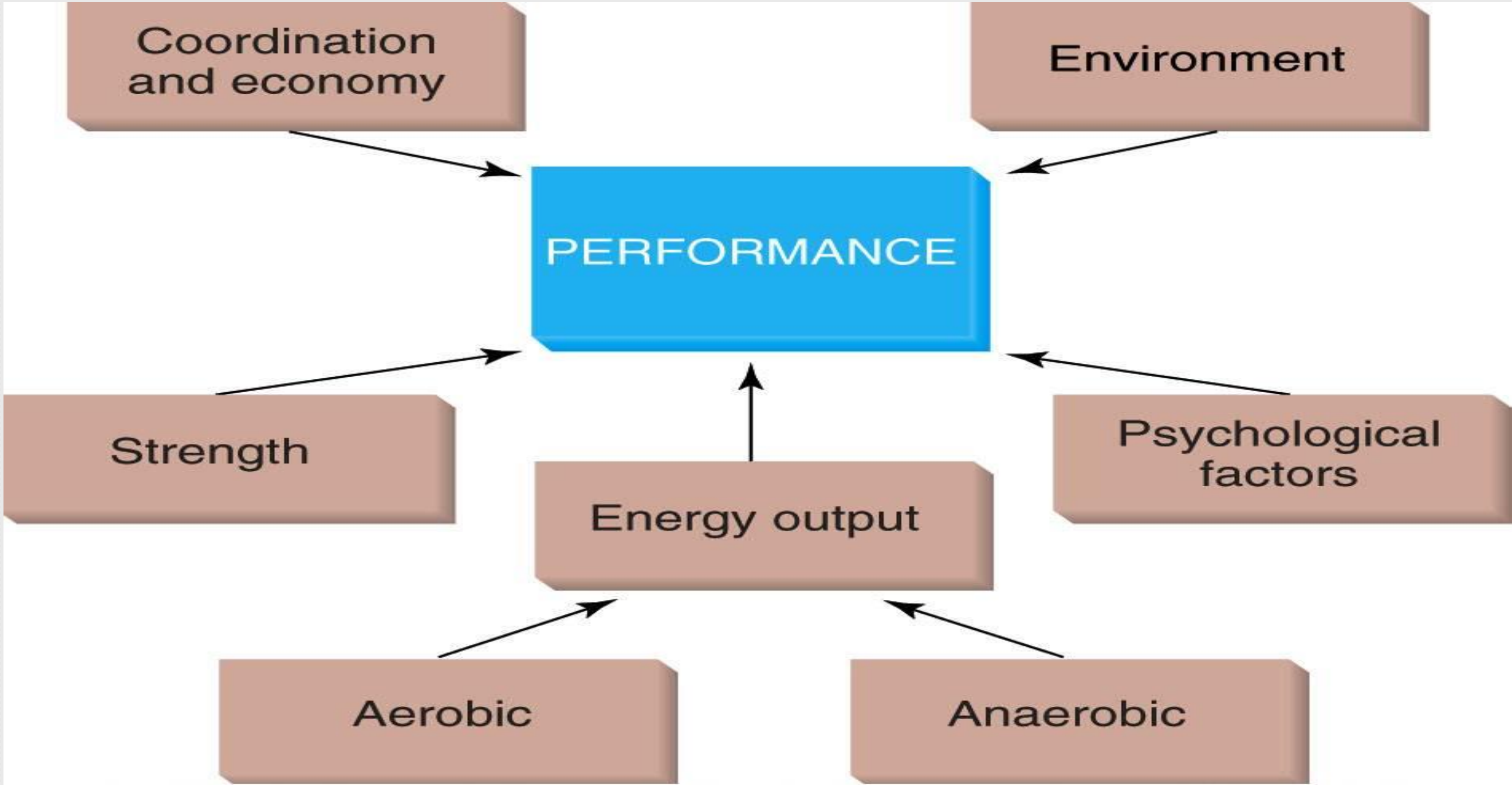
Laboratory Assessment of Human Performance


Sheffield Hallam University

Physiological Testing: Theory and Ethics



What the Athlete Gains From Physiological Testing

- Information regarding strengths and weaknesses
  - Can serve as baseline data to plan training programs
- Feedback regarding effectiveness of training program
- Education about the physiology of exercise

What Physiological Testing Will Not Do

- Difficult to simulate sports in laboratory
  - Physiological and psychological demands
- Difficult to predict performance from single battery of tests
  - Performance in the field is the ultimate test of athletic success

Components of Effective Physiological Testing

- Physiological variables tested should be relevant to the sport
- Tests should be valid and reliable
- Tests should be sport-specific
- Tests should be repeated at regular intervals
- Testing procedures should be carefully controlled
- Test results should be interpreted to the coach and athlete

Direct Testing of Maximal Aerobic Power

- A maximum rate at which an individual can consume O2 during maximal exertion.

- Expressed as the maximum volume of oxygen consumed/min

- **Absolute: litres per min (L/min)**

- **Relative: milliliters per kilogram per minute (ml/kg/min)**

VO_2 max depends on

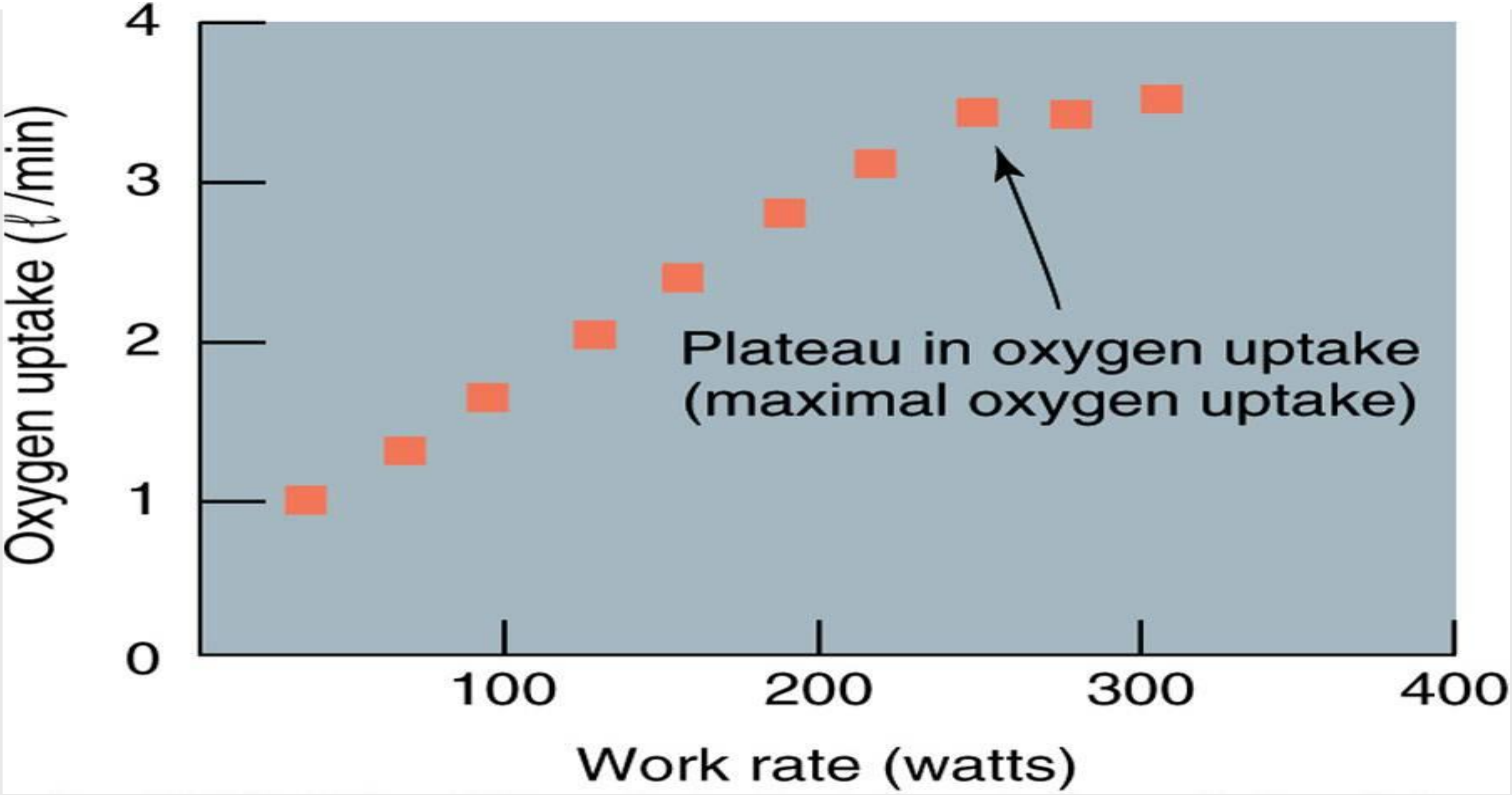
- Cardiovascular
  - Cardiac Output
  - Hemoglobin Content
  - Capillary Density
- Muscular
  - Muscle Mass
  - Fiber Type
  - Mitochondrial Density, Oxidative Enzymes
- Pulmonary
  - Pulmonary function

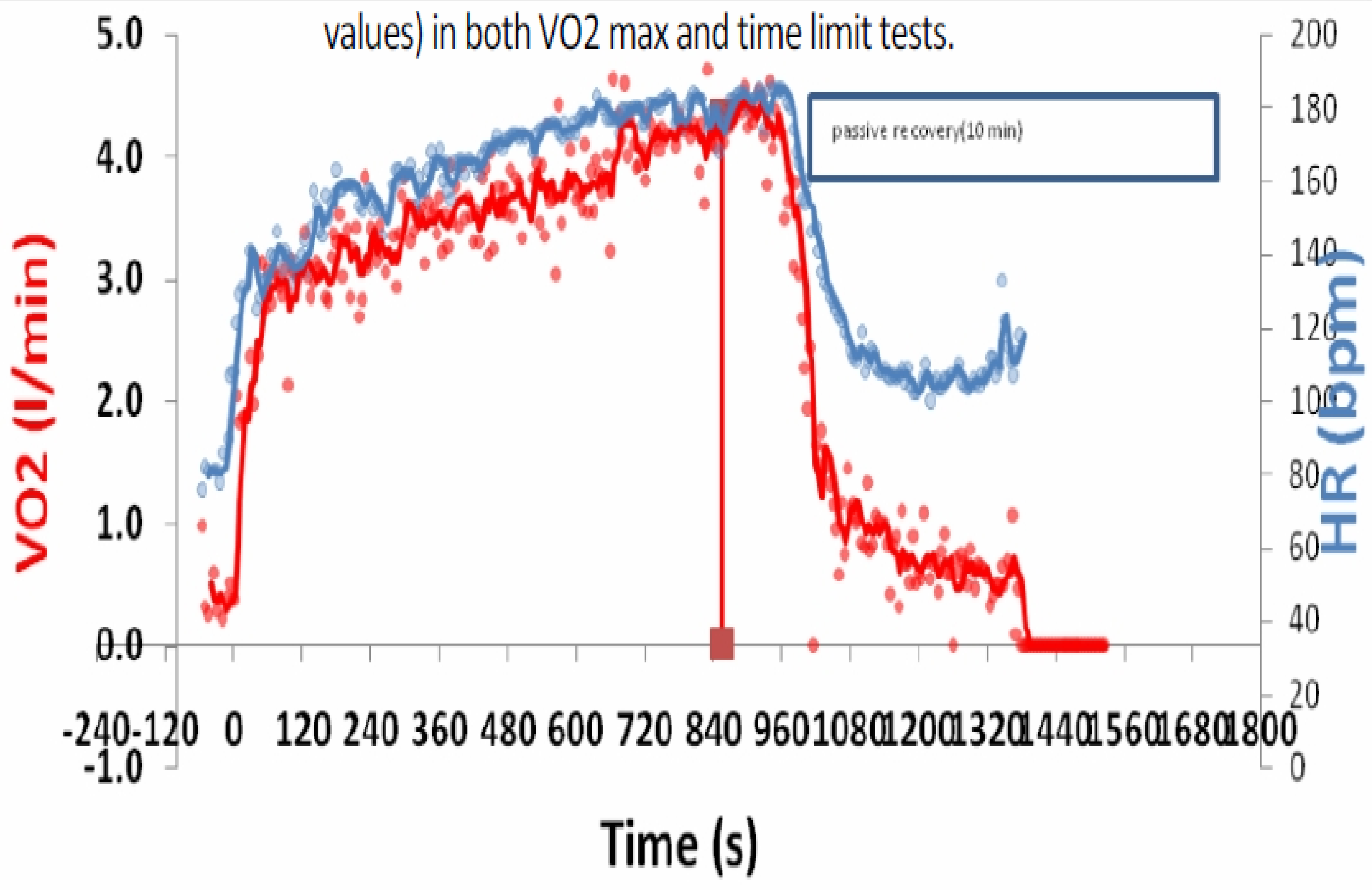
- VO_2 max is considered the best test for predicting success in endurance events
- Most accurate means of measurement is direct testing in laboratory
  - Open-circuit spirometry
- Specificity of testing
  - Should be specific to athlete's sport
    - Runners tested on treadmill

Exercise Test Protocol

- Should use large muscle groups
- Optimal test length 10–12 minutes
  - Start with 3–5 minute warm-up
  - Increase work rate to near maximal load
  - Increase load stepwise every 1–4 minutes until subject cannot maintain desired work rate
- **Criteria for VO_2 max**
  - Plateau in VO_2 with increasing work rate
  - Blood lactate concentration of >8 mmoles•L^{-1}
  - Respiratory exchange ratio ≥1.15
  - HR in last stage ±10 beats•min^{-1} of HR_{max}

Determining VO_2 Max




values) in both VO2 max and time limit tests.
passive recovery(10 min)
VO2 (l/min)
HR (bpm)
Time (s)
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
200
180
160
140
120
100
80
60
40
20
0
-240
-120
0
120
240
360
480
600
720
840
960
1080
1200
1320
1440
1560
1680
1800

	VO2 max test				Time limit test	
Subject	VO2 max(Liter/min)	VO2 max(ml/kg/min)	HR (bpm)	v VO2 max (Km/h)	t-lim (min)	HR (Bpm)
1	3.3	55.9	182	13	4.5	182
2	4.3	58.1	185	18	8.1	186
3	3.7	52.8	196	17	4.8	195
4	4.2	44.6	180	16	7.3	180

Norm Values for VO_2max (ml/kg/min)

Age(years)	Very High	High	Good	Average	Fair	Low
Males						
20-29	>61	53-61	43-52	34-42	25-33	<25
30-39	>57	49-57	39-48	31-38	23-30	<23
40-49	>53	45-53	36-44	27-35	20-26	<20
50-59	>49	43-49	34-42	25-33	18-24	<18
60-69	>45	41-45	31-40	23-30	16-22	<16
Females						
20-29	>57	49-57	38-48	31-37	24-30	<24
30-39	>53	45-53	34-44	28-33	20-27	<20
40-49	>50	42-50	31-41	24-30	17-23	<17
50-59	>42	38-42	28-37	21-27	15-20	<15
60-69	>39	35-39	24-34	18-23	13-17	<13

Determination of Peak VO_2 in Paraplegic Athletes

- Paraplegic athletes can be tested using arm exercise
  - Arm ergometers
  - Wheelchair ergometers
- Highest VO_2 measured during arm exercise is not considered VO_2 max
  - Called "peak VO_2"
- Higher peak VO_2 using accelerated protocol
  - Test starts at 50–60% of peak VO_2
  - Limits muscular fatigue early in test

Astrand sub maximal test

Minute	Subject 1		Subject 2		Subject 3	
	Load (Watt)	Heart rate (bpm)	Load (Watt)	Heart rate (bpm)	Load (Watt)	Heart rate (bpm)
1	100	95	100	70	75	130
2	100	110	100	90	75	142
3	100	119	100	95	75	151
4	100	127	100	107	75	154
5	100	132	100	110	75	156
6	100	135	100	112	75	158
Absolute oxygen uptake (L/min)	2.7 (l/min)		3.6 (l/min)		2.9 (l/min)	
Relative oxygen uptake (ml/kg/min)	37 (ml/kg/min)		62 (ml/kg/min)		45 (ml/kg/min)	

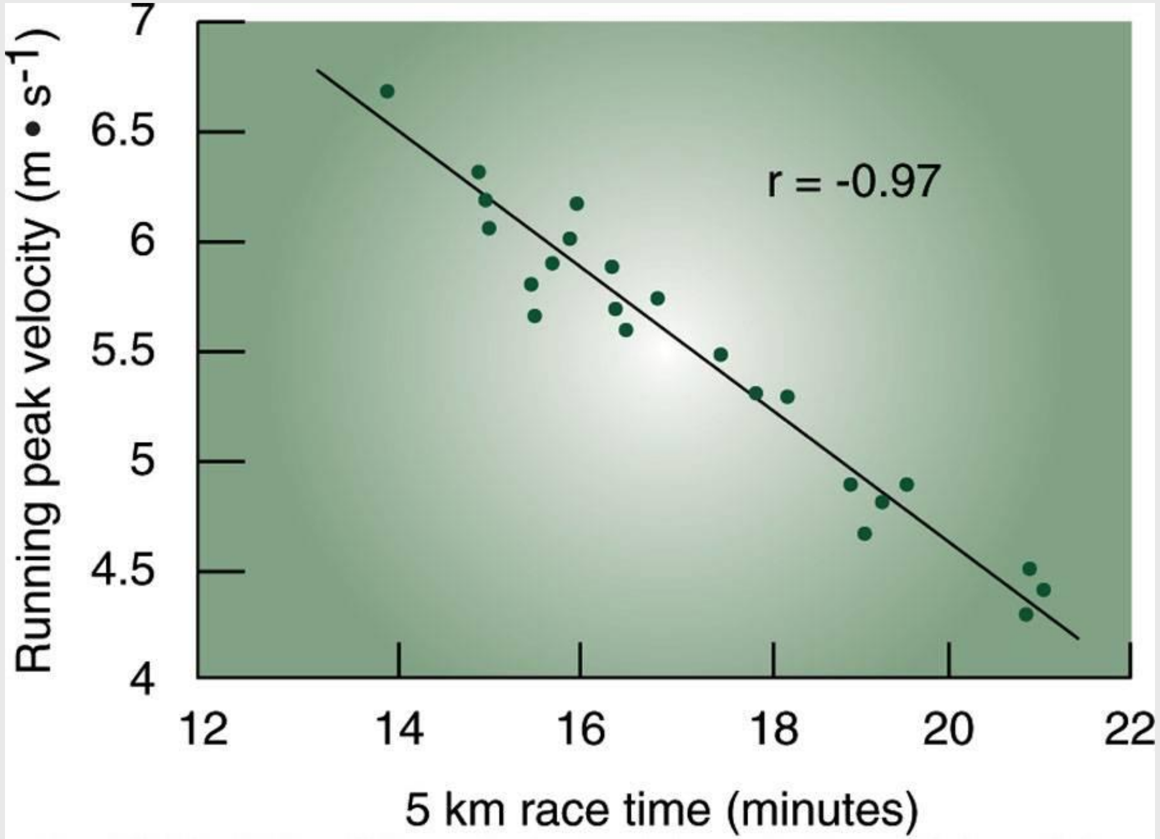
Laboratory Tests to Predict Endurance Performance

- **Peak running velocity**
  - Highest speed that can be maintained for >5 sec
- **Lactate threshold**
  - Exercise intensity at which blood lactic acid begins to systematically increase
  - Direct measurement
  - Estimation by ventilatory threshold
- **Critical power**
  - Speed at which running speed/time curve reaches plateau

Measurement of Peak Running Velocity to Predict Performance

- Peak running velocity
  - Tested on treadmill or on track
    - Progressively increasing speed on treadmill
  - Highest speed that can be maintained for >5 sec
- Excellent predictor of 5 km run performance
  - Strong correlation
    - r = –0.97
  - Also a good predictor of 10–90 km race performance

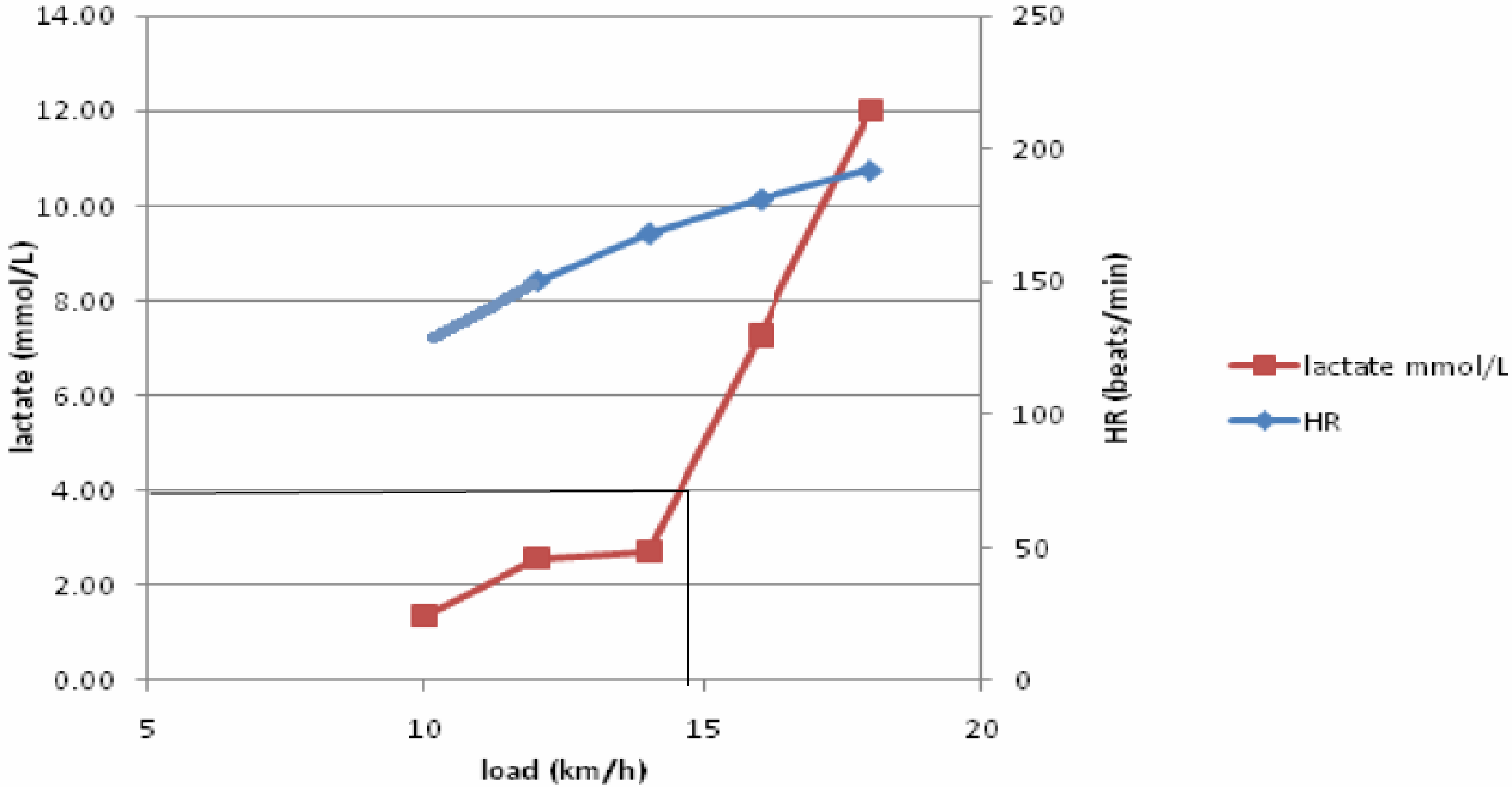
Relationship Between Peak Running Velocity and 5-km Race Performance



Use of the Lactate Threshold to Evaluate Performance

- Lactate threshold estimates maximal steady-state running speed
  - Predictor of success in distance running events
- Direct determination of lactate threshold (LT)
  - 2–5 minute warm-up
  - Stepwise increases in work rate every 4 minutes
  - Measure blood lactate at each work rate
  - LT is the breakpoint in the lactate/VO_2 graph
- Prediction of the LT by ventilatory alterations
  - Ventilatory threshold (T_{vent})
    - Point at which there is a sudden increase in ventilation
    - Used as an estimate of LT

Time (min)	Load (Km/hour)	HR (Beats per min)	Lactate (mmol/liter)
4	10	130	1.36
8	12	150	2.57
12	14	168	2.71
16	16	181	7.27
20	18	192	12.0



14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
lactate (mmol/L)
250
200
150
100
50
0
HR (beats/min)
5
10
15
20
load (km/h)
lactate mmol/L
HR

Measurement of Critical Power

- Critical power
  - Running speed at which running speed/time curve reaches a plateau
  - Power output that can be maintained indefinitely
    - However, most athletes fatigue in 30–60 min when exercising at critical power
- Measurement of critical power
  - Subjects perform series of timed exercise trials to exhaustion
- Prediction of performance in events lasting 3–100 minutes
  - Highly correlated with high VO_2 max and LT

Tests to Determine Exercise Economy

- Higher economy means that **less energy is expended to maintain a given speed**
  - Runner with higher running economy should defeat a less economical runner in a race
- Measurement of the oxygen cost of running at various speeds
  - Plot oxygen requirement as a function of running speed
  - Greater running economy reflected in lower oxygen cost

The Oxygen Cost of Running for Two Subjects

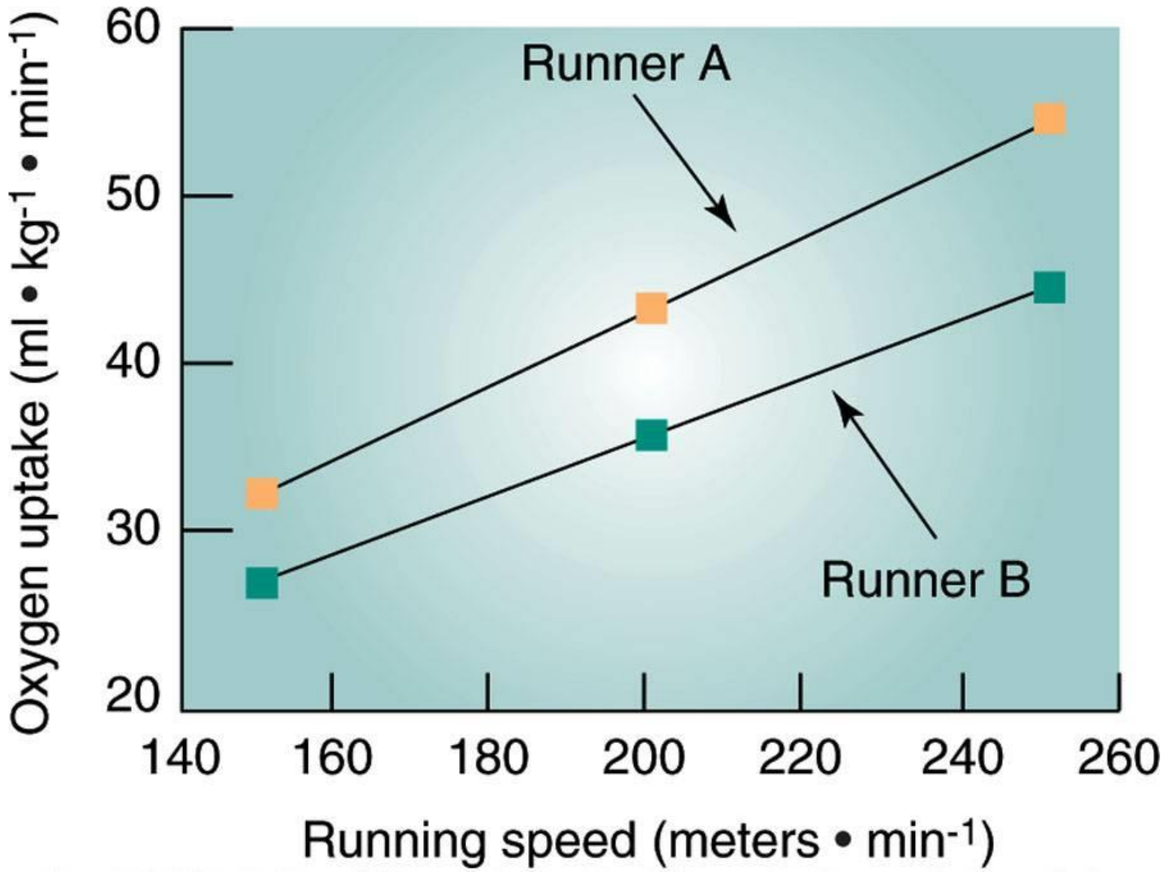


Figure 20.7

Determination of Maximal Anaerobic Power

- Testing should involve energy pathways used in the event
- Ultra short-term tests
  - ATP-PC system
- Short-term tests
  - Anaerobic glycolysis

Tests of Ultra Short-Term Anaerobic Power

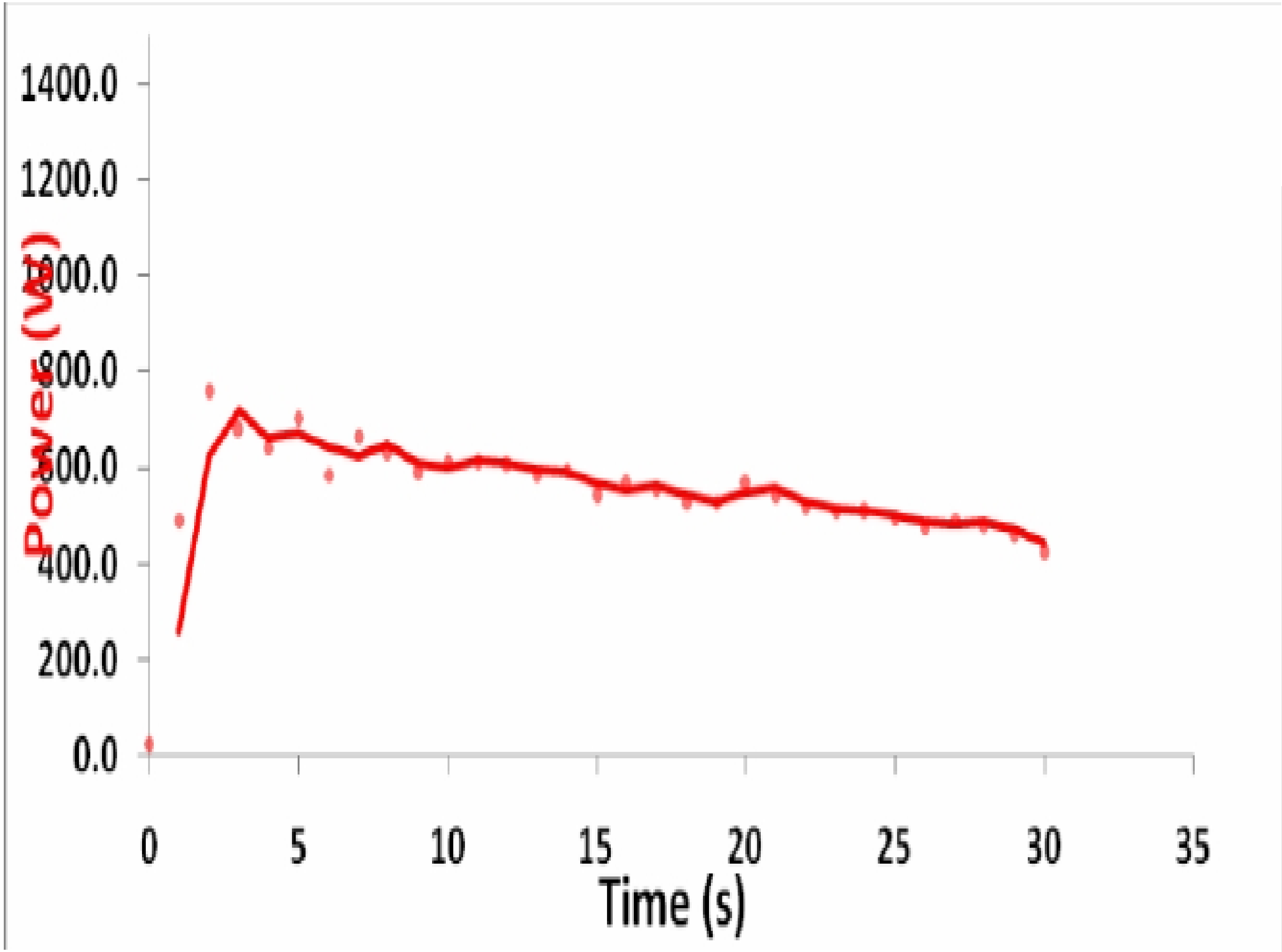
- Tests ATP-PC system
- Power tests
  - Jumping power tests

    Standing broad jump and vertical jump
  - Running power tests
    - *Shuttle Test (*intermittent shuttle running (running back and forth) between markers placed 20 meters apart.
  - Cycling power tests
    - Quebec 10-second test


VERTICAL JUMP

Tests of Short-Term Anaerobic Power

- Tests anaerobic glycolysis
- Cycling tests
  - Wingate test
    - Subject pedals as rapidly as possible for 30 seconds against predetermined load (based on body weight)
    - Peak power indicative of ATP-PC system
    - Percentage of peak power decline is an index of ATP-PC system and glycolysis
- Running tests
  - Maximal runs of 200–800 m
- Sport-specific tests



1400.0
1200.0
1000.0
800.0
600.0
400.0
200.0
0.0
Power (W)
0
5
10
15
20
25
30
35
Time (s)

	Age	Height	Weight	Peak power (W)	Peak power (W/Kg)	Power Drop (W)	Power drop (W/Kg)
Subject1	37	168	74	511.39	7.31	268.8	3.84
Subject2	27	171	75	773.4	10.31	335.75	4.48
Subject3	24	150	50	276.99	6.02	157.79	3.43
Subject4	23	168	86	686.89	7.9	370.19	4.26

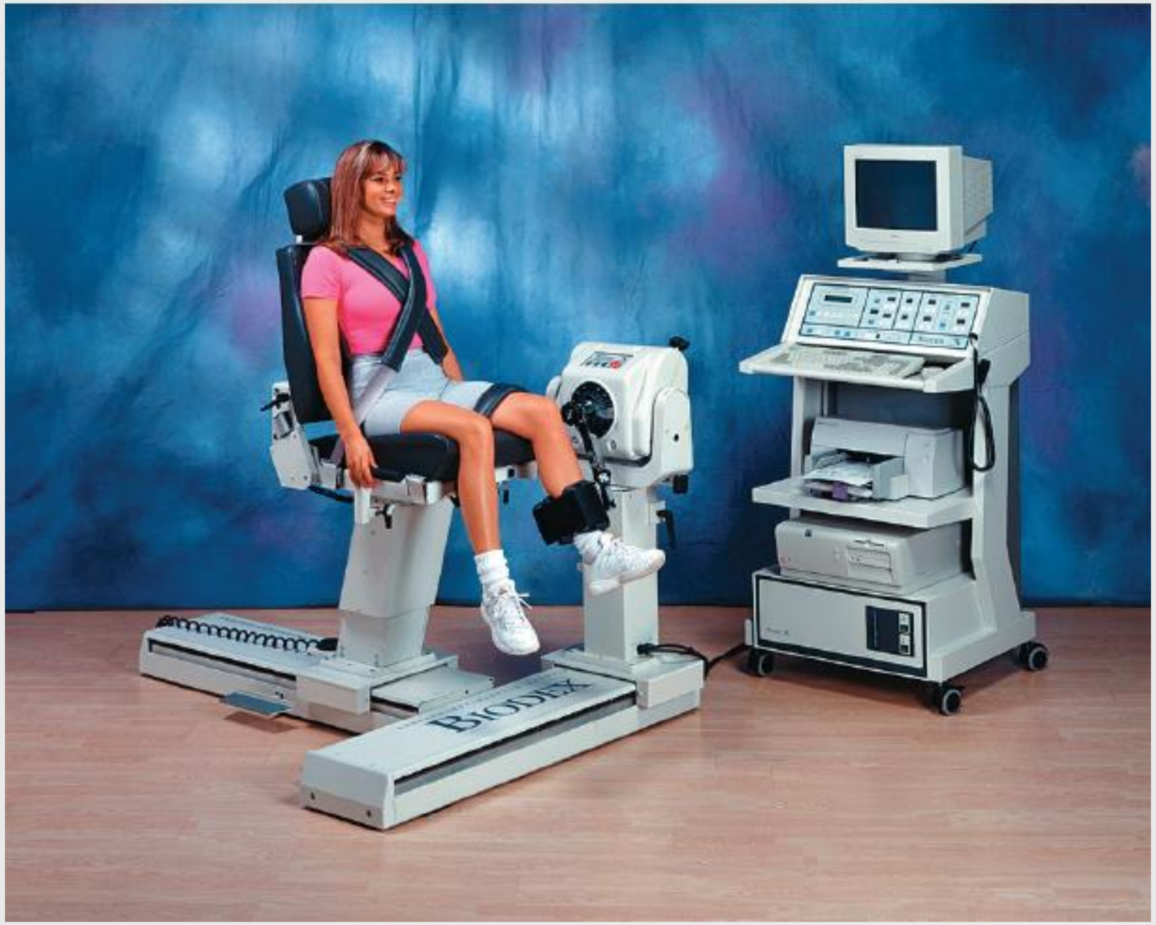
Muscular Strength

- Maximal force that can be generated by a muscle or muscle group
- Assessed by:
  - Isometric measurement
    - Static force of muscle using tensiometer
  - Free weight testing
    - Weight (dumbbell or barbell) remains constant
    - 1 RM lift, handgrip dynamometer
  - Isokinetic measurement
    - Variable resistance at constant speed
  - Variable resistance devices
    - Variable resistance over range of motion

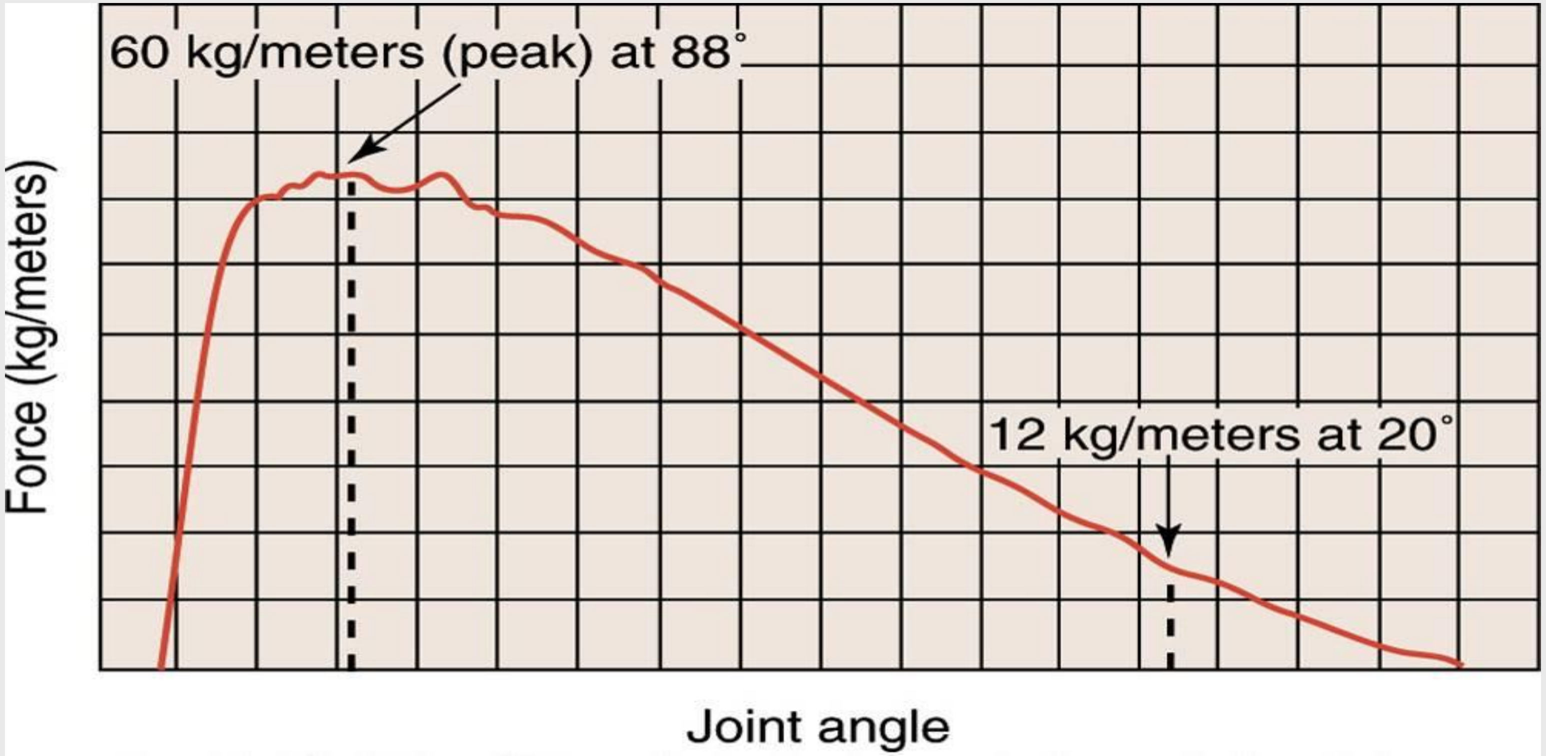
Measurement of Maximal Isometric Force During Knee Extension

Handgrip Dynamometer to Assess Grip Strength

Isokinetic Assessment of Knee Extension



Printout From Isokinetic Dynamometer During a Knee Extension



BIOIMPEDENCE

	Subject 1	Subject 2	Subject 3	Subject 4
Weight (Kg)	76.2	67.8	87.9	44.3
fat %	23	17.3	35.4	13.3
fat mass (Kg)	17.5	11.7	31.1	5.9
Ffm (Kg)	58.7	56.1	56.8	38.4
muscle mass (Kg)	55.8	53.3	53.9	36.4
Tbw (Kg)	41.8	39.7	44.0	26.3
Tbw%	54.9	58.6	50.1	59.4
Bone mass (Kg)	2.9	2.8	2.9	2.0
BMR (Kj)	7293	6791	7355	4916
Metabolic age	40	28	38	12
Visceral fat rating	6	5	12	1
BMI	26.4	24	31.1	19.7
Degree of obesity %	19.8	9.2	41.5	10.5
Ideal body	63.4	62.1	62.1	49.5