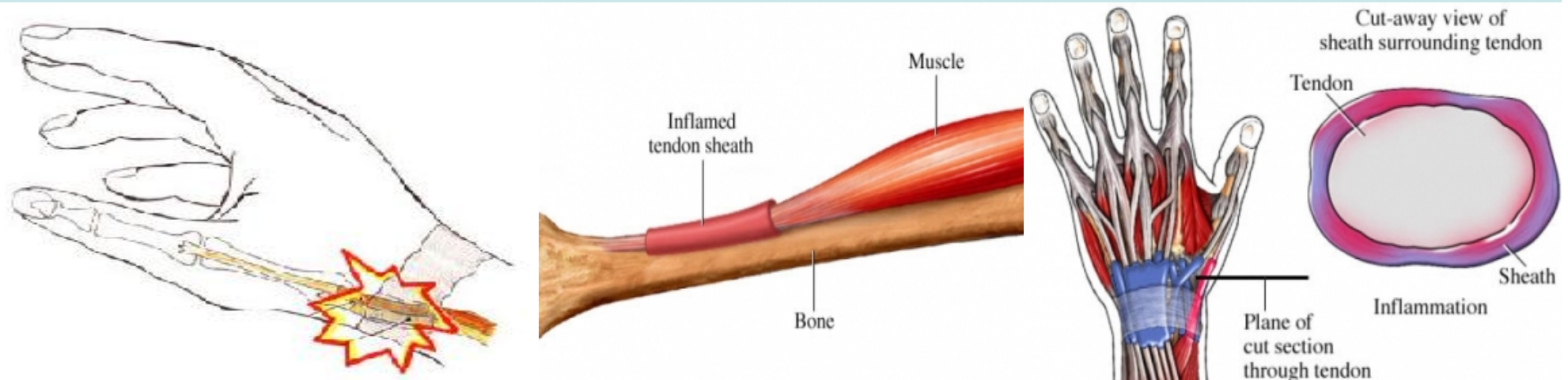
# Principles of hand tool and devices design

## Principle 1 Maintain a straight wrist

Avoid ulnar deviation and palmar flexion ( or both)

Results in **i. Tenosynovitis:**

**What is tenosynovitis?**



# What type of work results in tenosynovitis?

Example: Clothes wringing

Inserting screws

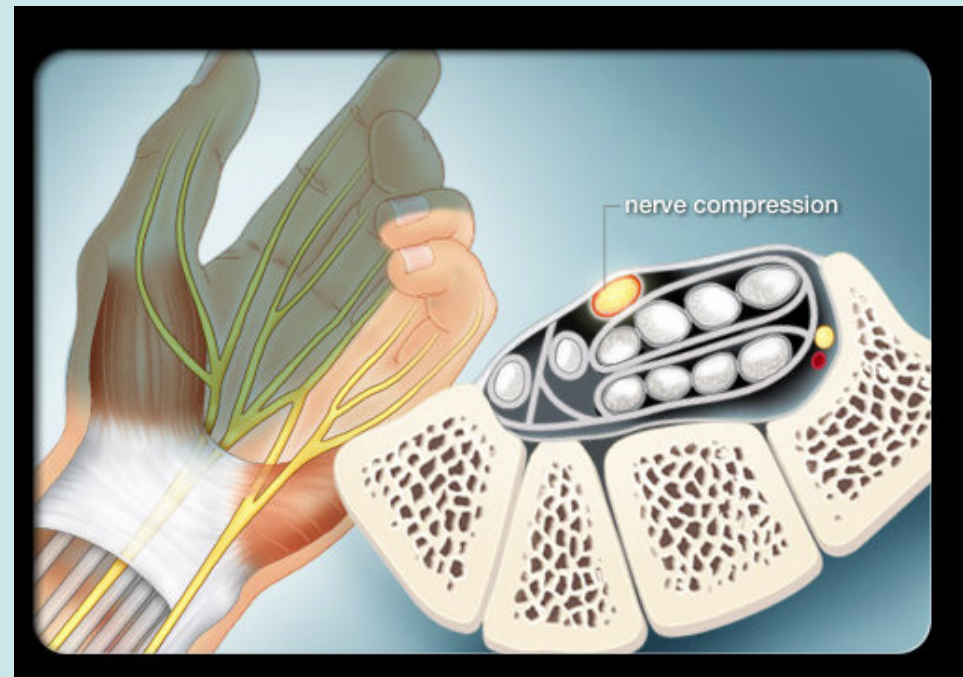
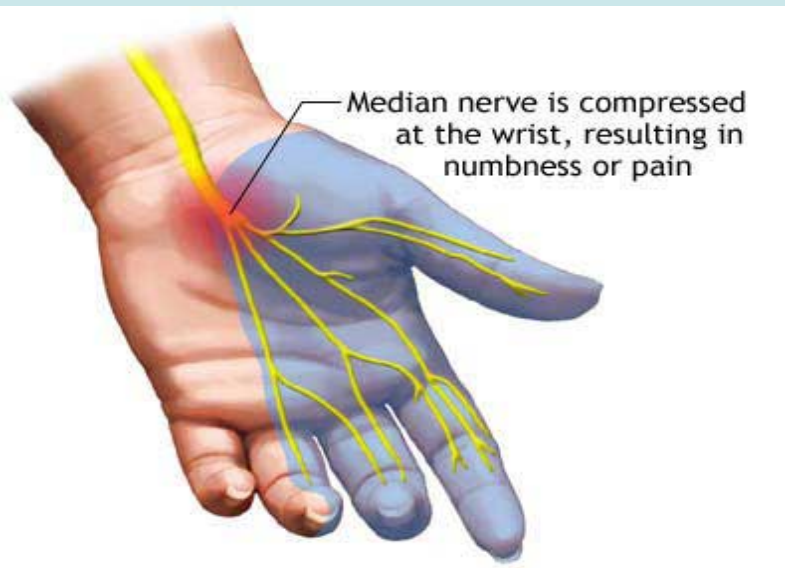
Starting handle of Motorcycle

Looping wire while using pliers



## ii. Carpal Tunnel Syndrome

### What is Carpal Tunnel Syndrome



- Symptoms of Carpal Tunnel syndrome



Types of Work involved

Jobs requiring high force application  
and short cycle times

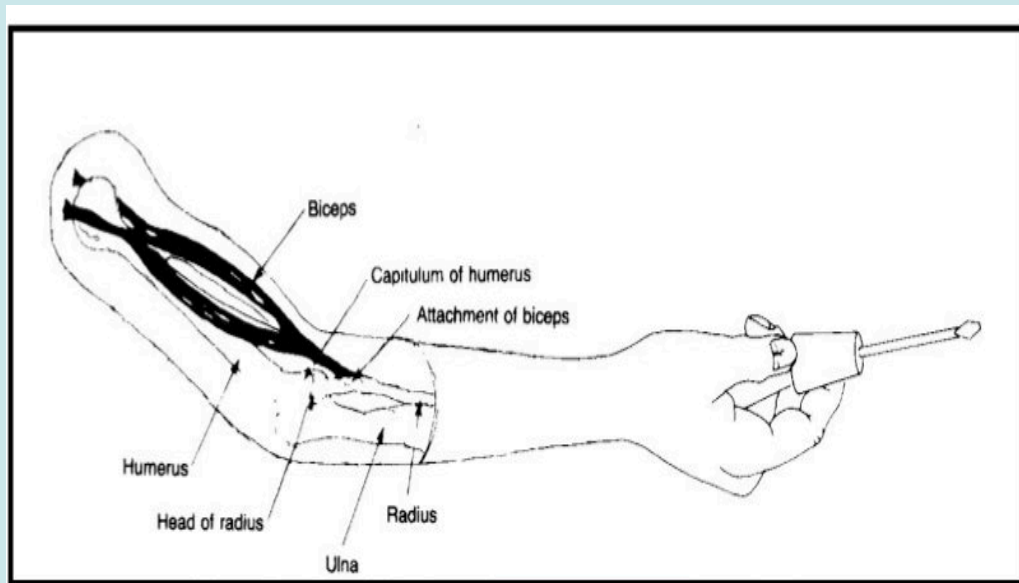
Assembly and Typing



### iii. Tennis Elbow

Radial Deviation when combined with pronation and dorsiflexion

What Happens? Pressure increases between head of the radius and the capitulum of the humerus in the elbow region.



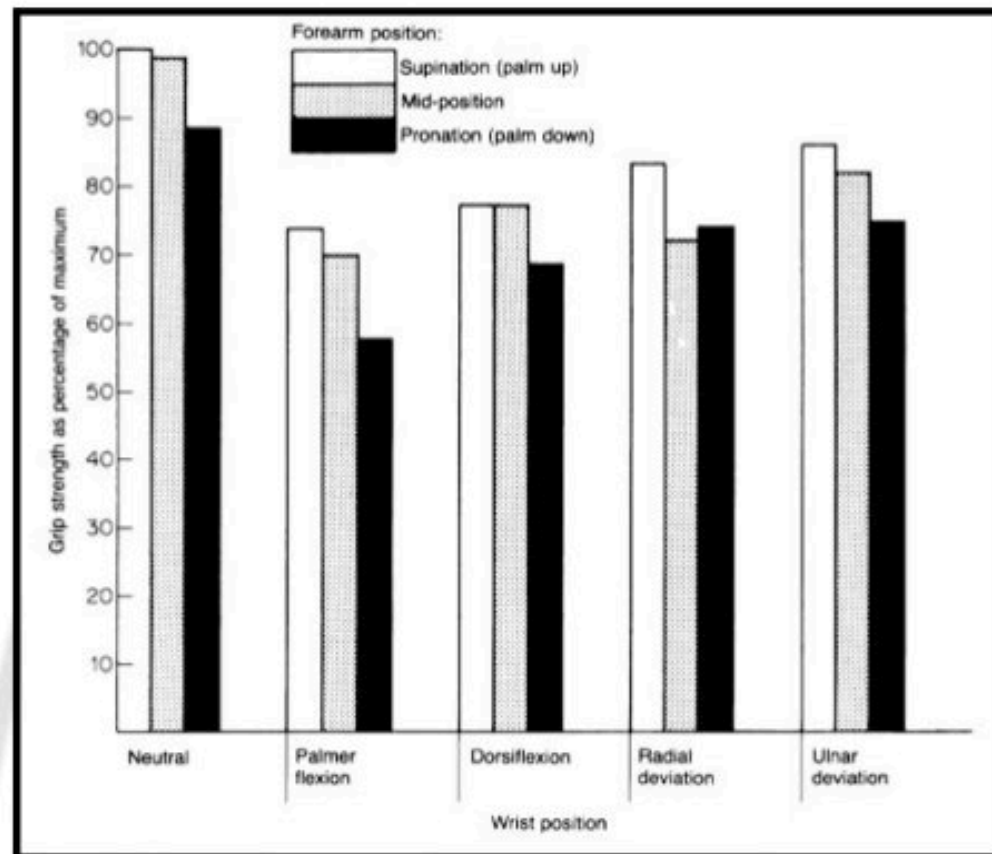
The elbow joint showing the connection of the bicep to the radius.

Figure 12.3



## iv. Grip strength is reduced if the wrist is bent.

Terrell and Purswell in 1976 reported that grip strength is reduced if wrist is bent in any direction

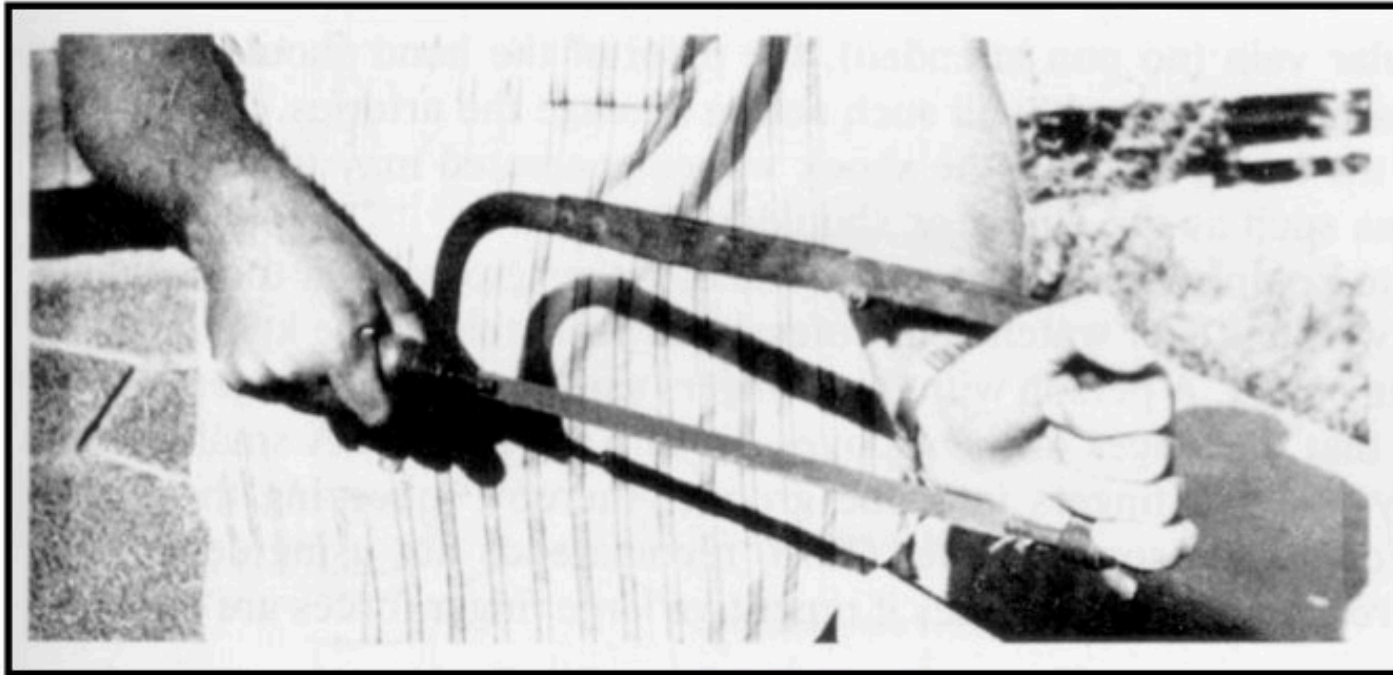


Grip strength as a function of wrist & forearm position.

Figure 12.7

- Problems of reduction in grip strength
  - User will lose control of the tool or drop it, leading to an injury.
  - poor quality of work
  - Attempts to maintain a strong grip will increase fatigue.

# Violating straight wrist principles

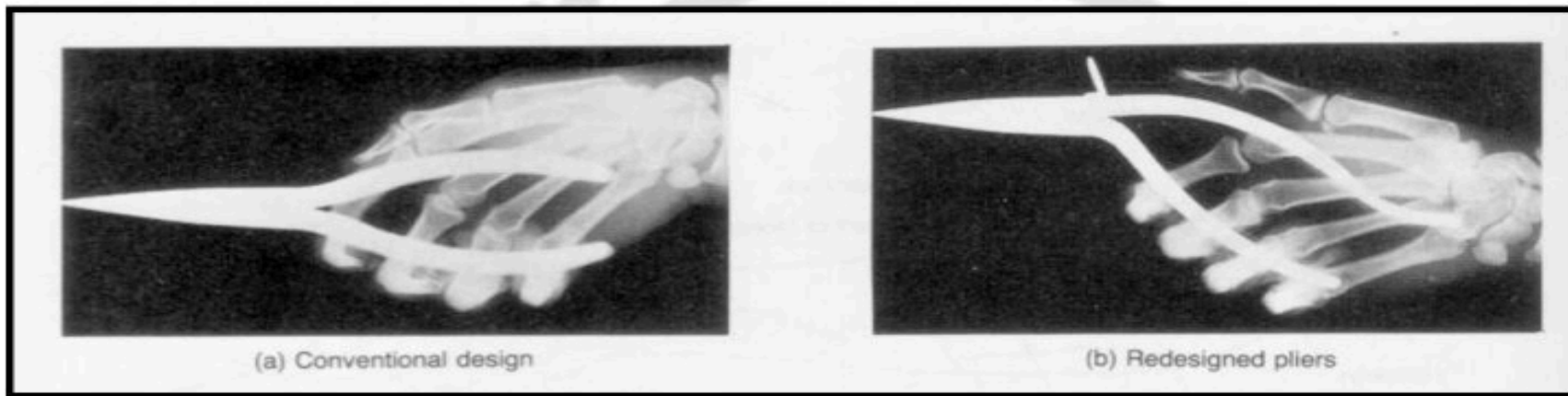


Man using a hacksaw.

Figure 12.8

# Suggestions for Principle 1

- Bending the handles rather than the wrist

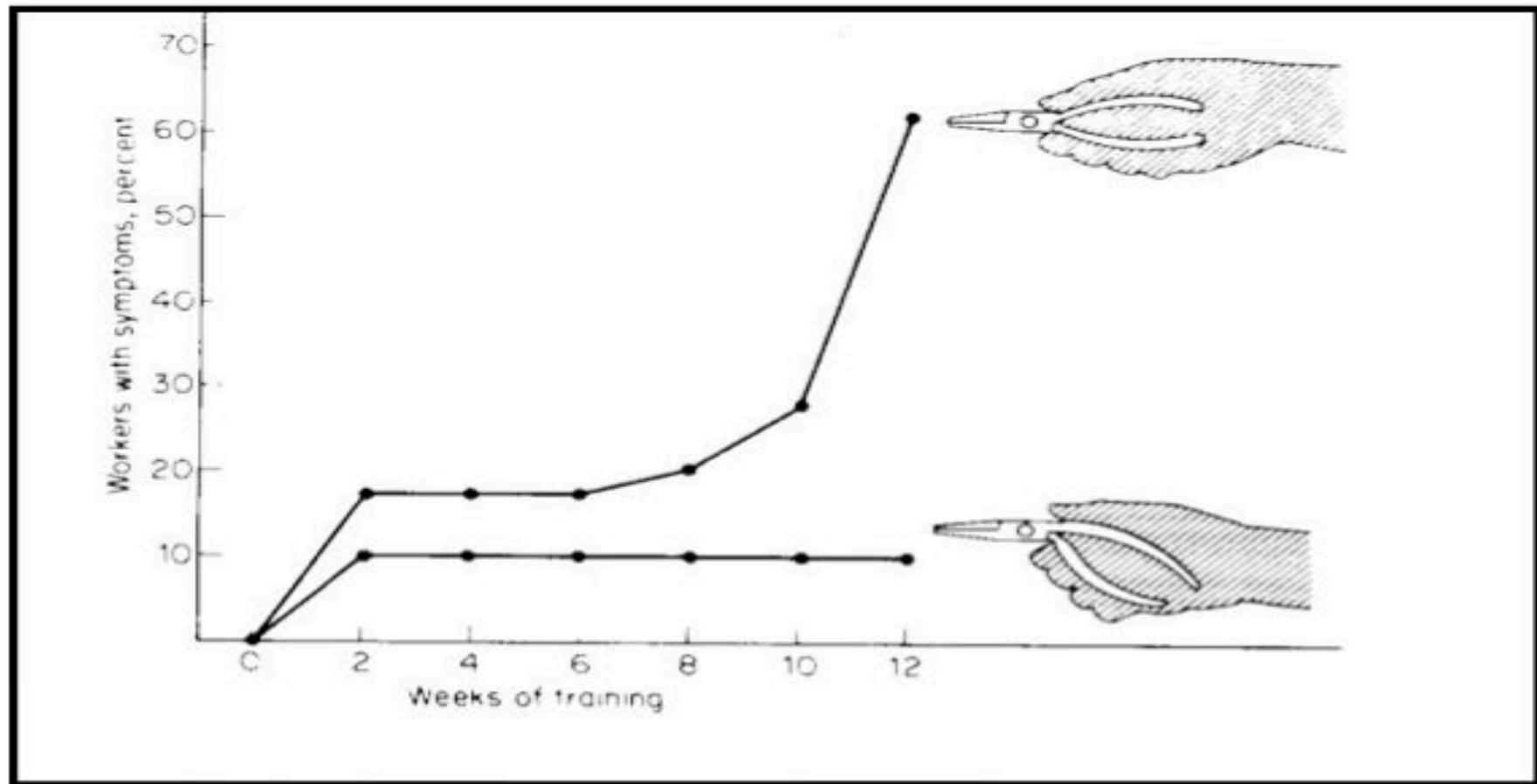


**X-rays of the hand using pliers.**

Tichauer 1976 reports the results of comparison of two groups of 40 electronics assembly workers

One group using conventional pliers

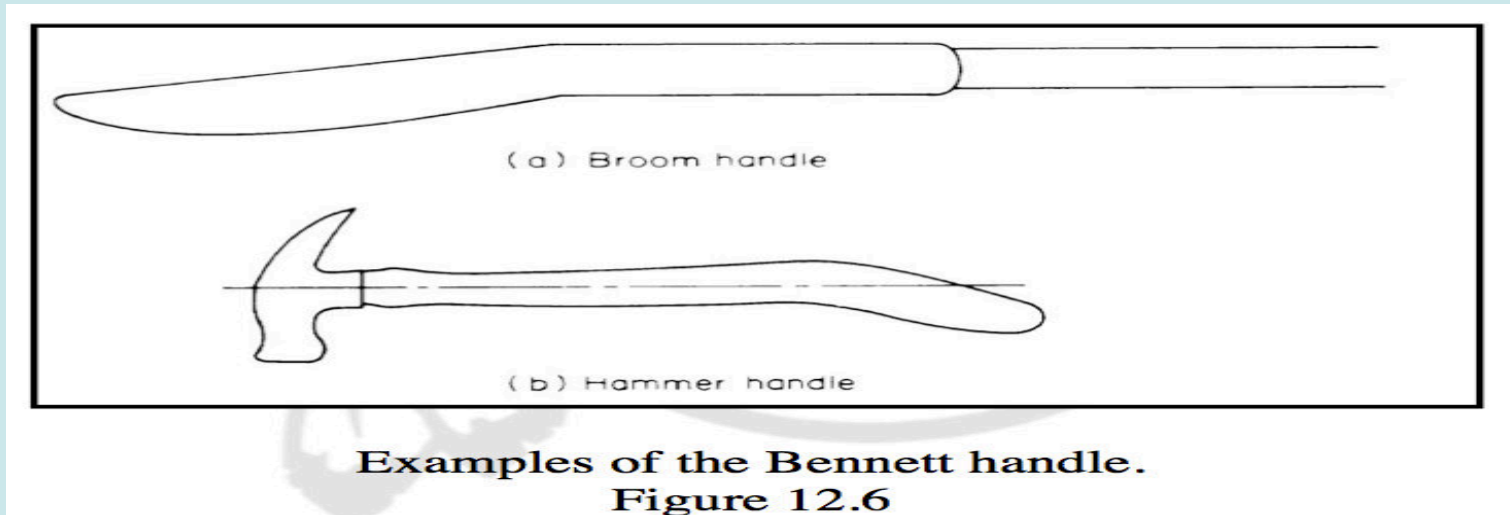
Another group using redesigned pliers.



**Comparison of two groups of pliers users.  
Figure 12.5**

## Many Researches

1. John Bennett 1980, patented the idea of bending handles for all tools and sports equipments by  $19^{\circ} \pm 5^{\circ}$



2. Schoenmarklin and Marras found that among novices the use of hammer with handle 20 or 40 degree bent resulted in less ulnar deviation

3. Knowlton and Gilbert also found similar results in 1983 by using professional carpenter as a subject by measuring the grip strength after and before driving 20 3,5 in nails into a block of wood.

4. Krohn and Konz also found people preferred a hammer handle with a slight bent 10 degree over traditional straight handle hammer in 1982.

- As an aside a softball bat with a bent in handle has been manufactured and is legal for the game



# Principle 2

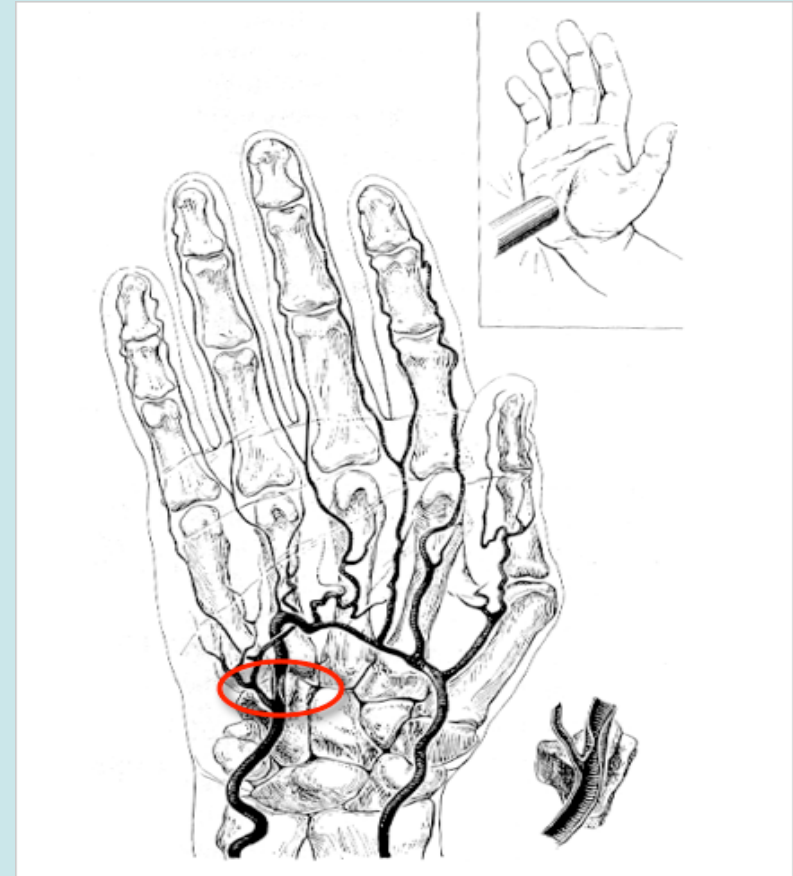
## 2. Avoid Tissue Compression Stresses

-Pressure sensitive areas are Ulnar and Radial arteries.

### Problem 1

Handle of the tool obstruct the blood flow of the sensitive areas and results in *ISCHEMIA* (numbness and tingling of the fingers).

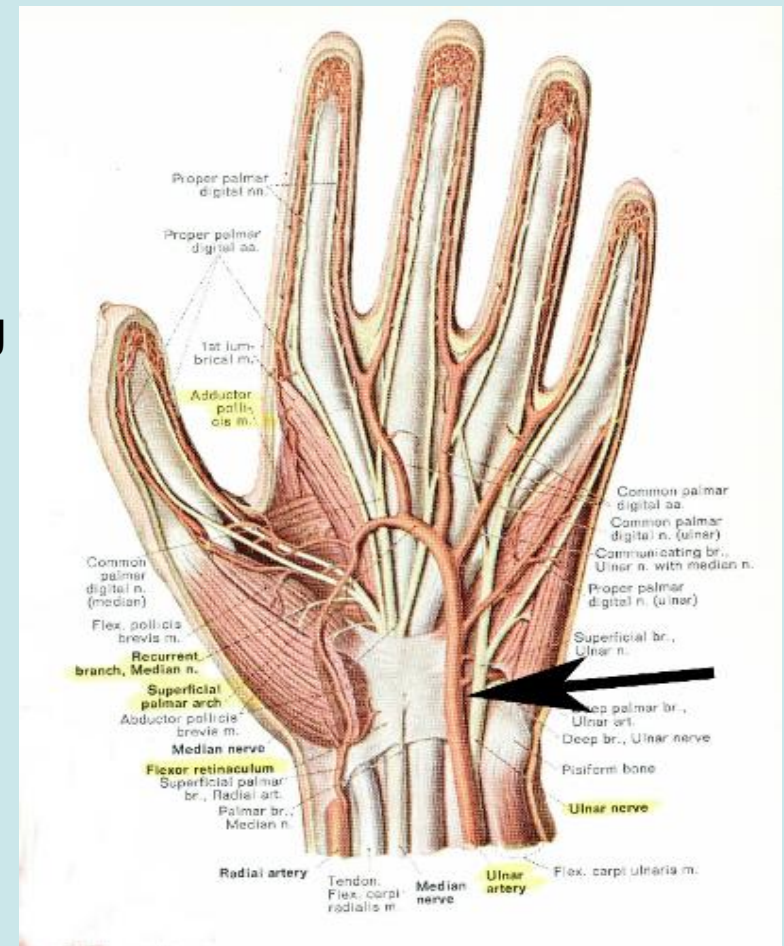
Results in temporary break of the workers from work to relieve the symptoms(Tichauer. 1978) .



## Problem 2: Ulnar Artery Thrombosis

The hand is supplied by two main blood vessels, the radial artery (on the thumb side of the wrist/hand) and the ulnar artery (on the small finger side of the wrist/hand). The ulnar artery may be injured by repetitive impact from catching baseball or use of a jack hammer. Blood may clot (thrombosis) inside the injured ulnar artery. Blood clots due to trauma are less common in the radial artery.

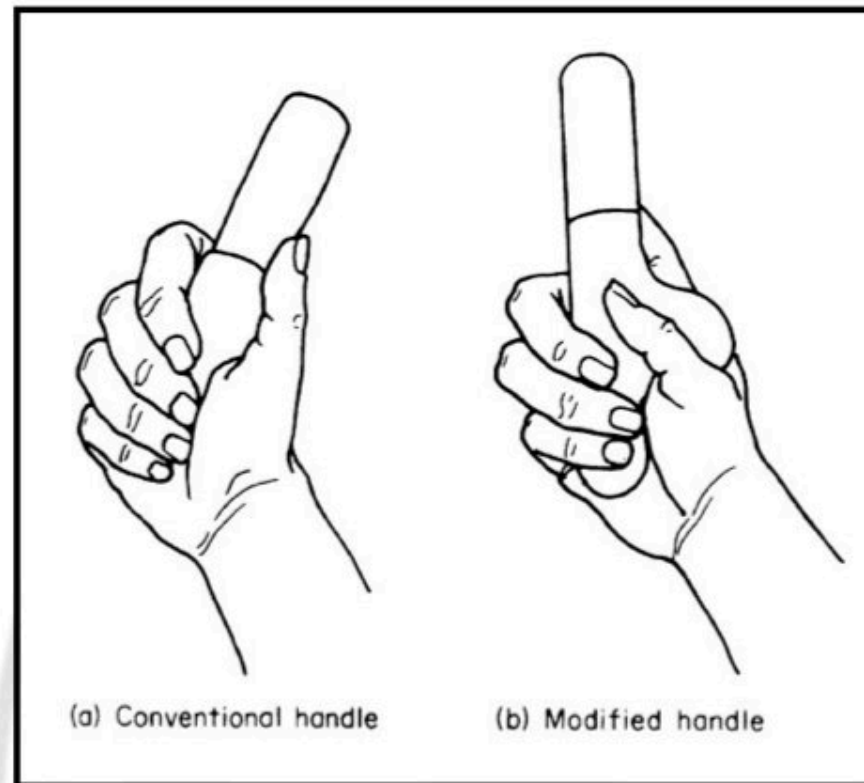
Blood clot inside the ulnar artery (ulnar artery thrombosis or UAT) results in diminished blood flow to the small finger side of the hand producing pain on that side of the hand including the small finger. Numbness may occur if the thrombosed ulnar artery enlarges and places pressure on the adjacent ulnar nerve



## ***Solution***

### ***Solution 1:***

***HANDLES SHOULD BE DESIGNED TO HAVE LARGE CONTACT SURFACES TO DISTRIBUTE THE FORCE TO DIRECT IT TO LESS-SENSITIVE AREAS***



Conventional and modified paint scrapers.  
Figure 12.9

- Solution 2:



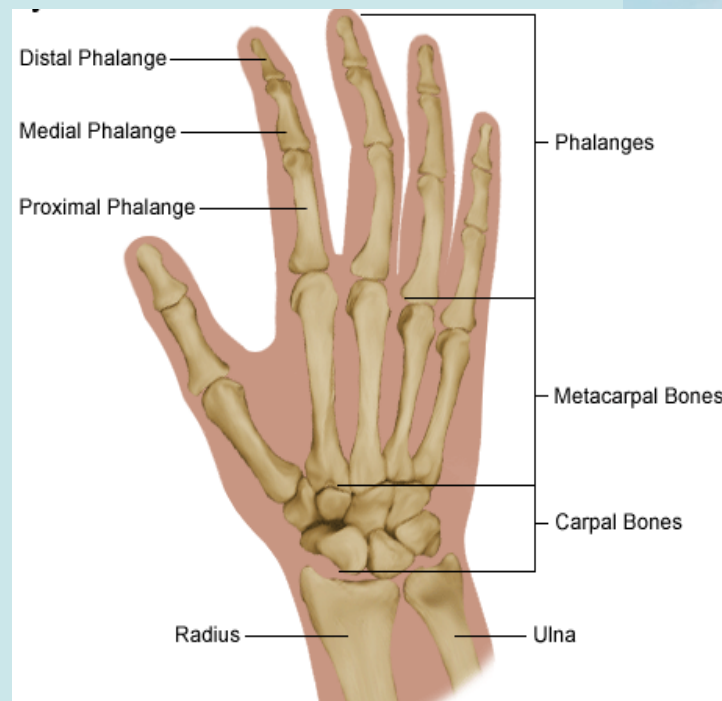
# Principle 3: Avoid Repetitive Finger Action

If Index finger is used excessively then problem occurs

Problem: Trigger Finger , a form of tenosynovitis.

- Affected person can flex but can not extend finger actively.
- When the finger is passively straighten an audible click may be heard.

This occurs when the handle of the tool is too large that the distal phalanx has to be flexed and middle phalanx must be kept straight.

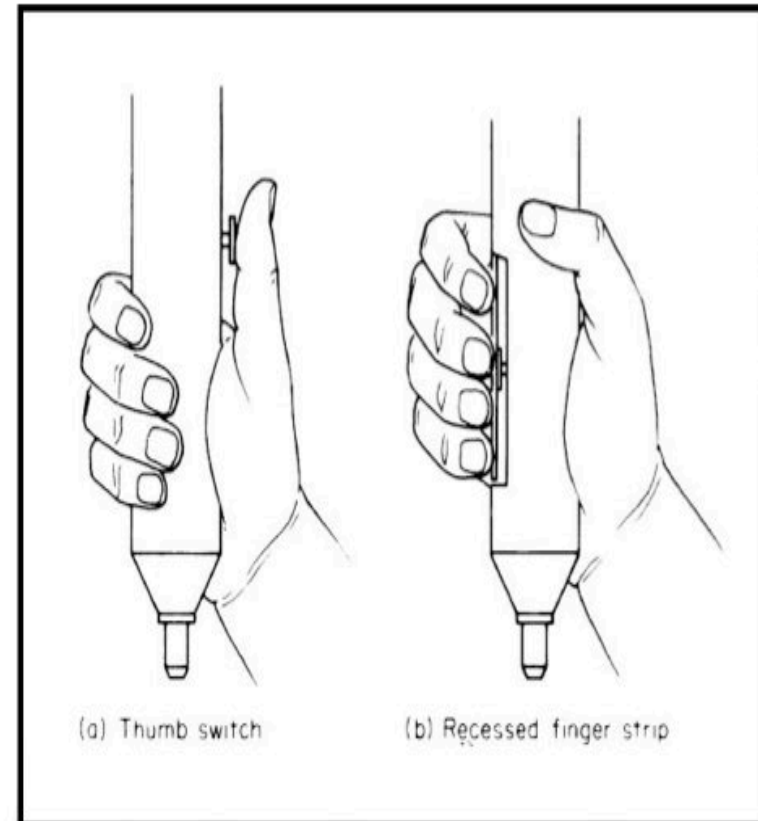


## SOLUTION

1, Thumb operated control: Should be used; as thumb is the only finger that is flexed, abducted and opposed by strong, short muscles located entirely within the palm of the hand.

**BUT NOT TO HYPER EXTEND THE THUMB.**

2. Finger strip control: Allows several fingers to share the load and frees the thumb to grip and guide the tool.



Thumb-operated and finger-strip operated pneumatic tools.

Figure 12.10

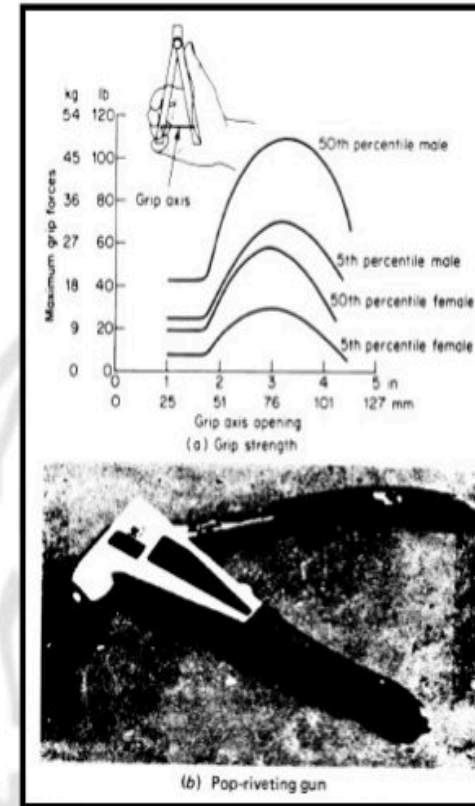
# How the grip axis should be?

GRIP STRENGTH is related to the size of the object being gripped.

Max grip strength for both male and female occurs with a grip axis between 2.5 and 3.5 in.

It varies in round objects , where the max grip strength occurs when diameter was 1.6 in.

Fig 12.11 b : Grip axis is 6 in, nearly impossible for most women to perform.



Maximum grip strength for various handle openings.  
Figure 12.11

# Principle 4: Design for Safe Operations

- This includes eliminating pinching hazards and sharp corners.

How? Putting guards.

Sharp corners and edges can be round.

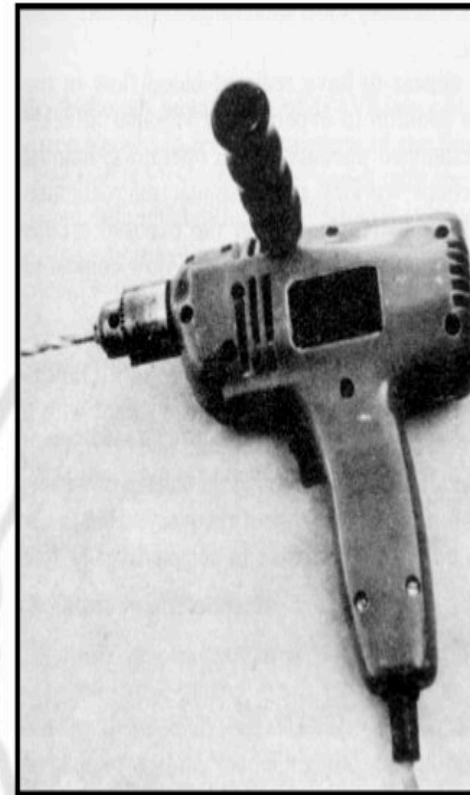
Power tool:

- like saw and drill can be designed with brake devices so that blade stops quickly when the trigger is released.
- Proper placement of the power switch.



# Principle 5: Remember Women and Left-handers

- Women make up approximately 50% and left-handers make up to approximately 8-10% of the world populations.



Drill with handle designed for right-handed operation.

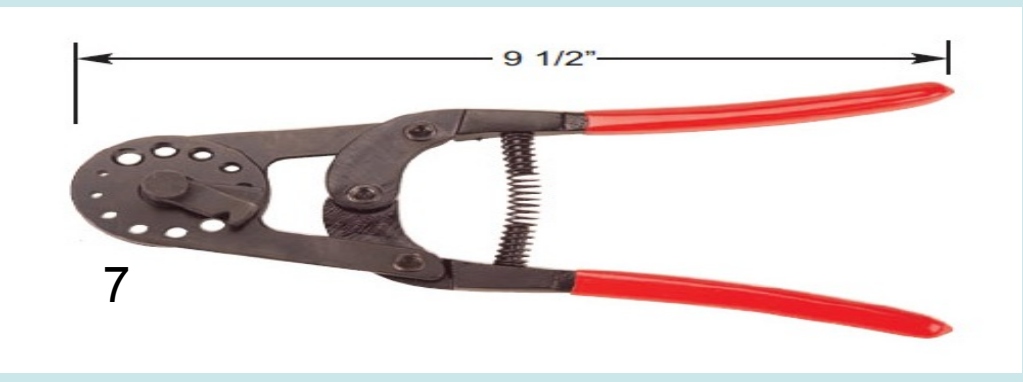
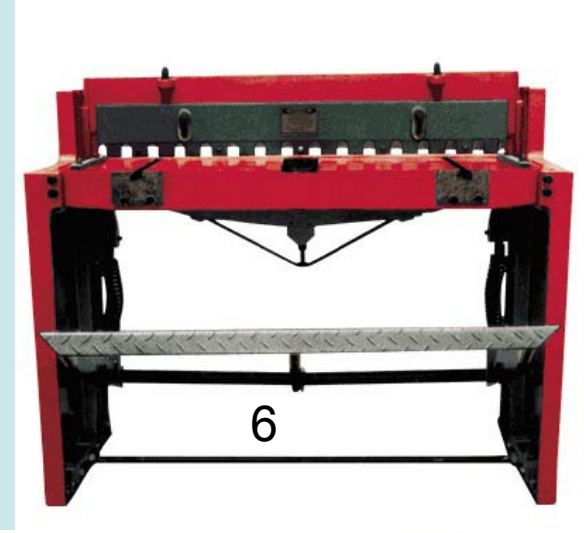
Figure 12.12

# Tool Related Problem by Air Force Females

Tool	Rated inadequate because	Percentage rating tool as inadequate
Wire strippers	Hard to hold in hand; handles too far apart to squeeze; too heavy; clumsy; too hard to squeeze; fingers get pinched	12 <sup>a</sup> ; 18 <sup>b</sup> ; 19 <sup>c</sup> ; 15 <sup>d</sup> ; 18 <sup>e</sup>
Crimping tool	Handles too far apart; too hard to squeeze; not able to manipulate	14 <sup>a</sup> ; 14 <sup>c</sup> ; 25 <sup>d</sup>
Soldering iron	Too heavy; handle too large; clumsy, too bulky	17 <sup>a</sup> ; 15 <sup>c</sup>
Soldering gun	Too heavy; cannot reach trigger; hard to hold in hand	15 <sup>a</sup>
Twist wire pliers	Too large to grip; handles too far apart	29 <sup>b</sup>
Metal shears	Too large; need two hands to cut	22 <sup>f</sup>
Rivet cutter	Too hard to squeeze; awkward	17 <sup>f</sup>
Caulking gun	Hard trigger; awkward	11 <sup>g</sup>

Tools rated inadequate by Air Force females.

Table 12.1

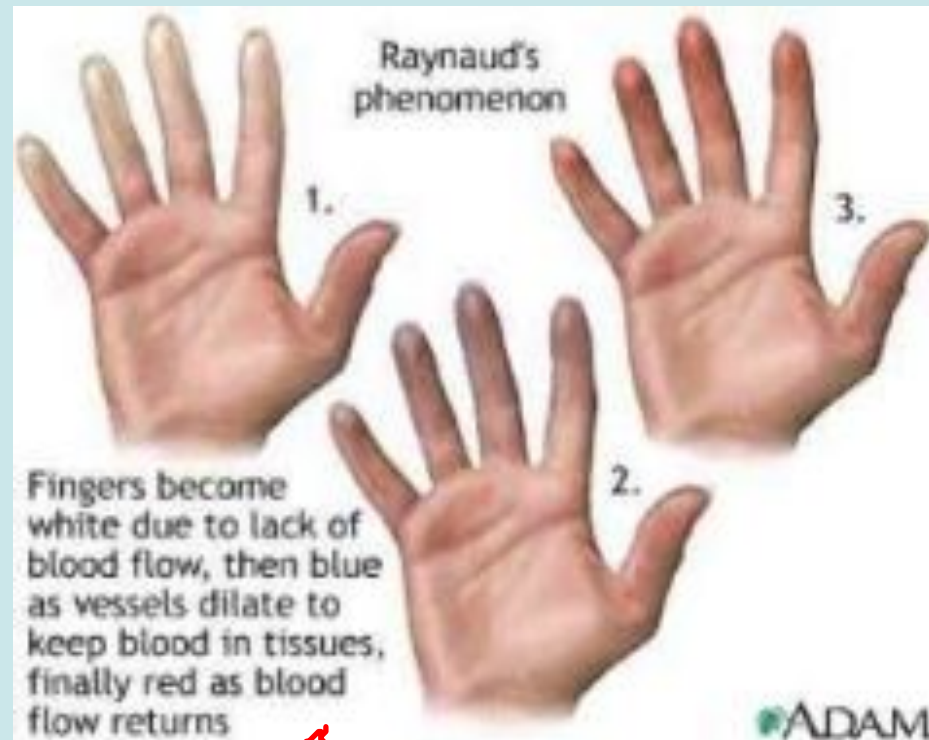


# VIBRATION

- **Two major types of vibration exposure:**
  - **Whole body vibration (4-8 Hz resonance)**
  - **Hand-arm vibration (segmental vibration)**
- **VIBRATION INDUCED WHITE FINGER  
/ VIBRATION SYNDROME/ HAND ARM  
VIBRATION SYNDROME (HAVS)**

# HAVS

- HAVS's complex pathology is not fully understood but probably involves damages to the nerves and smooth muscles of the blood vessels in the hand.



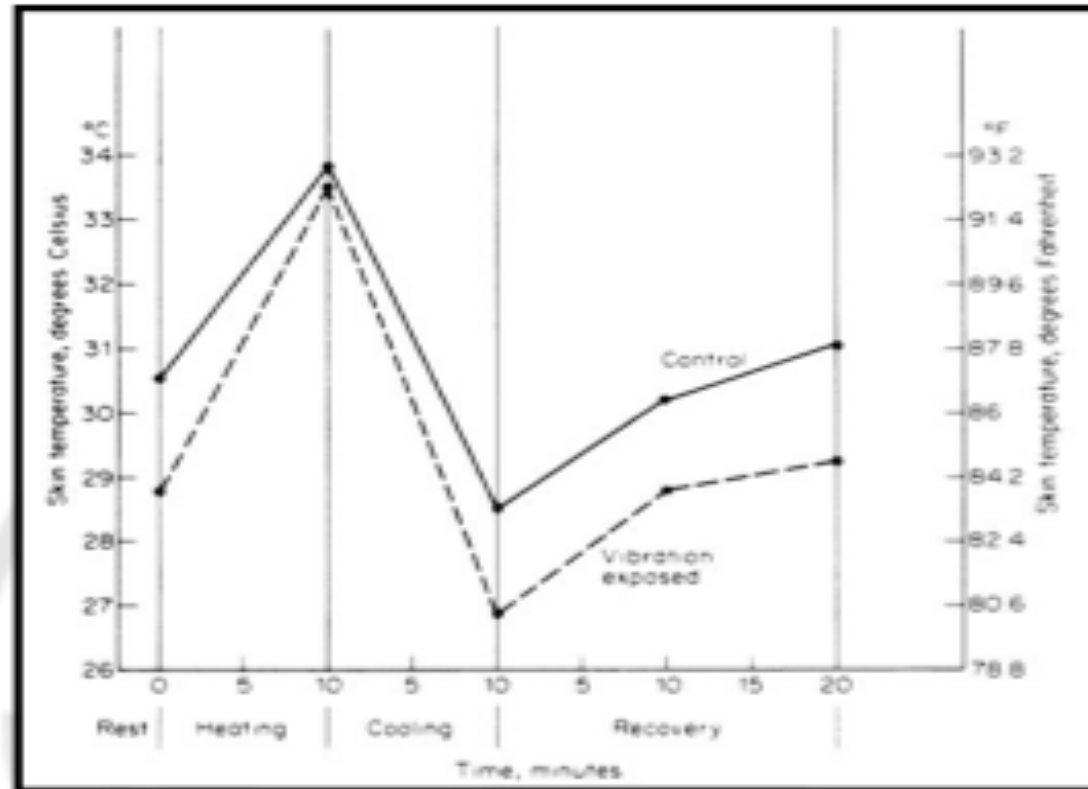
## • Symptoms:

- ~~-Reduction in blood flow to the fingers and hand.~~ Ultimate numbness in finger and hand
- Workers with HAVS will have vascular attacks within the hand or the fingers.
- The person will complain of pins and needles.
- These attacks seems to be brought on by cold.

## Consequences:

1. Workers affiliated with HAVS have reduced blood flow in hand under normal conditions. Koradecka(1977) found that the workers working with vibration has 38 to 67 % mean reduction in hand skin blood flow compared with control subjects.

2. Another consequence of this reduced blood flow is reduction in skin temperature.



**Skin temperature of the fourth finger during thermal testing of vibration exposed workers.**

**Figure 12.13**

(page 397)

Seack, University of Utah. 2005. ME 5120/6120: Human Factors in Engineering Design

Lower skin temperature is associated with a decrease in sensitivity and fine finger dexterity and a loss of grip.

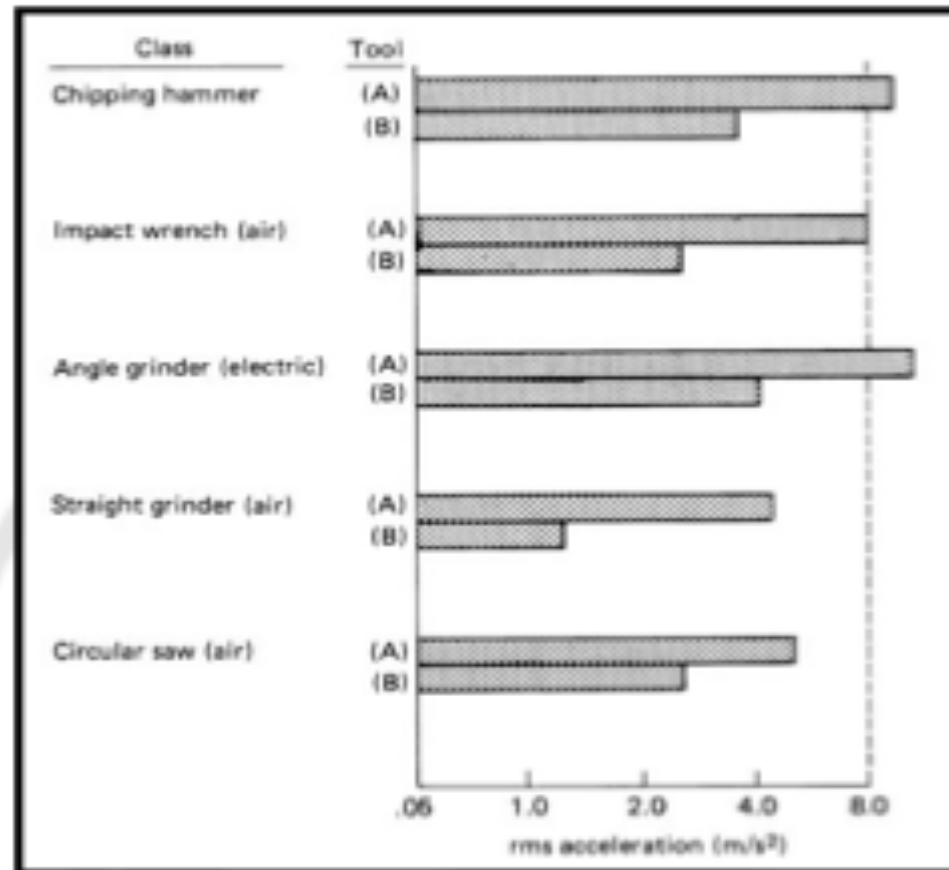
3. It may also cause numerous diseases like neuritis, decalcification, cysts of the radial and ulnar bones and pain and stiffness in joints.

Neuritis refers to an inflammation of the nerves, be it a single nerve or a series of nerves.  
Bone decalcification is the removal of calcium ions from the bone



# Controlling Hand-Arm Vibration Exposure

## 1. Select tools with lowest level of vibration.



Weighted hand-arm vibration accelerations in tools.

Figure 12.14

(page 399)

4

2. Properly maintain tools and keep cutting tools sharpened.

2

3. Use vibration reduction/ damping gloves

3

4. Minimize grip force needed to hold and control.

5

5. Alternate work tasks that do not require use of vibrating tools with those that do.

7

6. Limit daily use of vibrating tools.

8

7. Provide long rest breaks while using vibrating tools.

6

8. Limit number of days per week that vibrating tools are used by a worker.

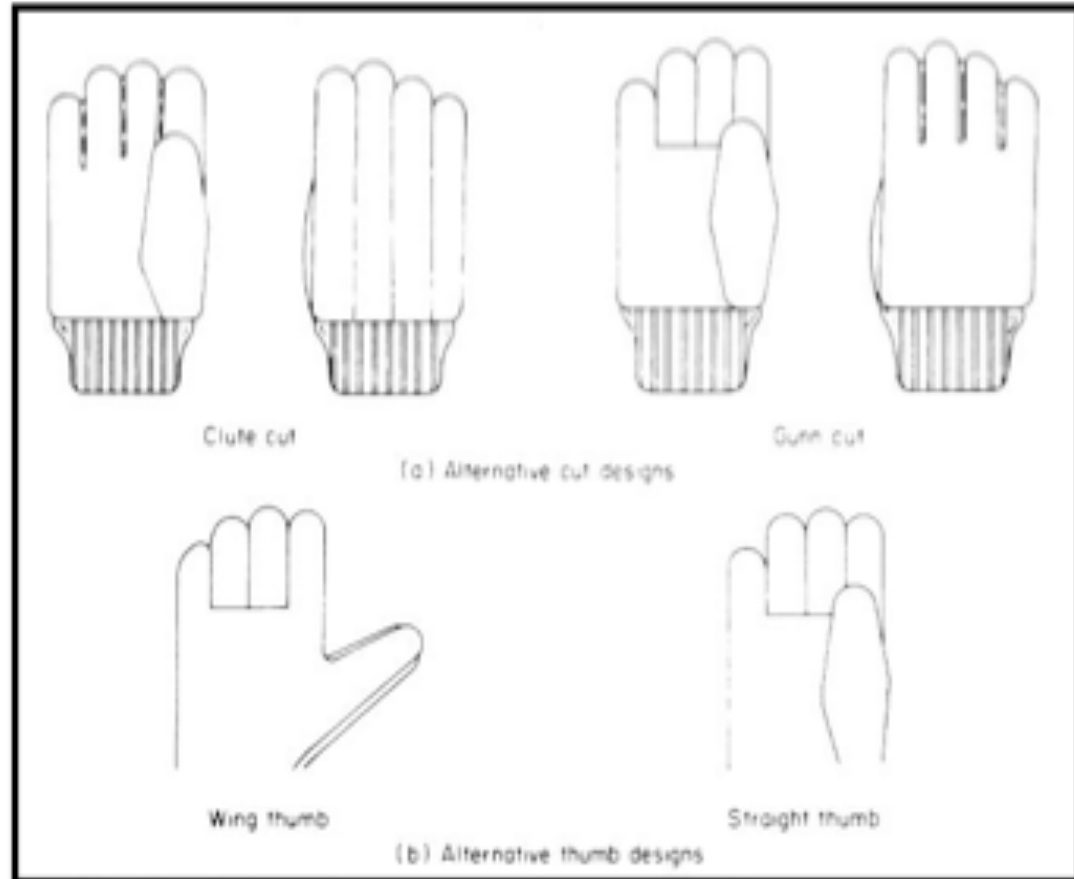
# Gloves

- Can protect the hands from physical and chemical insult.
- Can improve or hinder performance.
- Grip strength decreases while wearing gloves.
- One size does not fit all!

# GLOVES

Types.

1. Based on Material : Cotton, leather, vinyl, neoprene, asbestos, and even metal.
2. Based on cut: Clute cut and gunn cut
3. Based on the design of thumb: wing or straight,
4. Based on wristband (Knit, band, top, gauntlet, or extended length.)



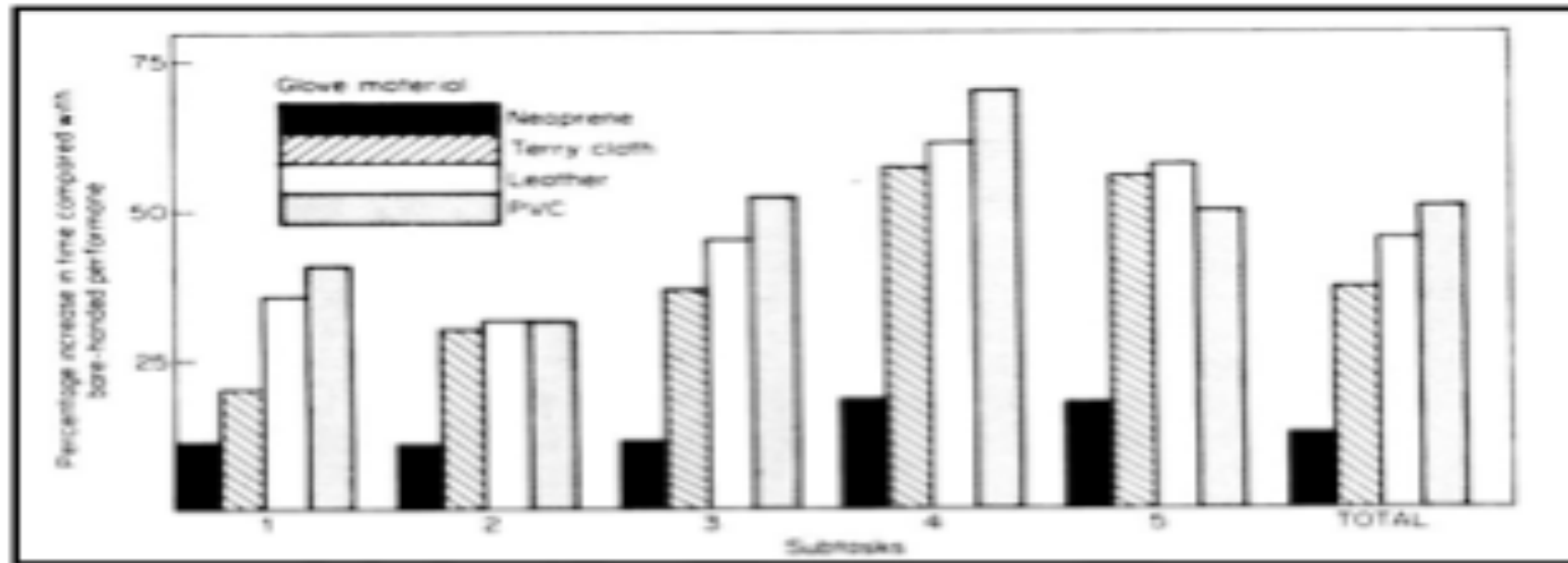
Common styles of work gloves.  
Figure 12.15

- **Clute Cut** – This is one of the patterns that is used on a cut-n-sew glove (material is cut into piece and sewn together to make the glove). A Clute cut glove has a seamless palm with **three** seams between the fingers all the way down the back of the glove. This pattern can be uncomfortable in thicker fabrics and leather.
- **Gunn Style** – This is another pattern that is used in a cut-n-sew glove. In this pattern there is a seamless back and **a seam** in the palm of the glove across **the base of the two middle fingers**. This places the “gunn” seam in a natural crease of the hand so that it is not uncomfortable. It is preferred for a heavy- duty glove.
- **Straight Thumb** – Designed for work that is done “Closed – fisted”. The seams on the glove are away from the gripping surface.
- **Wing Thumb** – Designed for work that is done “Open-handed”. The seams on the glove are away from the surface when the hand is open

# Effect on manual performances

Studies are based on only glove materials.

Weidman (1970) has a good example in this area, He compared 4 gloves and bare hand conditions on a performance of a maintenance type task.



**Performance time on maintenance-type task while wearing gloves.**

**Figure 12.16**

(page 401)

# Grip Strength and Gloves

Grip strength reduces with gloves.

WHY?

1. A certain amount of muscle force generated is lost between hand and glove.
  - Thickness of a glove changes the size of the grip axis.

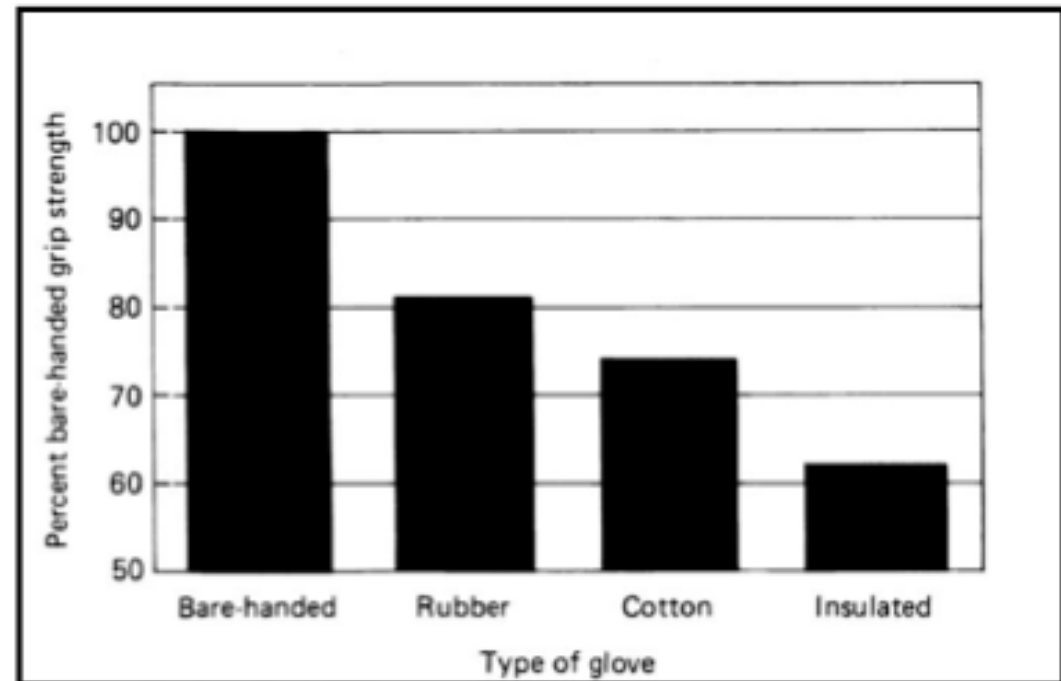
Consequences:

Dropping a tool

1 Poorer control of a tool

Lower quality work

Increased muscle fatigue.



Maximum voluntary grip strength while wearing various gloves.

Figure 12.17

# Other considerations

- The selection of proper glove material must take into account the evaluation of work environment and the type of hazards .
  - Knitted wristband can reduce the intrusion of potential irritants.
  - Neoprene or PVC coated gloves can reduce absorption of chemicals.

# **Grip Principles**

**2 types of Grip**

- i. Power Grip**
- ii. Precision Grip**

# Power Grip

- When Large forces are exerted.
- 4 fingers are in one side making a fist and the thumb is in other side.

## 3 types of power grips

- i. force parallel to the forearm (saw).
- ii. force at an angle to the forearm (hammer).
- iii. torque about the forearm (corkscrew).

# Precision Grip

Tool is pinched between the thumb and fingers.

For small forces

## 2 types of precision grip

- i. Internal Grip: Shaft of the tool is internal to the hand.
- ii. External Grip: Shaft of the tool is external to the hand.

## GRIP THICKNESS:

- i. Diameter – 40 mm for power grip// 50-60 mm in some cases  
>6 mm for precision grip
- ii. People with small hand should not perform repetitively grip with larger than 60 mm.
- iii. Cross tools like scissors should have max span 100 mm and min 60 mm.
- iv. Muscles of the hand closing is stronger than the muscles of the opening. A spring can be used to open the handles.

## Grip Length:

- i. 125 mm length is comfortable, where it should not limit tool head think about scissors opening and should avoid excess compressive force of the palm.
- ii. For external precision grip the length should be at least 100 mm and should be long enough to support the first finger and thumb.
- iii. For internal precision grip the length should past the palm.

## Grip Force:

For Swedish male :525 N and female:300 N, for 1 min without fatigue.

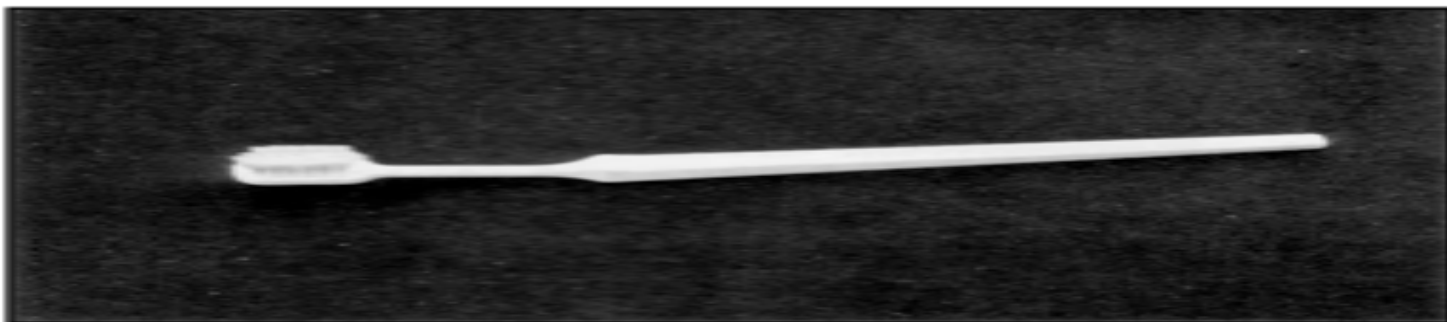
## Grip Surface characteristics:

Slightly compressive, non-conductive and smooth.

## Evaluation of Alternative Designs

**Tooth brush example in text:**

- Measure existing tools (toothbrushes) and existing users. 2 main objectives were found .**
- Question the target population.**
- Obtain expert opinion (dentists and hygienists)**
- Observe/measure subject performance while using existing products with time-motion film studies.**
- Measure outcome (performance) objectively**



**Reach toothbrush.  
Figure 12.18**

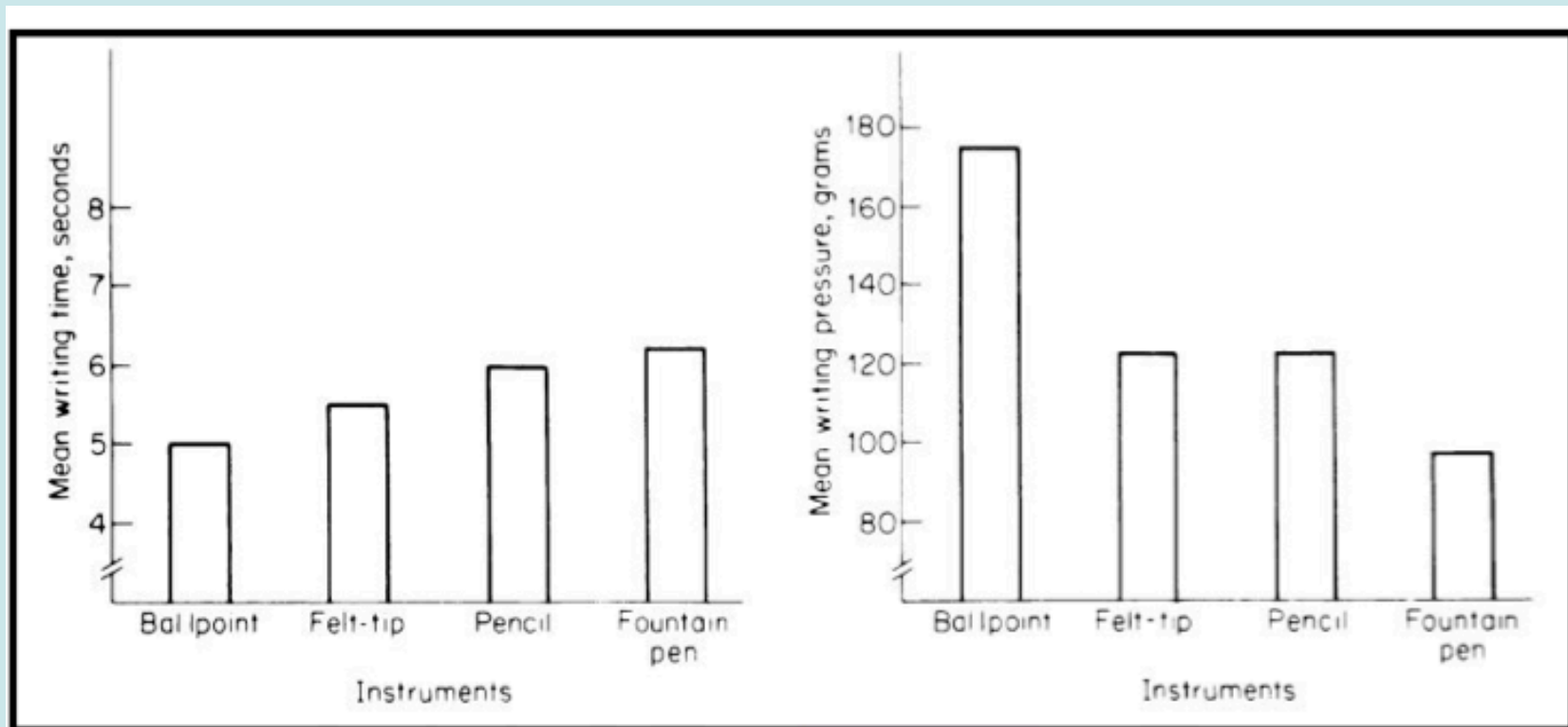
The new design includes

1. Small bi-level bristle head to concentrate brushing on a small area.
2. An angled (12 degree) and shaped handle.
3. A contoured thumb area.



# Writing Instruments

Trade off: Speed/ Fatigue



Comparison of writing speed and writing pressure with four writing instruments.