The association between occupations and musculoskeletal injuries was documented centuries ago.

Bernardino Ramazinni (1633-1714) wrote about work-related complaints (that he saw in his medical practice) in the 1713 supplement to his 1700 publication, "De Morbis Artificum (Diseases of Workers)."

Presently, Work Related to Musculoskeletal Disorder and Human Error are considered the research challenges in ergonomics field.
5 Trigger Finger

6 Tendon Damage and Pain

- Damage:
  - torn
  - tendinitis
  - tenosynovitis

Finkelstein’s test: the patient is instructed to grasp the thumb of the affected hand with the other fingers and actively pull the thumb towards the small finger. Sharp pain will be elicited over the area indicated by the red dot if the patient suffers from deQuervain’s tenosynovitis.

7 Tendon Inflammation

Examples

- Rotator Cuff Tendinitis

8 การบาดเจ็บบริเวณหัวไหล่

การอักเสบของเอ็นบริเวณเข่าไหล่
9. Epicondilitis
การบาดเจ็บบริเวณข้อศอก: Epicondylitis
การอักเสบของเอ็นข้อศอกบริเวณ Epicondyle

10. Epicondylitis (Elbow strain)
การบาดเจ็บของเอ็นกระดูกข้อเท้า
การบาดเจ็บของเอ็นกล้ามเนื้อข้อศอก

11. Raynaud’s Phenomenon

12. Carpal Tunnel Syndrome
Reducing Risk of Hand and Wrist

An example of research in Ergonomics
From: Applied Ergonomics

An evaluation of arborist handsaws
Gary A. Mirka\textsuperscript{a}, Sangeun Jin\textsuperscript{b}, Jeff Hoyle\textsuperscript{c}
\textsuperscript{a}Department of Industrial and Manufacturing Systems Engineering, Iowa State University, Ames, IA 50011-2194, USA
\textsuperscript{b}The Ergonomics Laboratory, Department of Industrial Engineering, North Carolina State University, Raleigh, NC 27695-7906, USA
\textsuperscript{c}The Ergonomics Center of North Carolina, Raleigh, NC 27606, USA

Form
Applied Ergonomics 40 (2009) 8–14

Low Back Problem of a Disc Ruptures

A disc that has been weakened may rupture or herniate. If the annulus ruptures, or tears, the material in the nucleus can squeeze out of the disc, or herniate. A disc herniation usually causes compressive problems if the disc presses against a spinal nerve. The chemicals released by the disc may also inflame the nerve root, causing pain in the area where the nerve travels down the leg.
Hamstring muscles cause the rotation of pelvises.

Changes in lumbar spinal curve resulting from pelvis rotation - increase disc pressure.

Andersson and et.al. (1974) - Changes in Spinal Disc Pressure at L3/L4 from Different Sitting Postures.

An example of research in Ergonomics:

Instrumentation for measuring dynamic spinal load moment exposures in the workplace.

William S. Marras*, Steven A. Lavender, Sue A. Ferguson, Riley E. Splittstoesser, Gang Yang, Pete Schabo
Institute for Ergonomics, Biodynamics Laboratory, The Ohio State University, 1971 Neil Avenue, Columbus, OH 43210, USA.
Wojciech Jastrzebowski created the word **ergonomics** in 1857 in a philosophical narrative, "based upon the truths drawn from the Science of Nature" (Jastrzebowski, 1857).

**Ergonomics Meaning**

- The word "Ergonomics" comes from the following two Greek words:
  
  **Ergonomics = Ergos + Nomos**
  
  - **Ergos** which means "work"
  - **Nomos** which means "laws"

  Useful work or Harmful work
An example of research in Ergonomics
From: Ergonomics

Estimation of hand force in ergonomic job evaluations

STEPHEN BAO* and BARBARA SILVERSTEIN
SHARP Program, Department of Labor and Industries, P.O. Box 44330, Olympia, WA 98504-4330 USA

Table 2. Pinch and power grip strength (in N)

<table>
<thead>
<tr>
<th>Gender</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
<th>95% Confidence interval</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pinch</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>64</td>
<td>19.2</td>
<td>20.6</td>
<td>14.1 – 24.4</td>
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<tr>
<td>Male</td>
<td>56</td>
<td>125.1</td>
<td>21.9</td>
<td>118.7 – 131.5</td>
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<tr>
<td>Power</td>
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<tr>
<td>Female</td>
<td>64</td>
<td>294.0</td>
<td>65.9</td>
<td>277.8 – 310.7</td>
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<tr>
<td>Male</td>
<td>56</td>
<td>470.0</td>
<td>78.1</td>
<td>449.6 – 490.4</td>
</tr>
</tbody>
</table>

Introduction to Ergonomics and Its Importance

25

An example of research in Ergonomics
From: Journal of Biomechanics

The effect of torque direction and cylindrical handle diameter on the coupling between the hand and a cylindrical handle

Na Jin Seo*, Thomas J. Armstrong, James A. Ashton-Miller*, Don B. Chaffin
*Department of Industrial and Operations Engineering, University of Michigan, Ann Arbor, MI 48109, USA
†Department of Mechanical Engineering, University of Michigan, Ann Arbor, MI 48109, USA

Introduction to Ergonomics and Its Importance

26

An example of research in Ergonomics
From: International Journal of Industrial Ergonomics

The effects of work height, workpiece orientation, gender, and screwdriver type on productivity and wrist deviation

Patrick G. Dempsey*, Raymond W. McGorry, Niall V. O'Brien
Liberty Mutual Research Center for Safety & Health, 71 Franklin Road, Haverhill, MA 01830, USA

Introduction to Ergonomics and Its Importance

27

An example of research in Ergonomics
From: Ergonomics

Evaluation of handle design characteristics in a maximum screwdriving torque task†

Y.-K. KONG*, B. D. LOWE†, S.-J. LEE† and E. F. KRIEG†
†Department of Systems Management Engineering, SungKyunKwan University, Suwon, Korea
‡National Institute for Occupational Safety and Health, Cincinnati, OH, USA
†The College of Medicine, Hanyang University, Suwon, Korea

Table 2. Dimensions of screwdriver handles (mm) (the nominal cross-sectional diameter is 45.0 mm)

<table>
<thead>
<tr>
<th>Shape</th>
<th>Diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylindrical</td>
<td>42.0</td>
</tr>
<tr>
<td>Reversed double frustum</td>
<td>42.0</td>
</tr>
<tr>
<td>Double frustum (DF)</td>
<td>42.0</td>
</tr>
<tr>
<td>Cone</td>
<td>33.5</td>
</tr>
</tbody>
</table>

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Department of Systems Management Engineering, SungKyunKwan University, Suwon, Korea
National Institute for Occupational Safety and Health, Cincinnati, OH, USA
The College of Medicine, Hanyang University, Seoul, Korea

Figure 1. Workplace for maximum torque task. (a) vertical workpiece orientation taken from a side view; (b) horizontal workpiece orientation taken from a top view.

An example of research in Ergonomics
From: Applied Ergonomics 40 (2009), 303-308

Shoulder strength of females while sitting and standing as a function of hand location and force direction

Amy Y. Chow, Clark R. Dickerson

Department of Kinesiology, University of Waterloo, 200 University Avenue West, Waterloo, Ontario, Canada N2L 3G1

Fig. 2. Experimental set-up for four test conditions.

An example of research in Ergonomics
From: Applied Ergonomics

Biomechanical assessment of new hand-powered pruning shears

Yves Roquelaure, Fabian D’Espagnac, Yves Delamarre, Dominique Penneau-Fortin

Department of Occupational Health and Ergonomics, University Hospital Angers, France
Doctoile S.A., 27 de Beaucourt, Bruay, France

An example of research in Ergonomics
From: International Journal of Industrial Ergonomics

The ergonomics of spray guns – Users’ opinions and technical measurements on spray guns compared with previous recommendations for hand tools

Gunnar Björing, Göran M. Hägg
An example of research in Ergonomics

From: International Journal of Industrial Ergonomics

Understanding work productivity and its application to work-related musculoskeletal disorders

Reuben Escorpizo\textsuperscript{a,b,m}

\textsuperscript{a}Department of Physical Therapy, Leesburg Regional Medical Center, 700 N Palmetto St., Leesburg, FL 34788, USA
\textsuperscript{b}College of Health Sciences, Des Moines University, 3200 Grand Avenue, Des Moines, IA 50312-4168, USA

An example of research in Ergonomics

From: Applied Ergonomics

Integrating ergonomics into production system development – The Volvo Powertrain case

W. Patrick Neumann\textsuperscript{a,b}, Marianne Ekman\textsuperscript{b}, Jorgen Winkel\textsuperscript{c,d}

\textsuperscript{a}Department of Mechanical and Industrial Engineering, Queen’s University, 250 Victoria St., Kingston, ON, Canada M5B 1M8
\textsuperscript{b}Department of Mechanical Engineering, Linkoping University, S-581 83 Linkoping, Sweden
\textsuperscript{c}Department of Work Science, University of Copenhagen, Sweden

ตัวอย่างงานวิจัยทางด้านการยศาสตร์

From: การประชุมวิชาการเครือข่ายวิศวกรรมอุตสาหการ IE NETWORK 2006

การพัฒนาระบบประเมินความเสี่ยงเพื่อการออกแบบทางด้านการยศาสตร์

The development of a risk evaluation system for ergonomics design:

A case study of welding shop in automotive industry

นเรศ ราชพฤกษ์ ผู้ช่วยผู้ใหญ่ วิศ. อุตสาหภูมิ

การวิเคราะห์อุบัติเหตุส่วนบุคคลโดยใช้กลักการยศาสตร์

From: การประชุมวิชาการเครือข่ายวิศวกรรมอุตสาหการ IE NETWORK 2009

21-21 ตุลาคม 2552

การป้องกันสภาพแวดล้อมของคุณภาพโดยใช้กลักการยศาสตร์:

การศึกษาทางอุตสาหกรรมรวมถึงวิศวกรรมอุตสาหกรรม

พุทธิพงษ์ ปุรุตทิศกุลประสิทธิ์ และ นริศ ราชพฤกษ์

การวิเคราะห์อุบัติเหตุส่วนบุคคล การซ่อมแซมอุปกรณ์ วิศวกรรมอุตสาหกรรม
**History of Ergonomics: IV**

Frank and Lillian Gilbreth made jobs more efficient and less fatiguing through time motion analysis and standardizing tools, materials and the job process.

By applying this approach, the number of motions in bricklaying was reduced from 18 to 4.5 allowing bricklayers to increase their pace of laying bricks from 120 to 350 bricks per hour.

**Case Study III**


**Toyota – Georgetown, KY**

62% Reduction in Cycle Time

Ergonomic risk reduced by 65%

**An example of research in Ergonomics**

From: Applied Ergonomics

Cost effectiveness of ergonomic redesign of electronic motherboard

Rabindra Nath Sen\textsuperscript{a,b}, Paul H.P. Yeow\textsuperscript{b}

\textsuperscript{a}Ergonomics Centre, Faculty of Management, Multimedia University, 63100 Cyberjaya, Malaysia
\textsuperscript{b}Ergonomics Centre, Faculty of Business and Law, Multimedia University, 75450 Melaka, Malaysia

The motherboard was redesigned to correct the design errors, to allow more components to be machine soldered and to reduce MC. This eliminated rejects, reduced repairs, saved US $581,495/year and improved operators’ OHS. The customer also saved US $142,105/year on loss of business.
World War II prompted greater interest in human-machine interaction as the efficiency of sophisticated military equipment (i.e., airplanes) could be compromised by bad or confusing design.

Design concepts of fitting the machine to the size of the soldier and logical/understandable control buttons evolved.

After World War II, the focus of concern expanded to include worker safety as well as productivity. Research began in a variety of areas such as:

* Muscle force required to perform manual tasks
* Compressive low back disk force when lifting
* Cardiovascular response when performing heavy labor
* Perceived maximum load that can be carried, pushed or pulled

There were ergonomic issues when reaching to a torque wrench in this assembly operation. Because there was no previous injury, management didn’t see the urgency to improve the job and lower the torque wrench.
Case Study I
Ref: Humantech, Inc (2004) by McGowan

Point of Motion Constraint Example

Lowering the tool 12” will save 0.26 second of wasted motion time, in addition to improved working postures. The reach is performed three times during a 45 second cycle for 8 hours resulting in a time savings of approximately 8+ minutes/shift.

Case Study II
Ref: Humantech, Inc (2004) by McGowan

Honeywell – Torrance, CA

Line Redesign Project
- Eliminated highest risk tasks
- 37% increase in productivity
- Operators very satisfied

Plant Workers’ Compensation Reduced by $2 Million Per Year

Postures effecting on shoulder muscle fatigue

Expected time to reach significant shoulder muscle fatigue for varied arm abduction angle. (Chaffin, 1973)

Shoulder abduction effecting on fatigue and performance

Performance and metabolic energy expenditure rates from study of 12 female grocery packers (Tichauer, 1978), from Chaffin (1991)
Effects of static effort on energy consumption (measured by oxygen consumption) for three ways of carrying a school satchel. Ref: Malhotra and Sengupta (1965)

Static muscular effort in the left arm during potato planting. Ref: Hettinger (1970)

History of Ergonomics: VII

Areas of knowledge that involved human behavior and attributes (i.e., decision making process, organization design, human perception relative to design) became known as cognitive ergonomics or human factors.

Areas of knowledge that involved physical aspects of the workplace and human abilities such as force required to lift, vibration and reaches became known as industrial ergonomics or product design ergonomics.
Ergonomics: Man-Machine Interaction

Labels that look like pushbuttons

www.baddesigns.com

Ergonomics: Man-Machine Interaction

www.baddesigns.com

Ergonomics: Man-Machine Interaction

www.baddesigns.com

Ergonomics: User Friendly Design

www.baddesigns.com

A.

B.

A. [Image of equipment]

B. [Image of equipment]

www.baddesigns.com

คําแนะนํา

Press Menu then to lock or unlock keypad.

Press Menu then to unlock.

ค่าแนะนํา

www.baddesigns.com
Ergonomics: Human Error

Definition of Ergonomics

a "good fit" between humans and all components in a working system

www.baddesigns.com

What is Ergonomics?
Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance.

Ref: IEA (International Ergonomics Association) <www.iea.cc>

Ergonomists contribute to the **design** and **evaluation** of tasks, jobs, products, environments and systems in order to make them compatible with the needs, abilities and limitations of people.

Ref: IEA (International Ergonomics Association) <www.iea.cc>

**IEA (International Ergonomics Association)**

The main goal of IEA:

To elaborate and advance the science and practice of ergonomics at the international level

To improve the quality of life by expanding the scope of ergonomics applications and contributions to global society

---

**IEA Technical Committee**

<table>
<thead>
<tr>
<th>Sector</th>
<th>Sub-sector</th>
</tr>
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<tbody>
<tr>
<td>Aging</td>
<td>Human-Computer Interaction</td>
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<tr>
<td>Agriculture</td>
<td>Human Reliability</td>
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<td>Auditory Ergonomics</td>
<td>Musculoskeletal Disorders</td>
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<td>Organizational Design and Management</td>
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<td>Building and Construction</td>
<td>Process Control</td>
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<td>Consumer Products</td>
<td>Psychophysiological in Ergonomics</td>
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<td>Cost-Effective Ergonomics</td>
<td>Quality Management</td>
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<td>Ergonomics for Children and</td>
<td>Rehabilitation Ergonomics</td>
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<td>Educational Environment</td>
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<td>Hospital Ergonomics</td>
<td>Safety and Health</td>
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<tr>
<td>Human Aspects of Advanced Manufacturing</td>
<td>Standards</td>
</tr>
</tbody>
</table>
Ergonomist in US.

The Certified Professional Ergonomist (CPE)
Certified Human Factors Professional (CHFP)

Associate Ergonomics Professionals (AEP)
Associate Human Factors Professionals (AHFP)
Certified Ergonomics Associate (CEA)

www.bcpe.org

Professional in Ergonomics

United States:
BCPE (Board of Certification in Professional Ergonomics)
http://www.bcpe.org
Certified Professional Ergonomist (CPE)
Certified Human Factors Professional (CHFP)

Canada:
CCCPE – Canadian certification Council for Professionnal ergonomists
http://www.ace-ergocanada.ca

Europe:
CREE - Centre for Registration of European Ergonomists
http://www.eurerg.org/index.htm

Professional in Ergonomics (cont.)

Australia:
Register of Certified Professional Ergonomists
http://www.ergonomics.org.au

New Zealand:
BCNZE - Board for Certification of New Zealand Ergonomists
http://www.ergonomics.org.nz

Japan:
JES (Japan Ergonomics Society)
JES Certification Programm for Professionnal ergonomists
http://www.ergonomics.jp/cpe/index_e.html

Thailand:
EST (Ergonomics Society of Thailand)
http://www.est.or.th

Similar Words in Ergonomics

- Human Factors in Engineering
- Human Engineering
- Work Physiology
- Sport Physiology
- Occupation Biomechanics
- Sport Biomechanics
- Cognitive Engineering
- Engineering Psychology
Ergonomics Concept

- Inappropriate Design
  - Effect on health
  - Effect on performance/productivity
  - Effect on quality
  - Effect on error, accident and safety

Ergonomics Problems

Where ergonomics knowledge come from:

- **Common Sense**
  - human experience learning
  - trial and error performing

- **Sophisticated Science**
  - scientific proof by measuring and experiments

Scientific Basics of Ergonomics

- Physics, Mechanics,
- Biology, Physiology
- Engineering psychology, behavior
- Statistics and epidemiology
- Anthropometry
- Job Analysis, Work Design

Ergonomics Philosophy

- Fit the job to the man
- Fit the man to the job

**What are the differences between the two philosophies above?**

**Others philosophies in ergonomics design**

- Human centered thinking
- User friendly design
Ergonomics Consideration

- Understanding human characteristics both in capacity and limitation
- Using the characteristics for new designs and improving existing design
- Evaluating the designs by the following criterions:
  - Easier: the design easy and shorten to learn
  - Better: the design convenient to use
  - Safer: the design safer than the previous

Ergonomics: Main Goals:

- Provide a safe and healthful working environment engineered to the capabilities of the human body
- Decrease worker fatigue and discomfort through the elimination of excess effort
- Increase efficiency and productivity by reducing worker fatigue
- Improve quality by providing designs that reduce the potential for human error
- Enhance customer service through improved worker morale
- Elevate job satisfaction
- Reduce injuries/illness
- Reduce costs

The Scope of Ergonomics

- Consumer products
- Office workplace
- Manufacturing process
- Transportation

Manufacturing Ergonomics

- Product Design
- Manufacturing Process Design
- Production System Design
- Personal Assignment
- Work Organization
An Ergonomics Model
All factors related to ergonomics consideration in design

A visual inspection task

Stress
- Physical workload
- Environmental workload
- Psychological/Mental workload
- Other psychosocial effects

Physical Strain
Physiological Strain
Psychological/Mental Strain
Epidemiology

Physical stress from awkward postures

- Incorrect head and neck position.
  - Tension in the neck muscles can lead to headaches.
- Feet not firmly on a footrest, pressure can build up.
- Wrist and hands out line with forearms causes a static load in:
  - Shoulders
  - Arms
  - Can lead to upper back and neck

A toy assembly operator
Sawing Operators

A sawing operator

Stress
- Physical workload
- Environmental workload
- Psychological/Mental workload
- Other psychosocial effects

Ergonomic Stressors:
- Force
- Repetition
- Awkward Postures
- Static Postures
- Vibration
- Contact Stress
- Environmental Factors

Physical Strain
Physiological Strain
Psychological/Mental Strain
Epidemiology

How to identify the job stress

- Subjective methods
- Objective methods

How to measure job stress and evaluate risk?

Subjective methods
- Body Discomfort Mapping
- Standard Nordic Questionnaire,
- Abnormal Index
- Biomechanical model
- NIOSH lifting equations
- RULA, REBA, OWAS
- Strain index
- Others

Objective methods
- Electromyography (EMG)
- Oxygen consumption
- Heart rate
- Body temperature
- Goniometer
- CFF
- Reaction time
- Others
Job stress studied in a sewing operation
(% of body part discomfort reported by workers, N=410)

- Neck (43.9%)
- Shoulders (53.2%)
- Upper back (51.5%)
- Upper arms (22.0%)
- Elbows (4.4%)
- Lower back (61.5%)
- Lower arms/Forearms (7.8%)
- Buttock (38.3%)
- Hands and wrists (13.2%)
- Upper legs (25.1%)
- Knees (26.6%)
- Lower legs (44.6%)
- Feet (19.8%)

From: N. Charoenporn (1994)

Example of a body discomfort check

A simple biomechanical model
(to calculate spinal load)

Goniometer
Electromyography (Surface EMG)

Purpose of Manufacturing Ergonomics

- To match the Design of Equipment, Tools and Work Assignments to the Capabilities and Limitations of the Operators
- To optimize Human Performance, Product Quality, Productivity, Health and Safety

Heart Rate Monitor

Human Characteristics

1. Physical Characteristics:
2. Physiological Characteristics:
3. Psychological/ Psychophysical/ Cognitive Characteristics
4. Behavioral Characteristics
1. Physical Characteristics

- Static anthropometric data: size, length, width, weight, others
- Dynamic Anthropometric Data: area or length of motions, reach

Physical Characteristics: Example

- Different body height

Anthropometric Data & Workstation Design

Anthropometric Data: Example

Standing

<table>
<thead>
<tr>
<th></th>
<th>Female</th>
<th></th>
<th>Male</th>
</tr>
</thead>
<tbody>
<tr>
<td>5th</td>
<td>50th</td>
<td>95th</td>
<td>5th</td>
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<tr>
<td>Standing</td>
<td></td>
<td></td>
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<tr>
<td>1. Tibial height</td>
<td>38.1</td>
<td>42.0</td>
<td>46.0</td>
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<tr>
<td>2. Knuckle height</td>
<td>64.3</td>
<td>70.2</td>
<td>75.9</td>
</tr>
<tr>
<td>3. Elbow height</td>
<td>93.6</td>
<td>101.9</td>
<td>108.8</td>
</tr>
<tr>
<td>4. Shoulder (acromion) height</td>
<td>121.1</td>
<td>131.1</td>
<td>141.9</td>
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<tr>
<td>5. Stature</td>
<td>149.5</td>
<td>160.5</td>
<td>171.3</td>
</tr>
<tr>
<td>6. Functional overhead reach</td>
<td>185.0</td>
<td>199.2</td>
<td>213.4</td>
</tr>
</tbody>
</table>

| A. Seat length (min) | 70-74 cm (28”-29”) | 70-74 cm (28”-29”) |
| B. Table top height (min) | 90-95 cm (36”-38”) | 90-95 cm (36”-38”) |
| C. Table top distance (max.) | 30 cm (12”) | 30 cm (12”) |
| D. Knee clearance | 10 cm (4”) | 10 cm (4”) |
| E. Elbow clearance (min.) | 40 cm (16”) | 40 cm (16”) |
| F. Foot clearance (min.) | 28 cm (11”) | 28 cm (11”) |
Do we need more handles for users with different heights?

- How can we select a suitable handle height?
- How can we locate the handle height for different size of people?
- How many should handles be installed?

The solution for locating handles of the cupboards and cabinets

Anthropometric Data: Example

Sitting

<table>
<thead>
<tr>
<th></th>
<th>Female 5th</th>
<th>Female 50th</th>
<th>Female 95th</th>
<th>Male 5th</th>
<th>Male 50th</th>
<th>Male 95th</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Functional forward reach</td>
<td>64.0</td>
<td>71.0</td>
<td>79.0</td>
<td>76.3</td>
<td>82.5</td>
<td>88.3</td>
</tr>
<tr>
<td>8. Buttock-knee depth</td>
<td>51.8</td>
<td>56.9</td>
<td>62.5</td>
<td>54.0</td>
<td>59.4</td>
<td>64.2</td>
</tr>
<tr>
<td>9. Buttock-popliteal depth</td>
<td>43.0</td>
<td>46.1</td>
<td>53.6</td>
<td>44.2</td>
<td>49.5</td>
<td>54.8</td>
</tr>
<tr>
<td>10. Popliteal height</td>
<td>35.9</td>
<td>39.6</td>
<td>44.3</td>
<td>39.2</td>
<td>44.2</td>
<td>48.0</td>
</tr>
<tr>
<td>11. Thigh clearance</td>
<td>10.6</td>
<td>13.7</td>
<td>17.5</td>
<td>11.4</td>
<td>14.4</td>
<td>17.7</td>
</tr>
<tr>
<td>12. Sitting elbow height</td>
<td>18.1</td>
<td>23.3</td>
<td>28.1</td>
<td>19.0</td>
<td>24.3</td>
<td>29.4</td>
</tr>
<tr>
<td>13. Sitting eye height</td>
<td>67.5</td>
<td>73.7</td>
<td>81.9</td>
<td>72.6</td>
<td>78.6</td>
<td>84.4</td>
</tr>
<tr>
<td>14. Sitting height</td>
<td>79.2</td>
<td>85.0</td>
<td>90.7</td>
<td>84.2</td>
<td>90.6</td>
<td>96.7</td>
</tr>
<tr>
<td>15. Hip breadth</td>
<td>31.2</td>
<td>36.4</td>
<td>43.7</td>
<td>30.8</td>
<td>35.4</td>
<td>40.6</td>
</tr>
<tr>
<td>16. Elbow-to-elbow breadth</td>
<td>31.5</td>
<td>38.4</td>
<td>49.1</td>
<td>35.0</td>
<td>41.7</td>
<td>40.6</td>
</tr>
</tbody>
</table>

Anthropometric Data: Example

Grip breadth

<table>
<thead>
<tr>
<th></th>
<th>Female 5th</th>
<th>Female 50th</th>
<th>Female 95th</th>
<th>Male 5th</th>
<th>Male 50th</th>
<th>Male 95th</th>
</tr>
</thead>
<tbody>
<tr>
<td>17. Grip breadth, inside diameter</td>
<td>4.0</td>
<td>4.3</td>
<td>4.6</td>
<td>4.2</td>
<td>4.8</td>
<td>5.2</td>
</tr>
<tr>
<td>18. Interpupillary distance</td>
<td>5.1</td>
<td>5.8</td>
<td>6.5</td>
<td>5.5</td>
<td>6.2</td>
<td>6.8</td>
</tr>
</tbody>
</table>

1 in. = 2.54 cm.
Special Anthropometric Data for Workspace

Recommendation of Working Height

Different heights of working surface & Different works

2. Physiological Characteristics

- **Functional Characteristic**
  - Muscle neural control system
  - Muscle contraction and effort
  - Metabolism process and the system related to create energy in human body

- **Load Characteristic:**
  Muscle strength, endurance and fatigues

Human Work & Physiology

- Posture & Motion
- Muscular effort
- Biomechanics & Strength
- Energy, Heat & Metabolism
- Blood need & flow
- Heart rate
- Physiology & Fatigue
- Others
Percentage increase in energy consumption for different bodily postures. (Grandjean, 1998)

Compared with energy consumption lying down:

- Sitting: 3–5%
- Standing: 8–10%
- Stooping: 50–60%
- Kneeling: 30–40%

Effects of static effort on energy consumption (measured by oxygen consumption) for three ways of carrying a school satchel. Ref: Malhotra and Sengupta (1965)

Physiological measurement: Example

Red area shows higher temperature because of higher blood flow.

White area presents lower temperature because lack of blood flow.

Hand Strength & Grip Span

Graph showing grip strength and grip span for different percentages of male and female populations.
3. Psychological/ Psychophysical/ Cognitive Characteristics

- Sensory
- Perception
- Decision
- Emotion
- Cognitive

Poor
Better

4. Behavioral Characteristics

- Spacious behavior characteristic
- Operating behavior characteristic
- Information behavior characteristic

Video to present a case study of human behavior in usability testing