#### Elementary Ergonomics

Introduction to Ergonomics – 1D

Dr. Johan F.M. Molenbroek EE, 11 Nov 2013

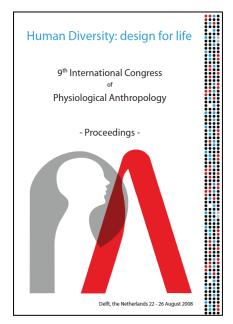




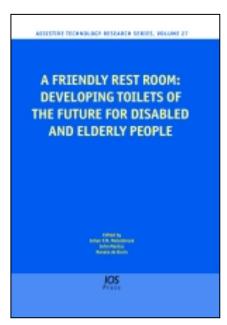




Books Johan Molenbroek and other sources on www.dined.nl



Physiological anthropology



FRR-book



Made to measure

www.dined.nl



### **Ergonomics and Human Factors**

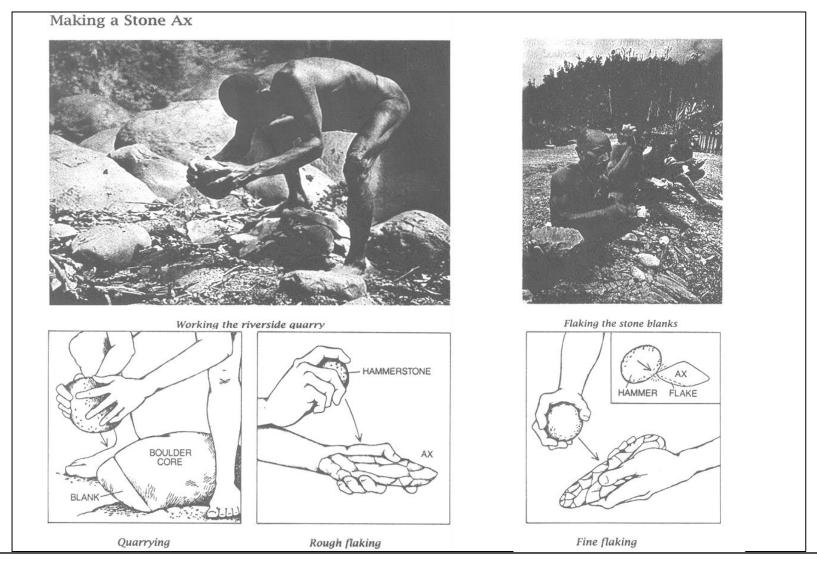
□ To optimize the human product interaction with respect to comfort, safety and efficiency. Also expressed as:

#### **Wellbeing and Productivity**

- Ergonomics is sub-divided into
  - Physical ergonomics
  - Cognitive ergonomics
  - Sensory ergonomics
  - Behavior ergonomics
  - Organizational ergonomics
- Sometimes also:
  - Product-ergonomics
  - Production-ergonomics of workplace ergonomics

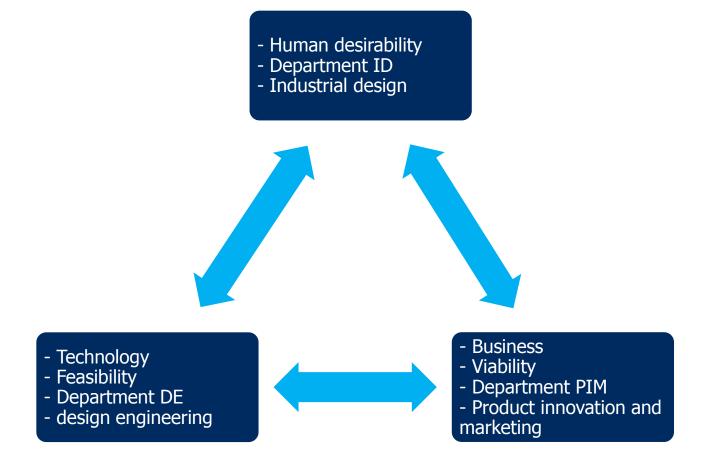


#### History Human factors and ergonomics





# Industrial Design Engineering





#### Basics of IDE



A pair of glasses as example of IDE product including the following aspects:

- Human (desirability)
- Business (viability)
- Engineering (feasibility)

These 3 are the pillars of IDE! Integration of these 3 = IDE



#### Product → Product services



#### **TOMTOM**

This navigator is a good example of the product-service combination.

One of our graduates contributed to TomTom



# Physical ergonomics

#### **Anthropometry**

■ Study of human body measurements in relation to the context

#### **Biomechanics**

 Study of mechanics of human body in relation to the context



# Different views on anthropometry

- 1D Percentiles
- 2D Ellipses
- We need a tool to describe the density in 3d space in the context of man-product-interaction (fit)
- We need in tool to describe the changes in **time** of this fit



# 1-Dimensional anthropometry

- Seems easy but solves only simple problems
- DINED → Made in Holland



# Example Physical Ergonomics Project 'Size China'

■ To measure 2000 Chinese heads: now he sells the digital and physical heads

This research was coordinated by Roger Ball. He received the Golden IDSA Award

- IDSA Industrial Design Society of America
- ☐ I was anthropometric consultant and later Co-promotor when he wrote his dissertation
- There was great media attention
  - » <u>Bekijk video</u> (Volkskrant TV augustus 2008)
  - » <u>Bekijk video</u> (NOS journaal 23 juli 2008)
  - » Lees artikel (De Pers 24 juli 2008)
  - » <u>Lees artikel</u> (Trouw juli 2008)
  - » Businessweek (28 juli 2008)
  - » Overige Media IDSA
  - » Overige Media
- http://www.sizechina.com





#### Cause of misuse of Anthropometric data



Unusable cash-dispenser

- The lack of the right data
- Unusable tables
- Improper data
- Lack of knowledge



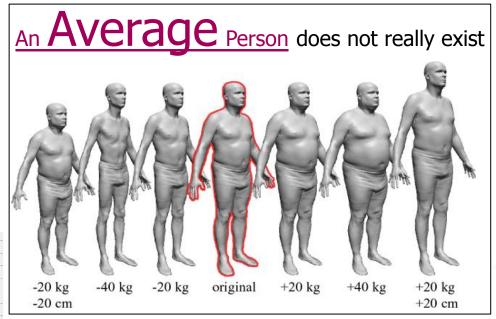
#### Content 1D tables

- Dutch reports 1980-2005, about children, students, adults and elderly
- 20 World populations from ILO 1990
- Formulas

(ILO = International Labour Organisation, Geneva)



### Diversity in human populations



Real people





**IDE ADAPS** 

**IDE SW** 



Afbeelding 75: Handen boven het hoofd om trui/shirt aan/uit te doen



Afbeelding 85: Arm gestrekt: om trui/shirt uit/aan te doen

#### The normal Distribution of 1-Dimension

- $\Box$  two characteristics :  $\overline{x}$  or sd ( $\sigma$ , standard deviation)
- percentiles and z-values
- extreme measurements: min and max or P1- P99
- inter-individual s<sup>2</sup> en intra-individual s<sup>2</sup>
- percentile profile of an individual person

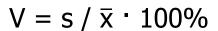


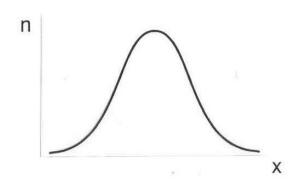
#### The normal Distribution of 1-Dimension

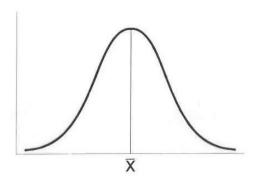
Average=mean

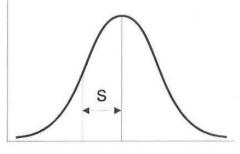
Variation coefficient

$$\bar{x} = \Sigma x/n$$









Standard deviation

Variance

S or sd = 
$$\sqrt{\sum (x - \overline{x})^2 / n-1}$$

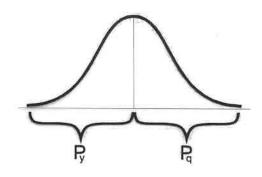
$$= S^2$$

#### Percentile values

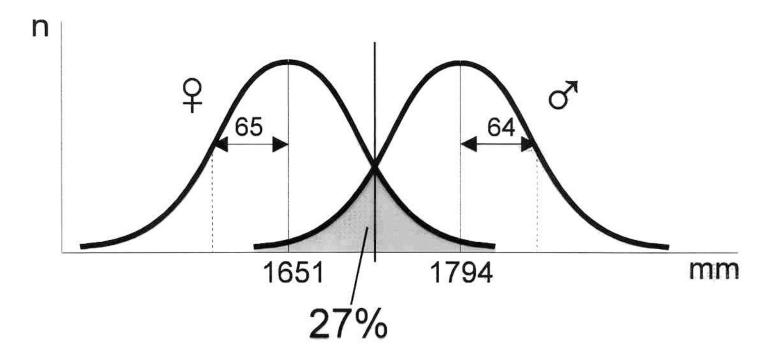
Most body dimensions follow the normal (Gauss)- distribution, they are nicely normally distributed

% eenzijdig oppervlak	z-waarde
25	0,67
30	0,84
35	1,04
40	1,28
45	1,65
47,5	1,96
49	2,33
49,9	3,09
34,1	1
47,7	2
49,86	
49,997	4

$$P_y = \bar{x} - z \cdot s \quad \text{voor } P_0 < P_y < P_{50}$$
  
 $P_q = \bar{x} + z \cdot s \quad \text{voor } P_{50} < P_q < P_{100}$ 



#### Percentile values

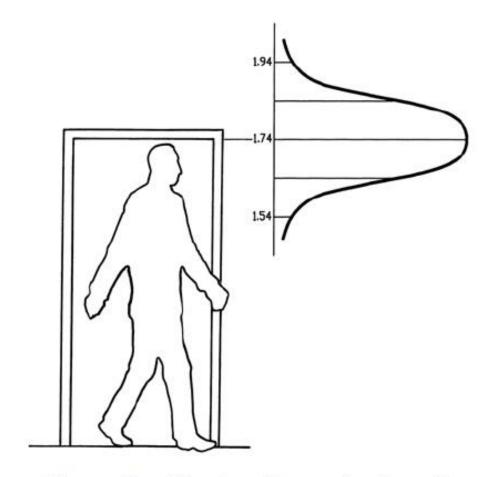


- ☐ Stature or Height (Dined-1, 1986)
- Overlap
- Adult Dutch male and female



## Door-height for average person

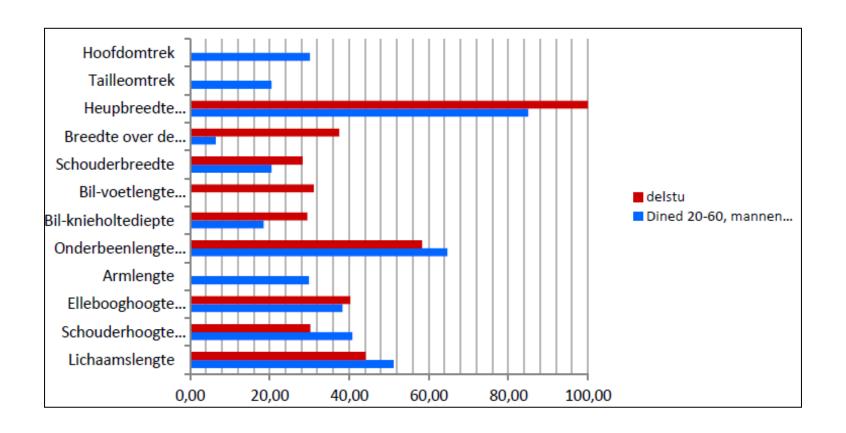
■ What is the door height for an average person?



Figuur 3 — Voorbeeld van deurhoogte

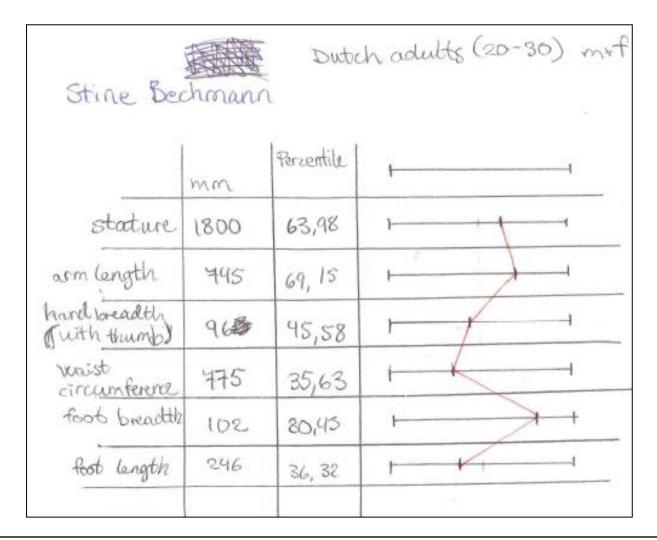


# Percentile profile 1st -years students



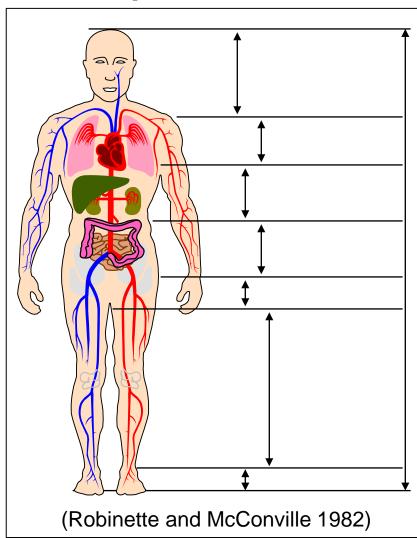


## Example percentile profile





# 1-D percentiles can not be added!



Sum of  $5^{th}$  %ile Parts = 136.89 cm

 $5^{th}$  %ile Height = 152.50 cm

Difference = 15.61 cm

Sum of  $95^{th}$  %ile Parts = 188.81 cm

 $95^{th}$  %ile Height = 173.06 cm

Difference = 15.75 cm

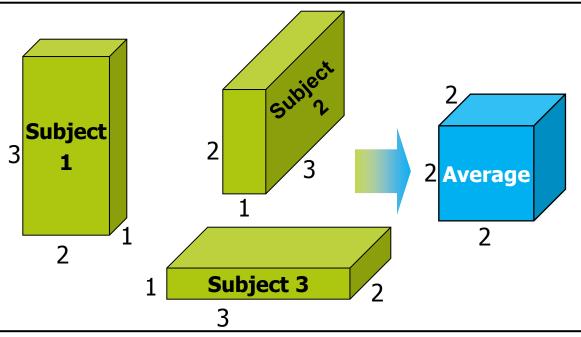


SAMPLE SIZE=3235



## 3-D modelling

3-D encourages truth in modelling (WEAR, 2005)



- Average is Different From Everyone!
- Average Person Does Not Exist! (Daniels 1952)
- Mythical Person from 1-D Measurements
  - hard to detect errors
- Mythical Person from 3-D Images is better

Average	2	2	2
Subject 3	3	1	2
Subject 2	1	2	3
Subject 1	2	3	1

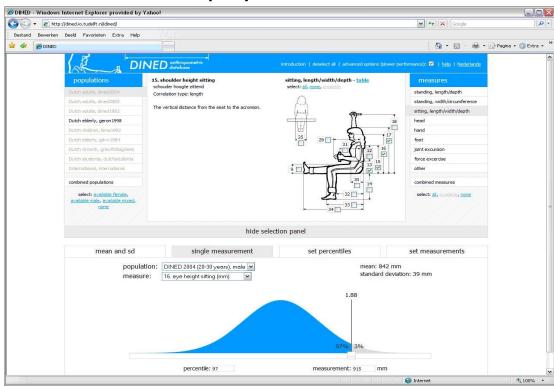


Attempt at 95<sup>th</sup> %ile man from 1-D Measures



#### **DINED**

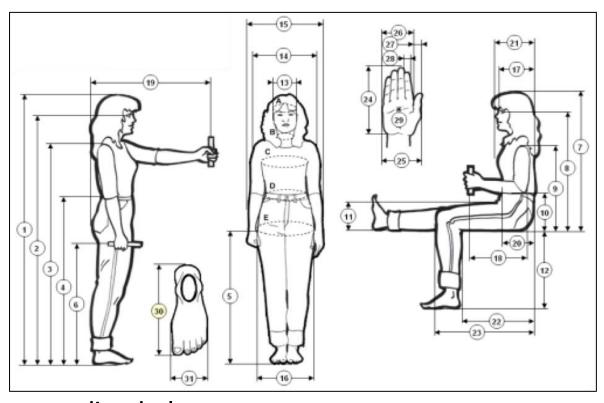
#### www.dined.nl to play with data



Made in 2009 made in javascript



# DINED 1-D anthropometry



www.dined.nl



## DINED after 32 years usage

#### **Negative**

- □ 1D
- To much trust
- Data needs update
- Easy to misuse

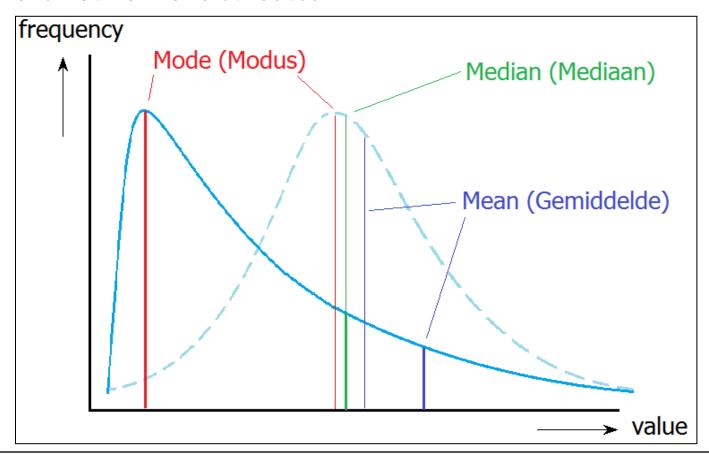
#### **Positive**

- Very popular
- Widely distributed
- Free of costs
- On the web
- Interactively
- Became national standard
- Easy to use



### Exceptions on normal distributions

**Body weight, body depth** and **thigh clearence** are not normal distributed





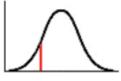
# User-product-interaction

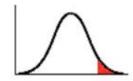
P1	P99	User	additional	Product
429	583	Buttock-popliteal depth	-5 cm	Seat depth
344	516	Popliteal height	+ heel height	Seat height
316	454	Hip breadth	+ clothing +comfort	Seat width
177	299	Elbow-rest height		Armrest height
362	570	Bi-acromial breadth		Width backrest
798	1015	Sitting height		Height head support
457	651	Acromial height		Height back support



# 7 ways to distribute your variations

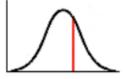
Procrustes

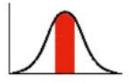




Design for the tall

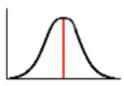
Ego Design

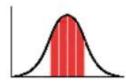




Design for adjustability

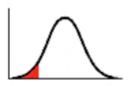
Design for the mean

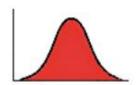




Design for more types (S, M, L, XL)

Design for the small





Design for all



#### How to work with **non**-normal distributions?

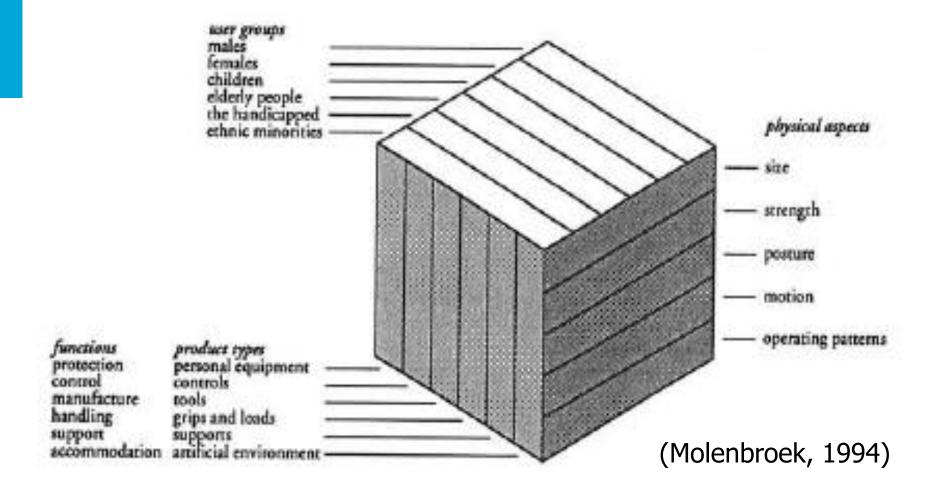
Work with raw measurements i.e. measure yourself

Or

- Work with 2 split normal curves
- Including a left and a right sd



#### Kubic model





# Anthropometric Design process

P-model-1 λ-model-1 P-model-2 A-model-2 maattekening computertekening prototype AP-model-4 GEREED PRODUKT

(Molenbroek, 1994)

Figuur 3.1: Het antropometrisch ontwerpproces schematisch weergegeven. De soorten A-modellen en Pmodellen staan in 3.2 en 3.3 beschreven.



# Help for doing anthropometry

- Handbooks
- Standards
- Tables
- Templates
- ☐ Manikins (2D)
- Digital Human Models (3D)

See www.dined.nl





## Limitations of percentiles

- Percentile values (writing) = percentiles (speaking)
- □ Percentiles → 1-Dimensional
- □ Correlations → 2-Dimensional
- Analyse and Design >> 2D and 3-Dimensional

#### So please remember

Using percentiles is acting short sighted

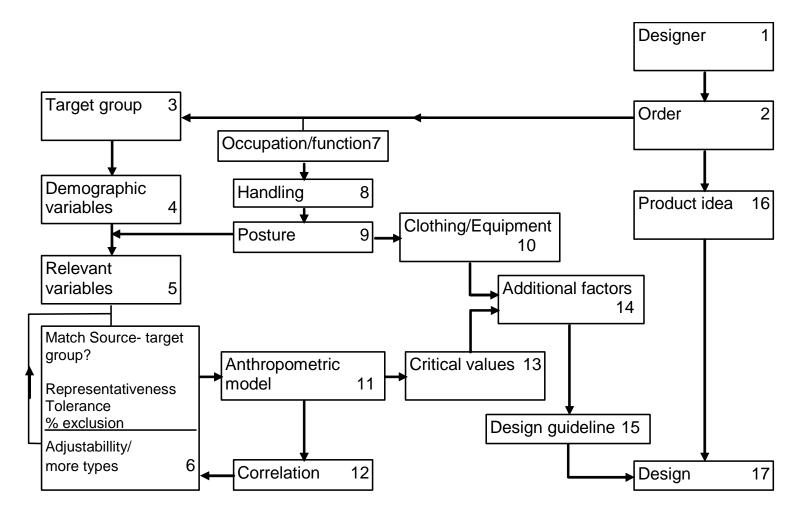


# Steps for better anthropometric design

- 1. Describe target group in terms of age, sex, etnicity, profession, by doing observational research (by video or sketch)
- 2. Describe /draw postures and manual handling
- 3. Describe source of data for this target group or do an estimation or start to measure yourself a sample  $\geq n=30$
- 4. Decide which dimensions are relevant
- 5. Decide which part of the population is critical i.e. small or large or ...
- 6. Try to exclude as less as possible unless it is intentionally
- 7. Inclusive design/design for all/universal design

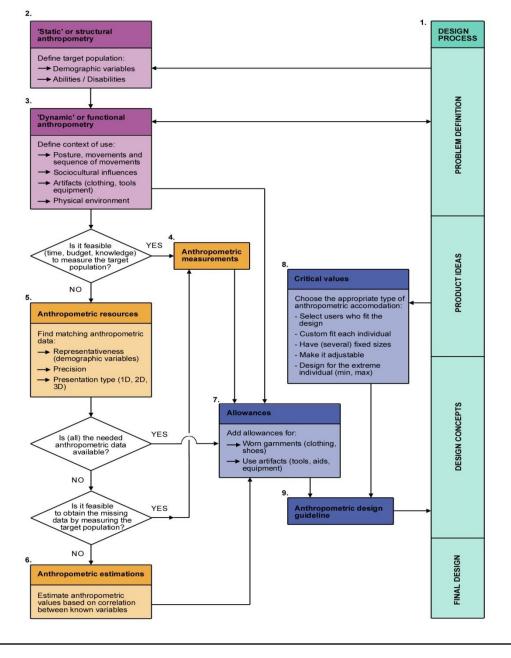


# Anthropometric design proces





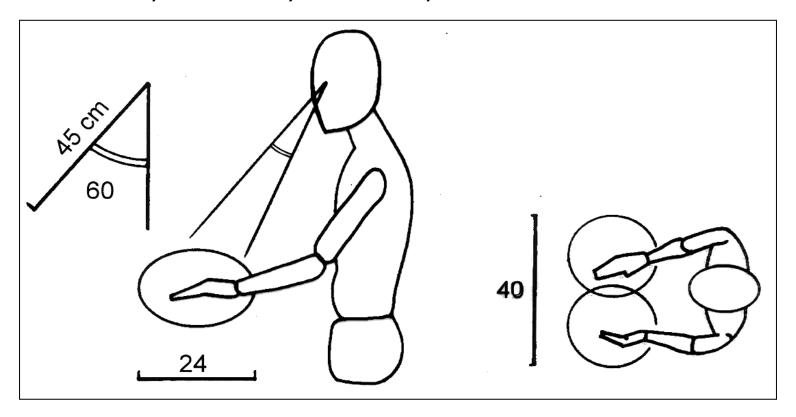
# Design Process flowchart





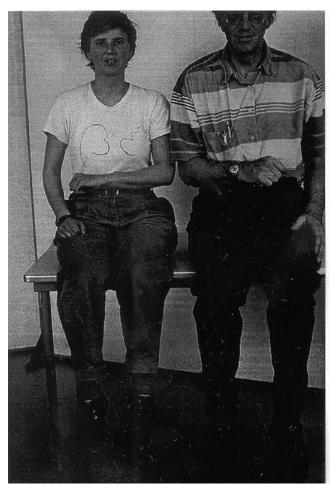
## Visual manipulative comfort zone (VMC)

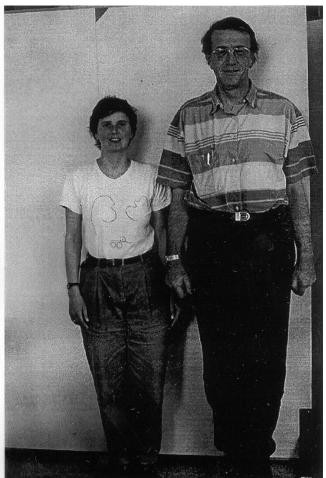
VMC=What you can easily reach with your hand and see at the same time



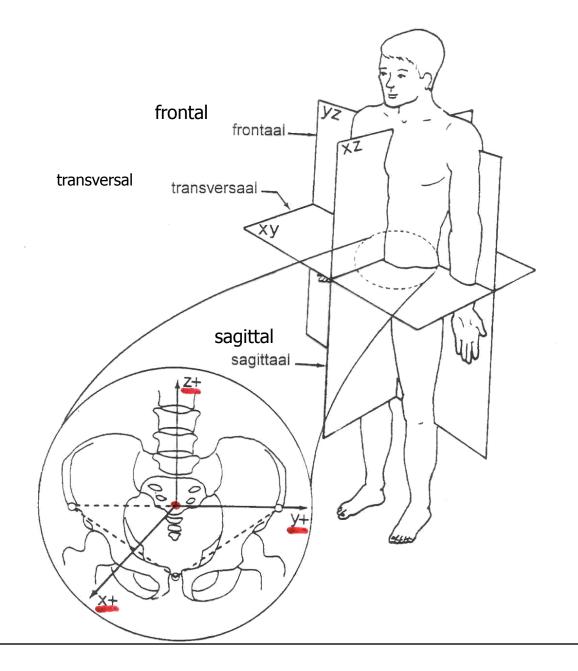


## different height in stature does not mean different height in elbow-seat: nobody is equal!







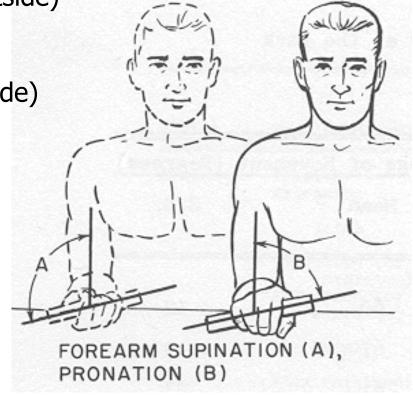




## Body joint movements

□ A; Supination(towards your outside)

B; Pronation (towards your inside)





## Body joint movements, Dempster 1954

gewricht	beweging	Dempster	Houy	Schnelle	AAOS*	ISOM**
schouder	anteflexie	188 (12)	178 (10)	150 - 180	180	170
	retroflexie	61 (14)	58 (11)	50	60	50
	abductie	134 (17)	124 (10)	170	180	170
	adductie	48 (9)	51 (5)		75	.75
	endo-rotatie	97 (22)	95 (12)	80 - 90	80	60
	exo-rotation	34 (13)	32 (9)	60	60	70
elleboog	flexie	142 (10)	138 (7)	130 - 140	150	150
	extensie	0 (0)	0 (0)	0	0	0
onderarm	supinatie	113 (22)	107 (17)	70 - 85	80	90
	pronatie	77 (24)	65 (13)	60 - 80	80	80
pols	ulnaire abductie	47 (7)	31 (5)	30 - 40	30	30
	radiale abductie	27 (9)	22 (5)	20 - 30	20	20
	palmair flexie	90 (12)	68 (10)	60 - 90	80	60
	dorsaal flexie	99 (13)	62 (9)	60 - 90	70	50



#### Demonstration how to measure

 Repeatedly measure 1 person creates insight in the accuracy of the measuring

#### Important are:

- Body posture
- Instrument
- Notation
- Definition of anatomical start-point and end-point



## Trends in Anthropometry

- From static to dynamic
- From structural to functional
- From 1D to 3D or 4 Dimensional
- From using once in the design process to using continuously
- From tables trough digital human models into mockups and testpersons
- From a distance to shape information



### Examples

- Biometry for identification like finger-, ear-, hand-, irisidentification
- In relation to cognitive demands like in prevention of RSI
- In relation to sports like swimming (we just finished a project called the fastest swimsuit)
- In the Sports-minor TU Delft students develop a size system for a kite harness (last year a wind surf suit)



## Anthropometry in media

- A prisoner escaped from the highly secured prison in Breda via a ventilation window of 17,5 bij 50 centimeter
- □ Solution: they now put bars in all windows
- I compared the student data and concluded that it is possible; I could have predicted this, if they had asked me ②



### Desired individual body shape and dimensions

- People buy clothing that gives them satisfaction in relation to their lifestyle
- People also modify their body to look like their idols
- Starting with high heels, corset, push- up something



## 'Beauty-models' past-present



Marilyn Monroe Britney Spears Angelina Jolie Katy Perry











### Barbie doll

Hair 10000 \$

Facelift 7000 \$

Brest 4000\$

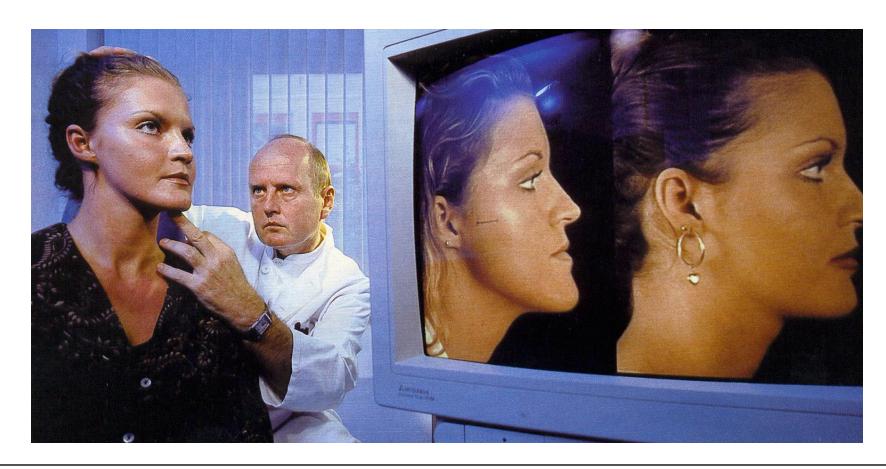
Thigh 3000 \$

The famous Barbie puppet has a waist of 27 cm if she would be scaled in height to 175 cm, which does not comply with human life!



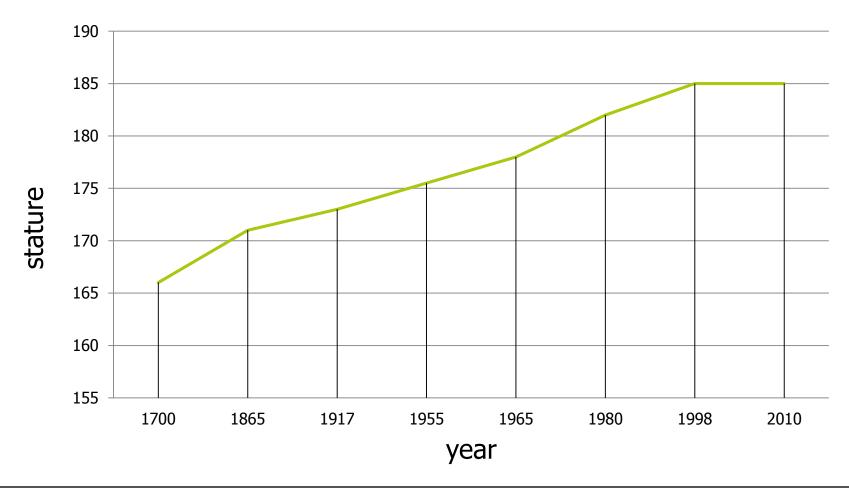


## Plastic surgery; shorten a chin





## Secular trend in the Netherlands for 20 year old boys did stop at 2010





#### 1998-2012

- Dutch do not grow anymore vertically (stature)
- Only horizontally (waist circumference)
- Because of too much food and too less motion



## The fashion of horizontal growth







We have 7 billion people on our earth: 20% is too heavy. In USA this percentage is 50%.



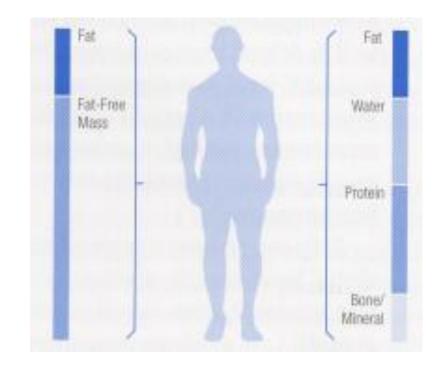
#### Famous indices

- Body mass index BMI (in dutch quetelet index QI)
  - = body weight / (height)<sup>2</sup>
- ☐ Standard: 20-25 kg/m<sup>2</sup>
- Average value for students is 21, but are your average?



## **Body composition**

- In normal is 10-15% fat for male and 15-25 for female
- Underweight BMI=18-
- Overweight BMI 25-30 kg/m<sup>2</sup>
- Obesitas BMI=30+ kg/m²





## Obesitas Society 2003 100-300 kg







# Better than BMI is: Waist circumference

- Healthy is 85 cm (female) and 95 cm for (male)
- Waist hip ratio WHR
- Standard for men <1.0</p>
- Standard for female < 0.8</p>

#### **New work for IDE!**

Bariatric wheelchairs, beds, rollators



## End of this presentation

More info at www.dined.nl

