How Do I Choose the Correct Ergonomics Assessment Tool(s)?

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POTVIN BIOMECHANICS INC

With Ergonomics Tools

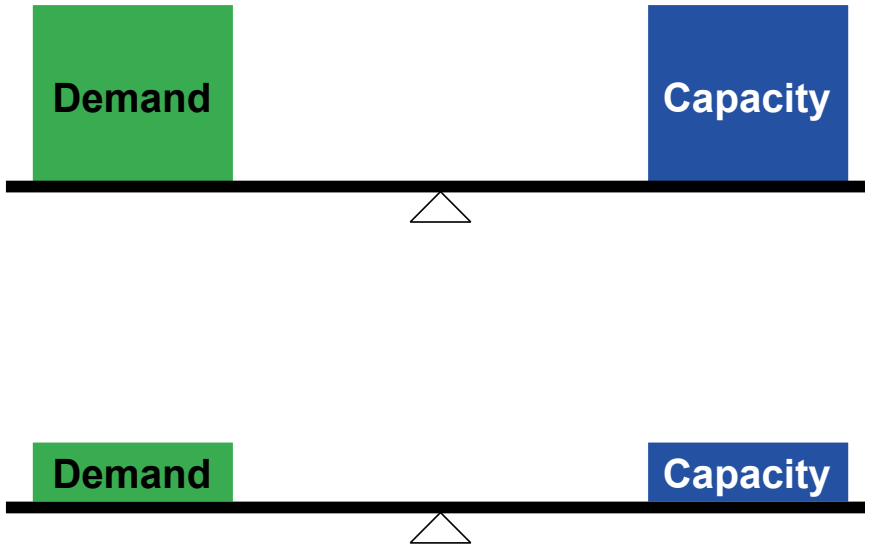
Read the Fine Print

Introduction

- **Why perform an ergonomics analysis?**
  - Evaluate risk
    - qualitative
  - Employee placement (or screening)
    - task requirements
  - Return to work after an injury
    - worker readiness
  - Determine acceptable loads
    - quantitative
    - provides evidence for design (or redesign)
    - cost-benefit justification

Introduction

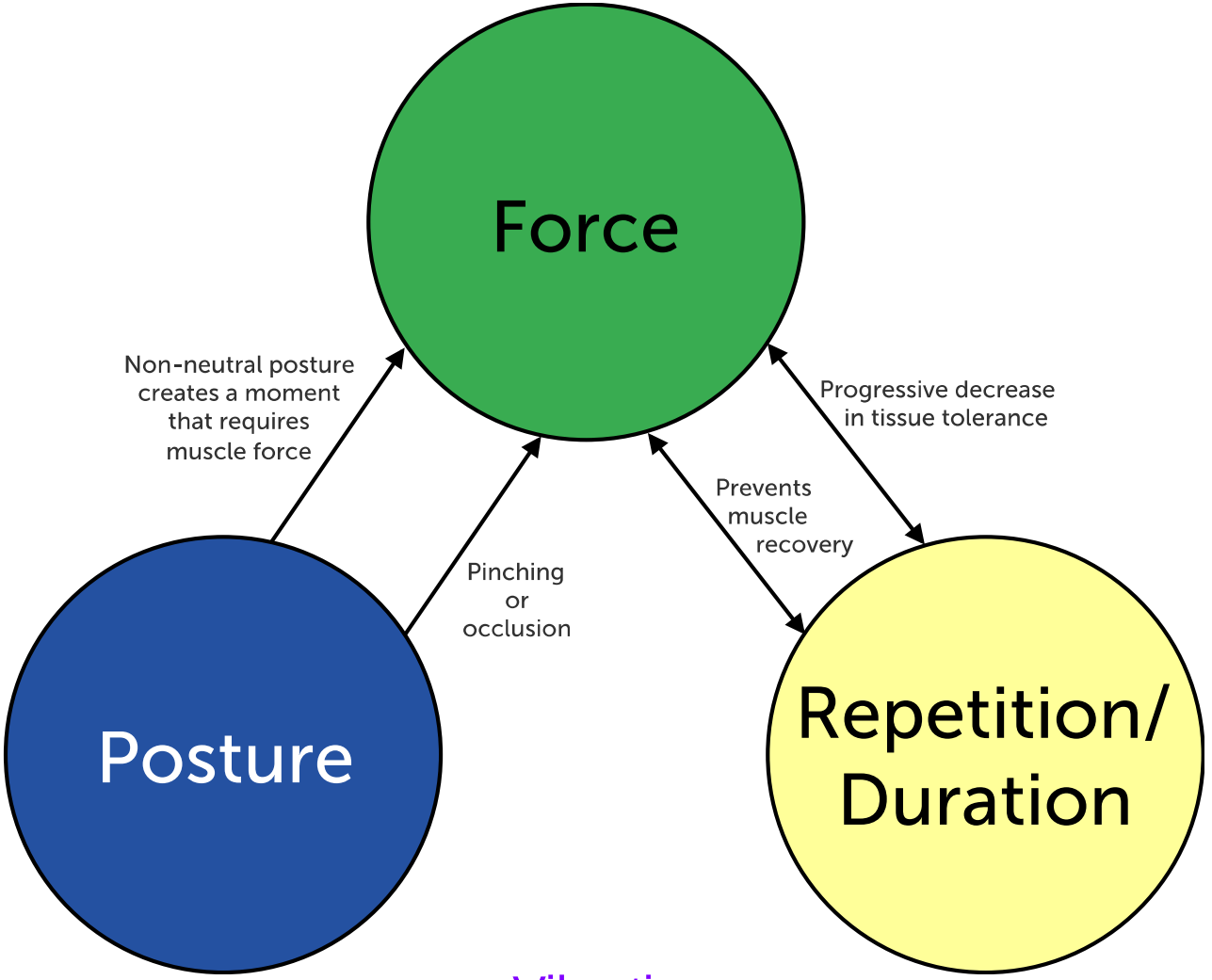
- **What is a ‘risk’ or a ‘hazard’?**
  - It is not ‘safe’ or ‘unsafe’
    - instead, risk resides on a continuum
  - Thus, some risk always exists
  - Risk = Load / Capacity
    - load relative to individual’s capacity
    - load versus population capacity
    - capacity of a system or tissue
      - muscle or tissue strength
      - endurance
      - both



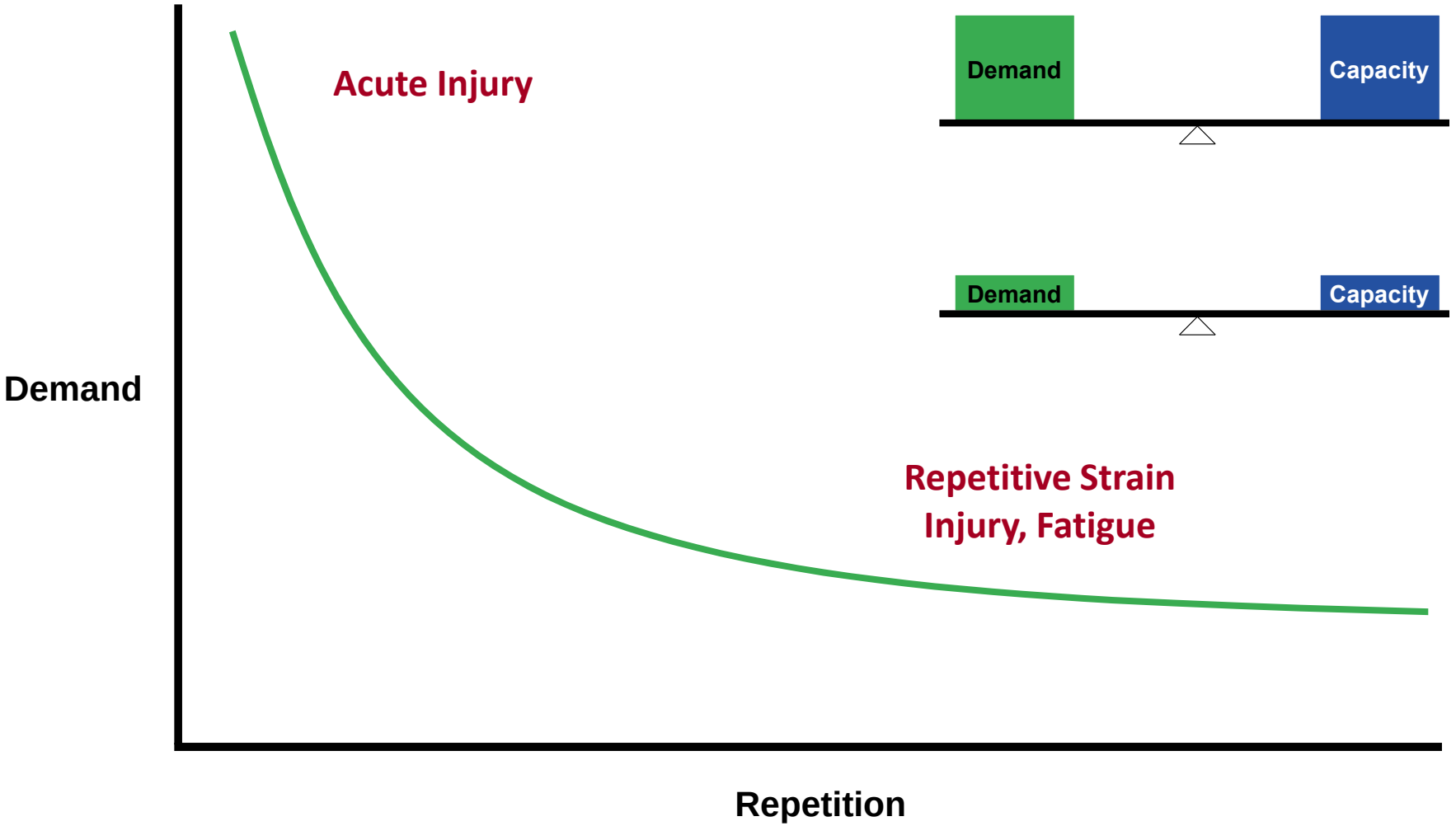
  - Example
    - shoulder moment demand = 42 Nm
    - individual’s strength is 35 Nm
      - Risk for that person = Demand/Strength = 42 / 35 = 1.20
    - population strength is 45±9 Nm
      - Risk for that population = Demand/Mean Strength = 42 / 45 = 0.93

Introduction

- **What are the risk factors?**



Acceptable Loads: Injury or Fatigue



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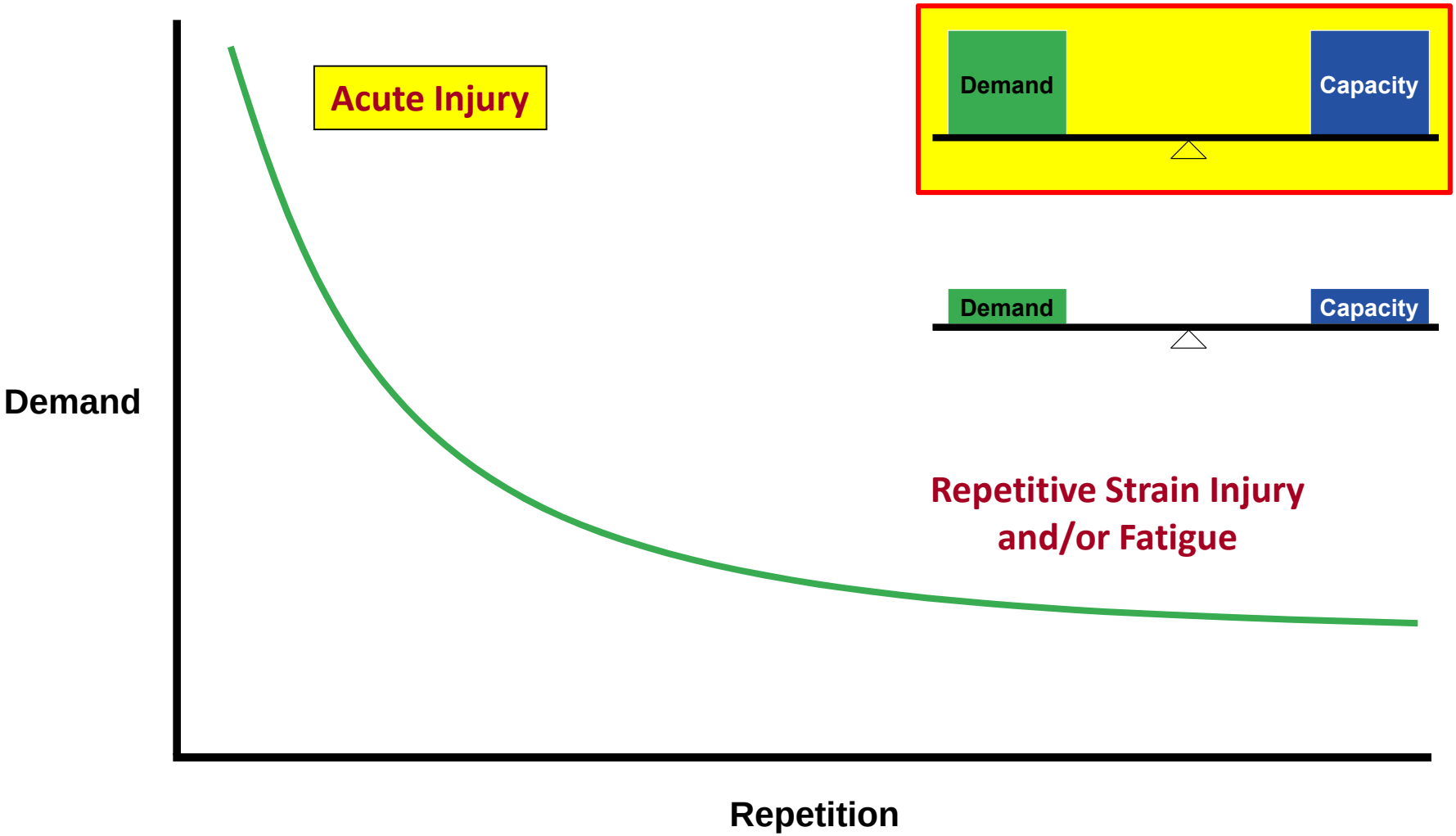
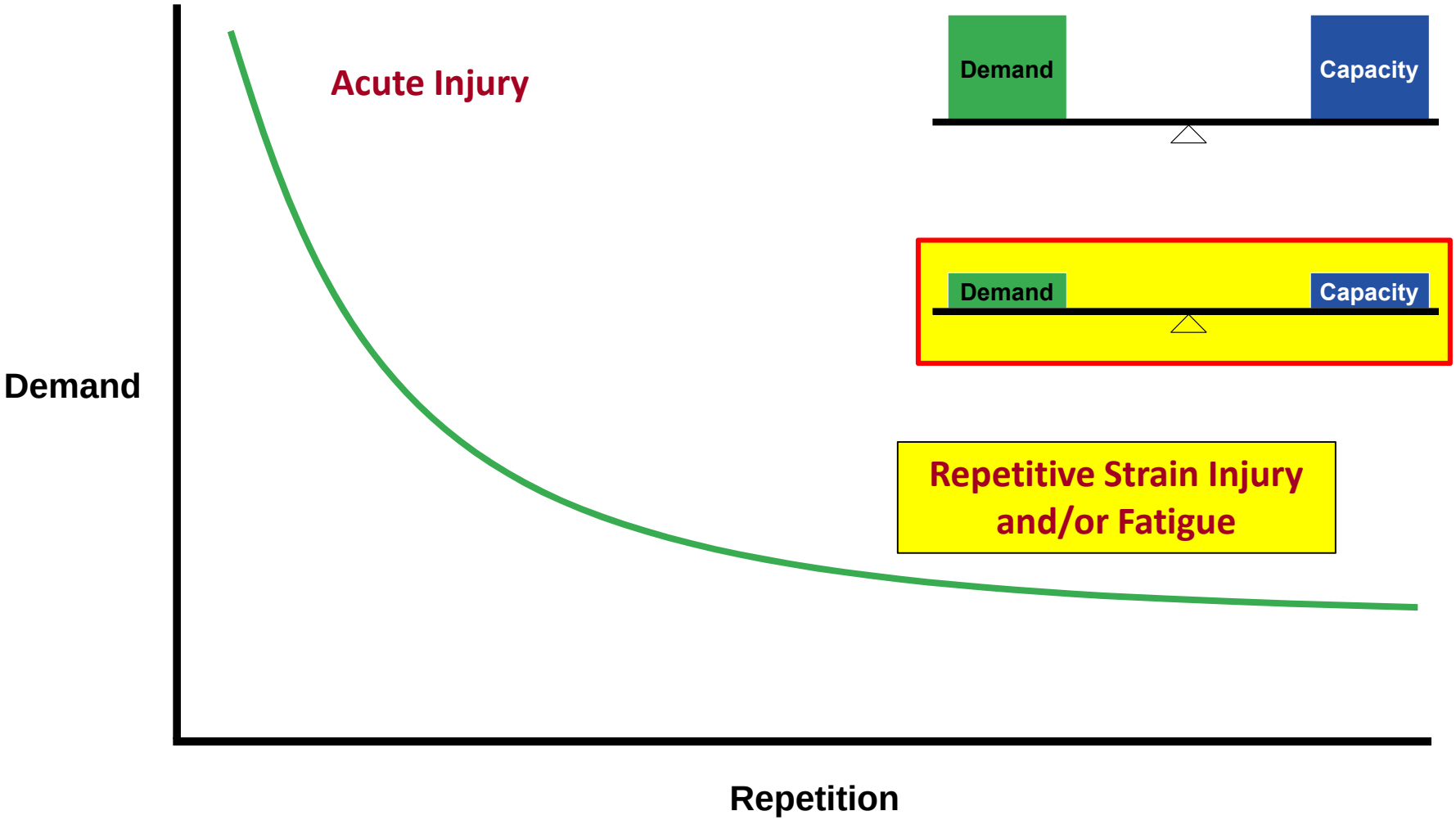


Acceptable Loads: Injury or Fatigue

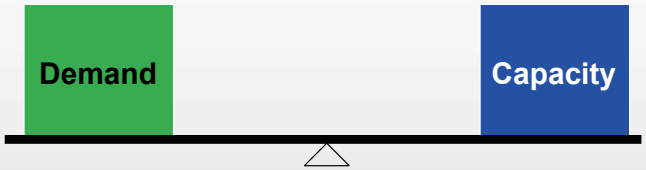


Introduction

- **What is 'acceptable' risk?**

  - Threshold Limit Value (TLV)
    - typically based on female workers
    - typically based on 25th percentile
      - ie. 75% capable
  - Where does the 75% capable come from?
    - Snook (1978)
      - "a worker is three times more susceptible to low back injury if performing a manual handling task that is acceptable to less than 75% of the working population"
        - » only based on 191 subjects
  - If <75% capable, will an injury certainly occur?
    - No
      - eg. car insurance

Horrible Task – High Risk



Great Design – Low Risk

Unacceptable Task

Deciding on the Best Tool(s) to Use

The Example of Manual Materials Handling Tasks

NIOSH
Lifting Guidelines

How Did NIOSH Determine Guidelines for Lifting?

- **The National Institute for Occupational Safety and Health developed a guideline for safe and non-fatiguing manual lifting in industry based on four scientific criteria:**

- **Epidemiology**
  - concerned with injury statistics and relating various task characteristics to the risk of injury

- **Biomechanics**
  - concerned with the forces that cause injuries.

- **Physiology**
  - concerned with the capacity to perform work for extended periods of time.

- **Psychophysics**
  - concerned with our ability to accurately perceive biomechanical and physiological loading.

Revised NIOSH Lifting Equation (RNLE)

RWL = 23 kg * H-fac * V-fac * D-fac * F-fac * A-fac * C-fac

H - 25/H

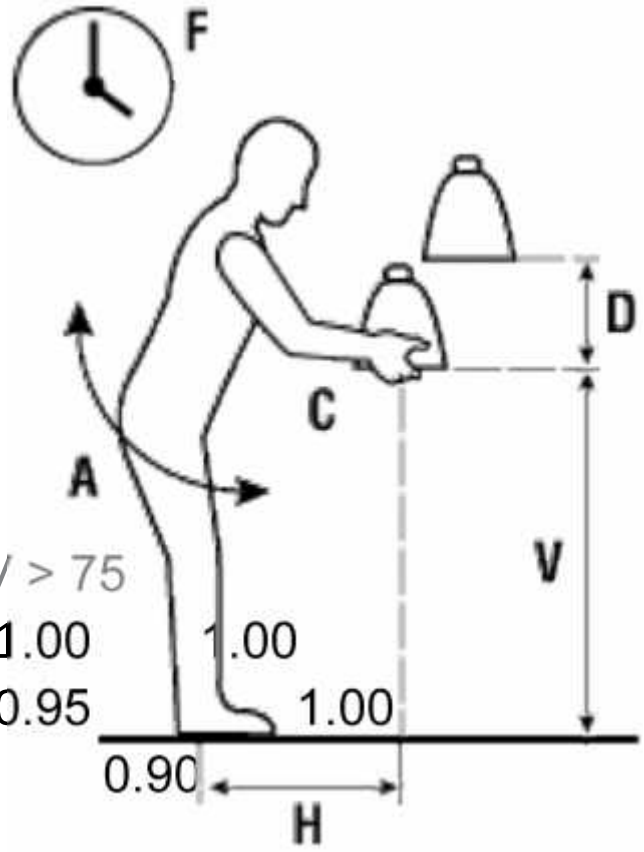
V - 1 - 0.003 | V - 75 |

D - 0.82 + (4.5/D)

A - 1 - (0.0032 * Angle)

C - Coupling

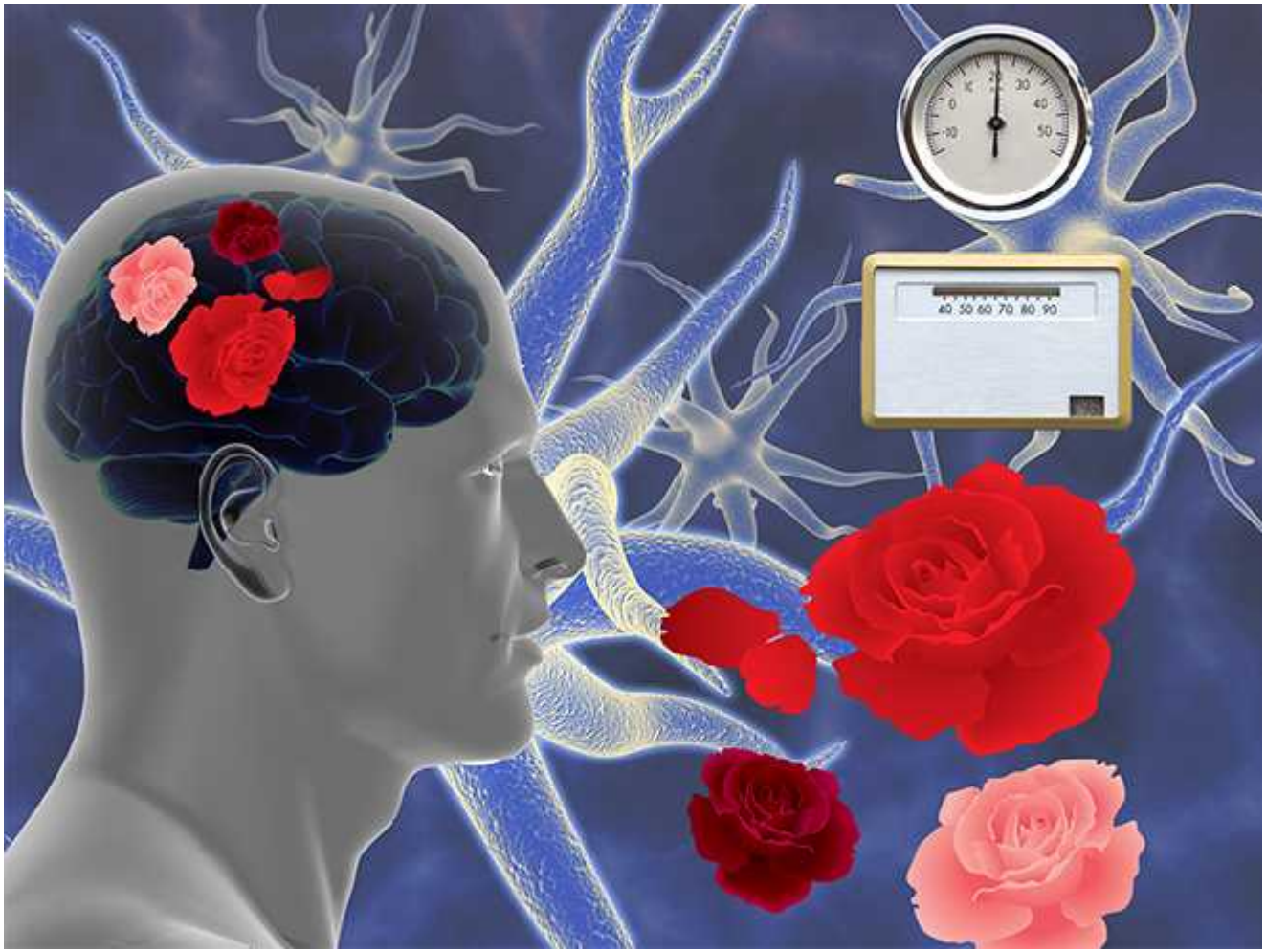
	V < 75	V > 75
Good	1.00	1.00
Fair	0.95	1.00
Poor	0.90	0.90



The Psychophysical Criterion

Psychophysics

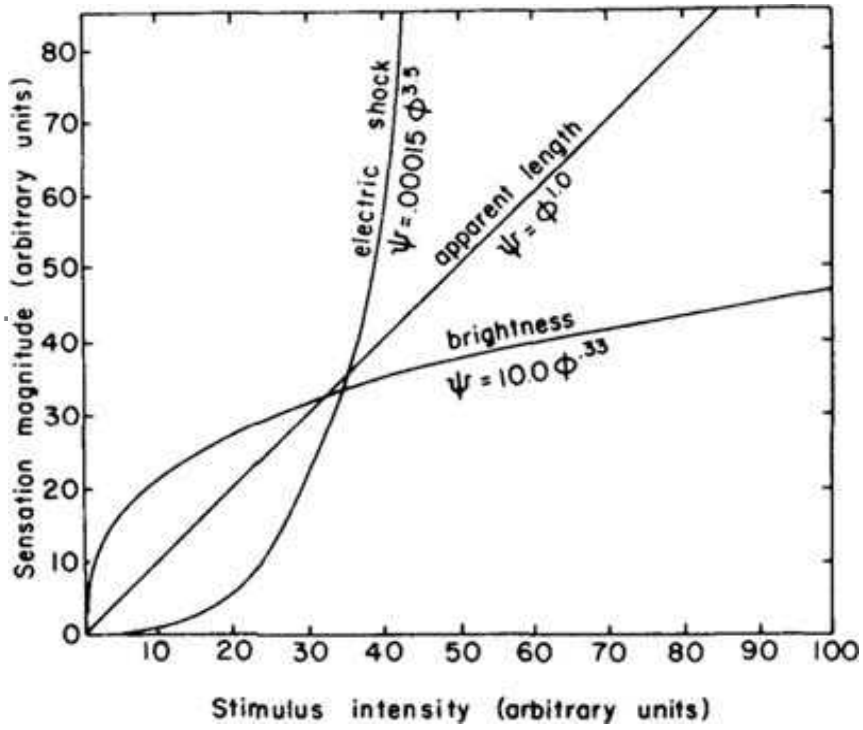
Definition: - the study of the relationship between sensations and their physical stimuli.



http://www.kth.se

Psychophysics In Ergonomics

- **The power law in psychophysics Stevens (1957)**
  - exponential relationship between sensations and their physical stimuli
  - raised to some power
    - these powers vary for different stimuli.



- **Snook (1968)**
  - 1st psychophysical study in ergonomics
  - determine acceptable demands for repetitive tasks.
    - manual materials handling tasks

Liberty Mutual / Snook & Ciriello Tables

Method:

- **huge psychophysical study (since 1968)**
  - trained workers
- **subject controls weight / force**
  - fill with lead shot for weight of lift/lower/carry
- **control resistance in pushing / pulling**
  - they set frequency, height, load size, distance
- **used special shelf (lift or lower)**
- **simulate 8 hour day**
- **work as hard as possible without undue strain or fatigue**
  - monitor fatigue and perceived exertion
  - heart rate, O2 consumption

Snook & Ciriello (1991)

- **Total conditions summarized in 6 studies**

	Female	Total			Male	
Snook (1978)	108	316			208	
Snook & Ciriello (1991)						
1. Lift, lower, push, carry	51		51		102	
2. Lift, push, pull	53	0		53		
3. Lift, lower, push, pull, carry		18	18			36
4. Lift, lower, push, pull, carry		42	0			42
Total	549			319		230
		(26%)	(31%)			(36%)

Snook & Ciriello (1991)

- **Interpolations and Assumptions**
  - *"It is important to note that not all of the values in Tables 2-10 are based upon experimental data; assumptions had to be made to fill in specific variations that have not been studied"*
  - eg. no lowering data for 49 and 75 boxes
    - based on lowering/lifting ratio for the 34 cm box
  - similar for vertical lowering distance
  - similar for frequency, box width and distance with S>AR lifting
    - based on F>K & K>S
  - similar for frequency and distance for pulling tasks
    - based on pushing
  - Snook (1978) based on 42 males (74%) & 15 females = 57 subjects
  - Snook & Ciriello (1991) based on 68 (57%) males & 51 females = 119 subjects

Female Lifting

Snook & Ciriello (1991)

Table 3. Maximum acceptable weight of lift for females (kg).

Width‡	Distance§	Percent¶	Floor level to knuckle height, One lift every: 5 s	9 s	14 s	1 min	2 min	5 min	30 min	8 h	Knuckle height to shoulder height, One lift every: 5 s	9 s	14 s	1 min	2 min	5 min	30 min	8 h	Shoulder height to arm reach, One lift every: 5 s	9 s	14 s	1 min	2 min	5 min	30 min	8 h
		90	5	6	7	7	8	8	9	12	5	6	7	9	9	9	10	12	4	5	5	6	7	7	7	8
		75	7	8	9	9	10	10	11	14	6	7	8	10	11	11	12	14	5	6	6	7	8	8	8	10
	76	50	8	10	10	11	12	12	13	17	7	8	9	11	12	12	13	16	6	7	7	8	9	9	10	11
		25	9	11	12	13	14	14	15	21	8	9	10	13	14	14	15	18	7	7	8	9	10	10	11	13
		10	11	13	14	14	15	16	17	23	9	10	11	14	15	15	17	20	7	8	9	10	11	11	12	14
		90	6	7	8	8	9	9	10	14	6	7	8	9	10	10	11	13	5	6	7	7	7	7	8	9
		75	7	9	9	10	11	11	13	17	7	8	9	11	12	12	13	15	6	7	8	8	9	9	9	11
75	51	50	9	10	11	12	13	14	15	21	9	9	11	13	14	14	15	17	7	8	9	9	10	10	11	13
		25	10	12	13	15	16	16	18	24	10	11	12	14	16	16	17	20	8	9	10	10	11	11	12	14
		10	11	14	15	17	18	18	20	27	11	12	14	16	17	17	19	22	9	10	11	12	13	13	14	16
		90	6	8	8	9	9	9	11	14	6	7	8	10	11	11	12	14	5	6	7	8	8	8	9	10
		75	8	10	11	11	12	12	13	18	7	8	9	12	13	13	14	17	6	7	8	9	9	9	10	12
	25	50	10	12	13	13	14	14	16	21	9	10	11	14	15	15	16	19	7	8	9	10	11	11	12	14
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	76	50	10	12	13	14	15	16	17	23	9	9	11	13	14	14	15	17	7	8	9	11	12	12	13	15
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		90	7	9	9	11	12	12	13	18	8	8	9	10	11	11	12	14	7	7	8	9	10	10	11	12
		75	9	11	12	14	15	15	16	22	9	10	11	12	13	13	14	17	8	8	9	11	11	11	12	14
34	51	50	11	13	14	16	18	18	20	27	10	11	13	14	15	15	17	19	9	10	11	12	13	13	14	17
		25	13	15	17	19	21	21	24	32	12	13	14	16	17	17	19	22	10	11	12	14	15	15	16	19
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		75	10	12	13	14	15	15	17	23	9	10	11	13	14	14	16	18	8	8	9	12	12	12	14	16
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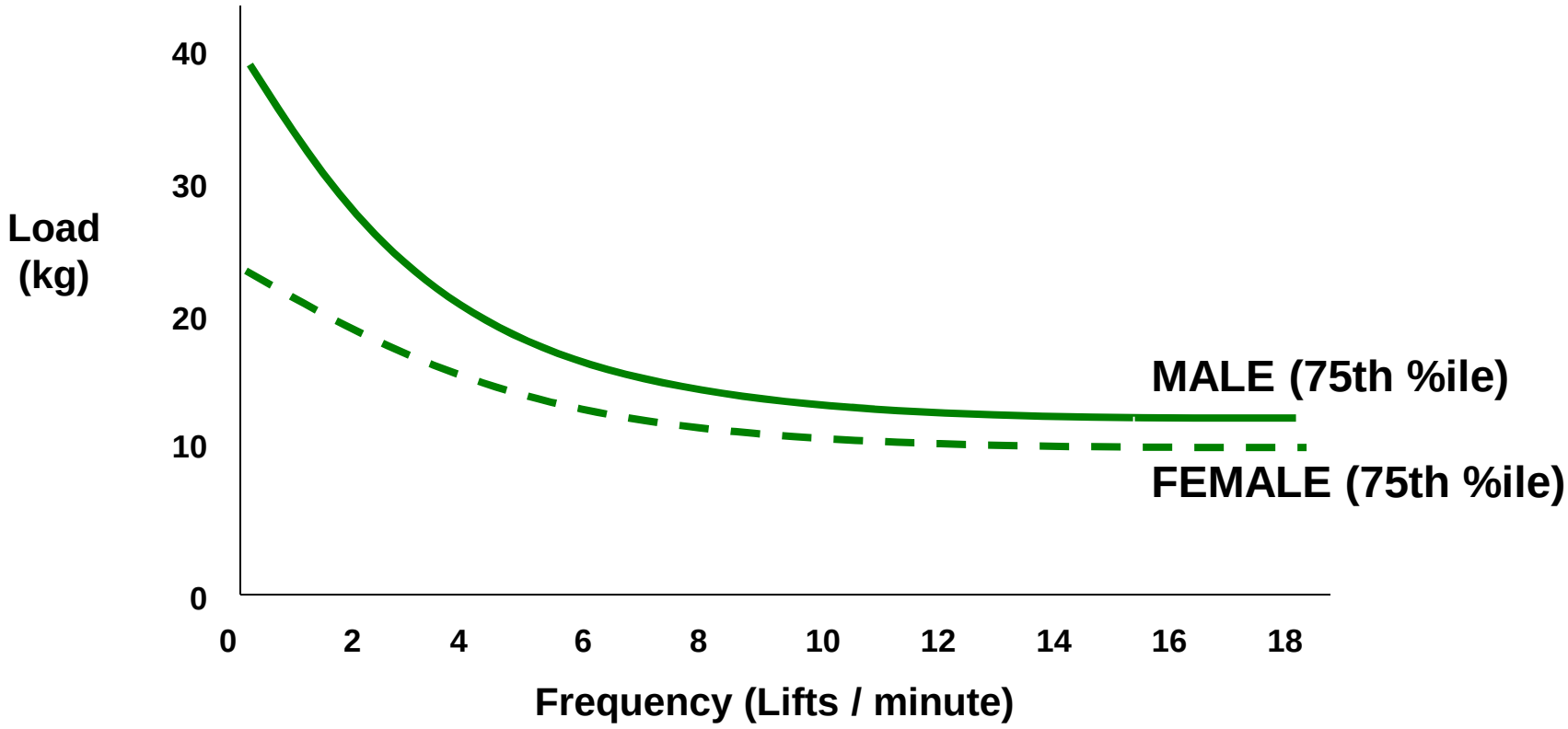
		25	14	17	19	20	22	22	24	33	12	13	14	18	19	19	21	24	10	11	12	15	16	16	18	21
		10	16	20	21	23	25	25	28	38	13	14	16	19	21	21	23	27	11	12	14	17	18	18	20	23

Sample Table: Female, Lifting

Table 3.

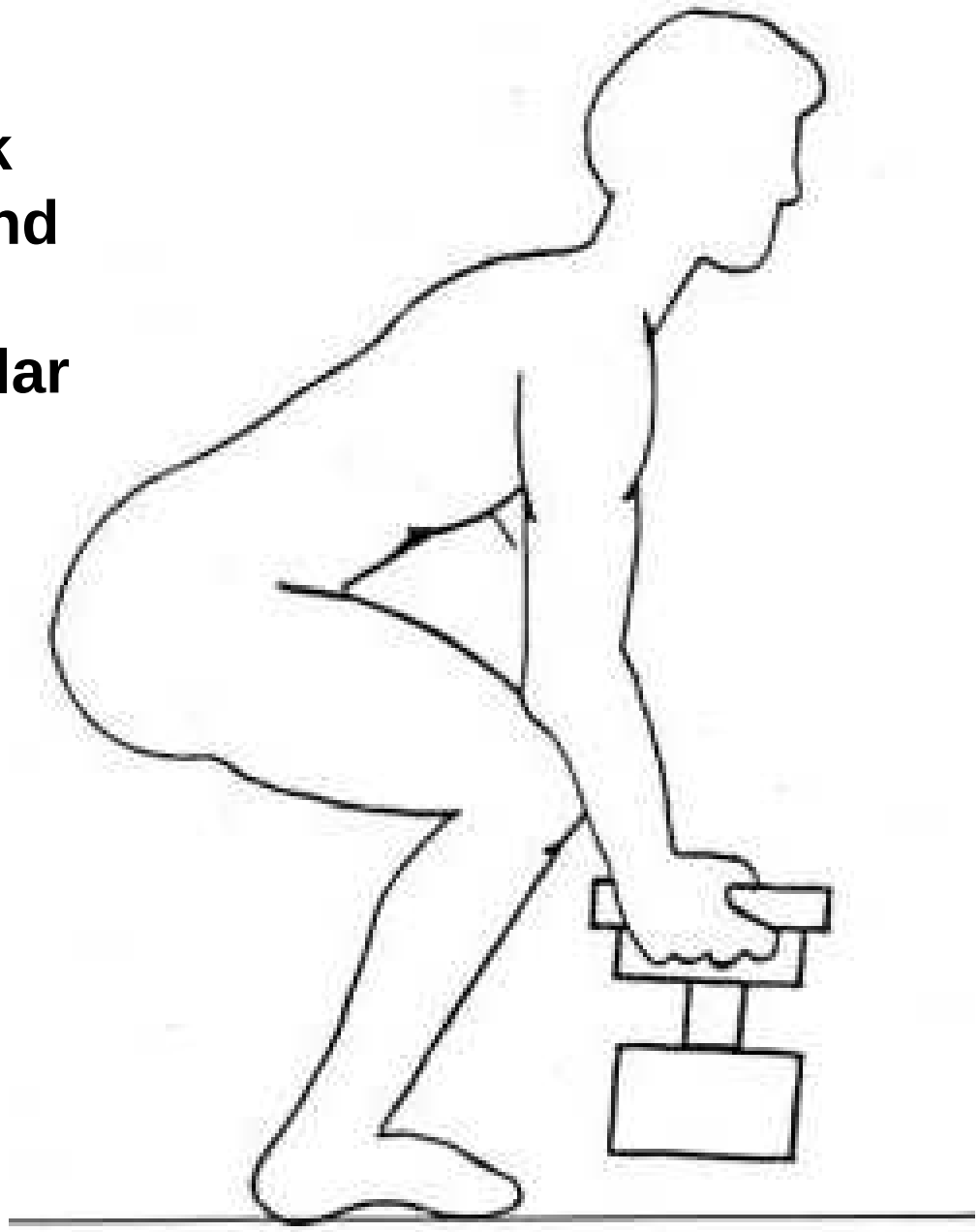
Width‡	Distance§	Percentile¶	Floor level to knuckle height One lift every 5 s	9 s	14 s	1 min	2 min	5 min	30 min	8 h
		90	*5*	6	7	7	8	8	9	12
		75	*7*	8	9	9	10	10	11	14
	76	50	*8*	10	10	11	12	12	13	17
		25	*9*	*11*	12	13	14	14	15	21
		10	*11*	*13*	*14*	14	15	16	17	23
		90	*6*	7	8	8	9	9	10	14
		75	*7*	*9*	9	10	11	11	13	17
75	51	50	*9*	*10*	11	12	13	14	15	21
		25	*10*	*12*	*13*	15	16	16	18	24
		10	*11*	*14*	*15*	17	18	18	20	27
		90	*6*	8	8	9	9	9	11	14
		75	*8*	10	11	11	12	12	13	18
	25	50	*10*	*12*	13	13	14	14	16	21
		25	*11*	*14*	15	15	16	17	19	25
		10	*13*	*16*	*17*	17	19	19	21	29

Psychophysical Criterion



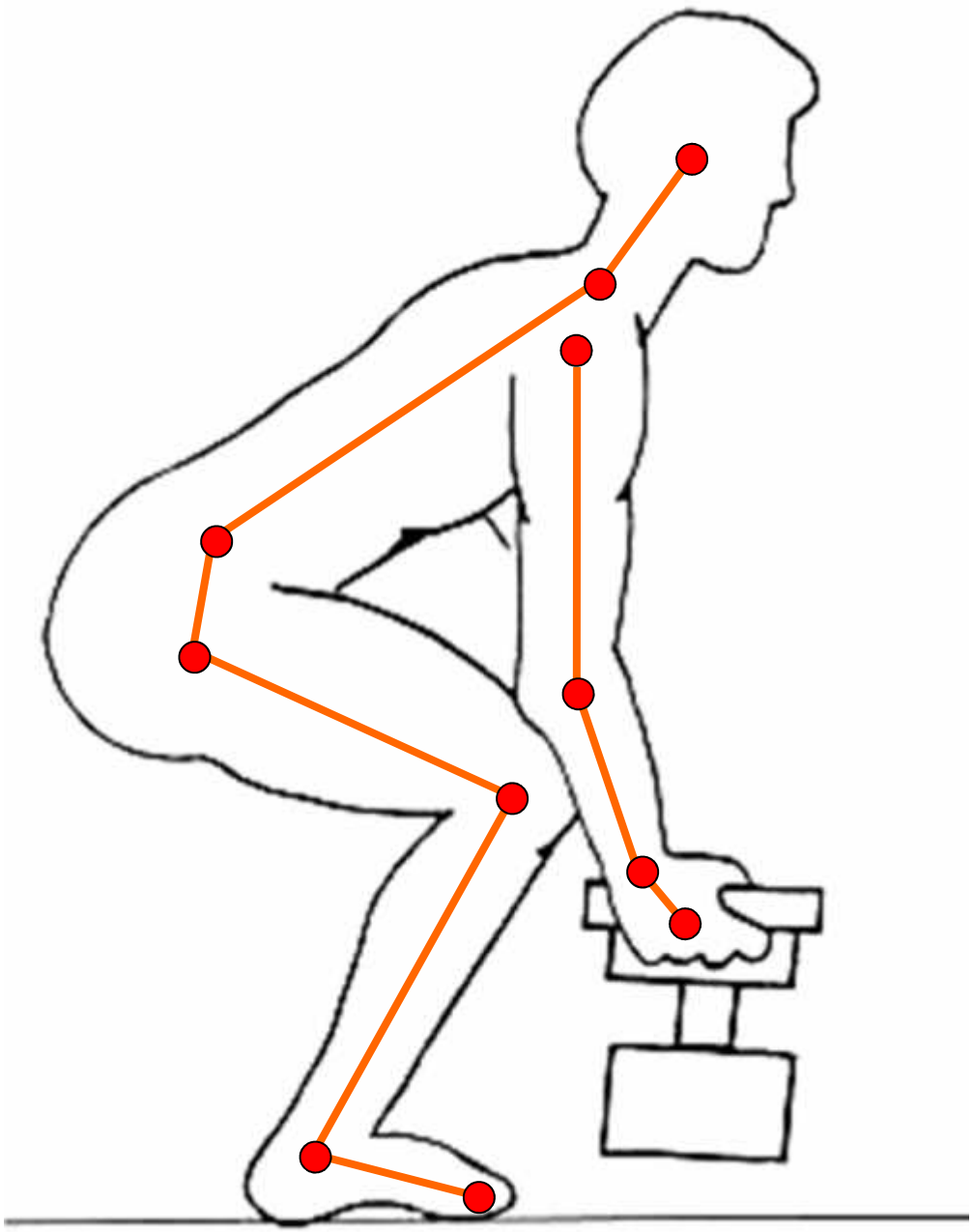
The Biomechanical Criterion

Determining Low Back compression, shear and other joint strength demands for a particular lifting condition



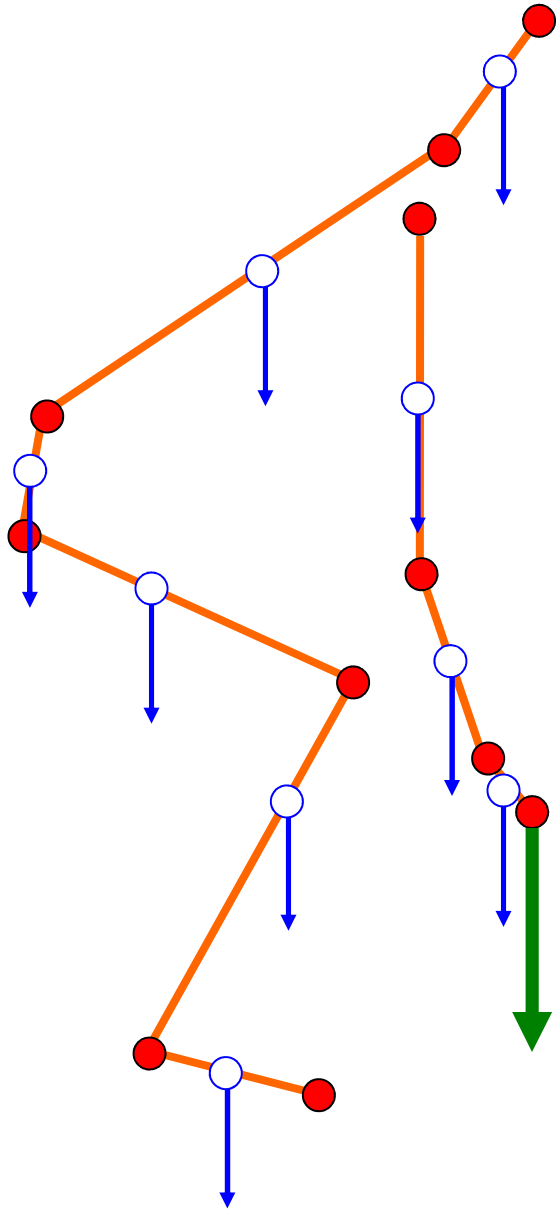
Step 1

Digitizing joints and segments or determining joint angles



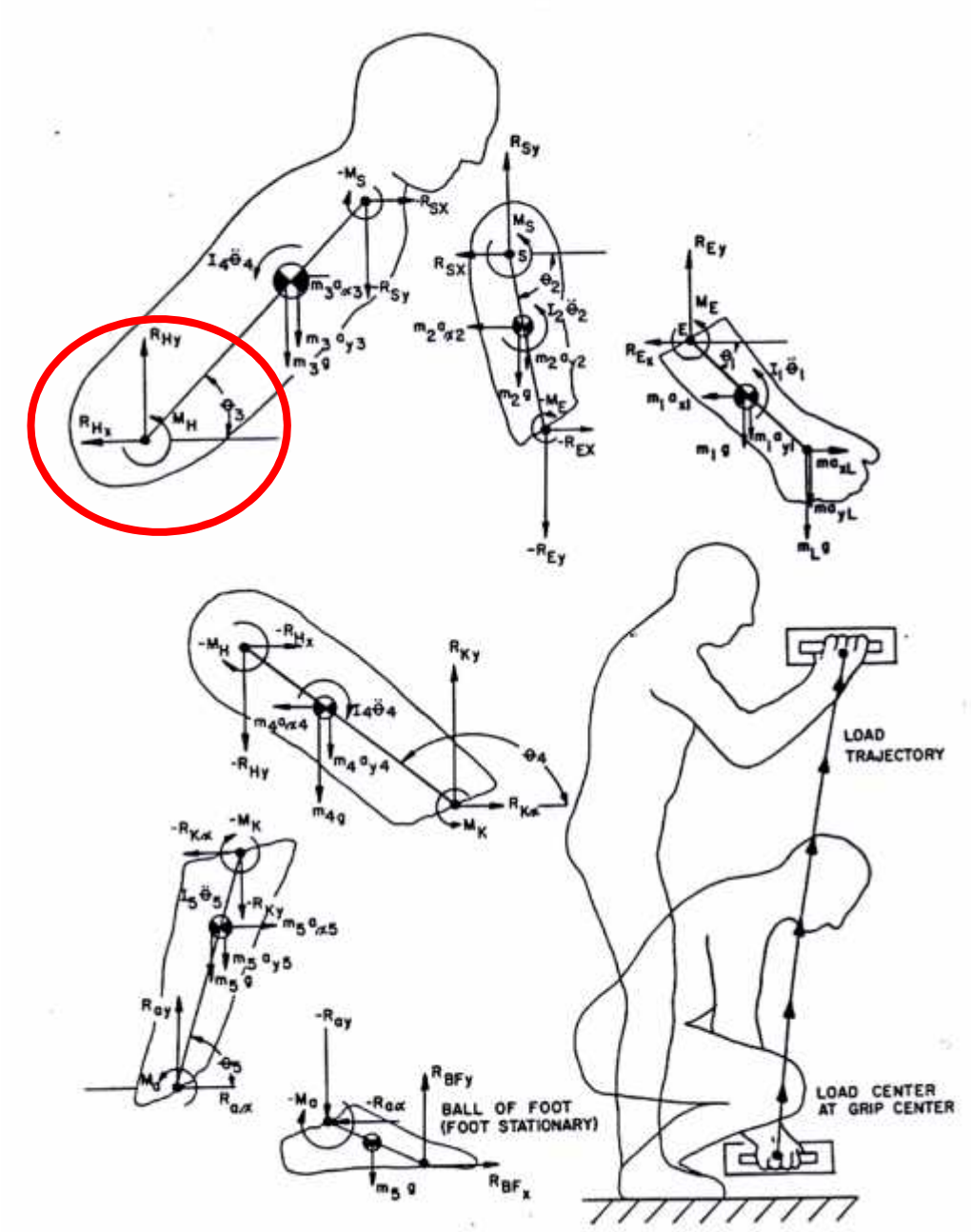
Step 2

Add external loads and determine the mass and location of each segment using standard anthropometrics



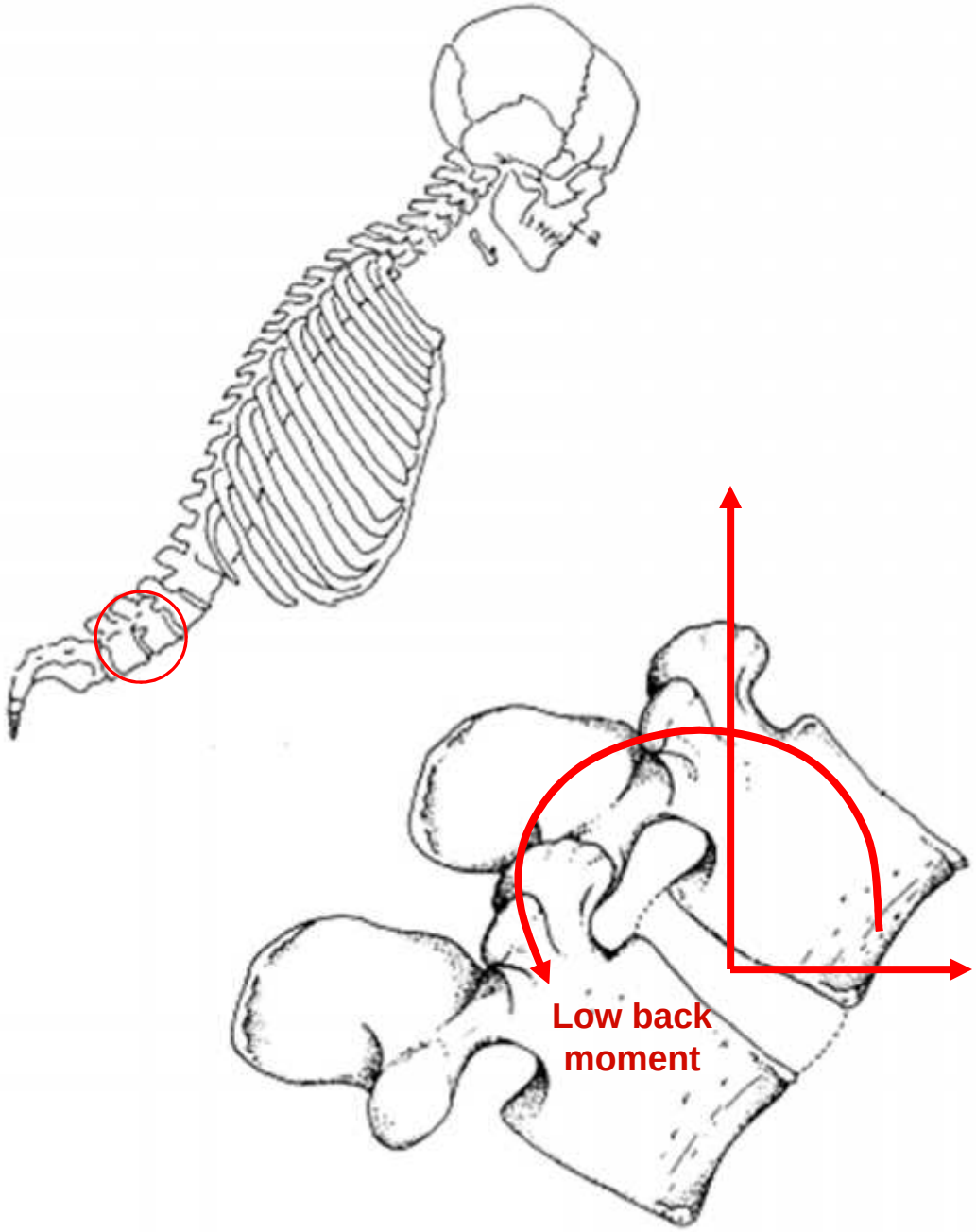
Step 3

Use biomechanical modeling to determine <u>static</u> joint moments and reaction forces



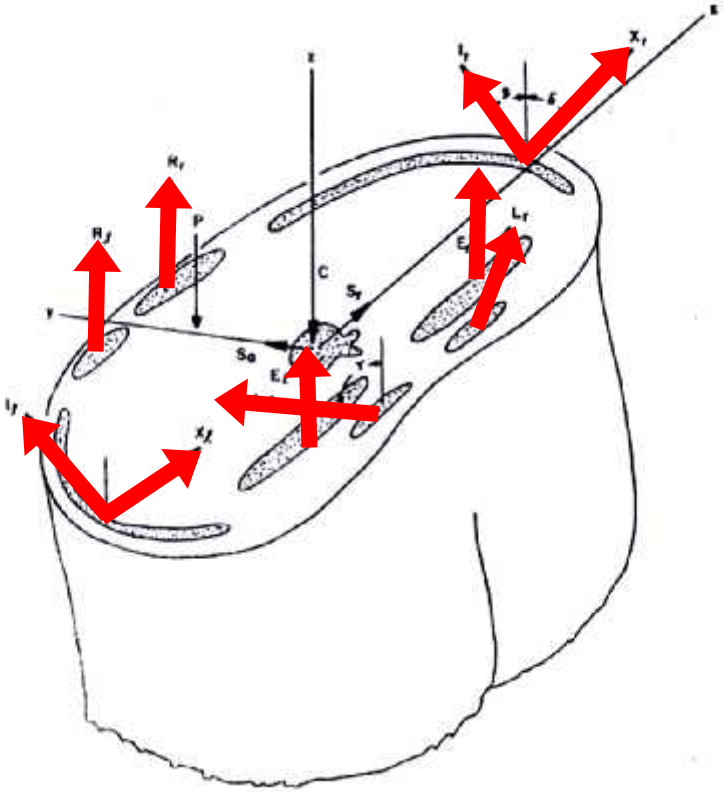
Step 4

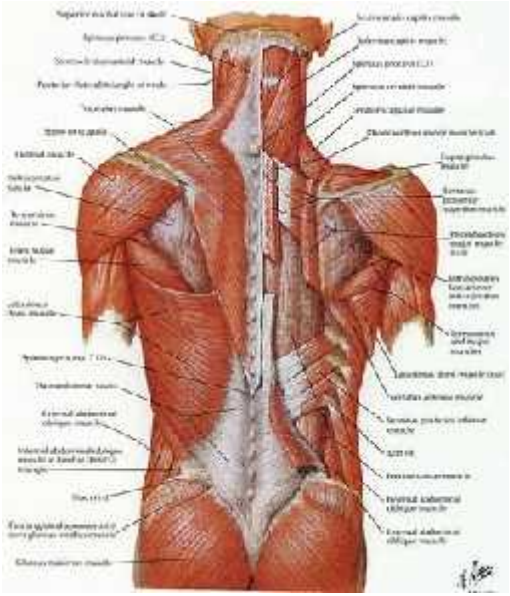
Specific interest is paid to the low back moments and forces



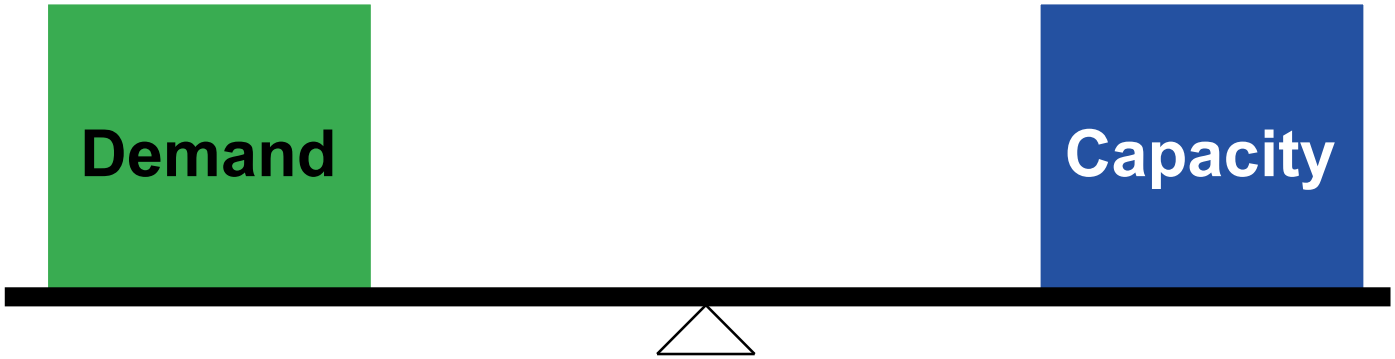
Step 5

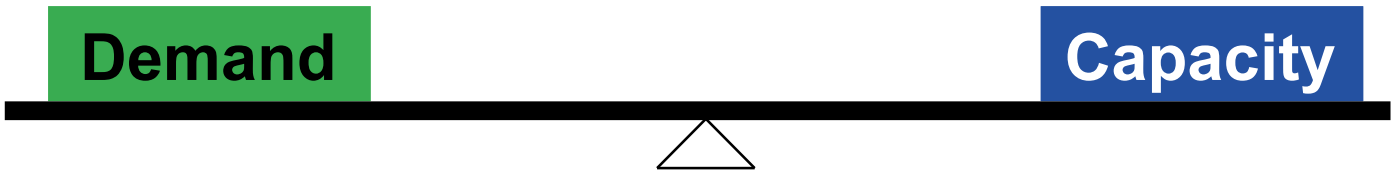
Make some assumptions about muscle locations and orientations to determine what muscle forces are required to resist the calculated low back moment



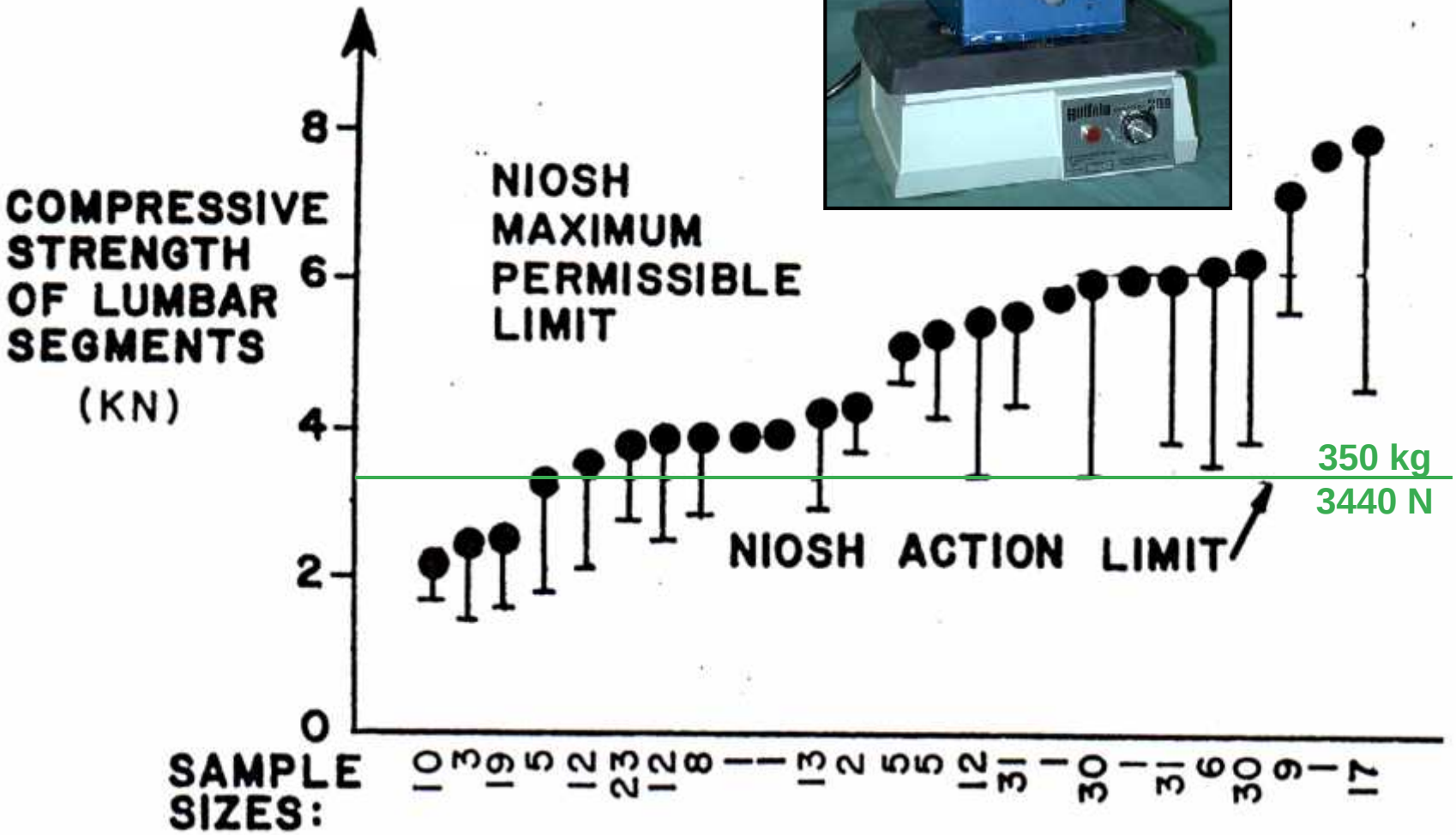


Injury Risk is proportional to: $\frac{\text{Demand}}{\text{Capacity}}$

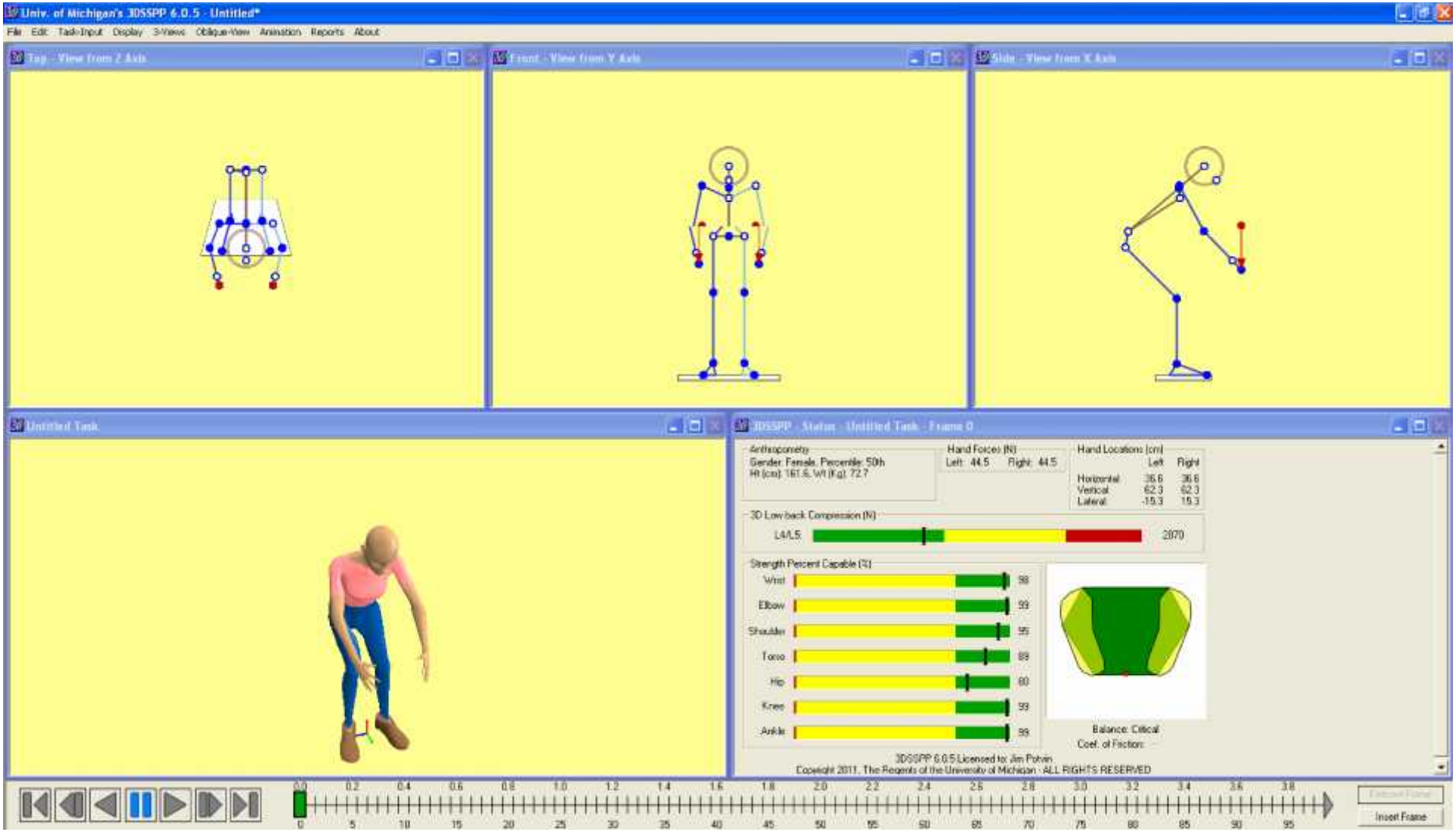




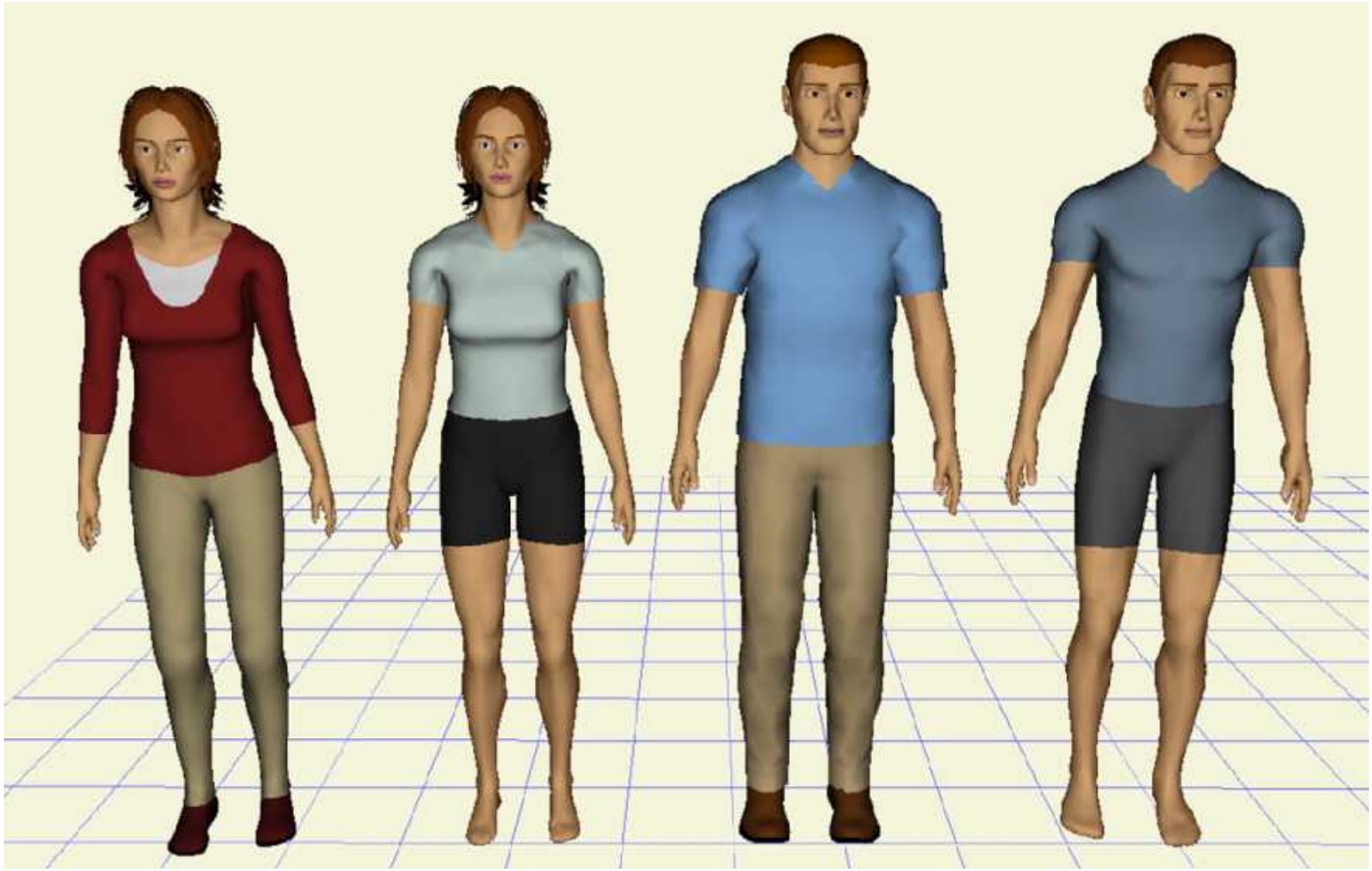
Compression Limits from *in vivo* Testing



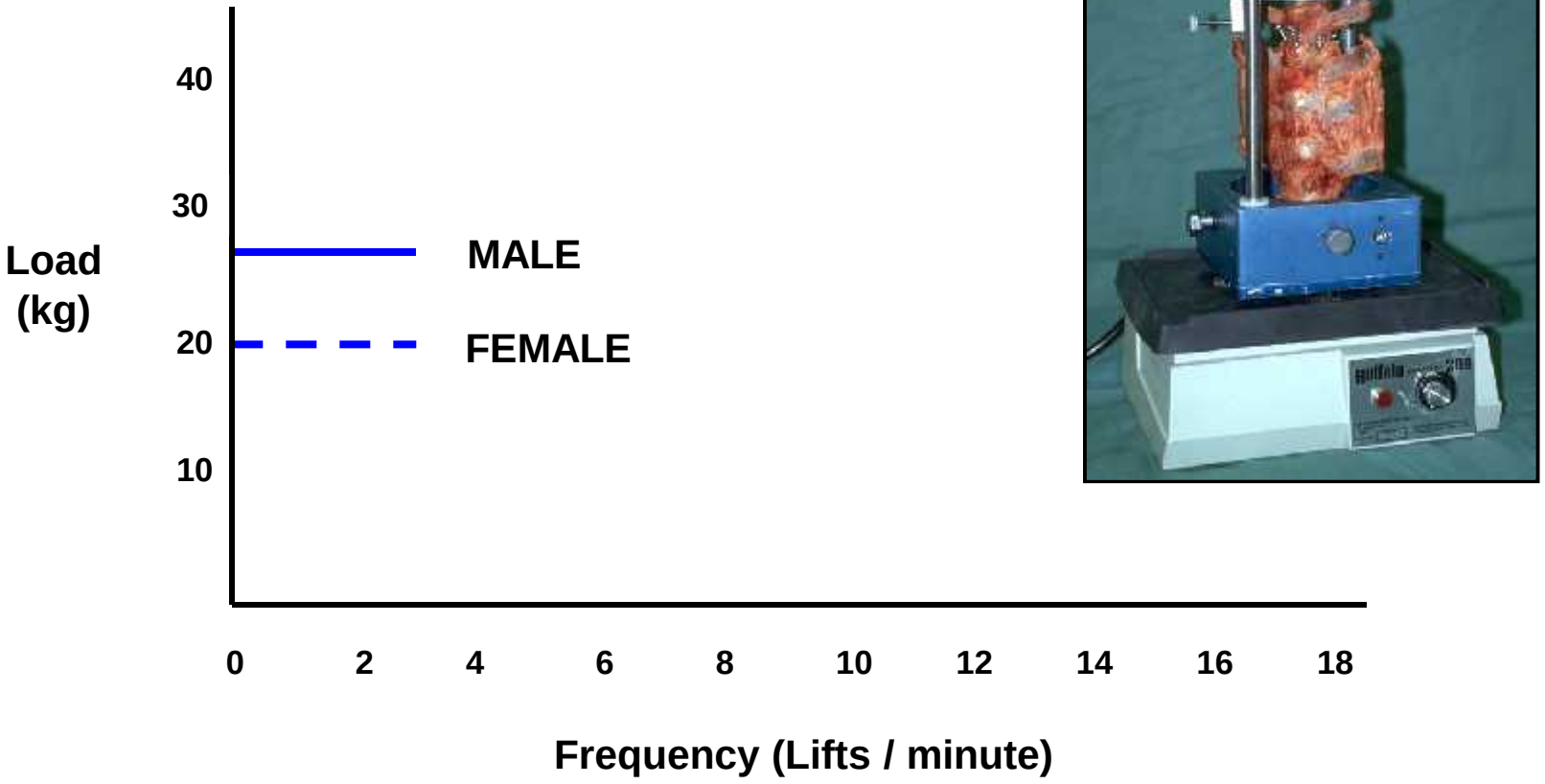
Example Software: 3DSSPP



More Sophisticate Manikins: Siemen's Jack



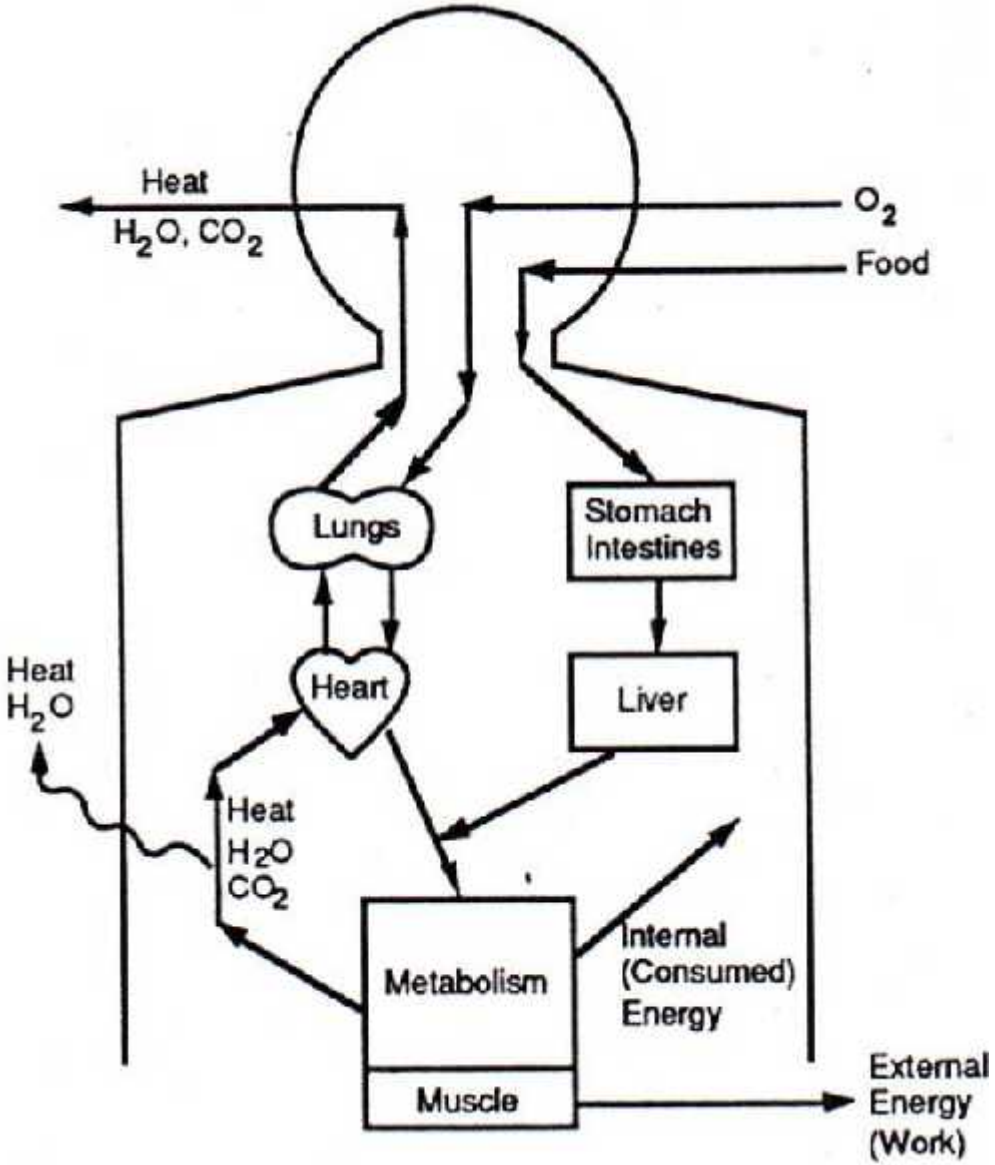
Biomechanical Criterion



The Physiological/Metabolic Criterion

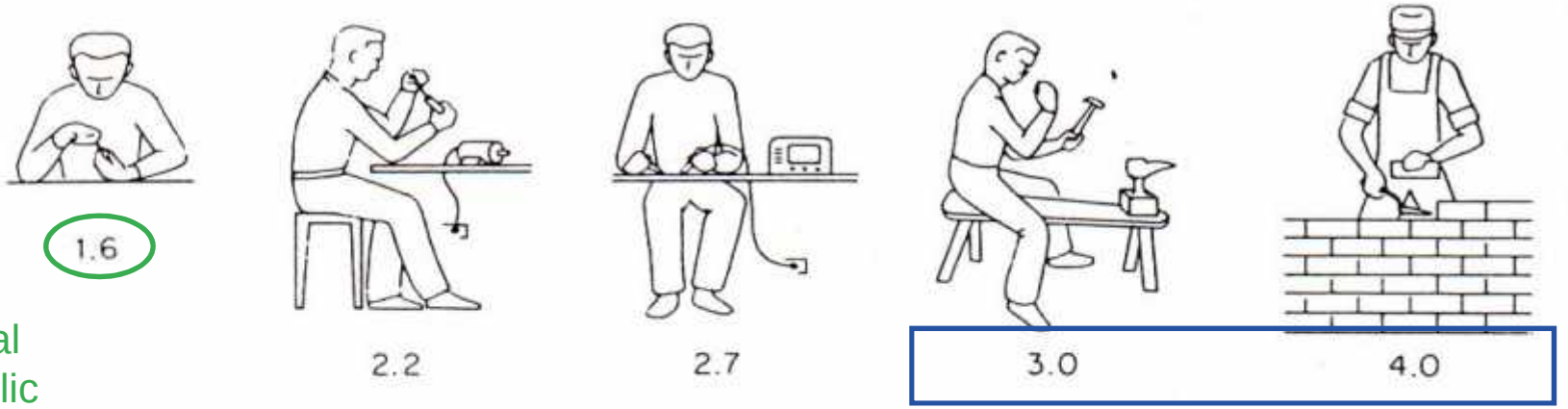
WORK PHYSIOLOGY

Energy Liberation

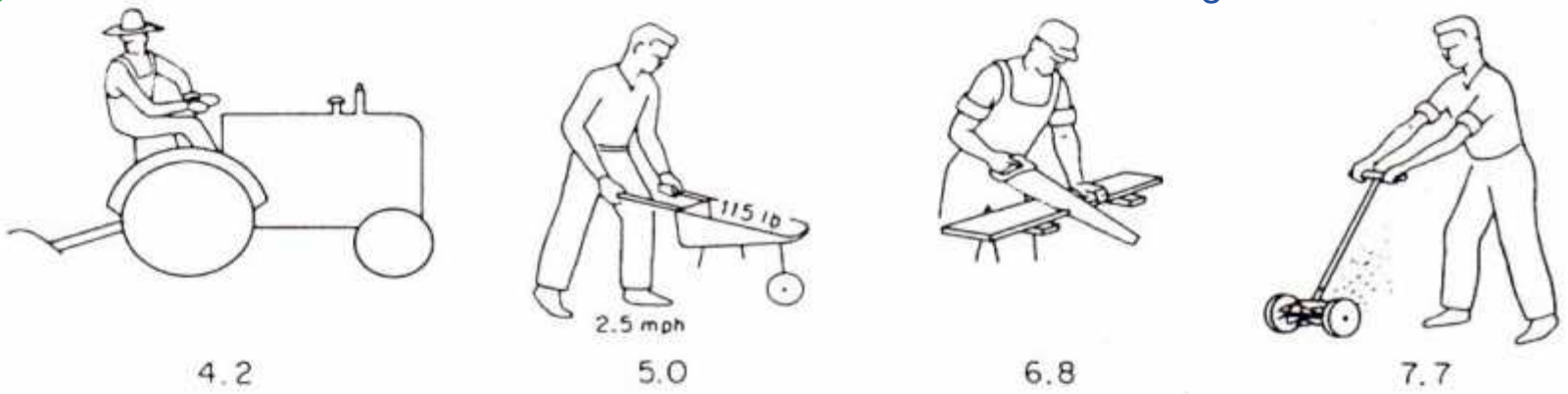


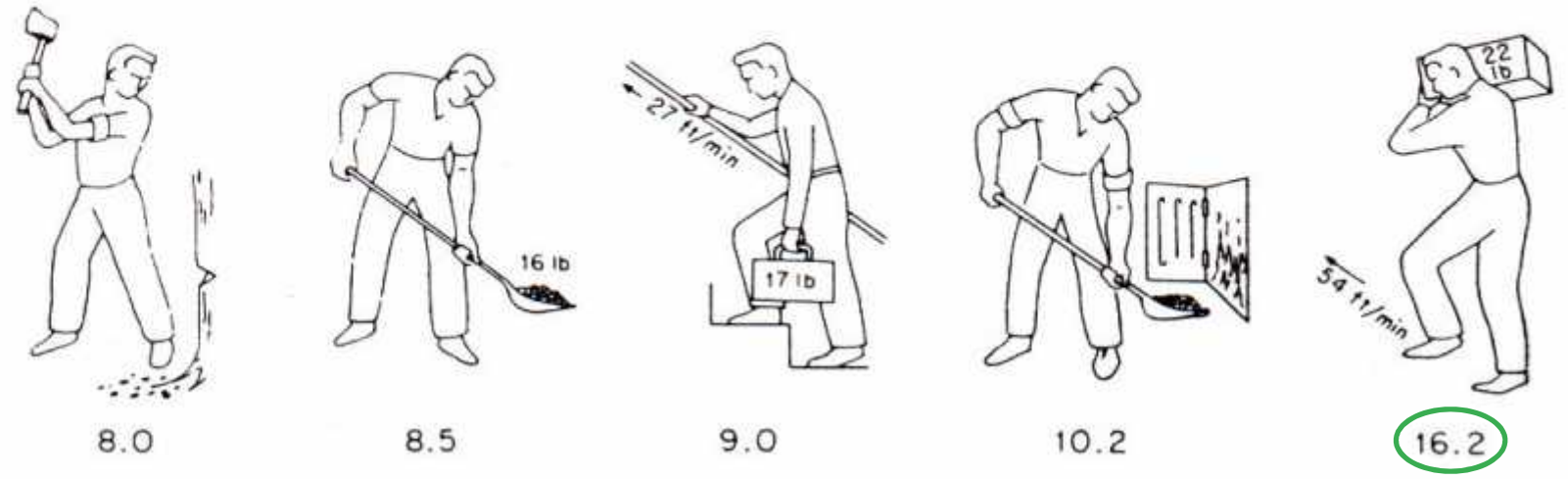
Astrand & Rhodal (1986)

Typical Metabolic Costs



Range of Limits



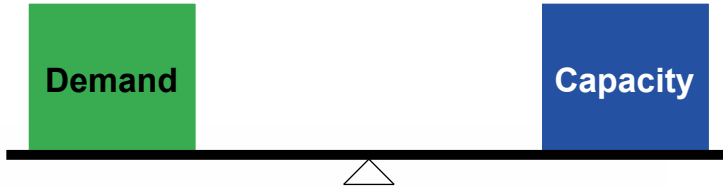


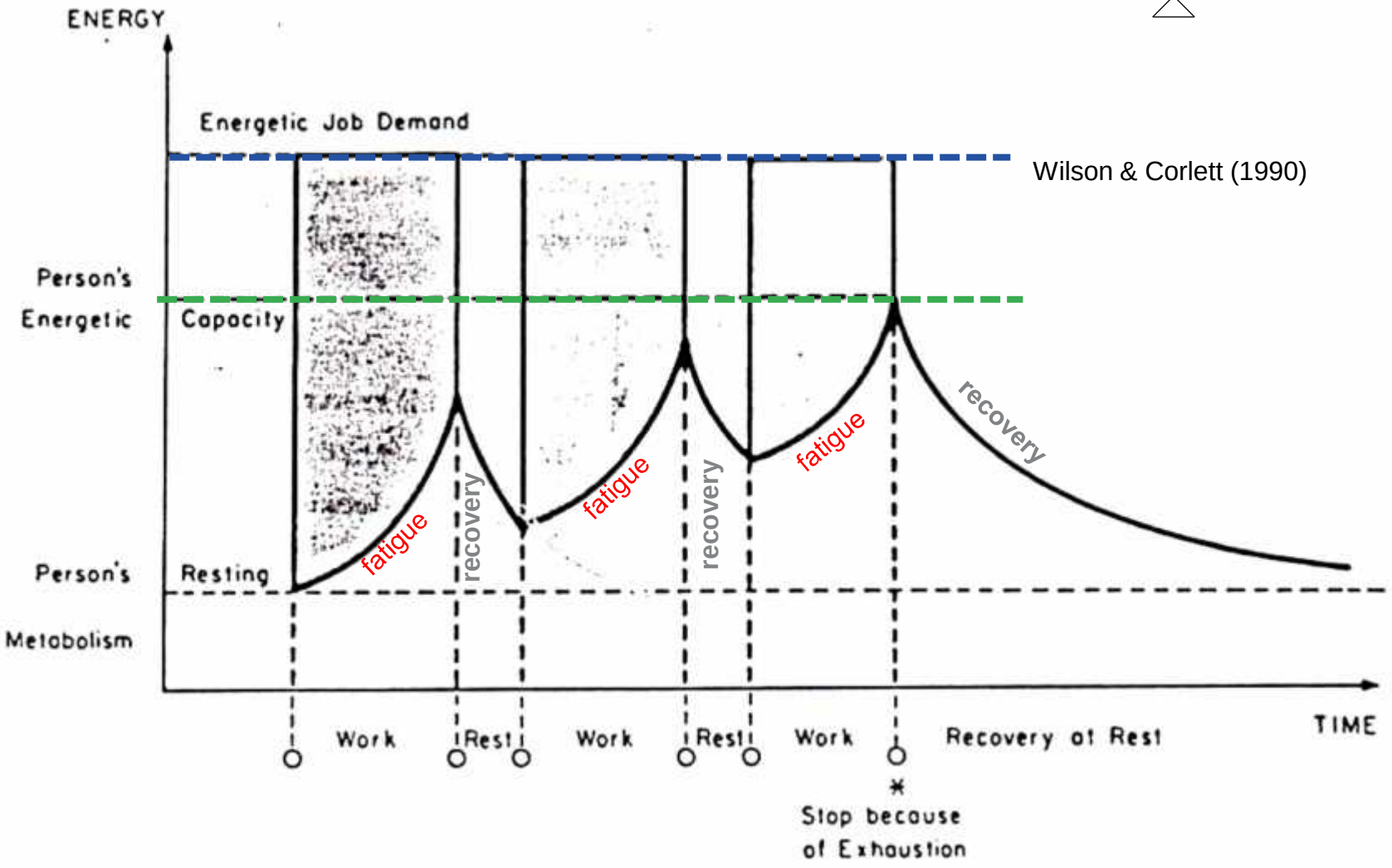
Sanders & McCormick (1989)

"Reasonable Upper Limit"

- guideline for max VO_2 = 16 kcal/min
- 30 to 40% VO_2 max

Rest Periods





Wilson & Corlett (1990)

Measuring Work Load

Direct

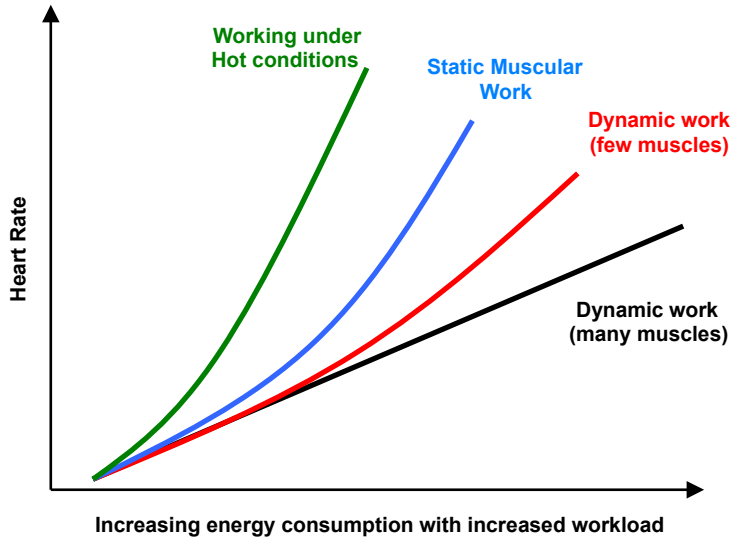
- Volume of oxygen consumed (VO_2)

Indirect

1) - heart rate
   - estimate (± 20%)
   - standardized, steady state

   - considerations
     - large vs. small muscle groups
     - static vs. dynamic activity

2) - physiological + psychological
   - more closely related to R.P.E.
   - Borg Scale



1-10 Borg Scale of Perceived Exertion	
0	Rest
1	Really Easy
2	Easy
3	Moderate
4	Sort of Hard
5	Hard
6	
7	Really Hard
8	
9	Really, Really Hard
10	Maximal

Garg et al (1978) Metabolic Equations

- 28 tasks
- 6 subjects (18 to 22 yrs)
- tote box lifted
  - 10 minutes (20 minutes rest)
- calculated metabolic energy expenditure
- least square error regression analysis

Example

Squat Lift (Kcal/lift):

$$E = (0.01)\,[\,(0.514)(\text{body weight})(0.81-\text{lower height}) + \{\,(2.19)(\text{load}) + (0.62)(\text{sex})(\text{load})\,\}\,(\text{change in height})\,]$$

Dempsey et al (2008) Metabolic Equations

- **Subjects**
  - 19 male & 19 female
- **Metabolic Cost**
  - lift & lower (n = 1,761)
  - push & pull (n = 1,132)
  - (de)palletising (n = 598)
  - carry & combinations (n = 4,907)
  - Total n = 8,398 trials
- **Data Collection**
  - VO_2 consumption
- **Data Analysis**
  - regression modelling

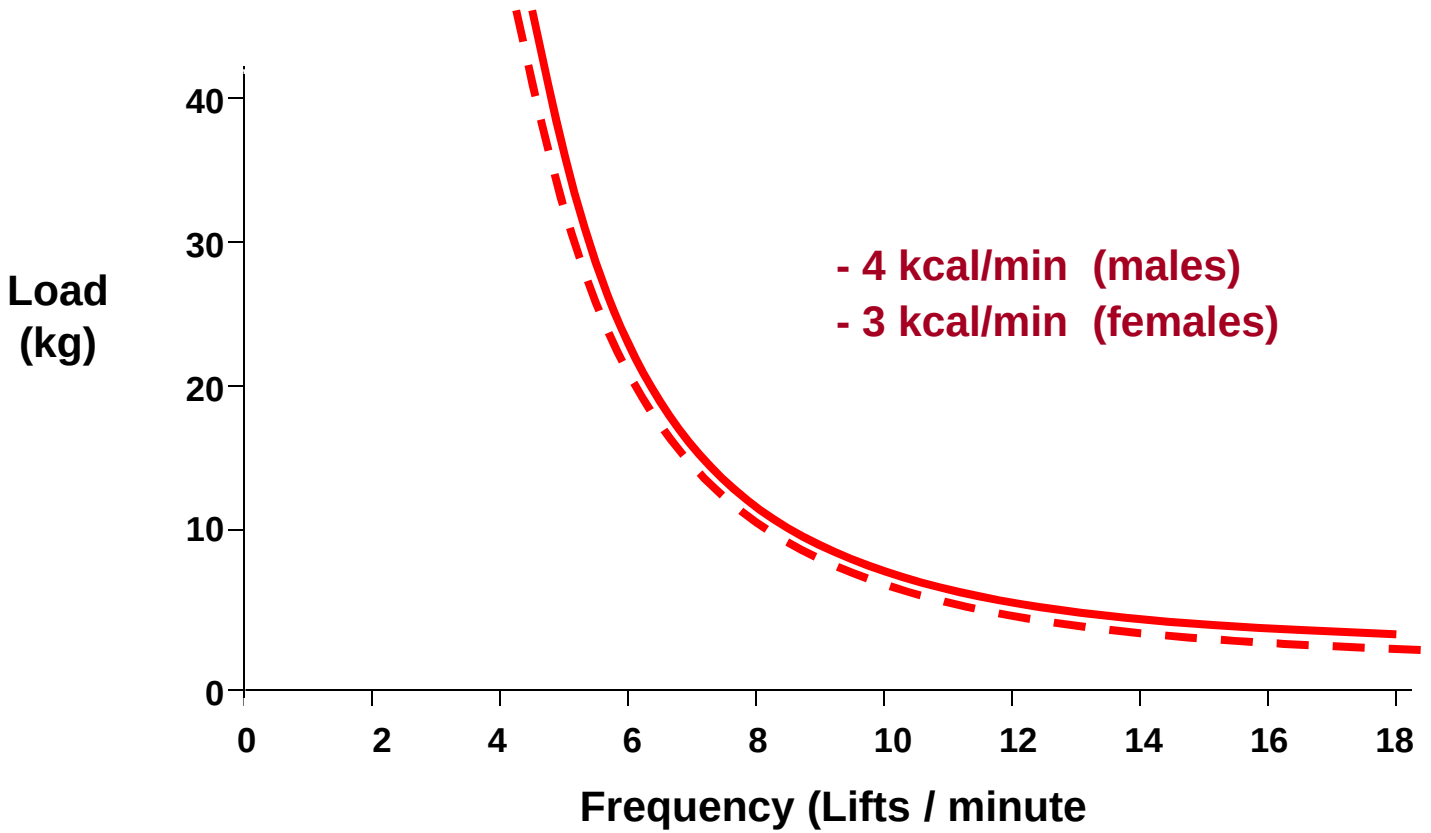
Dempsey et al (2008)

Task type	Model
Female	
Low lift	$\dot{V}O_2 = -232.5 + 4.8BW + 127.3BOX + 54.1FREQ + 34.4LOAD$
Centre lift	$\dot{V}O_2 = -308.7 + 5.9BW + 61.8BOX + 26.8FREQ + 37.5LOAD$
Low lower	$\dot{V}O_2 = -415.5 + 7.0BW + 50.1BOX + 52.5FREQ + 28.9LOAD$
Centre lower	$\dot{V}O_2 = -251.5 + 6.2BW + 48.8BOX + 20.1FREQ + 19.6LOAD$
Pushing	$\dot{V}O_2 = -864.1 + 6.4BW + 55.8FREQ + 24.4\ FREQDIS + 61.0FMEAS$
Pulling	$\dot{V}O_2 = -891.4 + 9.1BW - 83.0TRED + 39.3FREQ + 34.3\ FREQDIS + 41.9FMEAS$
(De)palletising	$\dot{V}O_2 = -568.5 + 12.3BW - 57.6DEPAL + 40.3BOX + 46.8FREQ + 25.9LOAD$
Carry-lower	$\dot{V}O_2 = -504.0 + 11.1BW + 18.2FREQ + 18.9FREQDIS + 22.3LOAD$
Carry-place	$\dot{V}O_2 = -275.4 + 8.7BW + 16.2FREQDIS + 14.0LOAD$
Carry-lift	$\dot{V}O_2 = -334.3 + 8.6BW + 14.2FREQ + 16.7FREQDIS + 26.5LOAD$
Lift-carry-lower	$\dot{V}O_2 = -657.9 + 12.8BW + 51.7FREQ + 21.9FREQDIS + 27.5LOAD$
Lift-carry-place	$\dot{V}O_2 = -541.2 + 11.7BW + 34.0FREQ + 18.6FREQDIS + 23.3LOAD$
Lift-carry-lift	$\dot{V}O_2 = -413.8 + 9.4BW + 44.0FREQ + 18.6FREQDIS + 33.3LOAD$
Lower-carry-lower	$\dot{V}O_2 = -412.8 + 9.8BW + 29.7FREQ + 18.6FREQDIS + 26.7LOAD$
Lower-carry-place	$\dot{V}O_2 = -318.7 + 9.1BW + 16.4FREQDIS + 20.2LOAD$
Lower-carry-lift	$\dot{V}O_2 = -232.8 + 6.7BW + 10.7FREQ + 21.2FREQDIS + 28.5LOAD$

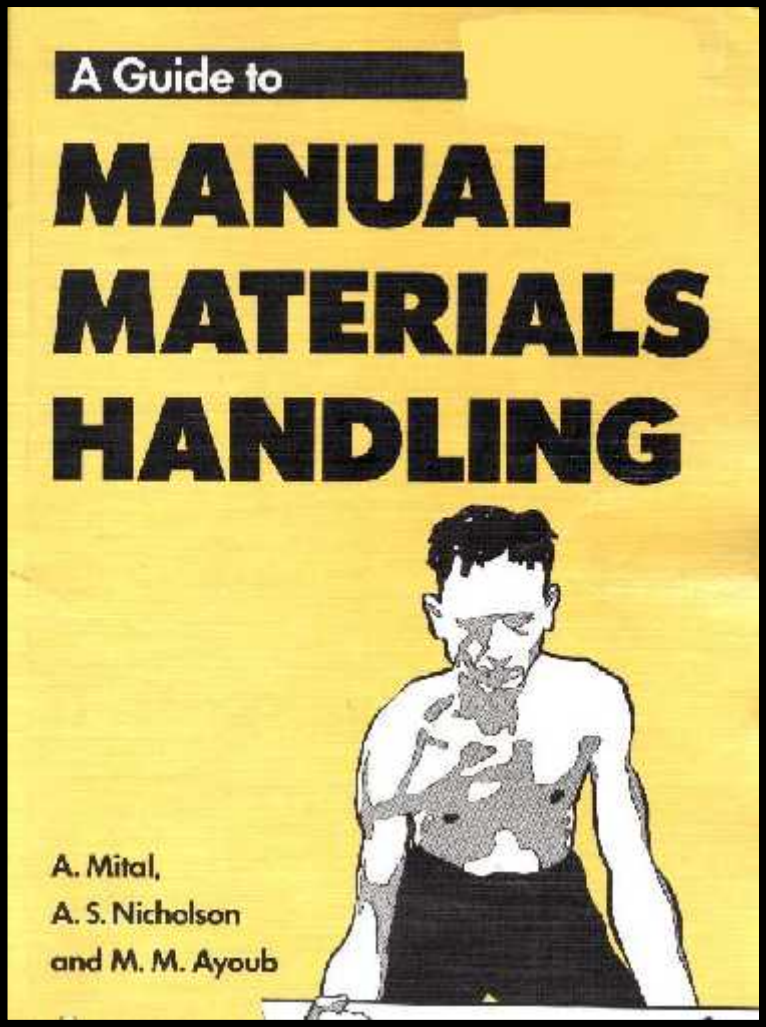
$\dot{V}O_2$ = oxygen consumption (ml), BW = body weight (kg), BOX = 1 for large box or 0 for small box, FREQ = repetitions per min, LOAD = box weight (kg), DEPAL = 1 for depalletising or 0 for palletising, TRED = 1 for treadmill or 0 for pushcart, FREQDIS = frequency (per min) × distance (m), FMEAS = measured sustained force (kg).

1000 ml = 1 litre = 4.8 kcal

Physiological Criterion



Integration of Lifting Analysis Methods

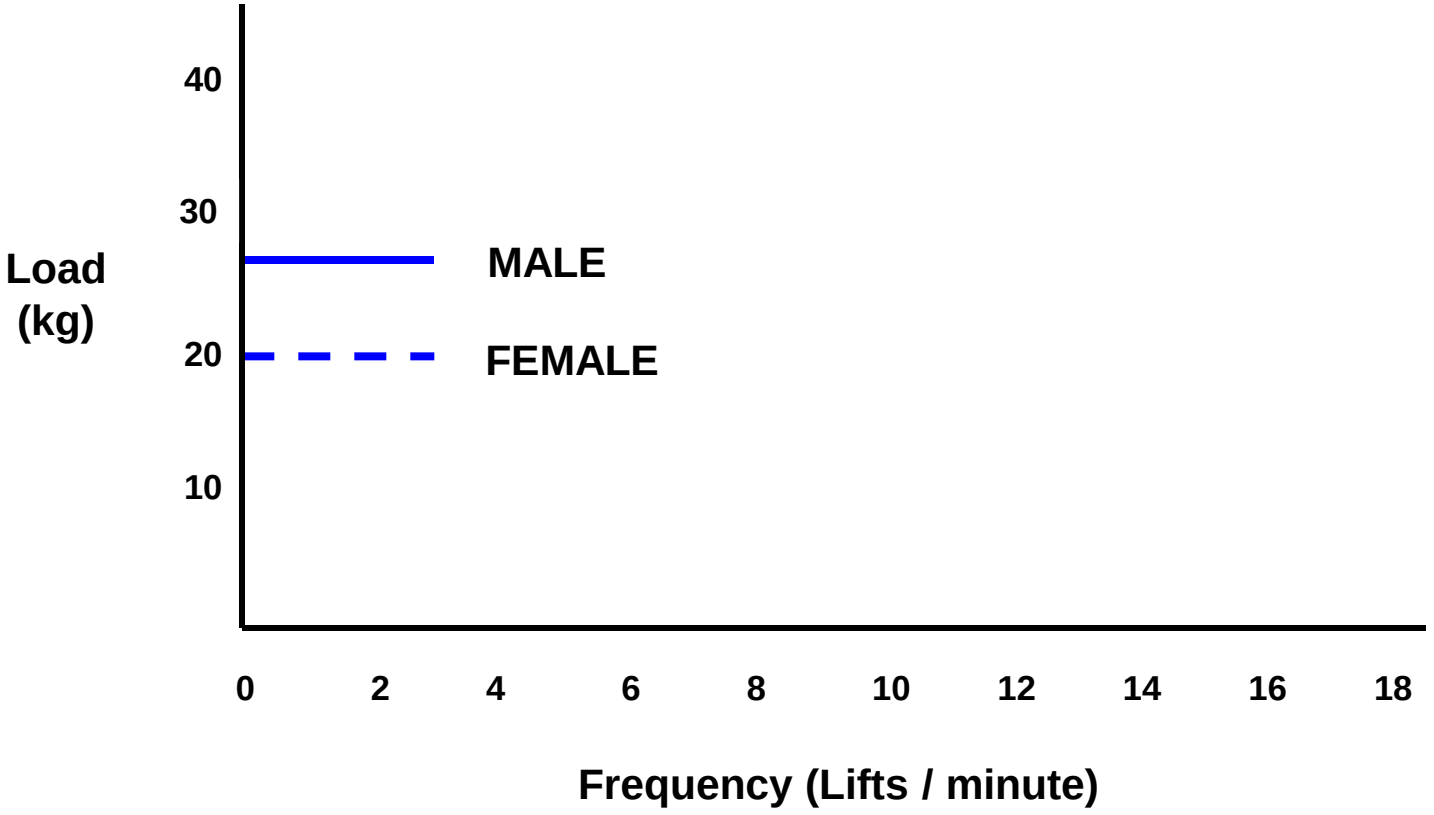


A GUIDE TO MANUAL MATERIALS HANDLING
Mital, Nicholson, Ayoub (1993)

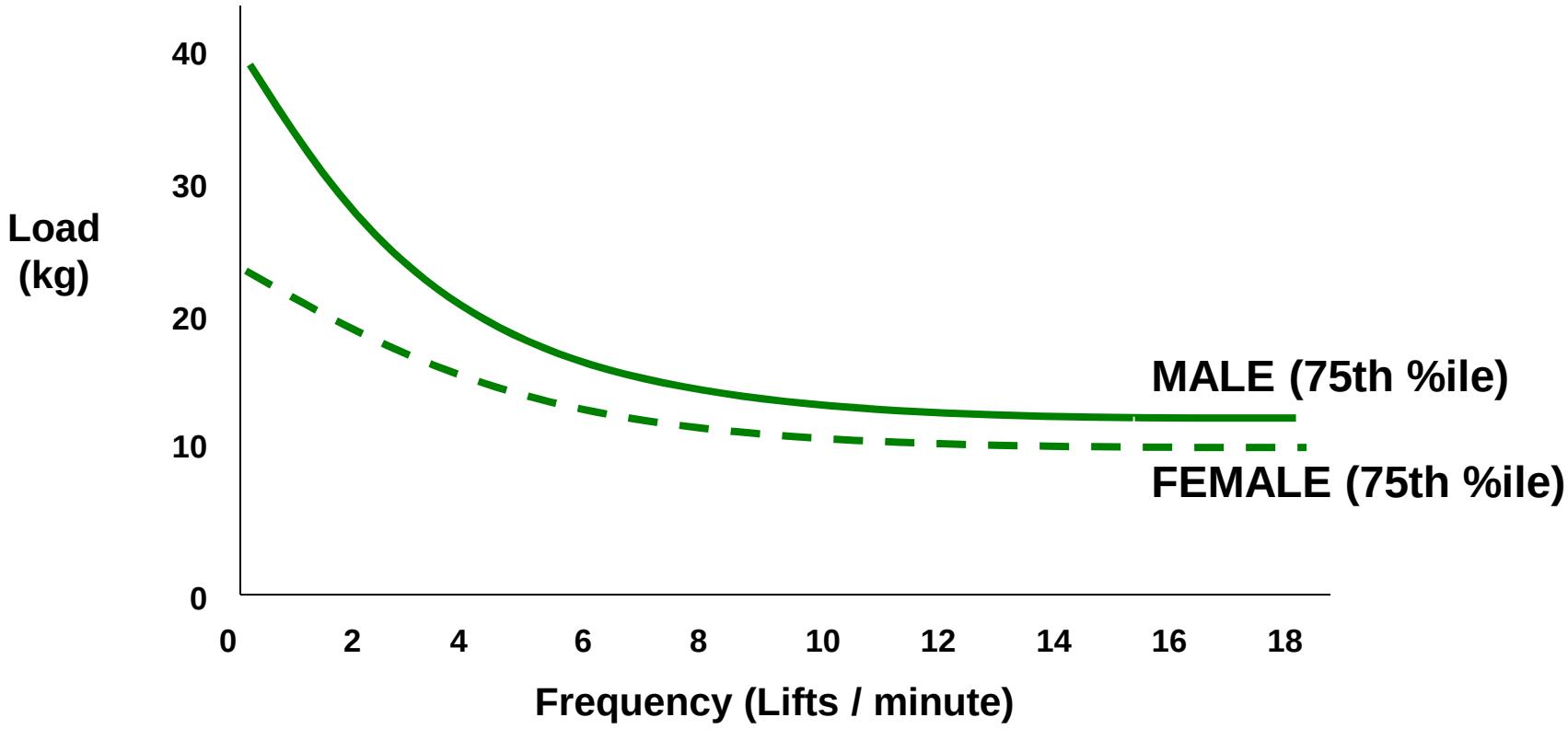
What Approaches Does Mital et al Use?

1. Epidemiological Criterion
2. Biomechanical Criterion
3. Physiological/Metabolic Criterion
4. Psychophysical Criterion

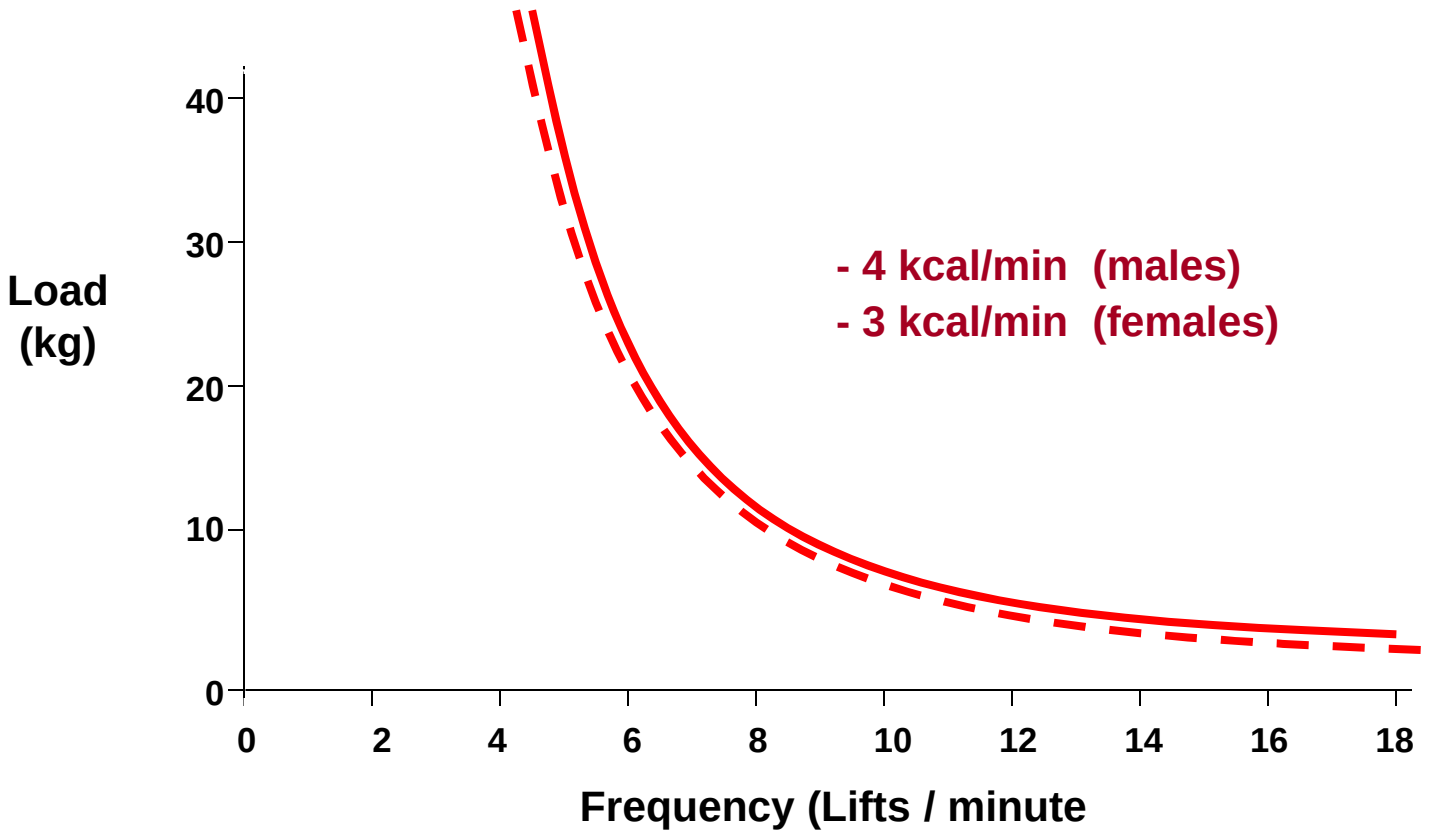
Biomechanical Criterion



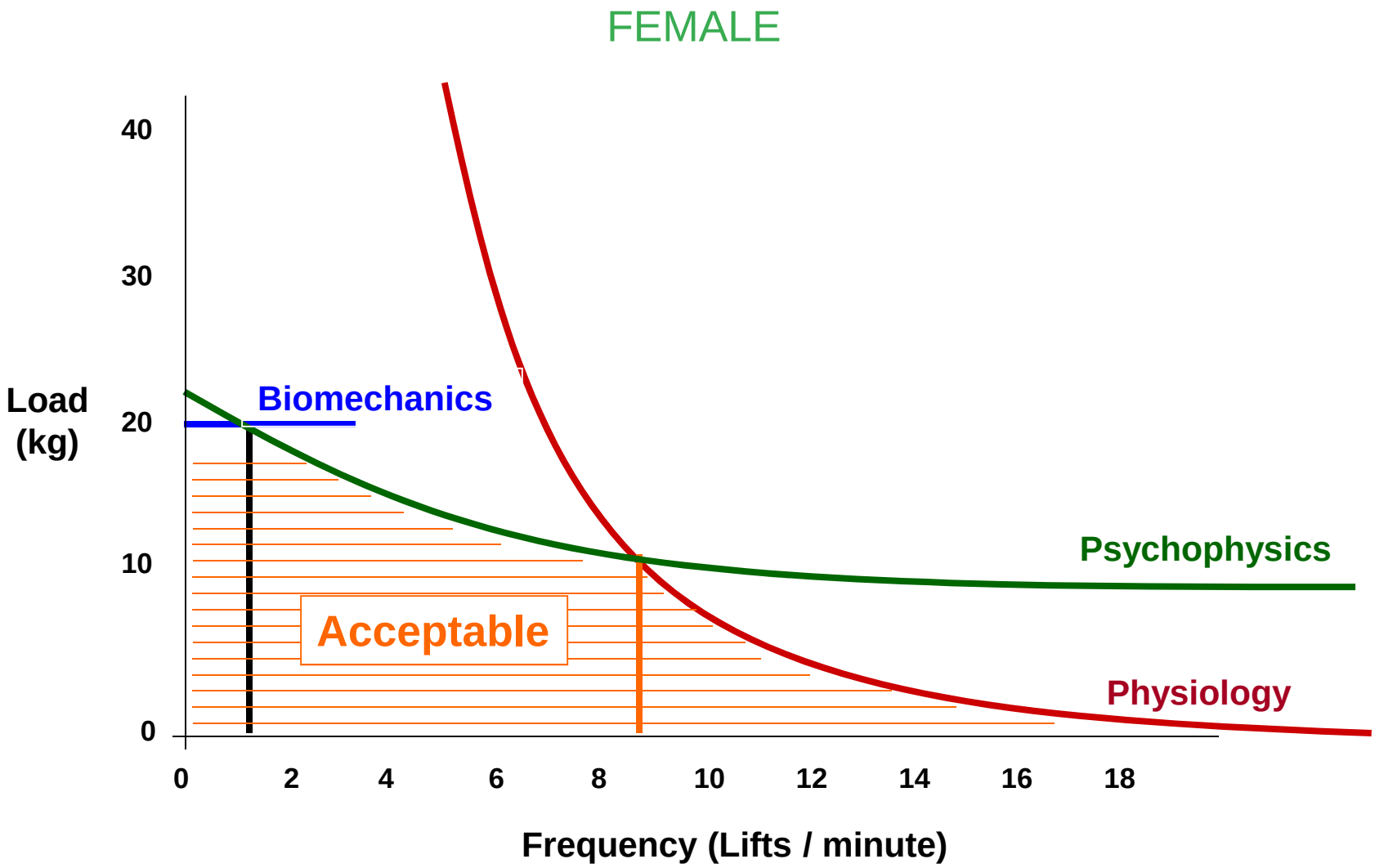
Psychophysical Criterion

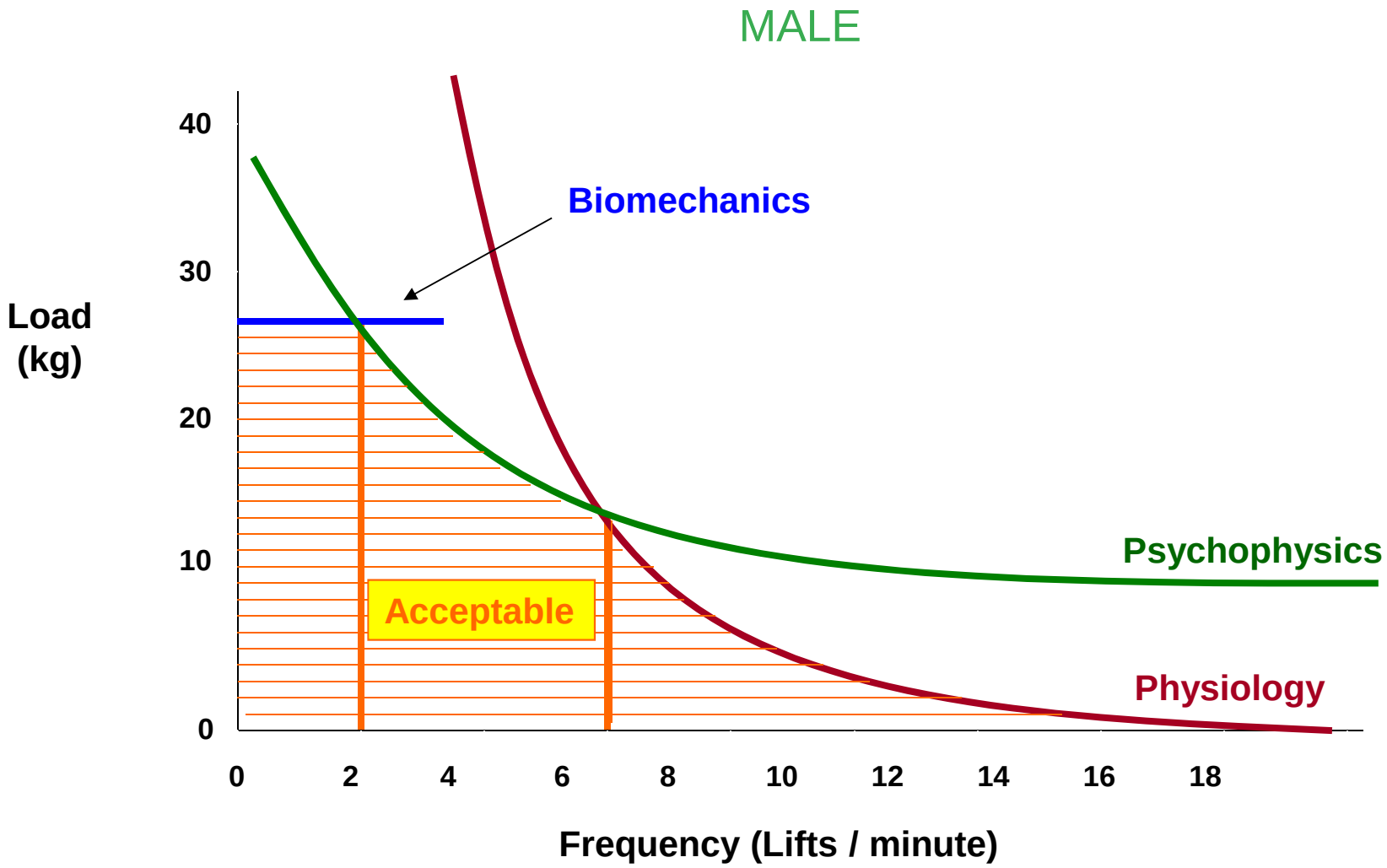


Physiological Criterion



- Start with **psychophysics** (Snook Tables)
- replace with **biomechanical** or **physiological** criterion where appropriate




MALE
Load (kg)
40
30
20
10
0
Biomechanics
Psychophysics
Physiology
Acceptable
0
2
4
6
8
10
12
14
16
18
Frequency (Lifts / minute)

Biomechanical
Physiological

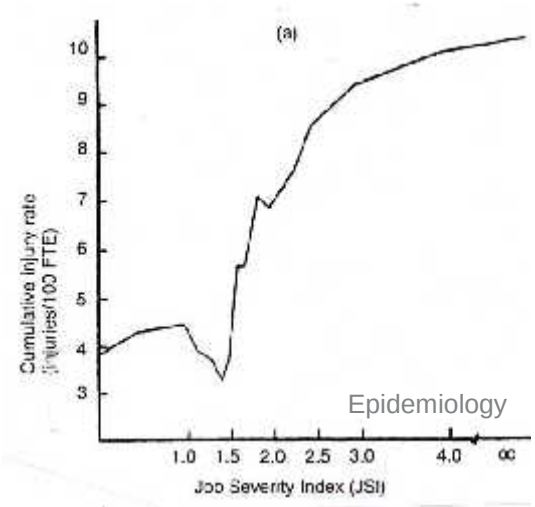
Table 4.2 Recommended weight of lift (kg) for male industrial workers for two-handed symmetrical lifting for 8 h.

Box-size (cm)	Percentile	Frequency of Lift: 1/8 h	1/30 min	1/5 min	1/min	4/min	8/min	12/min	16/min
Floor to 80 cm height									
75	90	17	14	14	11	9	7	6	4.5
	75	24	21	20	16	13	10.5	9	7
	50	27[a]	27[a]	27	22	17	14	12	9.5
	25	27[a]	27[a]	27[a]	27[a]	21	17.5	15	12
	10	27[a]	27[a]	27[a]	27[a]	25	20.5	18	14.5
49	90	20	17	16	13	10	7	7	6.5
	75	27[a]	24	24	19	14	10	10	9
	50	27[a]	27[a]	27[a]	26	19	15	12.5	10
	25	27[a]	27[a]	27[a]	27[a]	24	18.5	15	12
	10	27[a]	27[a]	27[a]	27[a]	28	22	17.5	15
34	90	23	19	19	15	11	7	7	6.5
	75	27[a]	27[a]	27[a]	22	17	10	10	9.5
	50	27[a]	27[a]	27[a]	27[a]	22	15	14	12
	25	27[a]	27[a]	27[a]	27[a]	27[a]	20	17	14
	10	27[a]	27[a]	27[a]	27[a]	27[a]	25	21	15

Manual Materials Handling
Ergonomics
Decision Process

How Do I Choose the Correct Ergo Assessment Tool?

- Example: Lifting
  - Criteria
  - Epidemiology
    - injury statistics
  - Biomechanics
    - lumbar compression force
    - joint strength demands
      - simple tools (2DSSPP, WatBak)
      - more complex (3DSSPP)
      - advanced (Jack, Santos, Delmia)
  - Psychophysics
    - how are these studies done?
      - Snook & Ciriello (1991)
  - Physiology & Metabolic Cost
    - cardiovascular demand
      - calories burned



Epidemiology


Compression Tolerance


Psychophysics


Metabolic Cost

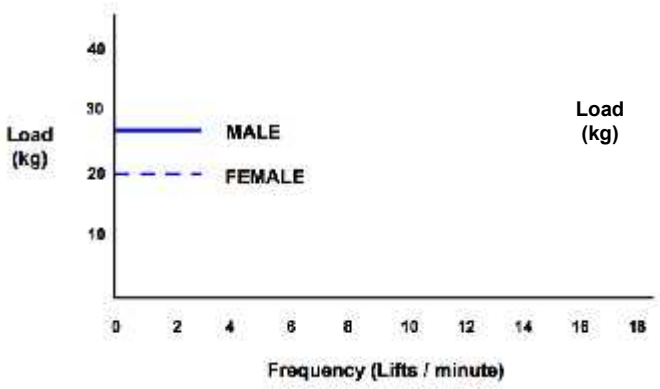
How Do I Choose the Correct Ergo Assessment Tool?

- Example: Lifting
  - Epidemiology
    - Strengths: can be gathered from all jobs, comprehensive
    - Limitations: not specific to a task or task elements, may not reflect tissue injuries
  - Biomechanics
    - Strengths: compression can be calculated with confidence, has capacity limits
    - Limitations: limited data on effects of repetition
  - Psychophysics
    - Strengths: based on an integration of senses, subjects were trained
    - Limitations: tends to overestimate acceptable loads at high and low frequencies
  - Physiology & Metabolic Cost
    - Strengths: can be used for a combination of tasks, can be measured accurately now (eg. Fitbit)
    - Limitations: overestimate capacity at low frequencies.

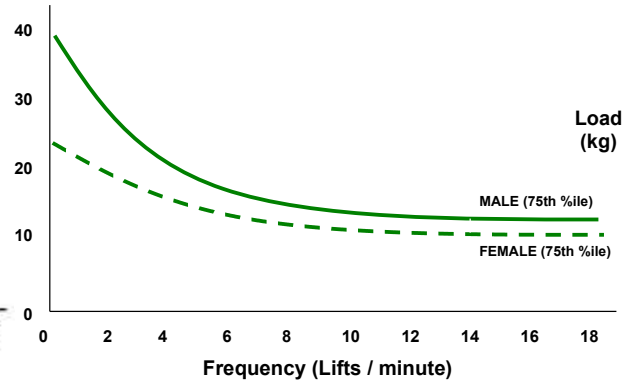
How Do I Choose the Correct Ergo Assessment Tool?

- Example: Lifting
  - Integrating Criteria
    - NIOSH Lifting Equation
      - Epidemiology: increased risk of injury for some
      - Biomechanics: compression of 3400 N at L5/S1
      - Psychophysics: 75% of women and 99% of men
      - Physiology: 3.5 kcal/min
    - Mital et al (1993)

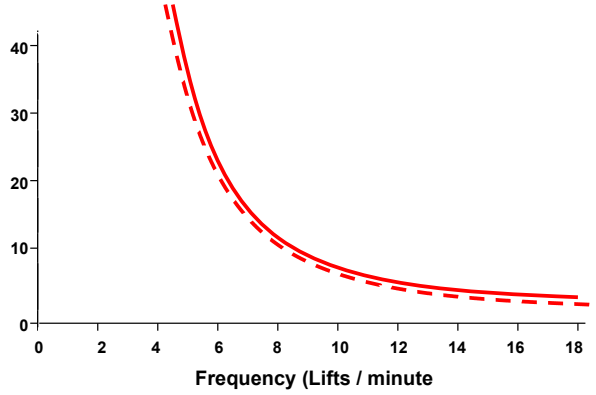
Biomechanics
(Compression Force)

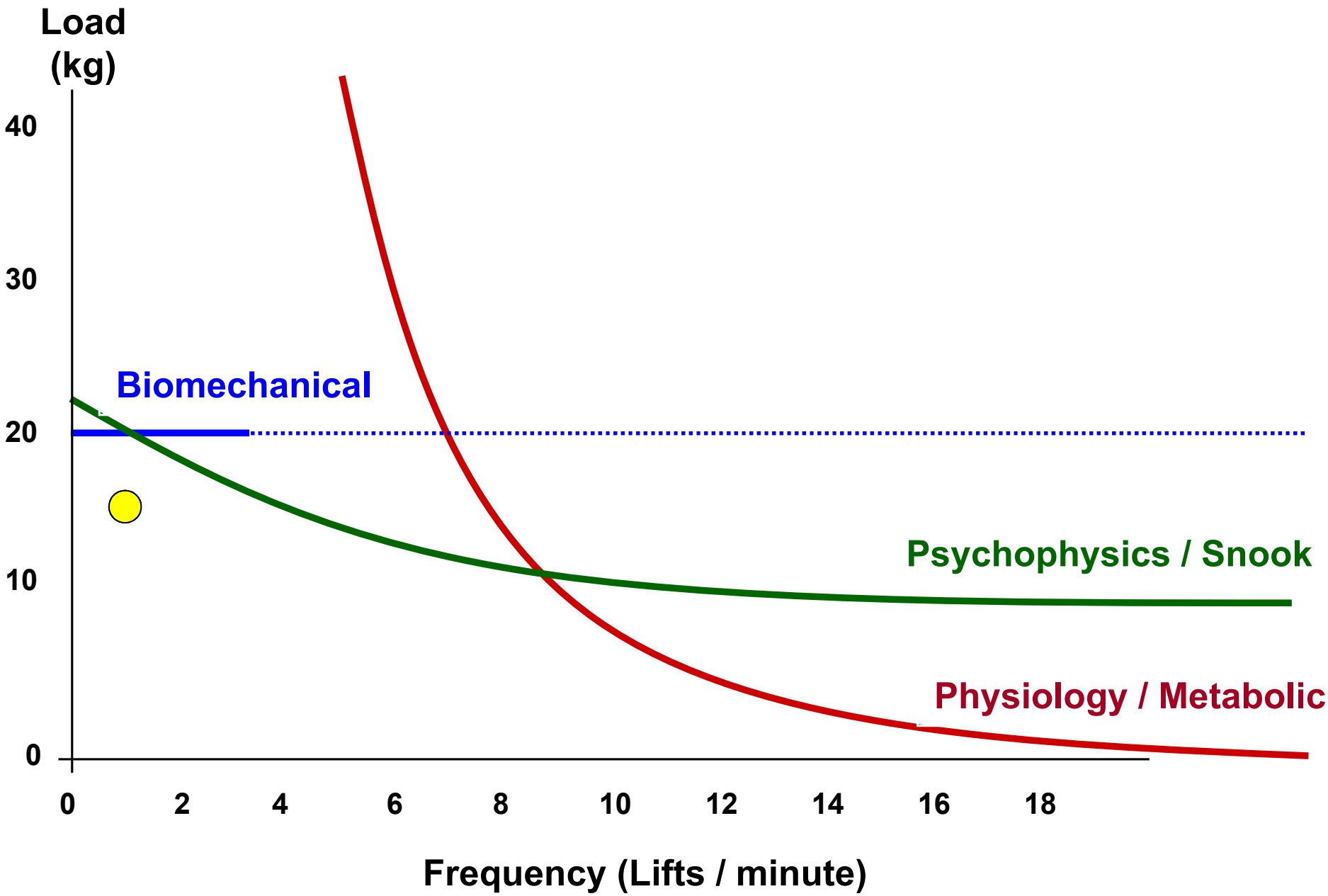


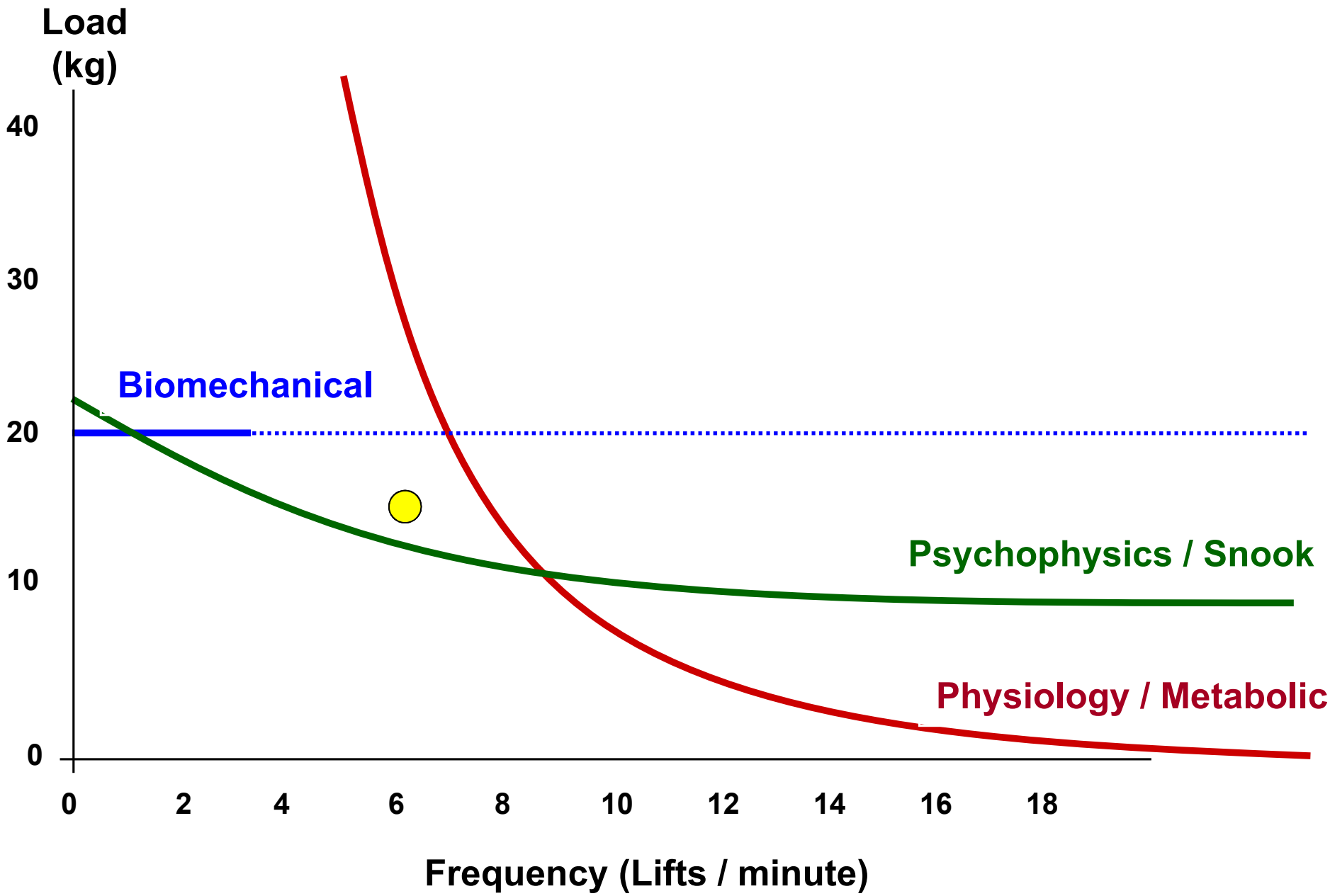
Psychophysics
(Acceptable Loads)

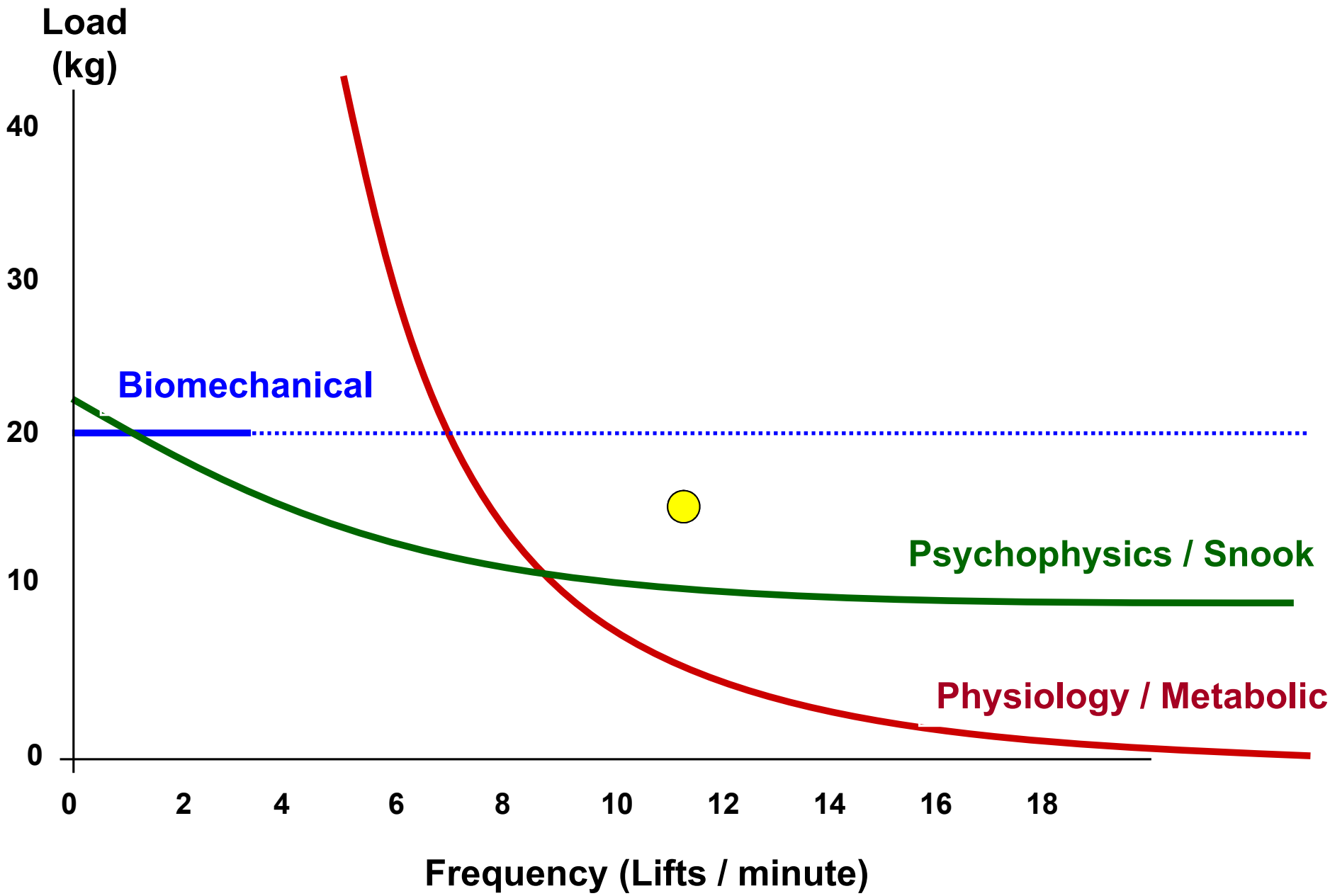


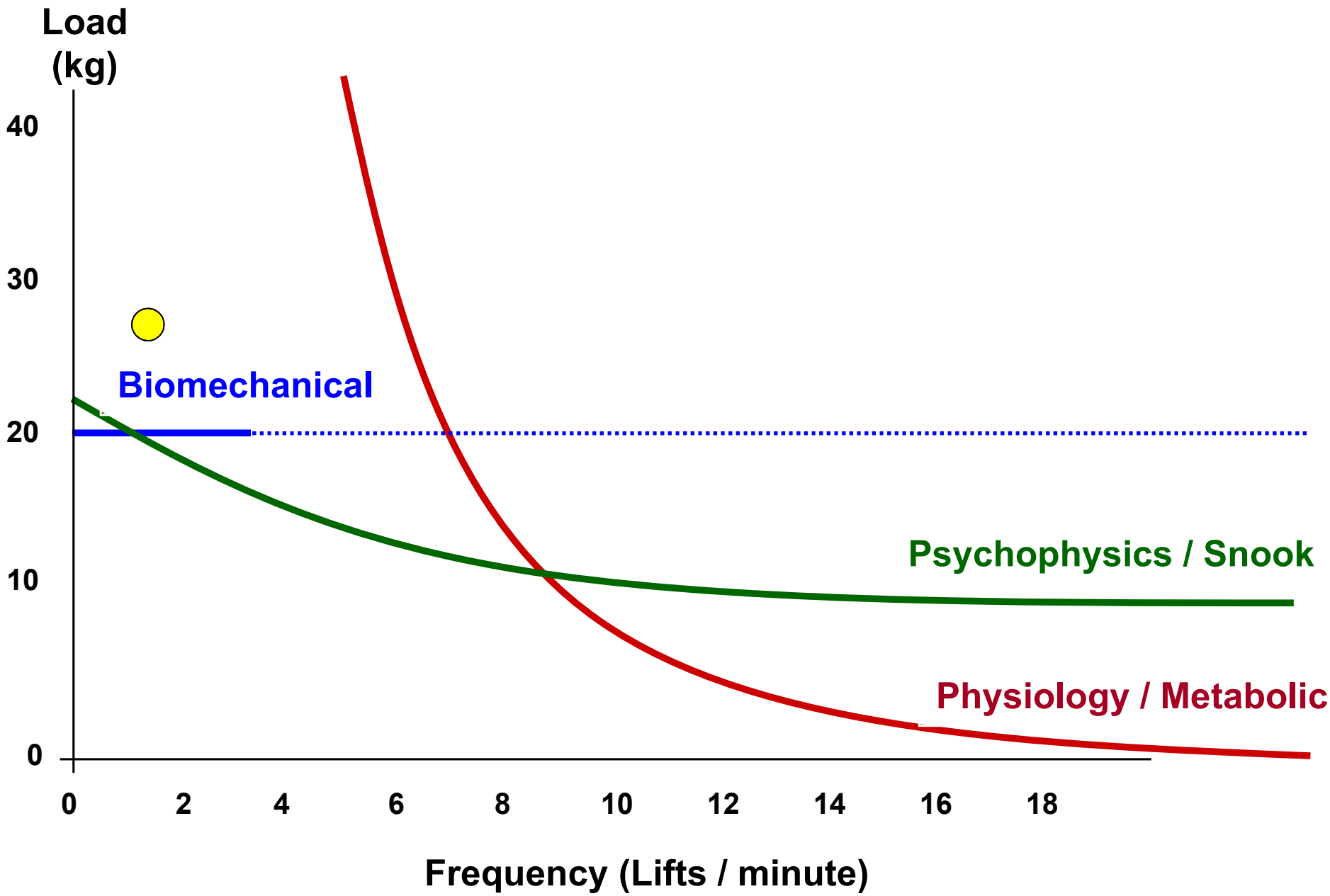
Physiology
(Metabolic Cost)

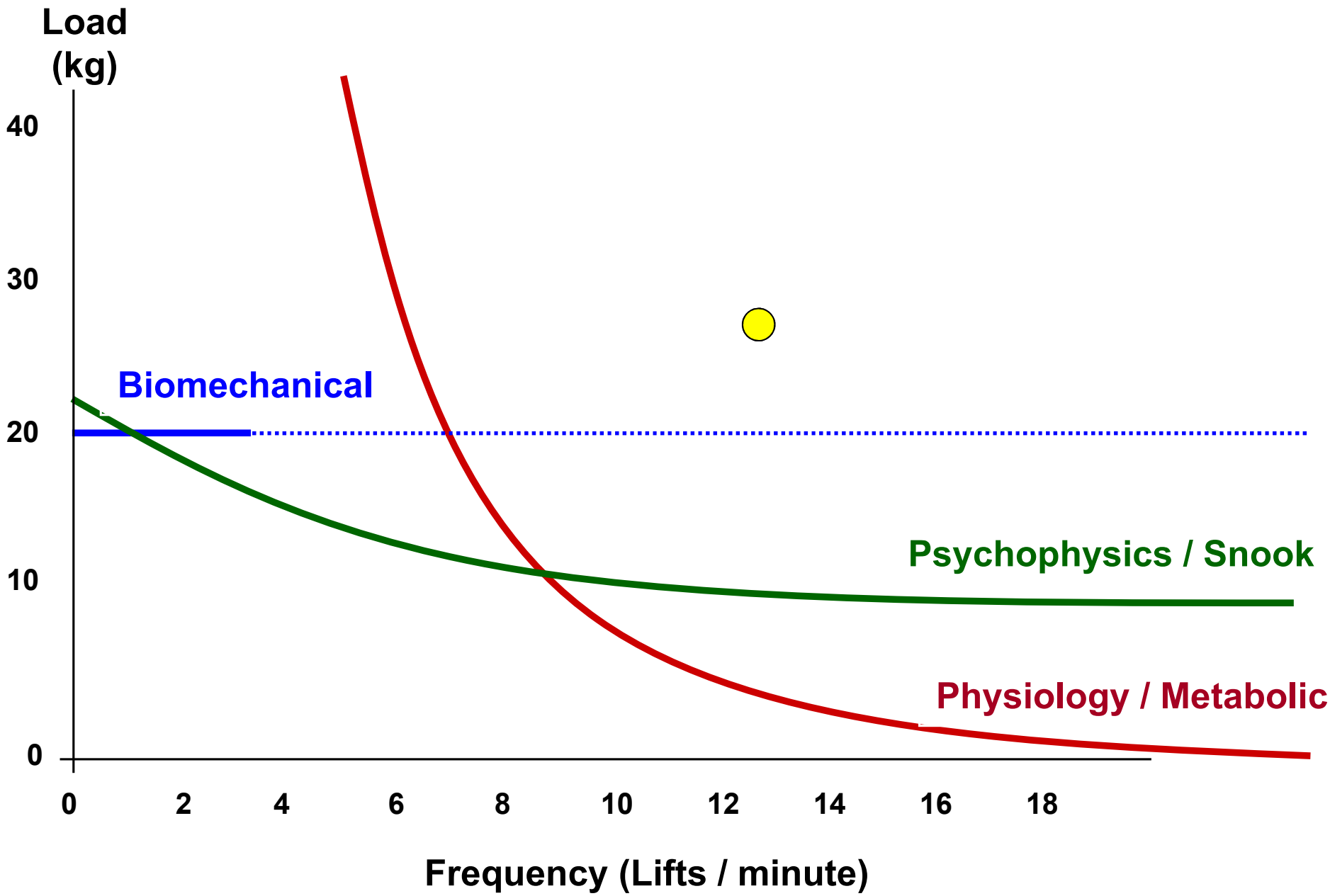



Load
(kg)
40
30
20
10
0
Biomechanical
Psychophysics / Snook
Physiology / Metabolic
0
2
4
6
8
10
12
14
16
18
Frequency (Lifts / minute)


Load
(kg)
40
30
20
10
0
Biomechanical
Psychophysics / Snook
Physiology / Metabolic
0
2
4
6
8
10
12
14
16
18
Frequency (Lifts / minute)


Load
(kg)
40
30
20
10
0
Biomechanical
Psychophysics / Snook
Physiology / Metabolic
0
2
4
6
8
10
12
14
16
18
Frequency (Lifts / minute)


Load
(kg)
40
30
20
10
0
Biomechanical
Psychophysics / Snook
Physiology / Metabolic
0
2
4
6
8
10
12
14
16
18
Frequency (Lifts / minute)


Load
(kg)
40
30
20
10
0
Biomechanical
Psychophysics / Snook
Physiology / Metabolic
0
2
4
6
8
10
12
14
16
18
Frequency (Lifts / minute)

Comparing the Revised NIOSH Lifting Equation to the Psychophysical, Biomechanical & Physiological Criteria used in its Development

J.R. Potvin

(2014, Human Factors)

Composite Acceptable Load (CAL)

					Frequency (Lifts/min)							
Range	V	D	Width	H	0.002	0.033	0.2	0.5	1	4.3	6.7	12
S-R	128.0	76	75	57.5	10	8	8	8	7	**5.4**	**2.8**	**0.6**
	140.5	51	75	57.5	11	9	9	9	8	**7.8**	**4.1**	**1.1**
	153.5	25	75	57.5	12	10	9	9	9	8	7	**2.9**
	128.0	76	49	44.5	11	9	8	8	8	**5.4**	**2.8**	**0.6**
	140.5	51	49	44.5	12	10	9	9	9	**7.8**	**4.1**	**1.1**
	153.5	25	49	44.5	13	11	10	10	9	8	7	**2.9**
	128.0	76	34	37.0	13	11	10	10	9	**5.4**	**2.8**	**0.6**
	140.5	51	34	37.0	14	12	11	11	11	**7.8**	**4.1**	**1.1**
	153.5	25	34	37.0	16	14	12	12	12	9	8	**2.9**
K-S	66.0	76	75	57.5	**12.3**	12	11	11	10	8	**4.6**	**1.3**
	78.5	51	75	57.5	**12.8**	**12.8**	12	12	11	9	**5.2**	**2.2**
	91.5	25	75	57.5	**14.0**	14	13	13	12	9	8	**5.8**
	66.0	76	49	44.5	14	12	11	11	10	8	**4.6**	**1.3**
	78.5	51	49	44.5	15	13	12	12	11	9	**5.2**	**2.2**
	91.5	25	49	44.5	17	14	13	13	12	9	8	**5.8**
	66.0	76	34	37.0	15	13	12	12	11	**8.8**	**4.6**	**1.3**
	78.5	51	34	37.0	17	14	13	13	12	**9.0**	**5.2**	**2.2**
	91.5	25	34	37.0	18	16	14	14	13	11	10	**5.8**
F-K	0.0	76	75	62.5	**10.9**	**10.9**	10	10	9	9	**2.5**	**0.0**
	12.5	51	75	62.5	**11.0**	**11.0**	11	11	10	9	**7.5**	**0.0**
	25.5	25	75	57.5	**11.0**	**11.0**	**11.0**	**11.0**	11	11	10	**0.0**
	0.0	76	49	49.5	**13.6**	12	10	10	10	9	**2.5**	**0.0**
	12.5	51	49	49.5	**13.7**	**13.7**	12	12	11	9	**7.5**	**0.0**
	25.5	25	49	44.5	**13.8**	**13.8**	13	12	12	11	10	**0.0**
	0.0	76	34	42.0	**15.7**	14	13	13	12	11	**2.5**	**0.0**
	12.5	51	34	42.0	**15.8**	**15.8**	15	15	14	12	**7.5**	**0.0**
	25.5	25	34	37.0	**16.0**	**16.0**	15	15	14	13	12	**0.0**

H = 20 + Width / 2
H = 25 + Width / 2

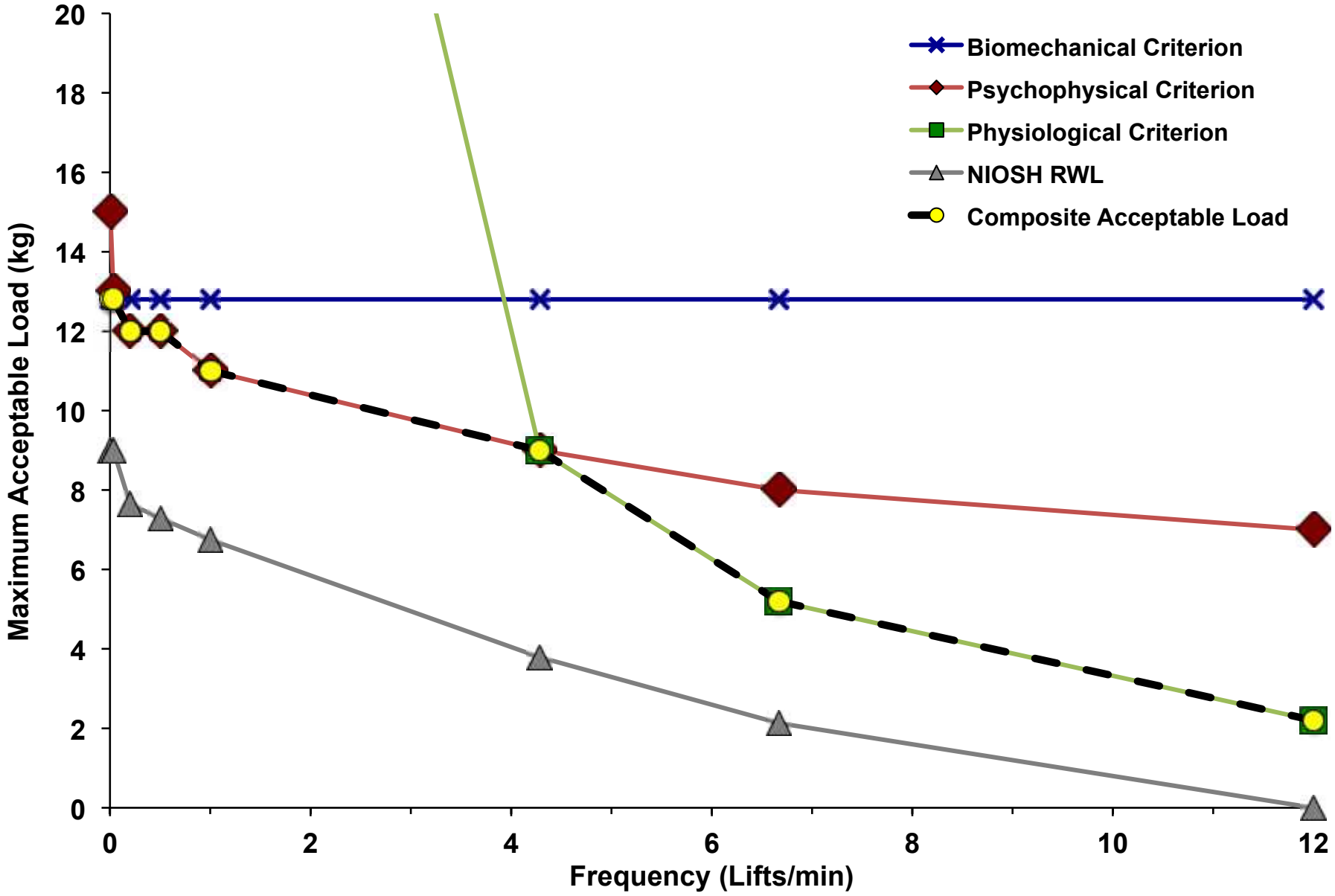
Compression = 3400 N

Snook = 75% Capable

Garg = 3.1 kcal/min (V ≤ 75 cm)
= 2.2 kcal/min (V > 75 cm)

Potvin (2014)

Example: Knuckle-Shoulder, D = 51 cm, box width = 75 cm



BakPak™ Software

File Edit Tools Option Help

Lift/Lower Inputs

Evaluate

Horizontal Displacement
Start 25
End 50

Percentile 75

Input Units
(•) cm
( ) Inches

Vertical Height
Start 8
End 100

Coupling
(•) Good
( ) Fair
( ) Poor

Asymmetry Angle
Start 0
End 60

Duration 8
Frequency 2

Lateral Displacement
Start 0
End 20

Actual Load 12 (kg)

Criterion

	Female	Male	
Lumbar Compress.	2888	3945	Newtons
Psychophysical	75	75	th %ile
Metabolic	2.9	3.9	kcal/min

Acceptable Load (•) kg ( ) lbs

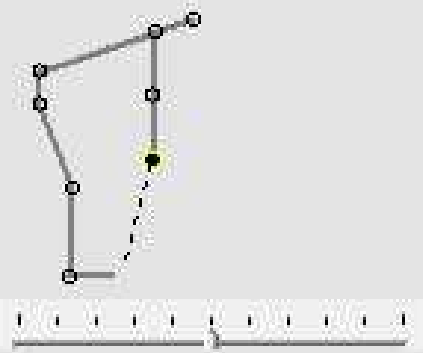
	Female	Male
Lumbar Compress.	9.9	14.5
Psychophysical	9.5	15.3
Metabolic	66.3	72.7
Epidemiology	20.0	27.0
Is the Actual Load Acceptable?	No	Yes

NIOSH Equations
'81 AL 7.6 '91 RWL 5.6

Animation

Female	Male
10.8	16.2

Compression based load limit for each posture



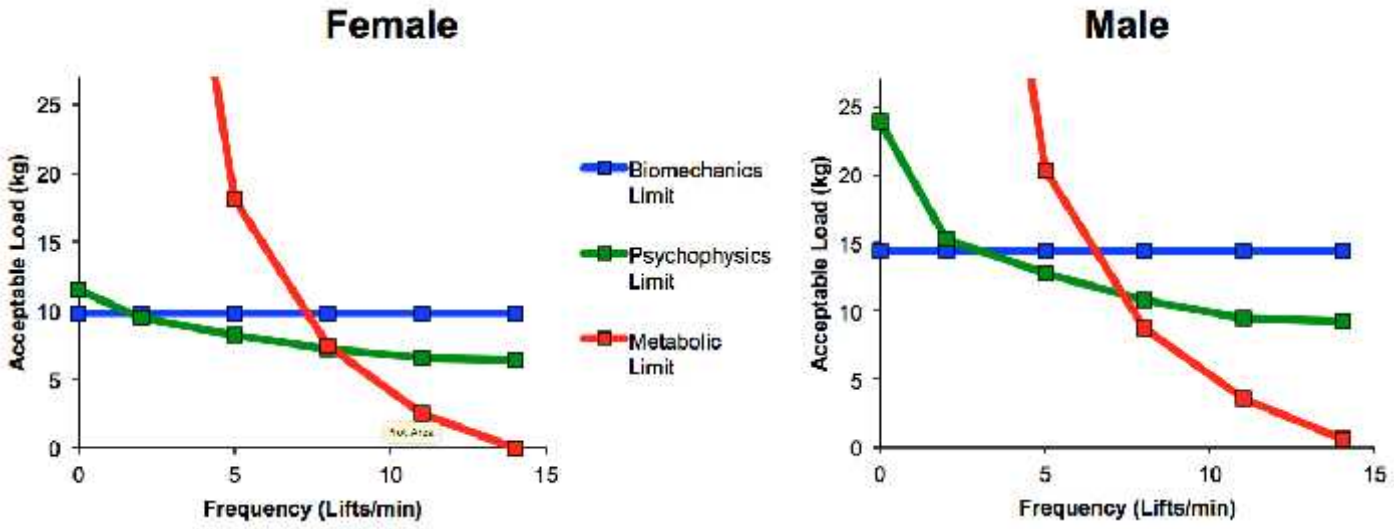
Percent of lift: 50% (Middle)

Animation Speed
( ) 0 ( ) I (•) II ( ) III

Frame Control/Indicator
Frame Control/Indicator to select/display various postures throughout the movement. Set the Animation Speed to '0' to allow for the selection of individual postures.

Summary of the Frequency Effect on BakPak Results

		Frequency per Minute					
		0.0005	**2**	**5**	**8**	**11**	**14**
Female	Compression = 2700 N **Biomechanics**	**9.8**	**9.8**	9.8	9.8	9.8	9.8
	Snook 75% capable **Psychophysics**	11.5	**9.5**	**8.2**	**7.2**	6.6	6.4
	Garg **Metabolic**	100+	61	18.1	**7.4**	**2.5**	**0.0**
Male	Compression = 2700 N **Biomechanics**	**14.4**	**14.4**	14.4	14.4	14.4	14.4
	Snook 75% capable **Psychophysics**	23.9	**15.3**	**12.8**	10.8	9.5	9.2
	Garg **Metabolic**	100	66.2	20.3	**8.8**	**3.6**	**0.6**



Recommendations

- Become familiar with all of the available tools
- Use tools that estimate physical quantities
  - lumbar spine compression
  - joint strength demands
  - metabolic cost
- Find good criteria to compare those quantities to
  - eg. 3400 N compression, 25th percentile strength, 3.5 kcal/min
- Understand the limitations of each tool
  - Be critical of the tools
  - What are the boundaries?
    - applicable frequency range?
    - constraints?
      - eg. symmetrical?, two-handed lifting?, good coupling? 8 hours?
- Choose the tool(s) that have the least severe limitations for your task
  - note: they all have limitations for every task

Thank you

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