CHAPTER 2: CAUSES OF OBESITY

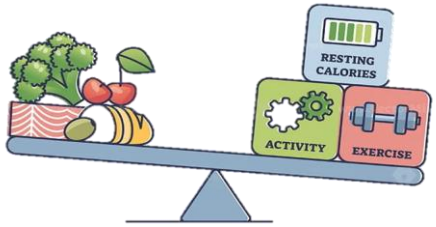
Part 4: Energy Balance

References:

1. **Peter G. Kopelman, Ian D. Caterson, William H. Dietz - Clinical Obesity in Adults and Children 4e-Wiley-Blackwell (2022): Main reference**

Introduction

- **A Fundamental Principle** is that:
  - Body weight change is associated with an imbalance between:
    - Energy content of food eaten
    - Energy expended by the body



- Obesity is often considered to result from the failure of homeostatic mechanisms that regulate body weight to cope with an **environment that encourages overeating and sedentarity**

Outline

1. Basic Concepts of Energy
2. Components of Energy Expenditure

PART 1: BASIC CONCEPTS

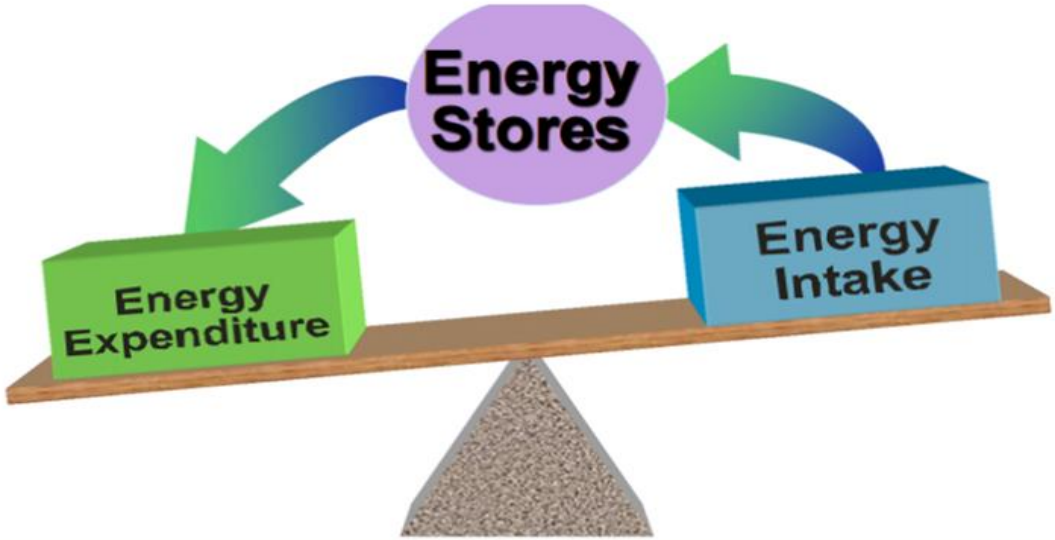
Basic concepts and principles in human energetics

Energy cannot be created nor destroyed but can only be transformed from one form into another.

The chemical energy obtained from foods is used to perform a variety of work, such as in the synthesis of new macromolecules (***chemical work***), in muscular contraction (***mechanical work***), or in the maintenance of ionic gradients across membranes (***electrical work***).

$$\text{Energy intake} = \text{Energy expenditure} + \Delta\text{Energy stores}$$

Energy Balance



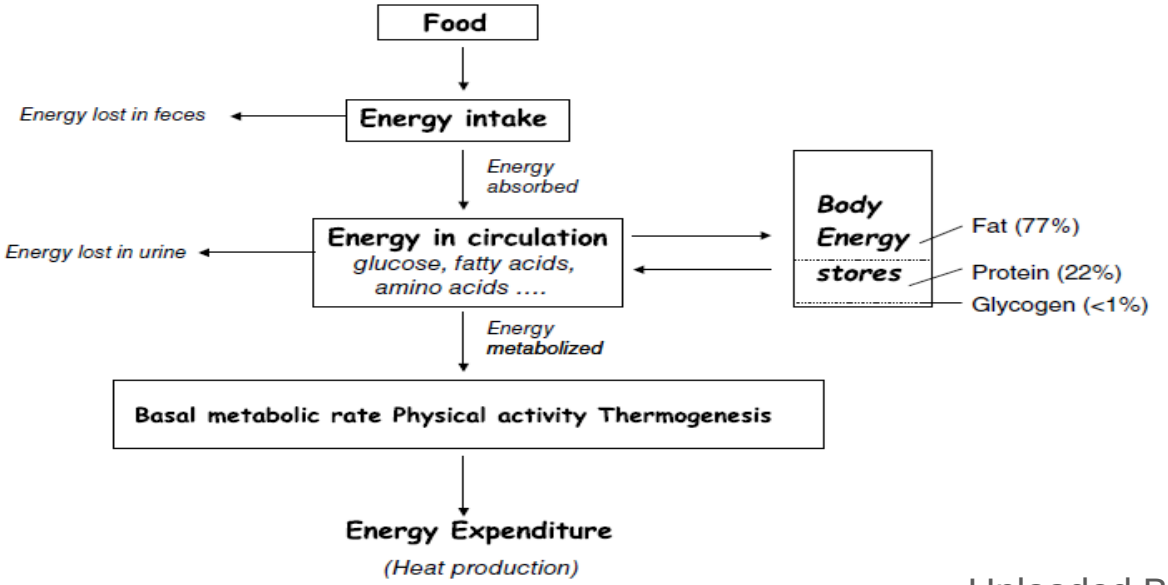
Energy intake - Energy expenditure = Δ Energy stores

If: EI = EE → Δ E stores = 0 → in E balance → weight maintenance
EI > EE → Δ E stores > 0 → +ve E balance → weight gain
EI < EE → Δ E stores < 0 → –ve E balance → weight loss

Basic concepts and principles in human energetics

"Transfer of energy from one form to another is an inefficient process, thus not all energy available for work"

These processes must be accompanied inevitably by a loss of heat.



Energy Stores

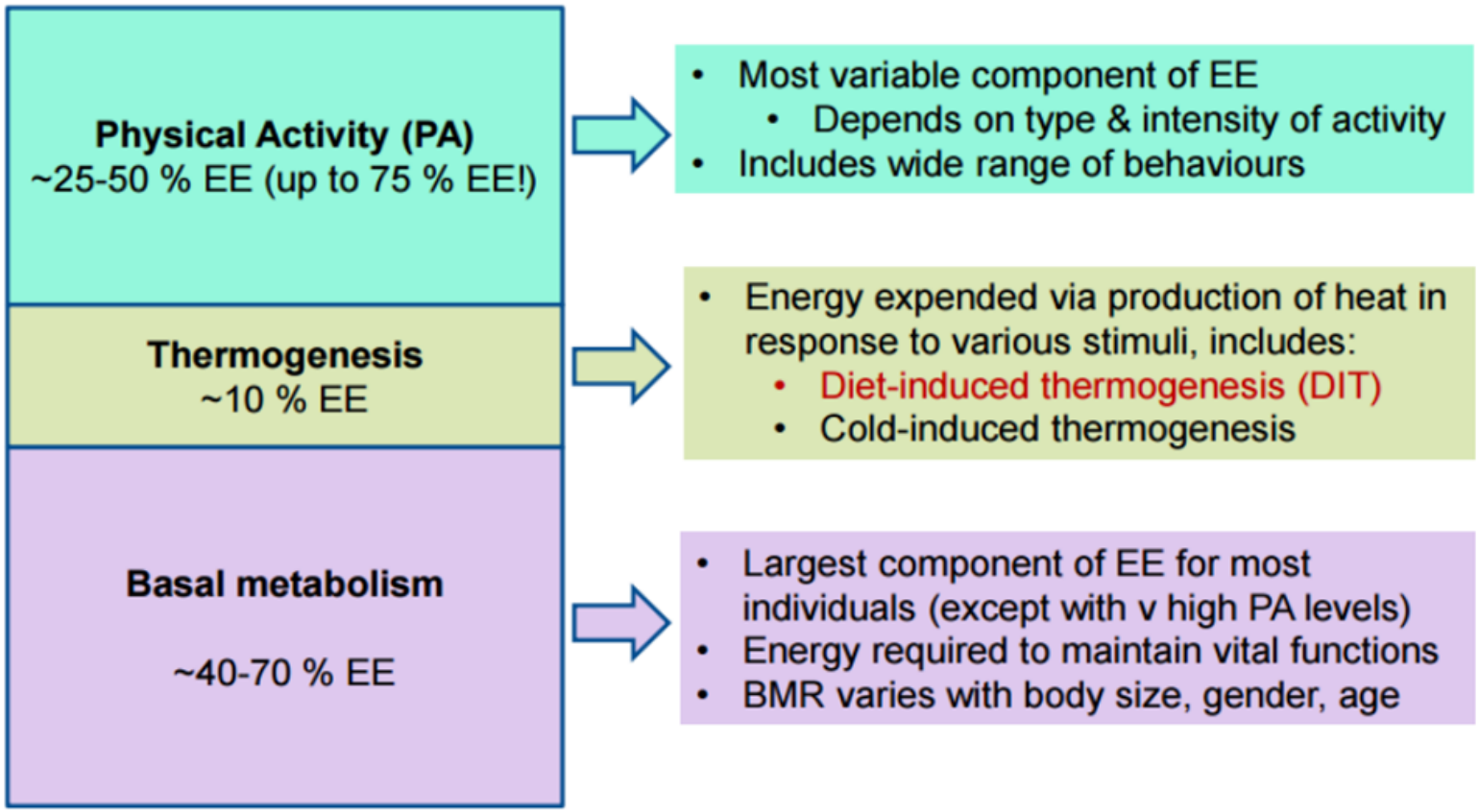
- Positive and negative E imbalances occur in short-term in free-living individuals → we need to consider long-term energy balance

- Human beings do not balance EI and EE on a day-to-day basis. Near equality of intake and expenditure most often appear over 1–2 weeks.

- This matching of long-term EI and EE must be extremely precise since a theoretical **error of only 1%** between EI and EE, if persistent, will lead to a gain or loss of about **10 kg per decade**

PART 2: COMPONENTS OF ENERGY EXPENDITURE

Components of energy expenditure

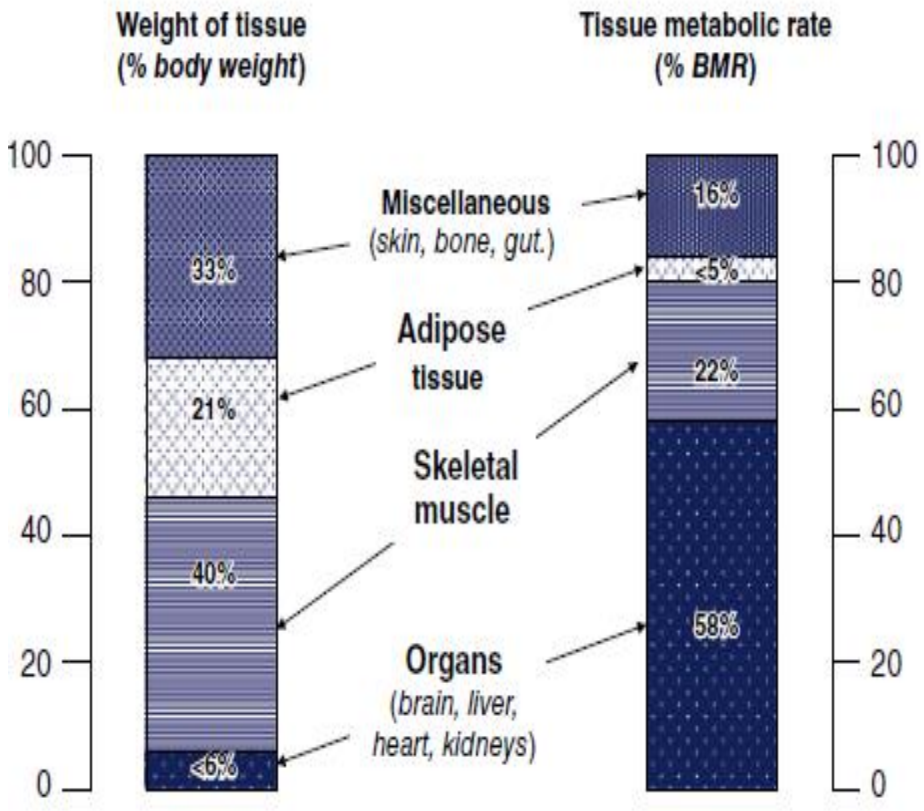


Components of energy expenditure

- ***Basal metabolic rate (BMR):***
  Typically, 60-75% of daily EE.

- What is Basal?
  - In an awake subject lying in the supine position
  - In a state of physical and mental rest
  - In a comfortable, warm environment,
  - In the morning in the post-absorptive state, usually 10–12 hours after the last meal.

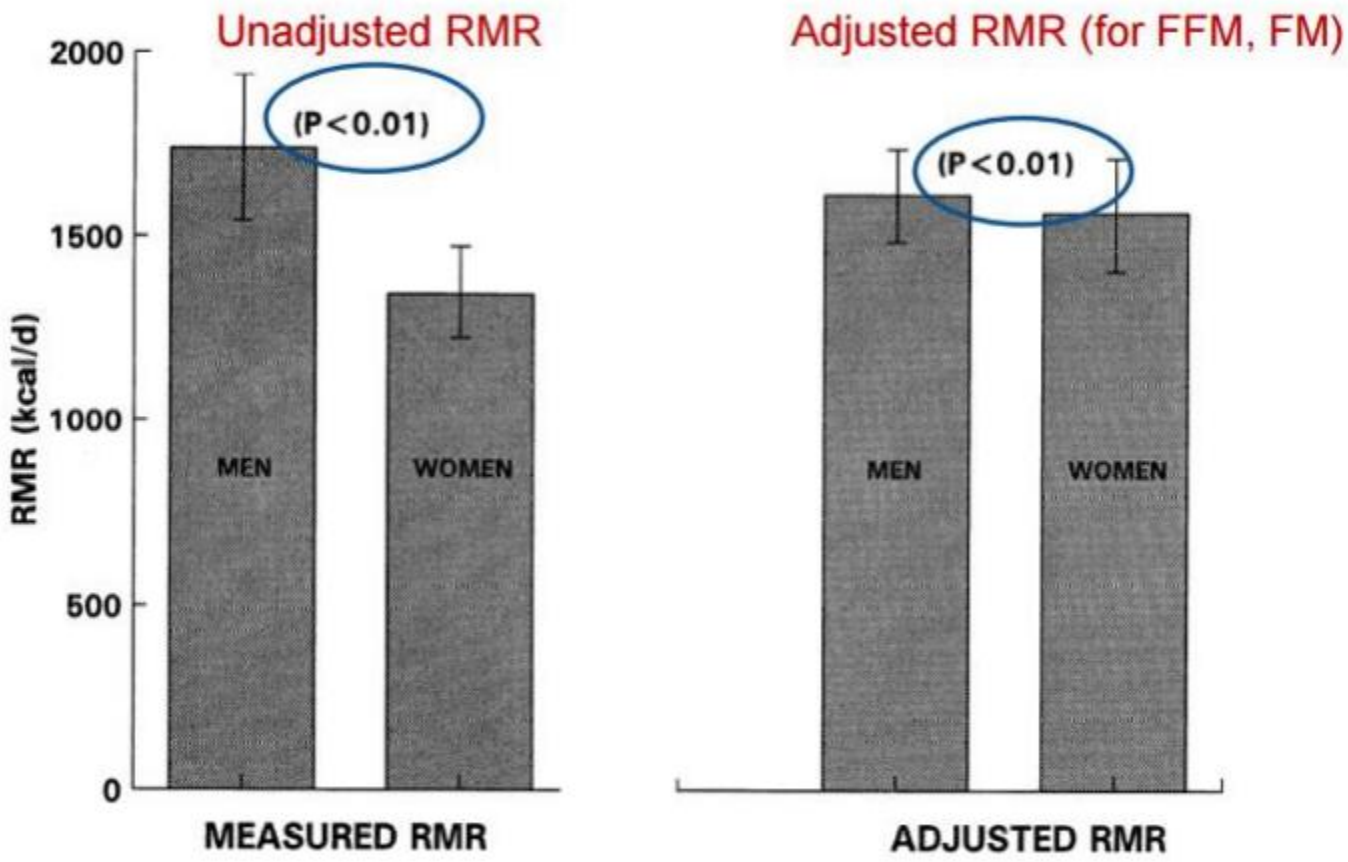
  These are “basal” as they should reflect the energy needed for vital functions (maintaining electrolyte equilibrium, cell and protein turnover, respiratory and cardiovascular functions, etc.).



Components of energy expenditure

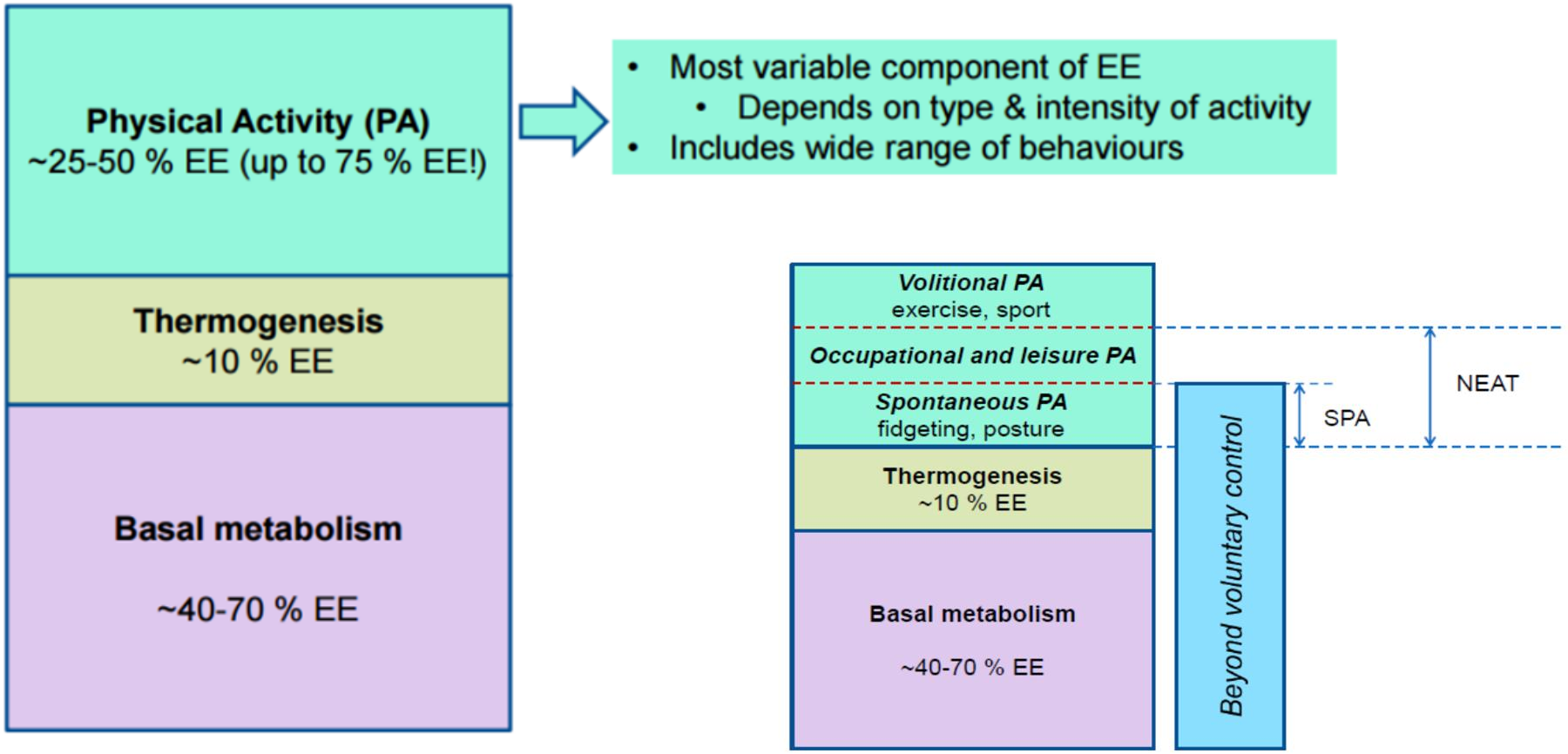
- Determinants of BMR:
  - Body size
  - Body composition (FM vs FFM)
  - Age
  - Gender
  - Genetics
  - Hormonal Influence:
    - Sex hormones
    - Thyroxine

Gender Effect



Components of energy expenditure

- ***Energy expenditure due to physical activity***



Components of energy expenditure

- ***Energy expenditure due to physical activity***

- Non-resting EE is divided into:

  a. Voluntary: volitional (e.g. exercise and sports),
  b. Obligatory: Occupational (going to work and performing work duties), household, and daily living
  c. Spontaneous: spontaneous and subconscious fidgeting and posture maintenance.

Spontaneous physical activity (SPA)

Describes all body movements associated with activities of daily living, change of posture, 'fidgeting'
(Ravussin *et al*, 1986)

Non-exercise activity thermogenesis (NEAT)

"The energy expended for everything we do that is not sleeping, eating or sports-like activity"

i.e. the normal EE of physical activities of everyday life: working, leisure, standing, walking, talking, 'fidgeting', toe-tapping, playing guitar, dancing, shopping, taking stairs instead of lift
(Levine, 2004)

- Most of the variance in **NEAT** is related to differences in occupation
- **SPA** becomes less with weight loss

Components of energy expenditure

- ***Energy expenditure due to physical activity***

Depends on the type, intensity, and duration of the various activities.

There is a wide variation in the energy cost of any activity both within and between individuals (Differences in body size, speed/dexterity with which an activity is performed)

Activity (1 hr)	130 lb (59 kg)	155 lb (70 kg)	180 lb (82 kg)	205 lb (93 kg)
Cycling, <10 mph, leisure bicycling	236	281	327	372
Cycling, >20 mph, racing	944	1126	1308	1489
Aerobics, low impact	295	352	409	465
Aerobics, high impact	413	493	572	651
Running, 5 mph (12 minute mile)	472	563	654	745
Soccer, competitive	590	704	817	931
Playing soccer	413	493	572	651
Carrying infant, level ground	207	246	286	326
Carrying infant, upstairs	295	352	409	465
Walking, under 2.0 mph, very slow	118	141	163	186
Walking, under 2.0 mph, very slow	118	141	163	186
Swimming leisurely, not laps	354	422	490	558
General cleaning	207	246	286	326

Components of energy expenditure

- *Energy expenditure due to physical activity*

In order to adjust for differences in body size, the energy cost of physical activities is expressed as multiples of BMR (called the metabolic equivalent of a task – MET).

These generally range from 1 to 5 for most activities but can reach values between 10 and 14 during intense exercise.

MET

- The resting metabolic rate, that is, the amount of oxygen consumed at rest, approximately 3.5 ml O2/kg/min (1.2kcal/min for a 70-kg person).
  - Two METS requires twice the resting metabolism
  - Three METS requires three times the resting metabolism

TABLE I Metabolic equivalents of household chores

Activity	METS[a]
Gardening	
digging	4.4
raking	3.5
weeding	3.5
Heavy housework	
carpentry	5–7
grocery shopping	2–7
painting	4–5
remodelling	4–5
repairing	4–5
washing floor	3.3
washing windows	4.9
Light housework	
cooking	2.5
dishes	2.1
ironing	2.0
making beds	3–5
mowing lawn with power mower	3–5
Mowing lawn (push mower)	5–7
Farm chores	4–5
Snow shovelling	5.1
Wood cutting	5–7

How do you choose an appropriate PA factor when estimating TER?

Activity Factor	Activity Level	Activity Level Definition
1.2	Sedentary	Little or no exercise. Desk job.
1.375	Lightly Active	Light exercise or sports 1-3 days per week.
1.55	Moderately Active	Moderate exercise or sports 3-5 days a week.
1.725	Very Active	Hard exercise or sports 6-7 days a week.
1.9	Extremely Active	Hard daily exercise or sports and physical job.

Task: Calculate your own PAL

TABLE 5.1
Factorial calculations of total energy expenditure for a population group

Main daily activities	Time allocation hours	Energy cost[a] PAR	Time × energy cost	Mean PAL[b] multiple of 24-hour BMR
Sedentary or light activity lifestyle				
Sleeping	8	1	8.0	
Personal care (dressing, showering)	1	2.3	2.3	
Eating	1	1.5	1.5	
Cooking	1	2.1	2.1	
Sitting (office work, selling produce, tending shop)	8	1.5	12.0	
General household work	1	2.8	2.8	
Driving car to/from work	1	2.0	2.0	
Walking at varying paces without a load	1	3.2	3.2	
Light leisure activities (watching TV, chatting)	2	1.4	2.8	
Total	**24**		**36.7**	**36.7/24 = 1.53**
Active or moderately active lifestyle				
Sleeping	8	1	8.0	
Personal care (dressing, showering)	1	2.3	2.3	
Eating	1	1.5	1.5	
Standing, carrying light loads (waiting on tables, arranging merchandise)[c]	8	2.2	17.6	
Commuting to/from work on the bus	1	1.2	1.2	
Walking at varying paces without a load	1	3.2	3.2	
Low intensity aerobic exercise	1	4.2	4.2	
Light leisure activities (watching TV, chatting)	3	1.4	4.2	
Total	**24**		**42.2**	**42.2/24 = 1.76**
Vigorous or vigorously active lifestyle				
Sleeping	8	1	8.0	
Personal care (dressing, bathing)	1	2.3	2.3	
Eating	1	1.4	1.4	
Cooking	1	2.1	2.1	
Non-mechanized agricultural work (planting, weeding, gathering)	6	4.1	24.6	
Collecting water/wood	1	4.4	4.4	
Non-mechanized domestic chores (sweeping, washing clothes and dishes by hand)	1	2.3	2.3	
Walking at varying paces without a load	1	3.2	3.2	
Miscellaneous light leisure activities	4	1.4	5.6	
Total	**24**		**53.9**	**53.9/24 = 2.25**

[a] Energy costs of activities, expressed as multiples of basal metabolic rate, or PAR, are based on Annex 5 of the previous consultation's report (WHO, 1985) (see also Annex 5 of this report).
[b] PAL = physical activity level, or energy requirement expressed as a multiple of 24-hour BMR.
[c] Composite of the energy cost of standing, walking slowly and serving meals or carrying a light load.

Examples:
Sedentary or light activity: If this PAL was from a female population, 30 to 50 years old, with mean weight of 55 kg and mean BMR of 5.40 MJ/day (*1 290 kcal/day*), TEE = 1.53 × 5.40 = 8.26 MJ (*1 975 kcal*), or 150 kJ (*36 kcal*)/kg/d.
Active or moderately active: If this PAL was from a female population, 30 to 35 years old, with mean weight of 57 kg and mean

Components of energy expenditure

- ***Energy expenditure in response to various thermogenic stimuli***

"Thermogenesis" can exist in various forms:

Psychological thermogenesis: Anxiety, anticipation, and stress stimulate adrenaline secretion, leading to increased heat production.

Components of energy expenditure

Cold- induced thermogenesis: At low temperatures, the resting metabolic rate (and hence heat production) increases, due to:

Shivering thermogenesis: rhythmic muscle contraction to produce heat *via* stimulation of motor nerves of peripheral nervous system

Non-shivering thermogenesis occurs due to increased sympathetic nervous system activity, esp in brown adipose tissue (BAT)

Components of energy expenditure

Diet- induced thermogenesis: Heat production increases following the consumption of a meal.

Obligatory component (energy costs of absorption and metabolic processing of nutrients or the energy cost of tissue synthesis during over-feeding)

Facultative component that in part results from the sensory aspects of foods (cephalic phase) and in part from stimulation of the sympathetic nervous system.

Components of energy expenditure

Drug- induced thermogenesis:

The consumption of caffeine and nicotine stimulate thermogenesis. Examples:

1. A cup of coffee (containing 60–80 mg caffeine) can increase BMR by 5–10% over an hour or two.
2. Oral intake of 100 mg caffeine every 2 hours during daytime increases daily EE by 5%
3. Smoking a pack of 20 cigarettes a day increases daily EE by 15%. → *cessation and weight gain?*