Temporal Ergonomics

Temporal (time related) aspects of job design

– the main concern is fatigue: over worked, over stressed etc., rest is required for recovery.

Fatigue is associated with

(1) Gradual decrement of work performance capacity of the worker

(2) Safety and health of the worker

Both the factors are equally important in job design

Fatigue ensues over time and reduces worker productivity

Overall objective is-

1. Maintains or increases work productivity
2. Provides "optimal" stress, such that health and safety not compromised and fatigue is not accumulated between shifts

- Consider and optimize both goals.

Factors that can lead to Fatigue

- Physical discomfort (and pain)
  - Static load on small muscle groups described as tense muscles, aching, numbness, hurting, stiff joint
- Physical exertion
  - (e.g., Heavy manual work: described as warm, sweaty, out of breath, heavy breathing, palpitation)
- Lack of energy (physical + mental) – worn out, drained, exhausted
- Lack of motivation (mental – uninterested, lack of initiative)
- Sleepiness (mental – yawning, drowsy, sleepy, lazy)

Occupations can have different combinations of fatigues, e.g., Truck driver, airline pilot, material handler, data entry operator

Locations of Fatigue

- Muscular fatigue (localized – physiological nature)
- General body fatigue (systemic, cardiovascular - physiological nature)
- Mental fatigue (brain - psychological/physiological nature)

Muscle Fatigue (EMG)

- When a single muscle fiber is repeatedly stimulated, force produced per stimulation gradually decreases. This may be due to change in chemical environment or nutrient level within the muscle cell.
- As a result, more number of muscle fibers are needed to be engaged to maintain a steady force level, which is reflected as increased RMS level of EMG.

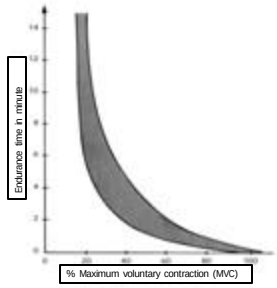
Muscle Fatigue (EMG)

- A muscle is composed of two types of muscle fibers:
  - Slow-twitch (slow action potential speed) – small, mostly depends on aerobic metabolism, brownish, sustained activities, postural load, fatigue resistant.
  - Fast-twitch (fast action potential speed) - mostly depends on anaerobic metabolism, light colored, provides short burst of high exertion, fatigable
- After fast-twitch fibers are fatigued, slow twitch fibers predominantly produce the required force, causing mean EMG frequency of the frequency spectrum of EMG to drop.
- Reduction of mean EMG frequency may also come from reduced speed of action potential, which may arise due to change in pH level from accumulation of lactic acid and CO_2.

Muscle Fatigue and discomfort

- A muscle contraction puts mechanical pressure on the blood vessels constricting its own blood supply. Reduction of blood supply starts at as low as 15-20% force of the MVC (Maximum Voluntary Contraction force) and the supply is completely stopped at about 60% force of the MVC of the muscle.
- Reduced blood supply means reduced level of oxygen supply. If the contraction is sustained, then muscle will start to use anaerobic pathway for energy production with lactic acid as metabolic waste.
- Accumulation of lactic acid will change the local ph level, which will produce a gradually increasing sensation of localized discomfort and pain.
- If the contraction is sustained, the pain will increase to such a level that muscle has to be relaxed. Pain and discomfort will contribute towards fatigue.
- When the muscle relaxes, blood flow will be resumed, causing flushing away the metabolites and relieving the pain.
- Localized fatigue and pain act of an internal mechanism to protect muscle cells from permanent damage.

Endurance times at different levels of sustained (or isometric) contraction

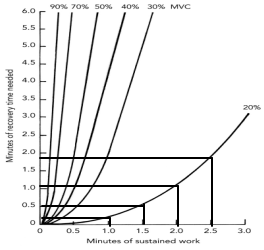


Endurance time means, maximum holding time until the pain becomes unbearable and the muscle has to relax.

This can be denoted as 100% fatigue level of the muscle

In work situation, lower level of fatigue can be present.

Levels of muscle fatigue and the recovery times



1. Recovery time to get back to resting state increases at a faster rate with the level of fatigue (non-linear increase)

2. Giving frequent rest breaks produces more work

3. If the rest breaks are insufficient, fatigue will accumulate over time

Static (muscular) work

- Static work is produced by isometric muscle tension.
- Majority of the static work arise from postural loads to counteract gravity.
- Holding, carrying, or force production without movement will produce static muscle tension.
- Localized muscle fatigue and pain due to static muscle tension is common in many industrial work.
- Strategies to reduce localized muscle fatigue:
  - reduce static force level
  - facilitate recovery by providing adequate rest (relaxation)
  - Alternate muscle group for static load
  - Keep the fatigue level low by providing frequent rest pauses. This is more economical.

Dynamic (muscular) work

- Dynamic muscular work is involved with movement of body parts, which is caused by intermittent contractions (force production) and relaxations of muscles.
- Dynamic work can be thought of series of static work interspaced by a series of rest periods. Consequently, the rate of accumulation of muscle fatigue is much slower in this kind of muscular work.
- With the increase of intensity of dynamic work (frequency, and force level), cardiovascular load increases (rate of cardiac output, VO_2, heart rate, pulmonary ventilation).
- In dynamic work cardiovascular fatigue is more common than localized muscle fatigue.

Physical work

- Most physical works put some muscles of the body under dynamic work and some muscles under static work. Depending upon the intensity level of each type of muscle work, either or both can contribute towards the sensation of fatigue.
- Examples: Checkstand cashiers, material handlers, Construction work, snow shoveling etc.

General body fatigue

- A whole body fatigue occurs from heavy dynamic work. There is no specific pain sensation, but sweaty, tired, worn out
  For 8 hours shift, acceptable limits 30% of ones max VO_2(Eastman Kodak), 5 kcal/min, Avg HR 110 bpm, 1 L/min VO_2 consumption.
- Percent of capacity depends on work duration - shorter the duration of work, higher % of VO_2 max can be tolerated without accumulation of fatigue.

Physical work and fatigue

Maximum physical work rate (without fatigue) that can be performed varies with duration of the work.

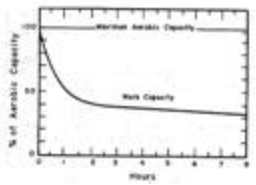
MMH tasks for 8 hrs -29% (28% for females) of bicycle max aerobic power

MMH tasks for 2 hrs – 40-53 % of treadmill maximal aerobic power.

Bicycle aerobic power is less than treadmill aerobic power

FIGURE 2.27

Aerobic work capacity declines with working time.



Physical work rate to avoid fatigue over 8 hrs shift

- Eastman Kodak
  - 33% for 8 hrs shift
  - 30.5% for 10 hrs shift
  - 28% for 12 hrs shift
- 350 W, 5 Kcal/min, 100-120 bpm for 8 hrs shift.
- 110 bpm and not to exceed 130 bpm for short period
- For extended period not more than 35 bpm over resting bpm.

Maximum aerobic power

TABLE 2.8

Maximum oxygen consumption $\dot{V}O_2$max, mL/(kg·min) for U.S. males with various ages and degrees of cardiovascular fitness.

Cardiovascular Fitness	AGE, YEARS Under 30	30–39	40–49	50+
Very poor	<25.0	<25.0	<25.0	—
Poor	25.0–33.7	25.0–30.1	25.0–26.4	25.0
Fair	33.8–42.5	30.2–39.1	26.5–35.4	25.0–33.7
Good	42.6–51.5	39.2–48.0	35.5–45.5	33.8–43.0
Excellent	51.6+	48.1+	45.1+	43.1+

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

Evaluation of whole body fatigue

Mr. Smith is 50 years old.
Mr. Smith is loading trucks with product that weighs 20 - 65 lbs.
The following heart rate (HR) data were obtained from an ECG over an 8 hrs shift.

Resting HR = 70 beats per minute
Work HR = 120 beats per minute over a duration of 60 min
Average HR over full 8 hour shift = 105 beats/min.
Highest HR = 160 beats/min over five min;
Estimated Max HR capacity = 220-50 = 170 beats per minute

Evaluate if the task too heavy for Mr. Smith?

Factors in Recovery Value of Rest

- How fatigued the muscle or cardiovascular system or brain is when the rest begins
- The length of the rest
- What happens to the muscle or cardiovascular system or brain during rest.

Truths to remember

- Most jobs have peaks and valleys of demand.
- Fatigue increases exponentially with time.
- Rest is more beneficial when it occurs prior to "too much" fatigue.
- The value of rest decreases exponentially with time.
- Different parts of the body have different recovery rates.
- Active rest and working rest are alternatives to passive rest.

Guideline 1

Have a Work Scheduling Policy

- Problem is insufficient rest.
- Avoid too many hours.
- Avoid work hours at the "wrong time."

Guideline 2

Optimize Stimulation During Work

- Problem is too much or too little stimulation.
- For too much stimulation, reduce environmental stimulation.
- For too little stimulation:
  - Add physical activity.
  - Add task variety.
  - Add environmental stimulation.

Guideline 3

Minimize the Fatigue Dose

- Problem is that fatigue may become too great.
- Reduce high stress levels.
- Permit rest before fatigue becomes excessive. Fatigue increases exponentially.
  - Schedule a break.
  - Use part-time workers.

Guideline 4

Use Work Breaks

- Problem is that there is no productivity during break.
- Work with a different part of the body to rest the fatigued part.
- Rest during the automatic part of a machine cycle.
- Consider job rotation.

Guideline 5

Give Frequent Short Breaks

- Problem is how to divide break time.
- Remember that fatigue recovery is exponential.
- Give breaks in small segments, during the work period.
- Permit operator-controlled breaks if possible.

Guideline 6

Maximize the Recovery Rate

- Problem is to recover as quickly as possible.
- Reduce contact with environmental stressors.
- Provide good blood circulation for muscle recovery.
- Take active rest.
- Consider working rest.

Guideline 7

Increase the Recovery/Work Ratio

- The problem is insufficient time to recover.
- Increase the recovery time or decrease the work time.
- Moonlighting and 12-h shifts can cause problems.
- Encourage rest on holidays, weekends, and vacations.