## Metabolic Rate

- It is the rate of energy production within the body.
- ATP molecules are the unit of biologic energy. ATP is converted to ADP to release energy, which is needed for all bodily functions, such as cell division, contraction of muscles, maintaining body temperature, movement of fluids etc.
- ATP can be synthesized from energy molecules (carbohydrate, protein and fat) aerobically or anaerobic ally.
- The rate of ATP production (to perform the bodily functions) is closely coordinated with cardiovascular response.
- Higher ATP consumption rate higher is oxygen consumption rate and higher the cardiac output.

## Unit of energy production (metabolism)

- Basic unit of 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 $1^0$ C.
- 1 Joule = 0.000239 kcal
- 1 kcal = 1/0.000239 J = 4184 J
- Rate of energy consumption = 1 Joule/sec = 1 watt
- 1 kcal/hr = 1/3600 Kcal/sec = 4184/3600 J/sec = 1.16 watt

## **Basal Metabolic rate**

Energy metabolism needed to maintain body temperature and body functions (regeneration of cells, respiration, circulation etc) at rest.

- 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.

## Digestion Metabolism

- Energy needed to digest food
- Approximately 10% of the total metabolic demand.

## Activity Metabolism

Activity Metabolism increases with physical exertion level. This is due to increase demand of ATP from muscle contraction, increase work of ventilation, increased work by the heart muscle.

Population values for Activity Metabolic Rates for various industrial tasks are available or can be predicted for job design purposes.

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

## RESPONSE TO EXERCISE

To match the energy demand for work, adjustment occurs in

1. HR – varies from resting 70 bpm to maximum (220-age)
2. SV – increases gradually up to 40% for MVC
3. A-V difference in $O_2$ concentration – resting arterial 19 mL/100 mL, venous 15 mL/100 mL
   In extreme situation venous $O_2$ concentration can drop to 6 mL/100 mL
4. Blood redistribution
5. Blood Pressure
6. Breathing rate
7. Ventilation

Each of these physical responses can be used to measure physical work load.

# Heart rate and activity metabolism rate

- Oxygen uptake rate during exercise provides good estimator of ATP use, hence the metabolic rate.
- In normal physical work, cardiac output (amount of blood pumped per minute) also matches the oxygen supply needed for a workload.
- CO = HR (/Min) *SV (liters) liters/min.
- 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.
- HR is an excellent predictor of workload or cardiovascular load for moderate to heavy intensity physical work.

# Heart rate and level of work intensity

- HR is effected by:
  - (i) Emotions especially at low metabolic level.
  - (ii) Ambient temperature
  - (iii) Exercise intensity
- When using heart rate for light work, other factors needs to be controlled appropriately.
- For lighter type of tasks also HR is often used to compare exertion levels of two tasks.
- Heart rate measurement is comparatively easy and often used in Ergonomics studies to compare physiological costs of work.

# Classification of physical work intensity

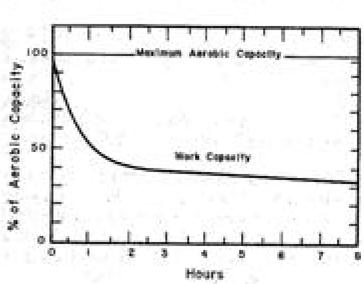
| Type of work | Kcal/Hr | Kcal/min | $O_2$ uptake L/min | HR (bpm) |
|---|---|---|---|---|
| Light | 0-189 | 0-3.15 | .5 | 90 |
| Moderate | 189-300 | 3.15-5 | .5-.99 | 90-110 |
| Heavy | 300+ | 5+ | 1-1.49 | 110-130 |

# MEASURMENT OF CARDIOVASCULAR LIMITS OF AN INDIVIDUAL

- VO2 max in mL/kg- min is a determinant of ones cardiovascular capacity or fitness level.
- It can be measured in laboratory
- Type of task to determine $VO_{2max}$ also has an influence on $VO_{2\ max}$. Larger muscle group used, produces larger values of VO2 max.
- $VO_{2\ max}$ varies with fitness level and age (Table 2.8 in text book for typical values in American Adult population)

FIGURE 2.27

Aerobic work capacity declines with working time.




# What proportion of Capacity should be reasonable?

- Average VO2 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 2.27)
- 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 or 5 Kcal/min
  - These capacities are again affected by gender, age and training.

## Effect of mental workload on HR

- Response to mental workload, Heart Rate variability (sinus arrhythmia) is reduced with higher mental workload.