Lever systems

Strength (force) capacity -
Posture factor – variation can be explained from muscle length and muscle mechanics
Individual factor – Widely varies – due to gender, age, training etc.
Force that can be held varies exponentially with time. A force = 15 to 20% of MVC can be maintained indefinitely.

Individual factors:
Gender – A simple approximation is females have about 2/3 the strength of males. However individual muscle groups may exhibit different proportion.
Primarily due to shorter size (lever arms) and smaller muscle mass.

For a same light repetitive task performed by males and females, females may be exerting at a higher percentage of their capacity. Hence the same task may be more fatiguing for females and consequently higher chance of MSD.

Age – Strength, velocity, cardiovascular capacity reduces with age. Experience may have a positive effect.

Training - Adaptation to work by
(i) increasing the number of contractile proteins – muscle mass increases – strength training > 50% of capacity
(ii) increasing capillary bed, number of mitochondria for aerobic metabolism in muscles and heart – increases cardiovascular capacity (lower working and resting heart rate), increases aerobic metabolism – endurance training.
(iii) Efficiency of muscle recruitment improves.

Metabolic rate: Rate of energy production. ATP molecules are the unit of biologic energy. It can be synthesized aerobically or anaerobic ally. How much ATP is produced to perform the bodily functions is closely coordinated with cardiovascular response. Higher ATP consumption rate higher is the cardiac output.

Energy = Force x distance = 1N x 1m = 1 Joule

Energy content in food is given in terms of Kcal (commonly referred as Calorie). Kcal is the amount of energy needed to raise the temp of 1 kg of water by $1^{o}C$.

1 Joule = 0.000239 kcal or 1 kcal = 1/0.000239 J = 4184 J

Power = Rate of energy consumption (usage) = 1 Joule/sec = 1 watt
1 kcal/hr = 1/3600 Kcal/sec = 4184/3600 J/sec = 1.16 watt.

Basal Metabolic rate
To maintain body temperature and body functions (regeneration of cells, respiration, circulation etc). 1.28 W/kg for males, 1.16 W/kg for females (higher percent of fat do not

need metabolism). Children have higher surface to volume ratio more heat loss, also higher growth rate so they have higher basal metabolic rate. More accurate measures are available relating age, body weight, gender etc. ERGO disk.

Activity Metabolism increases with physical exertion level.

	Kcal/hr	kcal/min
Light	0-189	0-3.15
Moderate	189-300	3.15-5
Heavy	over 300	over 5 Kcal/min

Population values for Activity Metabolic Rates for various industrial tasks are available or can be predicted for job design purposes. How did they determine these rates?

Oxygen is required for aerobic metabolism of ATP from carbohydrate, protein and fat. Oxygen is also required to remove the metabolic wastes such as lactic acid, for anaerobic metabolism (see Figure 4.26). From the oxygen consumption and carbon-dioxide production rates during activity, the kcal of energy expenditure can be predicted.

Digestion Metabolism

RESPONSE TO EXERCISE

To match the oxygen (energy) demand for work, adjustment occurs in

1. HR
2. SV
3. A-V difference
4. Blood redistribution
5. Blood Pressure
6. Breathing rate
7. Ventilation

Cardiac output (amount of blood pumped per minute) precisely matches the oxygen supply needed for a workload.

CO = HR (/Min) *SV (liters) liters/min

HR is effected by:

(i) Emotions especially at low metabolic level.
(ii) Ambient temperature
(iii) Exercise

For an individual SV is affected by the intensity of exercise. SV increases with exercise intensity and reaches its maximum level for an exercise of about 40% of ones maximum aerobic capacity. For an individual, it also changes with body posture.
As a result of these HR is an excellent predictor of workload or cardiovascular load for moderate to heavy intensity physical work.

	Kcal/hr	kcal/min	O_2 uptake	HR
Light	0-189	0-3.15	<0.5 L/min	<90
Moderate	189-300	3.15-5	0.5-.99 L/min	90-110
Heavy	over 300	over 5 Kcal/min	1.0-1.49 L/min	110-130

For lighter type of tasks also HR is often used to compare exertion levels of two tasks.

Hear rate measurement is comparatively easy and often used in Ergonomics studies to compare physiological costs of work.

Physiologic cost of work in terms of heart rate
See figure 4.26
Oxygen debt and repayment
Area under the curve

CARDIOVASCULAR LIMITS

(1) What is ones work capacity? (2) To what proportion of the capacity should be used?

VO_2 max in mL/kg-min is a determinant of ones cardiovascular capacity or fitness level. It can be measured in laboratory

Type of task also has an influence on $VO_{2\ max.}$ Larger muscle group used, produces larger values of $VO_{2\ max.}$ Why?

See Table 4.8.

Proportion of Capacity that would not cause fatigue in work
Average VO_2 over the shift should be
Eastman Kodak – 33% for 8 hour shift, 30.5% for 10 hr shift, 28% for 12 hr shift.
(See figure 4.27)

Where there is anaerobic content such as heavy lifting this should be reduced further.

For industrial population, assuming you wish to exclude only a small percent of population the limits should be
Average HR – 110 -120 /min
Average metabolic rate – 5 kcal/min

These capacities are again affected by gender, age and training.

Response to mental workload Heart rate variability is reduced with higher mental workload.