Human Factors
in Accident Prevention

People / Environment / Work
Force / Frequency / Posture

FPST 3213

Anthropometry

Part 2

Objectives

- Know what Anthropometry is
- Know the types of measurements that can be made
- Understand how anthropometry is used for ergonomics and workplace design

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Anthropometry

- From the Greek
  - Anthro- : man
  - pometry: measurements
  - Literal meaning: “measurement of humans”
- A branch of anthropology

FPST 3213 4

Anthropometric Data

- Tools should be adapted to accommodate different populations.
  - Reduce worker fatigue
  - Increase safety
  - Increase performance

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Expected value

The expected value is calculated by multiplying each of the possible outcomes by the likelihood each outcome will occur and then summing all of those values.

$$E(X) = \sum_{i=1}^{n} x_i \cdot p(x_i)$$

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For example, suppose Sarah is 1600 mm tall and the mean height of females in the population is 1650 mm.

What can we say about Sarah?

We can say that Sarah is 50 mm shorter than average.

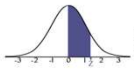
Now, suppose that the standard deviation of the distribution of female height is 100 mm.

What can we say about Sarah?

We can say that Sarah is one half of a standard deviation below the average height.

Using a statistic called the standard normal deviate, Z, we can calculate how tall Sarah is compared to all other females in the population.

$$z = \frac{(x - \bar{x})}{sd}$$



STANDARD NORMAL TABLE (Z)

Entries in the table give the area under the curve between the mean and z standard deviations above the mean. For example, for $z = 1.25$ the area under the curve between the mean (0) and z is 0.3944.

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.0000	0.0040	0.0080	0.0120	0.0160	0.0190	0.0239	0.0279	0.0319	0.0359
0.1	0.0398	0.0438	0.0478	0.0517	0.0557	0.0596	0.0636	0.0675	0.0714	0.0753
0.2	0.0793	0.0832	0.0871	0.0910	0.0948	0.0987	0.1026	0.1064	0.1103	0.1141
0.3	0.1179	0.1217	0.1255	0.1293	0.1331	0.1368	0.1406	0.1443	0.1480	0.1517
0.4	0.1554	0.1591	0.1628	0.1664	0.1700	0.1736	0.1772	0.1808	0.1844	0.1879
0.5	0.1915	0.1950	0.1985	0.2019	0.2054	0.2088	0.2123	0.2157	0.2190	0.2224
0.6	0.2257	0.2291	0.2324	0.2357	0.2389	0.2422	0.2454	0.2486	0.2517	0.2549
0.7	0.2580	0.2611	0.2642	0.2673	0.2704	0.2734	0.2764	0.2794	0.2823	0.2852
0.8	0.2881	0.2910	0.2939	0.2969	0.2995	0.3023	0.3051	0.3078	0.3106	0.3133
0.9	0.3159	0.3186	0.3212	0.3238	0.3264	0.3289	0.3315	0.3340	0.3365	0.3389
1.0	0.3413	0.3438	0.3461	0.3485	0.3508	0.3513	0.3554	0.3577	0.3529	0.3621
1.1	0.3643	0.3665	0.3686	0.3708	0.3729	0.3749	0.3770	0.3790	0.3810	0.3830
1.2	0.3849	0.3869	0.3888	0.3907	0.3925	0.3944	0.3962	0.3980	0.3997	0.4015
1.3	0.4032	0.4049	0.4066	0.4082	0.4099	0.4115	0.4131	0.4147	0.4162	0.4177
1.4	0.4192	0.4207	0.4222	0.4236	0.4251	0.4265	0.4279	0.4292	0.4306	0.4319
1.5	0.4332	0.4345	0.4357	0.4370	0.4382	0.4394	0.4406	0.4418	0.4429	0.4441
1.6	0.4452	0.4463	0.4474	0.4484	0.4495	0.4505	0.4515	0.4525	0.4535	0.4545
1.7	0.4554	0.4564	0.4573	0.4582	0.4591	0.4599	0.4608	0.4616	0.4625	0.4633
1.8	0.4641	0.4649	0.4656	0.4664	0.4671	0.4678	0.4686	0.4693	0.4699	0.4706
1.9	0.4713	0.4719	0.4726	0.4732	0.4738	0.4744	0.4750	0.4756	0.4761	0.4767
2.0	0.4772	0.4778	0.4783	0.4788	0.4793	0.4798	0.4803	0.4808	0.4812	0.4817
2.1	0.4821	0.4826	0.4830	0.4834	0.4838	0.4842	0.4846	0.4850	0.4854	0.4857
2.2	0.4861	0.4864	0.4868	0.4871	0.4875	0.4878	0.4881	0.4884	0.4887	0.4890
2.3	0.4893	0.4896	0.4898	0.4901	0.4904	0.4906	0.4909	0.4911	0.4913	0.4916
2.4	0.4918	0.4920	0.4922	0.4925	0.4927	0.4929	0.4931	0.4932	0.4934	0.4936
2.5	0.4938	0.4940	0.4941	0.4943	0.4945	0.4946	0.4948	0.4949	0.4951	0.4952
2.6	0.4953	0.4955	0.4956	0.4957	0.4959	0.4960	0.4961	0.4962	0.4963	0.4964
2.7	0.4965	0.4966	0.4967	0.4968	0.4969	0.4970	0.4971	0.4972	0.4973	0.4974
2.8	0.4974	0.4975	0.4976	0.4977	0.4977	0.4978	0.4979	0.4979	0.4980	0.4981
2.9	0.4981	0.4982	0.4982	0.4983	0.4984	0.4984	0.4985	0.4985	0.4986	0.4986
3.0	0.4987	0.4987	0.4987	0.4988	0.4988	0.4989	0.4989	0.4989	0.4990	0.4990
3.1	0.4990	0.4991	0.4991	0.4991	0.4992	0.4992	0.4992	0.4992	0.4993	0.4993
3.2	0.4993	0.4993	0.4994	0.4994	0.4994	0.4994	0.4994	0.4995	0.4995	0.4995
3.3	0.4995	0.4995	0.4995	0.4996	0.4996	0.4996	0.4996	0.4996	0.4996	0.4997
3.4	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4998

The Standard Normal Deviate: Z

Sarah is 1600 mm tall and the mean stature was 1650 mm and standard deviation 100 mm. Therefore, for Sarah, her z score is (1600–1650)/100 or −0.5.

We can see that for z = −0.5, the area under the normal curve to the left of z is 0.5 - 0.1915 = 0.3085.

This is the proportion of the normal distribution that lies to the left of z = −0.5. In other words, approximately 31% of females are shorter than Sarah—Sarah is of 31st percentile stature.

Percentiles to Real Measurements and Back Again

To find the measured value of a given percentile, use

$$x = \bar{x} + (z \times sd)$$

If Karen were 25th percentile stature and the mean and standard deviation female stature were 1650 and 100 mm, respectively, how tall would she be?

Percentiles to Real Measurements and Back Again

The value of z corresponding to the 25th percentile is z = −0.68 (the actual area in the table is 0.2517, rounded down to 0.25).

This means that Karen is 0.68 of a standard deviation shorter than the mean.

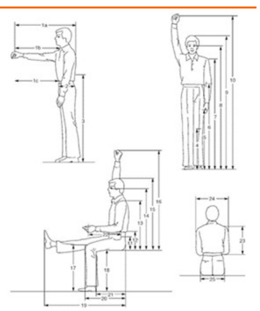
Percentiles to Real Measurements and Back Again

Therefore, Karen's stature, x, is

$$x = 1650 + (-0.68 \times 100) = 1650 - 68 = 1582\ mm$$

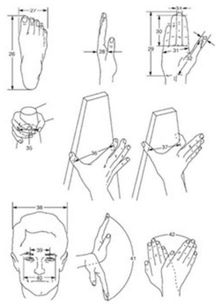
Anthropometric Dimensions

- Designing to maximize the fit between the person and the equipment is an art



Anthropometric Dimensions

- Few small people are in the 5th percentile for all measurements
- Few large people are in the 95th percentile for most of their measurements
- As more measures are added, the number of people accommodated will be reduced because of the variability.



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Distribution of Overhead Reach

- What body characteristics need to be considering while designing the process presented in the picture?

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Distribution of Overhead Reach

- Heights for valves or controls
- Strength for opening the valves

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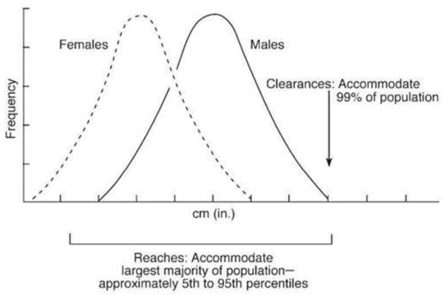
Reaches



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Distribution of Overhead Reach

- Maximum heights for valves or controls
  - The 5th percentile overhead reach is about 74 in

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Distribution of Overhead Reach

- Strength for opening the valves

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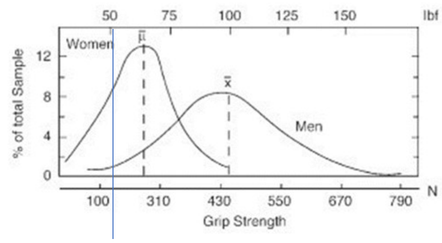
Distribution of Grip Strength

- Determine force requirements for performing a repetitive task



Distribution of Overhead Reach

- The control should be located below the 5th percentile shoulder height, or 49 in.
- Also be no lower than the 95th percentile knuckle height, or 32 in.

Selected Strength Data for Males and Females

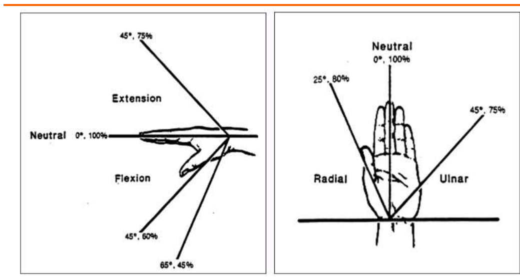
Pushing (N)[a]		Mean	Standard Deviation
Handle Height (m)			
1.7	Males	300	50
	Females	181	75
1.3	Males	337	83
	Females	221	103
0.7	Males	393	134
	Females	185	57
Pulling (N)[a]			
Handle height (m)			
1.7	Males	263	60
	Females	196	56
1.3	Males	347	55
	Females	223	80
0.7	Males	541	81
	Females	292	97
Wrist twisting			
Strength (Nm)[b]			
Males only			
Knob diameter (mm)			
9.5		52.75	12.8
12.7		65.21	12.54
19.1		111.65	26.2

[a] Daams, B.J. 1993. Ergonomics, 36: 397–406.
[b] Swain, A.D., Shelton, G.C., and Rigby, L.V. 1970. Ergonomics, 13: 201–208.

Distribution of Overhead Reach

- Was this process well designed?

Affect of Posture on Grip Strength



Hold your pencil in your hand……

Distribution of Grip Strength

- For example, using a wire crimper requires an exertion of about 176N when the wrist and hand are relatively straight
- But increasing the grip span reduces grip strength by about 40 percent.
- If the crimpers require more force than above, you can justify an automatic crimper for the task

Maximum Grip Strength

Condition	% of Max grip strength, bare-handed, 5-cm (2-in.) span, neutral wrist angles
45 degrees of wrist flexion	60
65 degrees of wrist flexion	45
45 degrees of wrist extension	75
25 degrees of radial deviation of wrist	80
40 degrees of ulnar deviation of wrist	75
Grip span of 2.5 cm (1 in.)	40
Grip span of 11 cm (4.5 in.)	45
Wearing rubber household gloves	81
Wearing gardening gloves	74
Wearing heavy heat-treated gloves	62
Wearing pressurized (3.5 psig) flight gloves	64

Power Grip


Cylindrical Grip


Spherical Grip


Hook Grip

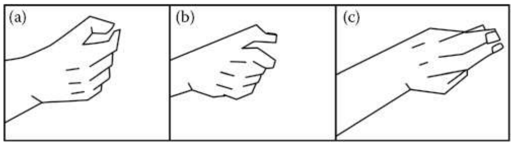
Pinch Grip

- Characterized by opposition of the thumb and the distal joints of the fingers

Tip pinch

Lateral pinch

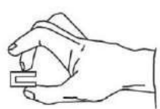
Chuck pinch



(a) Tip pinch, (b) key pinch, and (c) palm pinch.

Additional Types of Pinch Grips

Pulp - 2



Pulp - 3

TABLE 2.2
Hand Function Strengths for Men and Women (Chao et al., 1989)

		Functional Strength (kg)	
Type of function	n	Male	Female
Grasp	60	40 ± 9	23 ± 7
Tip pinch	124	6 ± 1	5 ± 1
Chuck pinch	60	6 ± 1	5 ± 1
Key pinch	84	11 ± 2	8 ± 1
Radial deviation of index finger	60	4 ± 1	3 ± 1
Radial deviation of middle finger	60	4 ± 2	3 ± 1
Radial deviation of ring finger	60	3 ± 1	2 ± 1
Radial deviation of little finger	60	2 ± 1	2 ± 1
Ulnar deviation of index finger	60	4 ± 1	3 ± 1
Ulnar deviation of middle finger	60	4 ± 2	3 ± 1
Ulnar deviation of ring finger	60	3 ± 2	2 ± 1
Ulnar deviation of little finger	60	3 ± 1	2 ± 1
Thumb abduction	47	4 ± 1	3 ± 1
Thumb adduction	47	7 ± 3	5 ± 2

Selected Grip and Pinch Strength Data for U.S. Adults 25–75 Years

	Males		Females	
	Mean	Standard Deviation	Mean	Standard Deviation
Grip strength				
Right hand	46.2	12.6	27.9	7.6
Left hand	41.4	12.3	24.0	7.0
Tip pinch				
Right hand	7.6	1.8	5.0	1.2
Left hand	7.3	1.8	4.8	1.1
Key pinch				
Right hand	10.9	2.0	7.2	1.3
Left hand	10.5	2.0	6.8	1.4
Palmar pinch				
Right hand	10.4	2.2	7.2	1.7
Left hand	10.2	2.4	7.0	1.6

Source: From Mathiowetz, V. et al. 1985. *Archives of Physical Medicine and Rehabilitation*, 66: 69.
Note: The strength is denoted in kilograms (kg).

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Distribution of Overhead Reach

- What body characteristics need to be considering while designing the process presented in the picture?
  - Height
  - Strength
  - Grip
  - ??

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Range of Motion

The most efficient work is done within the first 1/3 of the range of motion for a movement

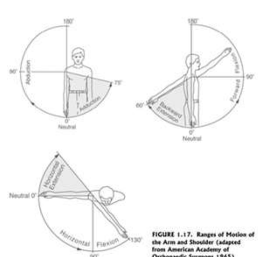

FIGURE 1.17. Ranges of Motion of the Arm and Shoulder (adapted from American Academy of Orthopaedic Surgeons 1965)

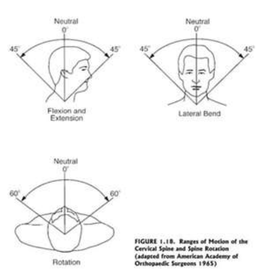

FIGURE 1.18. Ranges of Motion of the Cervical Spine and Spine Rotation (adapted from American Academy of Orthopaedic Surgeons 1965)

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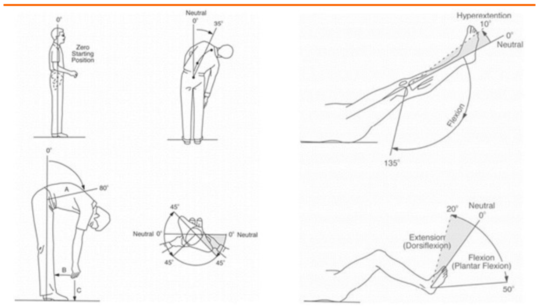
Range of Motion



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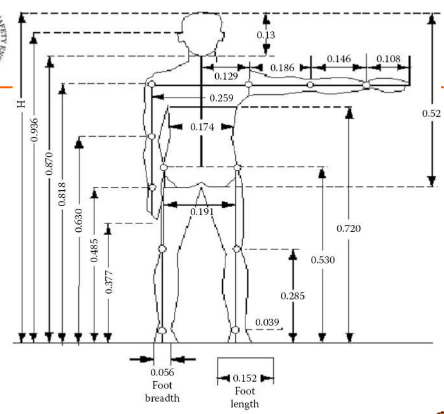

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Suggested Values of Anthropometric Data for Specific Design Needs

Measurement	Design Usage	Suggested Range, cm (in.)
Stature	Clearance for standing access	203 (80); add 13 cm (5 in.) for motion and clothing to the 99th-percentile male value
Eye height, standing	Visibility of signs, displays	140 to 164 (58 to 64)
Shoulder height, standing	Upper limit for lifting or working	114 to 126 (45 to 50)
Elbow height, standing	Height of hands in assembly tasks	95 to 100 (37 to 40)
	Height of hands in packing tasks	90 to 95 (35 to 37)
Hip height, standing	Height over which a person can bend for short durations	73 to 78 (29 to 31)
Knuckle height, standing	Lowest height for work close to the body	54 to 70 (22 to 28)
Sitting height, above seat height	Clearance for seated work—overhead	100 (39)
Sitting shoulder height, above seat height	Upper limit for lifting or working	48 to 52 (19 to 21)

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Suggested Values of Anthropometric Data for Specific Design Needs

Measurement	Design Usage	Suggested Range, cm (in.)
Sitting elbow height, above seat height	Height of hands in assembly or typing task, armrest height	17 to 20 (8 to 9)
Thigh thickness, seated	Minimum clearance under table or workbench	21 (8)
Buttocks-to-knee length	Forward minimum leg clearance, seated	67 (26)
Buttocks-to-popliteal length	Maximum length of seat to accommodate short thighs	44 (17)
	Minimum length of seat for people with long legs so 70% of thigh is supported	38 (15)
Knee height, seated	Lowest height for a seated work surface, from bottom	61 (24)
Popliteal height, seated	Lowest height of seat adjustability for small people	36 (14)
	Lowest height of seat adjustability for tall people	52 (20)

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Anthropometric Data

If a piece of equipment was designed to fit 90% of the male US. population, it would fit roughly 90% of Germans, 80% of Frenchmen, 65% of Italians, 45% of Japanese, 25% of Thais and 10% of Vietnamese.

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Anthropometric Data

- Most of U.S. data have been taken from military populations
- Will they have similar characteristics that an industrial population?

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Anthropometric Data

- Military population is skewed heavily toward those under age 40
- Military personnel tend to be more fit than the industrial population
- Using military data will have a negative effect on industrial plant design

FPST 3213 43

Anthropometric Data

- Example: access points and hatchways
  - Industrial workers are larger around the middle than military service personnel, requiring designers need to accommodate 99% of the population

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Anthropometric Data

- NASA (1978-1981)
  - https://msis.jsc.nasa.gov/sections/section03.htm
- 1988 US Army Anthropometry Survey (ANSUR)
- Table 1.9 (Kodak)
  - Suggests values of data for specific design needs
- Is there a “best source” for Anthropometric Data?
  - UMTRI (Transportation Research Institute)
  - http://mreed.umtri.umich.edu/mreed/downloads.html

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Distribution of a Body Size Characteristic

- Airplane seating
- Auditorium seating
- Desk heights

- Knee Room
- Thigh support to prevent sliding forward
- But not too much for short people or their feet will not touch the floor

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In summary

- Tools should be adapted to accommodate different populations.
  - Reduce worker fatigue
  - Increase safety
  - Increase performance

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Aerobic Work Capacities

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Aerobic Capacity

- The measure of the ability of the heart and lungs to get oxygen to the muscles
- Aerobic capacity refers to the maximum amount of oxygen consumed by the body during intense exercises, in a given time frame.

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Aerobic Capacities

- More oxygen
- Work harder work for longer periods of time

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Aerobic Capacities

- There is not much data on aerobic capacities of industrial workers.

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Aerobic Capacities

- Working long shifts is significantly different than exercising.
- For an eight hour shift the average workload should be about 27% of aerobic capacity for low lifting

Aerobic Effort Levels of Occupational Tasks

Task – Whole Body	Task - Upper Body	Usual Time	Effort Level	Equ. Exercise
Sitting in a car or Truck	Inspection Work	>2 hr	Light	fishing
Machining parts	Sewing	>2 hr	Moderate	Walking 2 mph
Digging Trench	Punch Press Standing	<1 hr	Heavy	Running 12 min mi
Chopping Wood	Power Tools Overhead	1-2 hr	Very Heavy	Jumping rope
Firefighting	Lifting cases 15/min	1-2 hrs	Extremely Heavy	Stair Treadmill

Team project - Feedback

- Sources
- One activity/task within the sector, per student
- READ FEEDBACK!

HW2 - Feedback

- 1. Insufficient cost analysis
- 2. Memo formatting

To do list

- HW 4 will be posted
- Team project