



Biomechanics lab.2

“Treadmill Test”

Al-Mustaqbal University College of Engineering
Department of prosthetics and orthotics engineering

Third Stage

By:

Eng. Aya Talib

Treadmill Test in Cardiac & Biomechanical Assessment

Clinical Application in Transtibial vs Transfemoral Amputees

Learning Objectives:

By the end of this lecture, students will be able to:

- Explain the purpose of the Treadmill Test
- Describe the Bruce Protocol
- Interpret normal vs abnormal findings
- Analyze biomechanical differences in amputee gait
- Compare transtibial and transfemoral cardiovascular demands

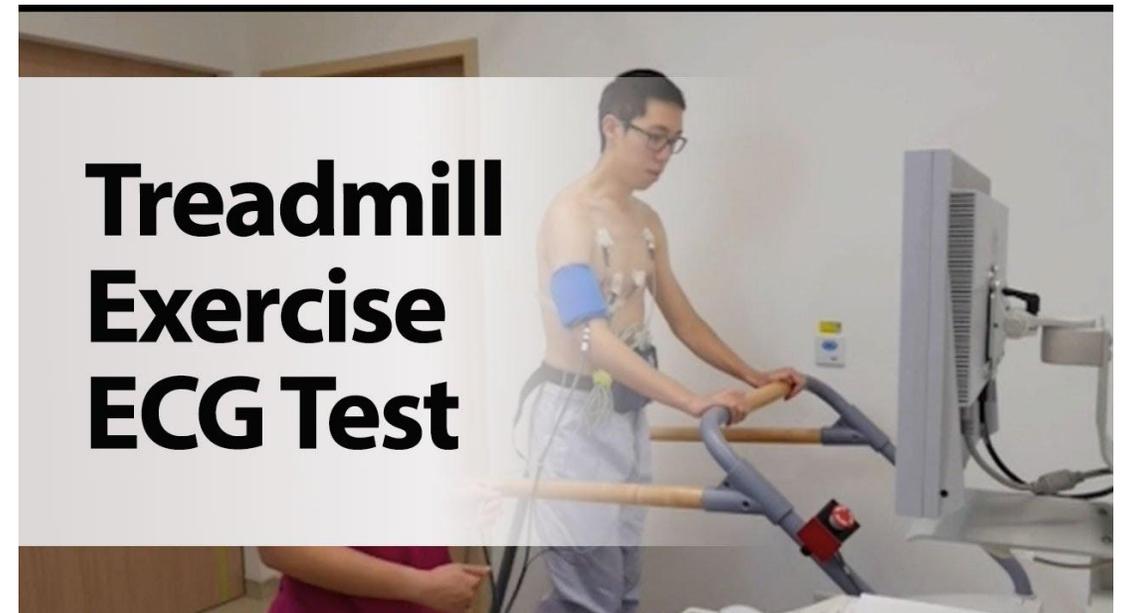
What is a Treadmill Test?

Also called Exercise Stress Test (TMT)

Evaluates heart response to graded exercise

Measures:

- ECG
- Heart Rate
- Blood Pressure
- Symptoms



Indications:

- Suspected coronary artery disease
- Chest pain evaluation
- Exercise tolerance assessment
- Pre-operative evaluation
- Rehabilitation monitoring



Physiological Response to Exercise

During exercise:

- ↑ Heart Rate
- ↑ Stroke Volume
- ↑ Cardiac Output
- ↑ Oxygen consumption (VO_2)

Formula:

Cardiac Output = HR × Stroke Volume

Maximum HR = 220 – Age

Target HR = 85% of Max HR

Bruce Protocol

Most commonly used graded treadmill protocol.

- 3-minute stages
- Gradual increase in speed & incline

Example:

Stage 1 → 1.7 mph, 10% incline

Stage 2 → 2.5 mph, 12% incline

Stage 3 → 3.4 mph, 14% incline

The Bruce Protocol is a standardized cardiac stress test procedure developed to evaluate cardiovascular function and endurance. It progressively increases treadmill speed and incline to measure how the heart responds to physical exertion. Widely used in clinical and research settings, it helps diagnose coronary artery disease and assess exercise capacity.

Bruce Protocol

| Stage | Minutes | % grade | km/h | MPH | METS |
|-------|---------|---------|------|-----|------|
| 1 | 3 | 10 | 2.7 | 1.7 | 5 |
| 2 | 6 | 12 | 4.0 | 2.5 | 7 |
| 3 | 9 | 14 | 5.4 | 3.4 | 10 |
| 4 | 12 | 16 | 6.7 | 4.2 | 13 |
| 5 | 15 | 18 | 8.0 | 5.0 | 15 |
| 6 | 18 | 20 | 8.8 | 5.5 | 18 |
| 7 | 21 | 22 | 9.6 | 6.0 | 20 |

Termination Criteria

Test stops if:

- Target HR reached
- Chest pain occurs
- ST depression ≥ 1 mm
- Severe fatigue
- Abnormal blood pressure response

Normal vs Abnormal Results

Normal:

- No ECG changes
- No symptoms
- Proper HR/BP response

Abnormal:

- ST-segment depression
- Arrhythmias
- Exercise-induced angina

Biomechanics of Treadmill Walking

Treadmill vs Overground:

- Moving belt surface
- Slightly shorter stride
- Reduced forward propulsion

Key variables:

- Step length
- Cadence التردد الحركي
- Ground reaction force
- Joint moments

Body Weight
Support

Robotic
Orthosis



(a)

IMUs and
EMG sensors

Treadmill

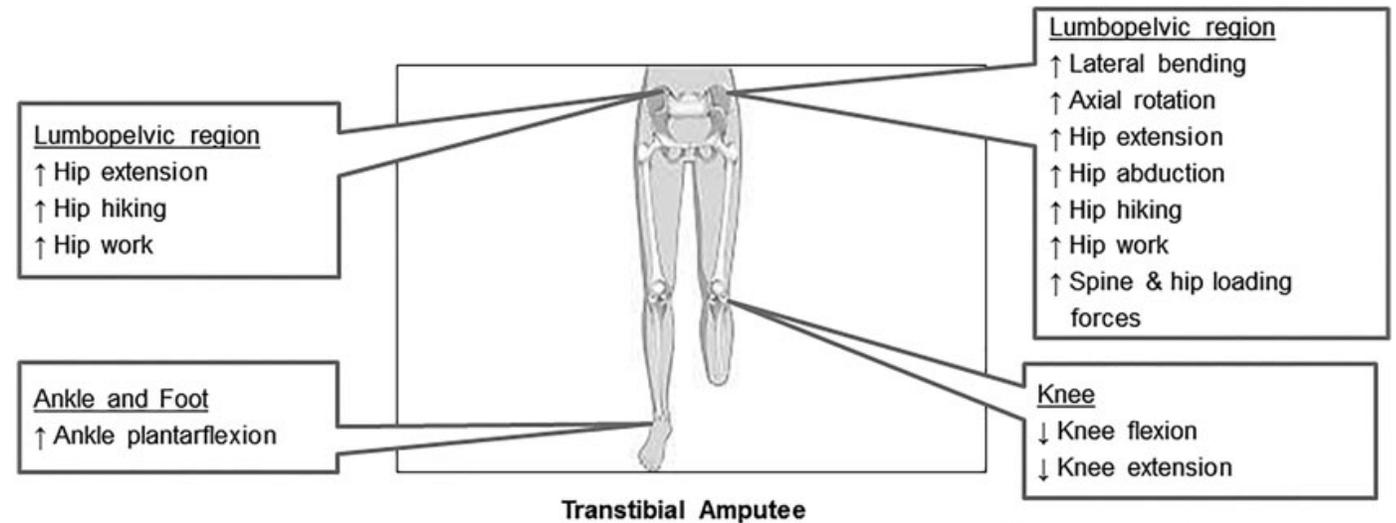
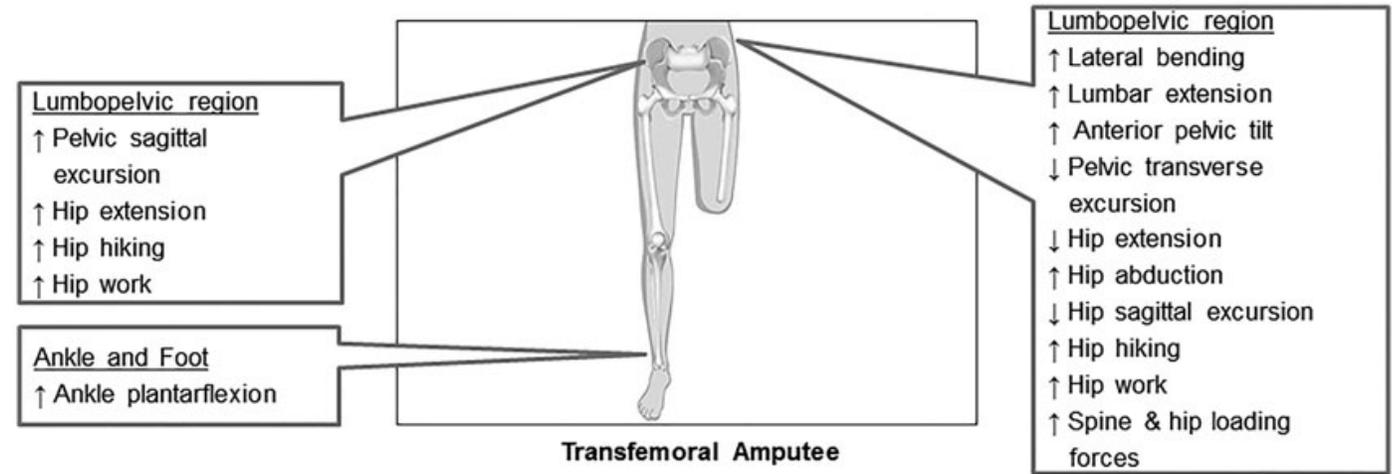


(b)

Effect of Incline

Incline increases:

- Hip flexion demand
- Knee extension moment
- Ankle plantar flexor activity
- Energy expenditure استهلاك



↑ = increased; ↓ = decreased

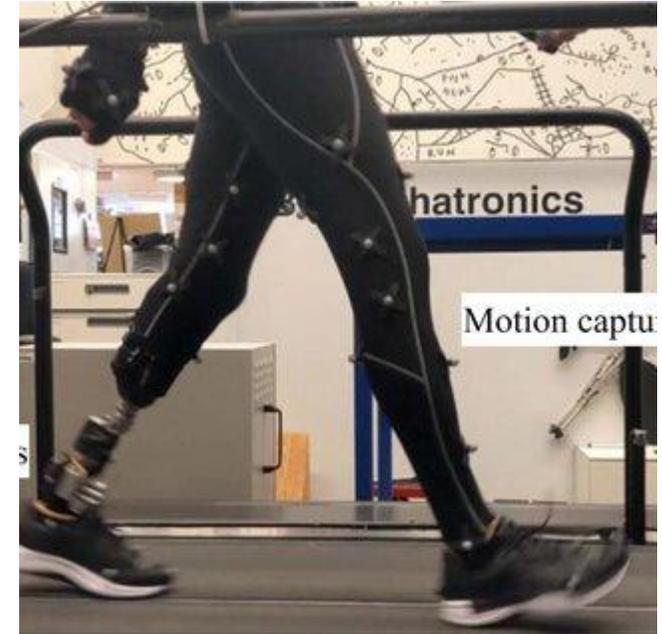
Energy Cost in Amputees

Compared to normal walking:

- Transtibial (TT): +10–20% energy cost
- Transfemoral (TF): +60–100% energy cost

Reasons:

- Loss of ankle push-off (TT)
- Loss of knee & ankle (TF)
- Greater hip compensation



Clinical Case – Transtibial Amputee

Patient:

- 45-year-old male
- Below-knee amputation

During TMT:

- Moderate HR increase
- Good endurance (8–10 min)
- Mild asymmetry

Biomechanics:

- Reduced push-off
- Slight hip compensation

Clinical Case – Transfemoral Amputee

Patient:

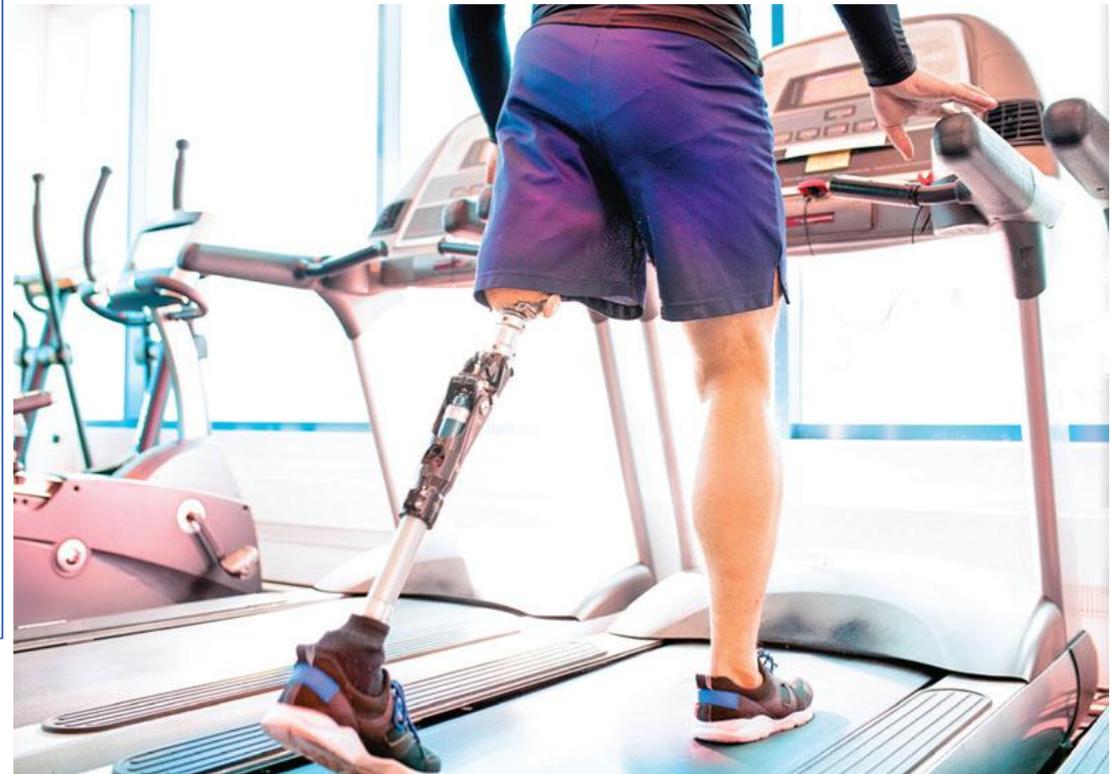
- 45-year-old male
- Above-knee amputation

During TMT:

- Rapid HR increase
- Early fatigue (5–6 min)
- High oxygen demand

Biomechanics:

- Circumduction
- Trunk lean
- Increased hip moment



Ground Reaction Force (GRF)

Normal:

- Double peak vertical GRF

TT:

- Reduced push-off peak

TF:

- Lower prosthetic peak
- Higher intact limb loading

Clinical risk:

Intact limb joint degeneration

Joint Moment Comparison

Normal:

- Strong ankle plantarflexion moment

TT:

- Reduced ankle moment

TF:

- No ankle/knee moment
- Increased hip extension moment

Cardiovascular–Biomechanical Link

Greater biomechanical inefficiency →

↑ Increased oxygen demand

↑ Higher heart rate

↑ Earlier fatigue

Especially significant in TF amputees.

Clinical Importance in Prosthetics

Treadmill testing helps:

- Evaluate prosthetic alignment
- Assess endurance
- Determine functional level
- Monitor rehabilitation progress

Discussion Questions

1. Why is energy expenditure higher in TF than in TT amputees?
2. How does prosthetic alignment influence cardiovascular demand?
3. When should treadmill testing be avoided?