Arizona Peace Officer Standards and Training
Basic Curriculum Lesson Plan

LESSON TITLE: PHYSICAL TRAINING - EXERCISE PHYSIOLOGY 8.3

SUBJECT:	Section 10
AZ POST DESIGNATION:	8.3.10
HOURS:	2
INSTRUCTOR TO STUDENT RATIO:	
COURSE CONTENT:	The basic study of the human body during exercise. This is necessary to develop and implement a successful physical fitness program for all types of individuals.
PERFORMANCE OBJECTIVES:	Upon completion of this course of instruction, students using notes, handouts and other support materials as references, within the allotted time, will be able to:

8.3.10.1. Identify and define the three (3) energy systems used by the body during exercise.

8.3.10.2. Define the difference between muscle fatigue and muscle soreness.

8.3.10.3. Define Max VO2.

8.3.10.4. Define stroke volume.

8.3.10.5. Define cardiac output.

8.3.10.6. Explain aerobic vs. anaerobic activity.

DATE FIRST PREPARED:	October 1997	
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AZ POST – APPROVAL:	Richard Watling	DATE: June 2004
AZ POST – APPROVAL:	Lori Wait	DATE: April 2022

LIST ANY PREREQUISITES:

LEAD INSTRUCTOR:

BACK-UP INSTRUCTOR(S):

INSTRUCTOR REFERENCES:

1. *Exercise Physiology*, Fourth Edition, by McArdle, Katch and Katch (published 1996).
2. Physical Fitness Specialist Manual issued by the Cooper Institute for Aerobic Research.

CLASS LEVEL: Instructor

TRAINING AIDS: Slide show on PowerPoint.

INSTRUCTIONAL STRATEGY: Instructional objectives will be obtained through the use of: lecture, reading assignments and group discussion.

SUCCESS CRITERIA: Success in this functional area will be demonstrated through the attainment of a 70% passing grade on a written objective examination comprising multiple choice and true/false questions.

COMPUTER FILE NAME: 8.3.10 Sec 10 Exercise Physiology

DATE RELEASED TO THE SHARE FILE: August 2023

I. INTRODUCTION

A. Instructor(s) – (self) introduction.

B. Preview of performance objectives.

II. EXERCISE PHYSIOLOGY

A. The study of the function of the body as it responds to exercise.

B. To develop a safe and effective training program, the fitness instructor should understand the functions of the human body during exercise.

C. Muscle contractions.

1. There are three (3) types of muscle tissue in the human body:

a. Skeletal.

b. Smooth.

c. Cardiac.

2. All three (3) need Adenosine Triphosphate (ATP) in order to contract.

3. Structure of the skeletal muscle:

a. Actin-thin protein filament.

b. Myosin-thick protein filament.

c. Crossbridge.

d. Z line.

e. Sarcomere – the functional contractile unit of the muscle tissue.

4. Sliding filament theory.

a. Developed by Huxley in the 1950's.

b. At rest, the actin and myosin overlap each other, but do not touch.

c. When a stimulus is received, the muscle shortens and lengthens when the actin and myosin link up via crossbridges and slide across each other without actually changing length.

d. Calcium, sodium, potassium and ATP must be present to generate a contraction.

e. Lactic acid can interfere with the crossbridge formation; therefore, resulting in muscle fatigue.

D. Adenosine Triphosphate (ATP) – the chemical energy molecule needed in virtually all cells of the body.

1. Needed for glucose transport, synthesis of hormones, enzymes, etc., and muscle contraction.

2. When the terminal phosphate group is split from ATP, energy is released and ATP becomes Adenosine Diphosphate (ADP).

3. ATP is utilized at the cross bridge between actin and myosin to generate the muscles ability to contract.

E. Energy systems.

1. ATP is needed in large amounts to sustain life. There are three (3) types of energy systems, all of which produce ATP. We always use the systems in some combination.

2. ATP-CP system (phosphagen system).

a. Creatine (CP) combines with ADP. Creatine phosphate is a high-energy phosphate reservoir.

b. Already stored in the muscle; very limited supply.

c. Used in short-term, severe exercise up to 10 seconds.

3. Anaerobic Glycolysis.

a. **Glucose → 2 lactic acid + 2 ATP.**

b. The breakdown of glucose in the absence of oxygen.

c. Used in high-intensity, short-duration exercise lasting 10-90 seconds.

d. Lactic acid:

i. Associated with muscle fatigue.

ii. Limiting factor to anaerobic performance.

iii. Interferes with crossbridge formation.

iv. Interferes with pH balance within muscle.

v. Produced when ATP demand is greater than ATP supply.

vi. Lactic acid is not the cause of muscle soreness.

4. Aerobic system:

a. Aerobic Glycolysis.

i. **Glucose + $6O_2 \rightarrow$ 36 ATP + 6 H_2O + 6 CO_2 + Heat.**

ii. **Fatty acid oxidation**.

iii. **Fatty acid + 23 $O_2 \rightarrow$ 129 ATP + 16 H_2O + 6 CO_2 + Heat.**

b. The breakdown of glucose, glycogen and fatty acids in the presence of oxygen.

c. Used in activities that last longer than two (2) minutes; lower intensity and longer duration.

d. Fatty acid oxidation predominates after 20 minutes of exercise.

F. Fuel for exercise.

1. Carbohydrates:

a. Found in the form of blood glucose, muscle glycogen and liver glycogen.

b. Dietary sources are fresh fruits, vegetables and whole grains.

2. Fats:

a. Found in the form of triglycerides and fatty acids in the bloodstream and as triglycerides in the adipose tissue.

b. Always abundantly available as a fuel source.

3. Amino acids (protein):

a. Provides a small contribution to ATP production.

b. Not a prime energy source.

4. Ideal diet is 60% carbohydrates, 25% fat and 15% protein.

5. We are always utilizing a combination of fats and carbohydrates during rest and exercise. This is determined by:

a. Availability of fuel.

b. Intensity of exercise.

c. Duration of exercise.

d. Cardiovascular level.

G. Types of muscle fibers:

1. Slow oxidative or Type I (a.k.a. slow twitch fibers).

a. Fatigue resistant.

b. Weakest fiber.

c. Found predominantly in endurance athletes (marathoners, triathletes, 10k, etc.).

2. Fast oxidative glycolytic or Type II-A.

a. Fatigue resistant.

b. Stronger fiber.

c. Found predominantly in middle distance athletes (one mile, 3k, 5k, etc.).

3. Fast glycolytic or Type II-B (fast twitch fibers).

a. Fatigue quickly.

b. Strongest fiber.

c. Found predominantly in strength/power/ speed athletes (100m, powerlifter, etc.).

III. METABOLIC RATE

A. Metabolic rate is the rate of calorie expenditure and is closely related to oxygen consumption.

B. Resting metabolic rate is the amount of oxygen consumed at any given time during rest.

C. The average amount of oxygen consumed at rest is 3.5 ml/kg/minute or MET (metabolic equivalent).

1. Individuals below this level have a low metabolism.

2. Individuals above this level have a high metabolism.

D. A calorie is defined as the amount of heat necessary to raise the temperature of one (1) gram of water by one degree (1°) centigrade.

1. When food is broken down into ATP, heat is given off as a waste product.

2. About 70% of the available energy in food is lost as heat.

E. Determining metabolic rate.

1. Heat given off by the body can be measured by a method called direct calorimetry (very expensive and time consuming).

2. Indirect calorimetry is much easier and takes less time.

   Expired air is collected and the oxygen content is measured.

3. Resting metabolic rate can be estimated using the Harris-Benedict formula. (See Addendum.)

   a. The subject must be completely sedentary and have a normal metabolism.

   b. The margin of error is +/- 10%.

F. Factors affecting resting metabolic rates are:

1. Age.

2. Thermic effect of food. (Yo-yo diets.)

3. Malnutrition.

4. The thyroid gland.

5. Testosterone.

6. Sympathetic stimulation (release of epinephrine and norepinephrine).

7. Exercise/amount of lean body mass.

8. Climate.

G. Recovery process:

1. Exercise increases metabolic rate.

2. Return to resting levels after exercise depends on intensity and duration.

3. Calories are still being burned after exercise because of a rise in body temperature and the energy utilized in replenishing glycogen.

4. Low-intensity and longer-duration exercises are very effective for weight loss.

IV. CARDIO RESPIRATORY PHYSIOLOGY

A. Terms to know:

1. Cardiac output – the amount of blood pumped by the heart per minute. Expressed in liters/minute.

2. Stroke volume – the amount of blood pumped by the heart per beat. Expressed in ml/beat.

3. A-V O2 difference – the difference in the amount of oxygen in the arteries vs. veins.

4. Max VO2 or VO2 max – the maximal amount of oxygen utilized by the body per minute. Expressed in ml/kg/min.

B. Formulas to know:

1. Cardiac output = heart rate x stroke volume
Q = HR x SV.

2. Oxygen consumption = cardiac output x arteriovenous oxygen difference VO2 = Q x a-v O2 difference.

V. CARDIOVASCULAR TRAINING

A. In order for cardiovascular endurance to improve, the body must be forced to perform work so that large amounts of oxygen are consumed. Frequency, intensity, duration and mode of exercise determine this.

1. Heart rate during aerobic exercise is usually a reliable reflection of how much oxygen is being consumed.

2. High heart rate usually indicates high oxygen consumption.

3. Aerobic activity performed at 70% of one's maximum heart rate will show an improvement in cardiovascular endurance.

4. Aerobic activities are characterized by the use of large amounts of oxygen, use of large muscles, rhythmical in nature, and can be maintained for longer than 20 minutes at moderate intensity.

5. Examples are: Running, biking, rowing, swimming, brisk walking, cross country skiing and stair climbing.

6. Current fitness levels are determined through assessment (1.5 mile run, 1-mile walk, etc.).

B. Calculation of target heart rate range:

1. Determine the predicted maximal heart rate. (Cooper's adaptation of Karvonen Formula.)

   a. Males: 205 – ½ age *

   b. Females: 220 – age (Karvonen Formula)

2. Subtract the resting heart rate in beats/minute from the predicted maximal heart rate. This is called the heart rate reserve.

3. Multiply the results of step two (2) by the desired intensity range (i.e., 60% to 70%).

4. Add the resting heart rate back to the results of step three (3). This is the target heart range (THR).

5. To determine a 10-second heart rate range, divide the upper and lower end by six (6).

6. Individuals taking beta blockers should not be given a training heart rate zone unless the actual maximal heart rate, without beta blockers, is known. Beta blockers are used to lower heart rate.

   a. The Borg Scale (the rate of perceived exertion) can be used for these individuals.

b. Individuals are asked to rate his/her perceived exertion during exercise. On a scale, "six (6)" is very, very light and "20" is very, very hard.

VI. ADAPTATIONS TO AEROBIC TRAINING

A. Increased number and size of mitochondria.

B. Increased Q max.

C. Increased max stroke volume.

D. Increased max a-v O2 difference.

E. Increased VO2 max.

F. Increased myoglobin.

G. Increased capillary density.

H. Increased ability to oxidize fats.

I. Increased blood volume.

J. Increased heart volume.

K. Increased strength of ventilatory muscles.

L. Increased ability to store glycogen.

M. Decreased heart rate.

VII. THE EFFECTS OF AGING

A. The aging process is inevitable.

B. Defined as "the diminished capacity to regulate the internal environment, resulting in a decreased probability of survival."

C. Humans differ in their rates of aging based on many factors:

1. Genetics.

2. Disease.

3. Dietary habits.

4. Physical activity/fitness levels.

D. Aging has a negative impact on both maximal cardiac output and max a-v O2 difference.

E. The maximum heart rate (MHR) declines by approximately one (1) beat per year as we age.

1. 205 – ½ age for males = MHR.

2. 220 – age for females = MHR.

3. The possible cause is the stiffening of the heart walls.

F. Maximal stroke volume is affected because the valves of the veins begin to deteriorate thus reducing the amount of blood returning to the heart.

1. The valves of the heart also deteriorate.

2. The size of the heart will also decrease.

G. Strength declines with age.

1. Muscle atrophy.

2. Loss of Type II muscle fibers.

3. Inability to recruit muscle fibers.

H. It is never too late to begin a strength-training program.

1. A lifestyle of cardiovascular and strength training can slow down the aging process of most of the above maladies.

2. A study performed with elderly subjects showed that a strength-training program improved muscle strength and muscle mass significantly.

VIII. PHYSIOLOGICAL DIFFERENCE BETWEEN MEN AND WOMEN

A. The fitness instructor should understand the differences in physiology between men and women.

1. Hormones.

a. Testosterone:

i. Significant for muscle enlargement.

ii. Develops secondary, male sex characteristics.

iii. Higher levels are found in men.

b. Estrogen:

i. Helps the body from body fat.

ii. Retains calcium in the bones.

iii. Higher levels found in women.

B. Red blood cell (RBC) production.

1. Blood carries nutrients throughout the body.

2. Blood transports oxygen to muscle and tissue.

3. Iron deficiencies in women affect RBC production while testosterone increases RBC production.

C. Muscle vs. fat.

1. Women have a higher percentage of body fat than men. (Essential body fat % Women +12%, Men = 3%.)

a. Properties of estrogen.

b. Needed for childbearing.

2. Men have more lean muscle mass.

a. Properties of testosterone.

D. Bone density.

1. Estrogen helps the bones retain calcium.

a. During menopause, estrogen production reduces significantly.

b. Without proper calcium reservoirs, loss of bone density will occur.

2. Osteoporosis.

a. Afflicts 24-25 million Americans.

i. Ninety percent (90%) are women.

ii. In older individuals, especially women over 60, it has reached near epidemic proportions.

b. Low bone density leads to bone fractures particularly in the hip, wrist and vertebrae.

i. Cause of 1-1.5 million fractures a year.

ii. Hip fractures in the elderly have shown a 15% mortality rate because of complications.

iii. Annual healthcare cost for osteoporosis is 7-10 billion dollars.

3. Osteoporosis is preventable and treatable.

a. Risk factors are:

i. Age.

ii. Female.

iii. Fair skin (Anglo/Asian).

iv. Low body weight.

v. Childless.

vi. Sedentary lifestyle.

vii. Cigarette smoking.

viii. Excessive caffeine intake.

ix. Excessive alcohol intake.

x. Excessive protein intake.

xi. Menopause.

xii. Amenorrhea.

xiii. Inadequate boron and vitamin C.

xiv. Other unknown factors.

b. Most of the above-listed risk factors can be avoided through a lifestyle change – simply, proper nutrition and regular exercise.

E. Other physiological differences:

1. The average man stands taller and weighs more than the average woman.

2. Size and strength are determined by the length of the skeletal bones, amount of muscle fibers and the size of the lung and heart.

3. Biomechanical differences are:

a. The size of the joint levers which affect joint movement.

b. Physique – women tend to have wider hips and narrower shoulders.

IX. RACIAL DIFFERENCES IN PHYSIOLOGY

A. Differences in physiology of Olympic athletes have a significant effect on performance.

B. Black sprinters and high jumpers tend to have longer legs and narrower hips than their white counterparts.

C. These biomechanics assist in propelling.

D. Asian athletes have shorter legs in relation to the torso.

1. Advantageous in short and long distance running.

2. Also in weightlifting.

X. CONCLUSION

A. Review of performance objectives.

B. Final questions and answers.

C. Instructor closing comment(s).

ADDENDUM

Harris Benedict Formula for males:

66 + (6.22 X weight) + (12.7 X height in inches) – (6.8 X age) = daily calories necessary to support resting metabolism.

Harris Benedict Formula for females:

665 + (4.36 X weight) + (432 X height in inches) – (4.7 X age) = daily calories necessary to support resting metabolism.