Fitness for Paramedics: A Guide for Students at Cambrian College

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Customized for Paramedic Fitness

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Contents

Chapter 10 - Nutrition

Chapter 11 - Weight Management

Attribution and OER Revision Statement

DAWN MARKELL AND DIANE PETERSON

This open textbook is a modified version of "Concepts of Fitness and Wellness" from Georgia Highlands College (also found in the Open Textbook Library). It includes only chapters 1-10 of the original 13, to better accommodate a 10 week length course (quarter system) at Mt Hood Community College. Proprietary links were either updated or removed. Terminology lists were relocated to the beginning of each chapter, just after the original list of Objectives. The primary focus of this revised version is on assessment and development of functional goals in fitness training, nutrition, and stress management. Publication and descriptive metadata were added to facilitate library cataloging: MARC record available at the end of the book.

Attribution and OER Revision Statement

AMANDA SHELTON

This open textbook is a remixed version of several OER sources including "Health and Fitness for Life" by Dawn Markell & Diane Peterson, "OU Human Physiology" by Heather Ketchum & Eric Bright, "Body Physics: Motion to Metabolism" by Lawrence Davis, and "Human Anatomy" by Marcos Gridi-Papp, among other resources. This textbook is a resource used to support the Exercise Science course at Mt. Hood Community College as part of the Fitness Professional Certificate program and Exercise and Sport Science transfer degree.

INTRODUCTION TO FITNESS FOR PARAMEDICS

Welcome!

Welcome!

MARTIN DUBUC

Hello Paramedic students, and welcome to your textbook!

This book has been assembled from two texts (see previous acknowledgements) to provide you with the tools you require to succeed in your Fitness courses as you pursue the Paramedic program at Cambrian College. Whether you are new to fitness and have never worked out before or have years of experience training to be your best, this textbook will provide you with knowledge and skills to apply to your lifestyle to meet your fitness goals. Although this book provides skills to train your body effectively, ***it's your responsibility to cultivate the discipline and motivation to APPLY what you've learned!*** No amount of knowledge can replace the hours you'll need to push your body to improve and meet the Paramedic program's fitness standards (see next section).

PARA Fitness Test Descriptions

MARTIN DUBUC AND GREATER SUDBURY EMERGENCY SERVICES

There are three primary fitness tests students will complete on multiple occasions while studying in the Paramedic program at Cambrian College:

1. Paramedic Evaluation Test (PET Test)
2. 20m Shuttle Run (Beep Test)
3. Stair Chair and Scoop Test

Although these tests tend to measure individual components of fitness (e.g., 20m Shuttle measures Cardiorespiratory endurance), a student needs to train all of their components of fitness (cardiorespiratory endurance, muscular strength, muscular endurance, and flexibility) to succeed in all three. During Semesters 1 and 2, each test is attributed a weight that counts towards your final grade in that Fitness course. This means a student could theoretically be unsuccessful in the PET Test yet still pass their Fitness course. However, in Semester 3, **students must pass all three fitness tests to pass the course.** Take the time to carefully read over the test descriptions, which have been copied from the City of Greater Sudbury's Paramedic Services and modified to reflect Cambrian College's testing environment, below.

1. Paramedic Evaluation Test (PET Test)

The following PET Test description has been copied directly from the City of Greater Sudbury's Paramedic Services and modified to reflect Cambrian College's testing environment.

The PET circuit is a series of job performance physical ability tests that simulate the most common daily physical demands of Emergency Medical Services (EMS) work. The test involves a three-cycle obstacle course, identifying four typical physical labour tasks that paramedics must perform on a daily basis, including strength, agility, anaerobic capacity, and flexibility.

The physical aspects of EMS work can be described by these four physical activities and are considered crucial, essential and critical. The PET circuit must be successfully completed within a standardized pre-determined time.

In each cycle of the obstacle course, at least two of the above physical labour tasks are challenged. Aspects of the test duplicate a scenario where a paramedic must (a) get to the patient, (b) physically attend to the patient, and (c) remove the patient. As the level of performance demanded varies per situation, the test is practical and deemed to be both realistic and reasonable.

<u>Stations</u>

1. Obstacle Course – Mobility Run: The PET circuit consists of an approximately 300m (984 ft) obstacle run where the student must demonstrate gross motor abilities such as mobility, agility, flexibility, power, and general aerobic endurance.
2. Strength Station: The strength station consists of a pull unit where the student must suspend a 50lb (23kg) weight off the ground and travel through four 180-degree arcs, keeping the weight elevated during the entire exercise.
3. Body Drag: The body drag session of the PET circuit requires the student to drag an approximate 90lb mannequin over a distance of 30m (100ft). A hose/sled weighted to 90lb may be used to stimulate the dummy. *In Cambrian's Paramedic program, a 90lb sled is used.*

<u>Description of the PET</u>

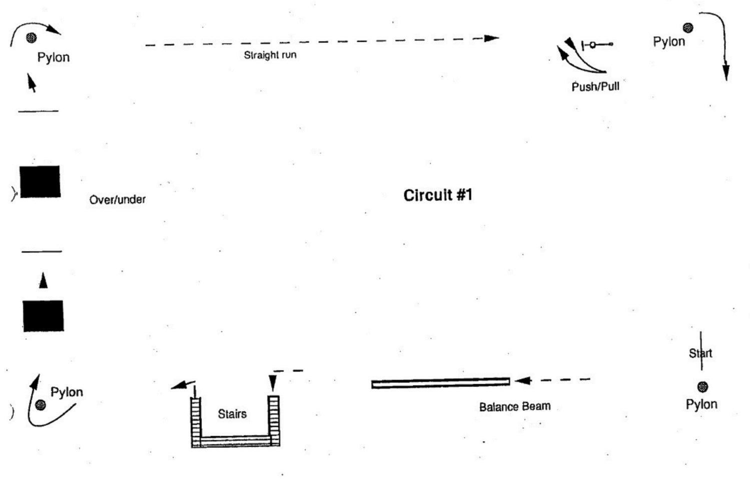
The PET consists of three cycles/laps at a controlled time pace. The first cycle consists of an approximately 100m obstacle run where the student must demonstrate gross motor abilities such as agility, flexibility, and general endurance. Further details on grade attribution (e.g., the weight of this test or what time needs to be achieved to obtain passing grades) can be found in the next section of the textbook. The PET is laid out in the following manner (see images after cycle descriptions).

Lap 1 and Lap 3:

1. Starting from the start marker pylon, the student runs straight ahead to the first obstacle – the balance beam. The balance beam must be crossed lengthwise. **If a foot touches the floor, the student must go back to the beginning of the beam.**
2. From the balance beam, the student runs forward to the second marker and proceeds up and down the staircase twice.
3. From the stairs, the student runs forward to the end of the gym around the last pylon to the outside and faces the over/under components. The student must go over the first obstacle (pommel horse), go fully under the second obstacle (low bar), go over the third obstacle (pommel horse), and go fully under the last obstacle (low bar). When going over the pommel horse, the entire body must travel over the top of the obstacle (i.e., cannot swing legs over the side). **Failure to maintain proper form could lead to going back to complete the obstacle again. If any of the bars are knocked off, the student is penalized five seconds per bar.**
4. Upon exiting the over/under component, the student proceeds forward around the outside of the next marker and continues forward in a straight run to the pull component. Upon reaching the pull unit, the student grasps the rope and pulls the weight (50lb/23kg) off the floor. Maintaining the weight in this position (elbows are to be flexed), the student moves through four arcs of 180 degrees. The weight is then lowered in a controlled manner to the floor. *In order to maintain balance, a shuffle movement of the feet is suggested,*

the back should be kept straight while the abdominal muscle contract, thus stabilizing the pelvis. **For every occurrence of the weight touching the floor, an additional penalty arc is given.**

5. From the pull unit, the student goes outside of the next marker and returns to the starting line, completing the first cycle/lap.

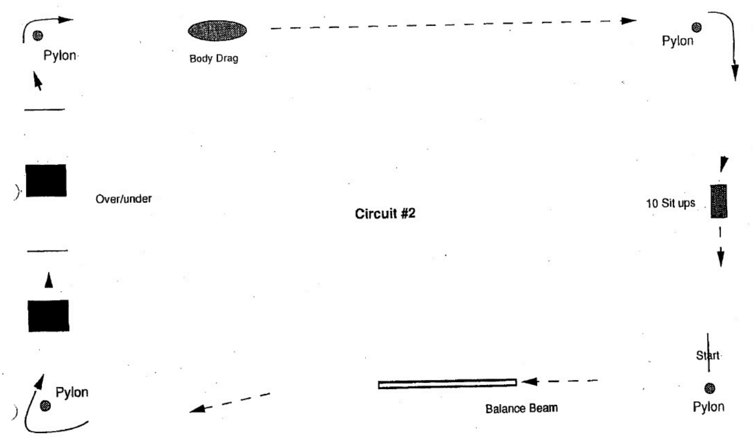


Lap 2:

1. From the start marker, the student runs to the balance beam as in Lap 1.
2. After the balance beam, the student runs forward to the end of the gym, bypassing the stairs, and turns around the last pylon to face the over/under components.
3. The student completes the over/under components as in Lap 1.
4. After the over/under components, the student proceeds forward, runs around the outside of the next marker, and returns to the body drag (located next to the outside marker). In a safe and controlled manner, the student must drag the 90lb sled along the gym floor for a distance of 30m (100ft),

moving backwards throughout. Once completed, they proceed to the mat for the sit-up component.

5. At the floor mat, the student lies flat on their back with knees at a 90-degree angle and performs, or at least attempts, ten consecutive, controlled sit-ups. The feet must remain on the floor, and the wrists must pass the knees on each contraction. Upon completing ten sit-ups, the student gets up and proceeds to the start pylon.



Lap 3: Identical to Lap 1, with the start line becoming the finish line.

In summary, the PET test breaks down as follows:

Lap 1 and Lap 3:

- Start
- Balance Beam
- Stairs (2x)
- Marker
- Over/Under
- Marker
- Straight Run
- Pull Station

- Marker / Start / Finish line

Lap 2:

- Start
- Balance Beam
- Straight Run (no stairs)
- Marker
- Over/Under
- Marker
- Body Drag (with sled)
- Sit-ups
- Marker/Start line

Common Faults:

- Stepping off the balance beam
- Failing to clear the Over/Under stations fully
- Failing to run around the **outside** of the pylons/markers
- Failing to maintain the weights off the floor at the pull station
- Not maintaining proper technique in the sit-ups

In each case, the student is asked to re-do the portion of the test or replace the knocked down item and assessed a penalty.

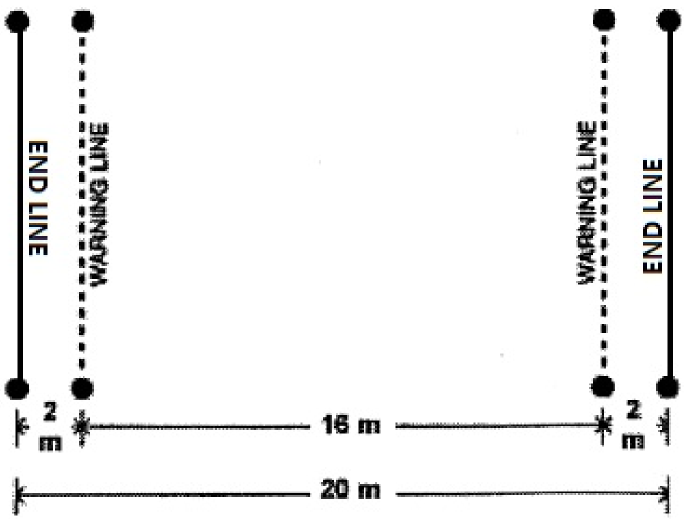
2. Shuttle Run (Beep Test)

The Shuttle Run, also known as the Leger 20m Shuttle Run or Beep Test, evaluates the student's aerobic fitness or work capability for physically demanding tasks on the job as well as everyday paramedic activities. In this test, the student runs back and forth between two marked lines over a 20m distance in time with an audio track (producing "beeps" as cues). The time permitted to cover the 20m at the beginning of the test requires a slow jog. As the test's stages progress, the time between the beeps shortens, requiring the student to run faster to keep up with the audio track's cues. The audio track will also inform the student which stage they have reached as the test progresses.

In each leg of the Shuttle Run, warning lines (placed 2m before each of the 20m end lines) must be reached before the permitted time elapses and the beep is heard. If the student fails to cross the warning line before the beep, the test will be terminated *(the professor may choose to provide a warning if the student is clearly learning the pace of the beeps)*. If the student crosses the warning line but fails to reach the end line before the beep, the professor will give the student a warning, and they must still reach the end line before returning to the other end line. If the student receives a warning but reaches the following end line before the next beep, the warnings are reset to zero. However, **if the student receives two consecutive warnings (i.e., the student crosses the warning line but does not reach the end line before the beep), the test will be terminated.** The test can also be terminated if the student chooses to stop.

For best performance, *it is crucial that students learn to run at the pace of the audio track – running quickly in the early stages of the test to get a longer "break" at the end lines typically leads to worse performance.* This is because their heart rate is slowly increasing to meet the exercise demand, yet the "breaks" keep initiating recovery and lowering it, leading the heart to constantly be playing catch up and creating a greater anaerobic response than required. This is why the aim should be to reach the end lines exactly when the beep is heard.

In the Cambrian College Paramedic program, **the Shuttle Run will be completed as a group, no more than 10 minutes after the last student has performed the PET Test.** In other words, students will perform the PET test, and 10 minutes after the last student has completed their PET Test, the entire group will complete the Shuttle Run together. Further details on grade attribution (e.g., weight of this test, or which stage to reach to obtain passing grades) can be found in the next section of the textbook.



3. Stair Chair and Stretcher Carry

The Stair Chair and Stretcher Carry test evaluates the student's muscular strength, endurance, and cardiorespiratory endurance, as well as their ability to communicate and coordinate their efforts with a partner. For both tests, the emphasis is placed on proper lifting technique and patient safety, and require the pair of students to complete each component in six minutes or less. The following describes the test along with test termination criteria, but further marking rubrics can be found in the next section of this textbook.

For the Stair Chair, the pair of students will carry a stairchair with a weighted manikin up and down four flights of stairs within six minutes and are permitted to place the stairchair down on the landings without penalty. Students may set-down the stairchair outside of the landings (no more than twice) but will incur a penalty on their marking rubric as a consequence. Students can choose who begins at the head/foot position of the stairchair but will switch positions halfway up. They can also choose starting positions upon descending but will again switch positions halfway down. For the Stretcher Carry (also known as Scoop), pairs of students will safely demonstrate the ability to lift a weighted manikin secured to a scoop stretcher and carry them up/down one flight of stairs, secure to 35, transport to an ambulance where the patient will be safely loaded and secured, then unloaded and returned to the starting position. Students may choose who lifts at each end but will remain at that end throughout the test. Students will have six minutes to complete this task.

Termination Criteria due to Unsafe Critical Errors

If the following errors are committed, the test will be terminated at the faculty's discretion due to safety concerns (i.e., preventing an injury), unsuccessful performance, etc.

- Gross unprofessionalism, such as profanity, disrespect, emotional display unbecoming of a paramedic, gross negligence of equipment use, etc.
- More than two controlled set-downs outside of the landings (i.e., in the flight of stairs). Two or less controlled set-downs will lead to mark deductions.
- Action causing patient harm (i.e., dropping a chair in an uncontrolled manner, tipped over, patient head striking wall or railing, carried head down, etc.)
- Delay causing patient harm – either test exceeds six minutes.
- Required spotter to maintain balance, prevent fall, or assist in any manner. This can include excessive use of a wall or railing for support.

PARA Fitness Test Standards

MARTIN DUBUC

Fitness Test Weight

The weight of each test (i.e., how much each test counts towards your final grade) will vary based on your current semester/course code in the Paramedic program. The table below indicates the weight of each test for each Paramedic Fitness course. ***Note – for Semester 3 PAR 1301, all three Fitness Tests must be successfully completed to pass the course, regardless of the attributed weight.***

Test / Semester	Semester 1 – FIT 1101	Semester 2 – FIT 1201	Semester 3 – PAR 1301
PET Test	10 %	10%	10.5%
Shuttle Run	10%	10%	10.5%
Stair Chair / Strecher Carry	40%	40%	31%

Fitness Test Performance Goals

The Paramedic Fitness courses are designed to build upon one another, beginning with the lowest performance goals in Semester 1 and the highest performance goals (equivalent to the City of Greater Sudbury's Emergency Services fitness standards) in Semester 3. This allows students to gradually develop their fitness throughout their time in the program so they may succeed during preceptorship and upon graduation. With this in mind, the Time and Stage standards (and attributable grades) become harder for the PET Test and Shuttle Run, respectively, while the weight of the manekin increases significantly for the Stairchair and Stretcher Carry. You will find a detailed breakdown of the Performance Goals for the PET and Shuttle Run in the table below:

PET TEST	1101	1201	1301		SHUTTLE	1101	1201	1301
Male	Grade	Grade	Grade		Male	Grade	Grade	Grade
≤ 2:35	100	100	100		10	100	100	100
2:36-2:40	95	95	95		9.5	95	95	95
2:41-2:45	92	92	92		9	90	90	90
2:46-2:49	90	90	90		8.5	85	85	85
2:50-2:54	88	88	88		8	80	80	80
2:55-2:59	85	85	85		7.5	78	78	78
3:00-3:04	82	82	82		7	75	75	75
3:05-3:09	80	80	80		6.5	70	70	70
3:10 -3:14	78	78	78		6	65	65	0
3:15-3:19	75	75	75		5.5	62.5	0	0
3:20-3:25	72	72	72		5	60	0	0
3:26-3:30	70	70	70		<5	0	0	0
3:31-3:45	60	0	0					
≥3:46	0	0	0					

PET TEST	1101	1201	1301		SHUTTLE	1101	1201	1301
Female	Grade	Grade	Grade		Female	Grade	Grade	Grade
≤2:50	100	100	100		8	100	100	100
2:50-2:54	95	95	95		7.5	90	90	90
2:55-2:59	92	92	92		7	80	80	80
3:00-3:04	90	90	90		6.5	70	70	70
3:05-3:09	85	85	85		6	65	65	0
3:10-3:14	82	82	82		5.5	62.5	0	0
3:15-3:19	80	80	80		5	60	0	0
3:20-3:25	75	75	75		<5	0	0	0
3:26-3:30	70	70	70					
3:31-3:45	60	0	0					
≥3:46	0	0	0					

Stairchair and Stretcher Carry manekin weight increments

The mannequin's weight will increase per semester/fitness course as follows

- Semester 1 – FIT 1101: **70kg (154 lbs)**
- Semester 2 – FIT 1201: **80kg (176 lbs)**

- Semester 3 – PAR 1301: **90kg (209 lbs)**

Beyond the need to avoid Unsafe Critical Errors, which would lead to test termination during the Stairchair and Stretcher Carry, performance will be assessed using the marking rubric below. As has been previously mentioned and made evident by the rubric, marks are emphasized for proper technique and patient safety.

Unsafe 0%	Marginal 70%	Competent 80%	Highly Competent 90%	Exceptional 100%
• Gross unprofessionalism • >2 set-downs • Harm to pt. • Delay >6 min for either lift • Spotter assistance to prevent fall/injury • Performance compromises safety of self, partner, or patient. Serious remediation required, unsuitable for progression.	• 2 controlled set-downs • Ongoing rough pt handling • Poor equip. knowledge • U/p to partner/pt. • Postural concerns/back exposed • Feet together -loud step kick • Body angled • Poor teamwork • Minimum standard, improvement recommended: suitable for supervised practice w/ some remediation.	• 1 controlled set down • Rough pt handling • Limited comm. w/ partner/pt. • Proper posture majority of time • Feet proper width majority • Body squared -mild kick • Understands equipment basics • Teamwork is present • Often to standard, ready for independent practice / progression with only minor concerns.	• Safe pt. handling • Adequate partner/pt comm. • Proper posture throughout • Feet apart • Full knowledge of equipment • Ongoing effective teamwork • Entire lift safe, controlled, and pt comfort ensured. • Occasionally exceeds standard, little improvement needed.	• Ongoing comm/thought for partner/pt. • Thorough knowledge and use of equipment • Teamwork is paramount • Lift is smooth, controlled, and efficient • Arms at 90 / strong posture entire lift • Consistently exceeds standards, positive example for others.

Extra text

CHAPTER 1 - HEALTHY BEHAVIORS AND WELLNESS

Objectives

1. Define the nine dimensions of wellness
2. Identify health problems in the United States
3. Identify the behaviors that promote wellness
4. Behavior Modification: how change occurs, barriers to change, and how to successfully overcome barriers and make lasting lifestyle changes

Terminology

- **Health** – Absence of Disease
- **Wellness** – optimal state of mind and body
- **Behavior Modification** – the alteration of behavioral patterns through specific techniques
- **Goal Setting** – the process of identifying something you want to accomplish and establishing measurable goals and timeframes
- **Barriers** – something that stands in the way of you achieving your goals

Why Study Wellness?

DAWN MARKELL AND DIANE PETERSON

As most college students do, you have probably set goals. Obviously, your individual goals differ from those of your fellow classmates, but everyone's goals share one common attribute: their intention to improve individual wellbeing. However, there are as many ideas about how to do that as there are individuals. Do your goals involve making more money, achieving better health, improving your relationships? Holistic wellness involves all those aspects of life and more. This chapter explains the importance of overall wellness, which is about more than being physically and mentally healthy, free from illness and disease. In fact, the study of wellness incorporates all aspects of life. Achieving overall wellness means living actively and fully. People in this state exude confidence, optimism, and self-efficacy; they have the energy reserves to do what needs to be done today and to plan for a better tomorrow. The most effective and transformative goals are those designed to achieve the highest level of personal wellness.

Dimensions of Wellness

DAWN MARKELL AND DIANE PETERSON

Wellness is a familiar term, but what is its true definition? Is it simply the absence of disease? This chapter will define all the components of holistic wellness and describe the factors that contribute to not only a person's physical and mental health, but also their ability to develop, thrive, succeed, enjoy life, and meet challenges head on with confidence and resolve.

To achieve this type of overall wellness, a person must be healthy in nine interconnected dimensions of wellness: physical, emotional, intellectual, spiritual, social, environmental, occupational, financial, and cultural. A description of each dimension follows.

The Nine Dimensions of Wellness

1. Physical Wellness

People who are physically well actively make healthy decisions on a daily basis. They eat a nutritionally balanced diet, they try to get an adequate amount of sleep, and they visit the doctor routinely. They make a habit of exercising three to five times per week, they have the ability to identify their personal needs and are aware of their body's limitations. They maintain positive interpersonal relationships and make healthy sexual decisions that are consistent with their personal values and beliefs.

2. Emotional Wellness

An emotionally well person successfully expresses and manages an entire range of feelings, including anger, doubt, hope, joy, desire, fear, and many others. People who are emotionally well maintain a high level of self-esteem. They have a positive body-image and the ability to regulate their feelings. They know where to seek support and help regarding their mental health, including but not limited to, seeking professional counseling services.

3. Intellectual Wellness

Those who enjoy intellectual wellness engage in lifelong learning. They seek knowledge and activities that further develop their critical thinking and heighten global awareness. They engage in activities associated with the arts, philosophy, and reasoning.

4. Spiritual Wellness

People who can be described as spiritually well have identified a core set of beliefs that guide their decision making, and other faith-based endeavors. While firm in their spiritual beliefs, they understand others may have a distinctly different set of guiding principles. They recognize the relationship between spirituality and identity in all individuals.

5. Social Wellness

A socially well person builds healthy relationships based on interdependence, trust, and respect. Those who are socially well have a keen awareness of the feelings of others. They develop a network of friends and co-workers who share a common purpose, and who provide support and validation.

6. Environmental Wellness

An environmentally well person appreciates the external cues and stimuli that an environment can provide. People who have achieved environmental wellness recognize the limits to controlling an environment and seek to understand the role an individual plays in the environment.

7. Occupational Wellness

An occupationally well person enjoys the pursuit of a career which is fulfilling on a variety of levels. This person finds satisfaction and enrichment in work, while always in pursuit of opportunities to reach the next level of professional success.

8. Financial Wellness

Those who are financially well are fully aware of their current financial state. They set long- and short-term goals regarding finances that will allow them to reach their personal goals and achieve self-defined financial success.

9. Cultural Wellness

Culturally well people are aware of their own cultural background, as well as the diversity and richness present in other cultural backgrounds. Cultural wellness implies understanding, awareness and intrinsic respect for aspects of diversity. A culturally well person acknowledges and accepts the impact of these aspects of diversity on sexual orientation, religion, gender, racial and ethnic backgrounds, age groups, and disabilities.

For more information on the nine dimensions of wellness, click on the link below:

Nine Dimensions of Wellness

To watch a video about the nine dimensions of wellness, click on the following link:

Video on the Nine Dimensions of Wellness

Health Problems in the United States

DAWN MARKELL AND DIANE PETERSON

Americans today experience health problems that people who lived 100 years ago did not encounter. What are the factors that account for these health problems that have arisen over the past 100 years?

Most health problems faced by people in the U.S. are chronic diseases that are preventable and caused by everyday choices and unhealthy lifestyles.

The link below provides more information about the leading causes of death in the United States:

Leading Causes of Death

To see a 2014 chart that shows the leading cause of death by age group, click on the link below:

Leading Cause of Death by Age Group

In the video linked below, you will learn about the determinants of health as outlined by Healthy People 2020. Healthy People 2020 is a federal advisory committee comprised of non-federal, independent subject matter experts who gather data and provide advice on how to promote health and prevent disease in America:

Healthy People 2020 and Determinants of Health

Behaviors That Promote Wellness

DAWN MARKELL AND DIANE PETERSON

Bad habits are hard to break, but choosing to eat healthier and exercise more provides benefits that go far beyond a more ideal body weight and shape. Being physically fit can stave off many of the diseases and medical conditions discussed in the previous section, including heart disease, the number 1 killer in America. Exercise reduces stress and eases depression. Healthier employees are also more productive. Being physically fit nurtures the mind, body, and spirit and is the cornerstone of wellness. The links below provide information about behaviors within your control that contribute to an improved quality of life and increased wellness.

Six Behaviors That Contribute to Wellness

Lifestyle Choices and Their Effect on Wellbeing

Behaviors that Contribute to Wellness Presentation

Behavior Modification

DAWN MARKELL AND DIANE PETERSON

Making permanent lifestyle changes is one of the greatest challenges a person can face. This section will explore how changes to behavior occur, the psychological barriers that hamper efforts to change, and tips for making lasting change.

How Changes in Behavior Occur

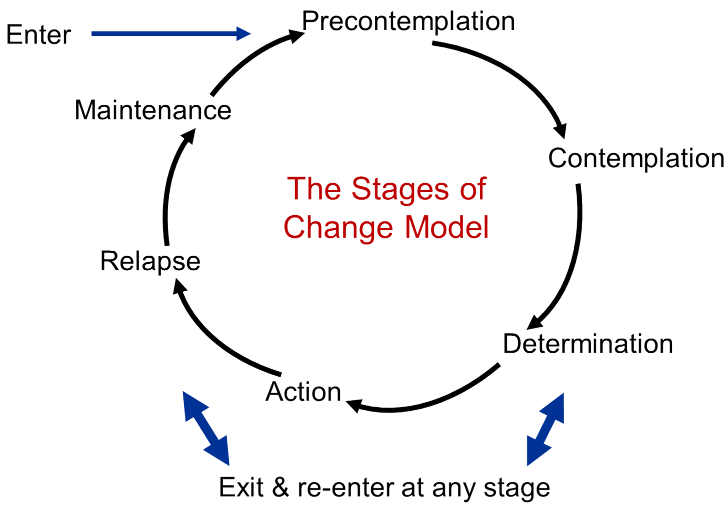
The Transtheoretical Model, also called the **Stages of Change Model**, was developed by James Prochaska and Carlo DiClemente in the late 1970s. Considered the dominant model for describing how behavior changes occur, it evolved through studies examining the experiences of smokers who quit on their own and comparing them with the experiences of those requiring further treatment. The goal of those studies was to understand why some people were capable of quitting on their own. It was determined that people quit smoking if they were ready to do so. Thus, the Transtheoretical Model (TTM) focuses on the decision-making of the individual and is a model of intentional change. The TTM operates on the assumption that people do not change behaviors quickly and decisively. Rather, change in behavior, especially habitual behavior, occurs continuously through a cyclical process. The TTM is not a theory but a model; different behavioral theories and constructs can be applied to various stages of the model where they may be most effective.

The TTM posits that individuals move through six stages of change: precontemplation, contemplation, preparation, action, maintenance, and termination. Termination was not part of the original model and is less often used in application of stages of change for health-related behaviors. For each stage of change, different intervention strategies are most effective at moving the person to the next stage of change and subsequently through the model to maintenance, the ideal stage of behavior.

Six Stages of Change:

Stage 1: Precontemplation

In this stage, people do not intend to take action in the foreseeable future (defined as within the next 6 months). People are often unaware that their behavior is problematic or produces negative consequences. People in this stage often underestimate the pros of changing behavior and place too much emphasis on the cons of changing behavior.



Stage 2: Contemplation

In this stage, people are intending to start the healthy behavior in the foreseeable future (defined as within the next 6 months). People recognize that their behavior may be problematic, and a more thoughtful and practical consideration of the pros and cons of changing the behavior takes place, with equal emphasis placed on both. Even with this recognition, people may still feel ambivalent toward changing their behavior.

Stage 3: Preparation (Determination)

In this stage, people are ready to take action within the next 30 days. People start to take small steps toward the behavior change, and they believe changing their behavior can lead to a healthier life.

Stage 4: Action

In this stage, people have recently changed their behavior (defined as within the last 6 months) and intend to keep moving forward with that behavior change. People may exhibit this by modifying their problem behavior or acquiring new healthy behaviors.

Stage 5: Maintenance

In this stage, people have sustained their behavior change for a while (defined as more than 6 months) and intend to maintain the behavior change going forward. People in this stage work to prevent relapse to earlier stages.

Stage 6: Termination

In this stage, people have no desire to return to their unhealthy behaviors and are sure they will not relapse. Since this is rarely reached, and people tend to stay in the maintenance stage, this stage is often not considered in health promotion programs.

Goal Setting:

One of the most effective tools for changing behavior is goal setting. The link below provides information on how to set goals effectively to achieve greater success in goal attainment.

Video on S.M.A.R.T. Goals

Lifestyle Modification Barriers

DAWN MARKELL AND DIANE PETERSON

Dr. James M. Olson, a psychology professor at the University of Western Ontario, London, has identified several psychological barriers that commonly prevent people from taking action, even when inaction poses a threat to their health. These barriers occur during 3 stages of behavior modification: admission of the problem, initial attempts to change, and long-term change as outlined below:

Barriers to Admission of the Problem

> The first step in lasting change is admitting a problem exists. People often fail to change behavior that poses a risk to their health because they deny a risk exists, trivialize their personal risk, feel invulnerable, make a faulty conceptualization, (i.e., they attribute early warning signs to a benign cause), or experience debilitating emotions when contemplating preventative measures.

Barriers to Initial Attempts to Change

> At this stage, people acknowledge the need to change but struggle to accomplish their goals. This failure is a result of lack of knowledge, low self-efficacy (the belief in one's own ability to succeed at change), and dysfunctional attitudes.

Barriers to Long-term Change

> Just because a person has experienced success in changing a behavior, that doesn't mean the change is permanent. Barriers to long-term change include cognitive and motivational drift (diminishing enthusiasm for the need to change), lack of perceived improvement, lack of social support, and lapses.

To read more about these barriers to change, including strategies for overcoming these barriers, read Dr. Olson's article linked below:

Psychological Barriers to Behavior Change

A presentation on overcoming barriers to change by the National Institute for Health and Clinical Excellence (NHS) is linked below:

Overcoming Barriers to Change

Fostering Wellness in Your Life

DAWN MARKELL AND DIANE PETERSON

You are once again feeling motivated to eat better, exercise more, drink less caffeine or make any number of the positive lifestyle changes you have been telling yourself you want to make. You have tried before—probably declaring another attempt as a New Year's resolution—but without experiencing much success. Making a lifestyle change is challenging, especially when you want to transform many things at once. This time, think of those changes not as a resolution, but as an evolution.

Lifestyle changes are a process that take time and require support. Once you are ready to make a change, the difficult part is committing and following through. So do your research and make a plan that will prepare you for success. Careful planning means setting small goals and taking things one step at a time.

Here are five tips from the American Psychological Association (APA) that will assist you in making lasting, positive lifestyle and behavior changes:

Make a plan that will stick.

Your plan is a map that will guide you on this journey of change. You can even think of it as an adventure. When making your plan, be specific. Want to exercise more? Detail the time of day when you can take walks and how long you will walk. Write everything down, and ask yourself if you are confident that these activities and goals are realistic for you. If not, start with smaller steps. Post your plan where you will most often see it as a reminder.

Start small.

After you've identified realistic short-term and long-term goals, break down your goals into small, manageable steps that are specifically defined and can be measured. Is your long-term goal to lose 20 pounds within the next five months? A good weekly goal would be to lose one pound a week. If you would like to eat healthier, consider as a goal for the week replacing dessert with a healthier option, like fruit or yogurt. At the end of the week, you will feel successful knowing you met your goal.

Change one behavior at a time.

Unhealthy behaviors develop over the course of time, so replacing unhealthy behaviors with healthy ones requires time. Many people run into problems when they try to change too much too fast. To improve your success, focus on one goal or change at a time. As new healthy behaviors become a habit, try to add another goal that works toward the overall change you are striving for.

Involve a buddy.

Whether it be a friend, co-worker or family member, someone else on your journey will keep you motivated and accountable. Perhaps it can be someone who will go to the gym with you or someone who is also trying to stop smoking. Talk about what you are doing. Consider joining a support group. Having someone with whom to share your struggles and successes makes the work easier and the mission less intimidating.

Ask for support.

Accepting help from those who care about you and will listen strengthens your resilience and commitment. If you feel overwhelmed or unable to meet your goals on your own, consider seeking help from a psychologist. Psychologists are uniquely trained to understand the connection between the mind and body, as well as the factors that promote behavior change. Asking for help does not mean a lifetime of therapy; even just a few sessions can help you examine and set attainable goals or address the emotional issues that may be getting in your way.

Start with "Why?"

DAWN MARKELL AND DIANE PETERSON

Making changes in habitual behavior requires a deep and abiding belief that change is needed. Your desire to change may be motivated by personal goals, or it may be the result of the impact your improved wellness will have on those you love. Nietzsche said, "He who has a strong enough *why* can bear almost any *how*."

Once you have a compelling reason to change, develop a plan and commit to that plan. If you experience a moment of weakness, do not waste time on self-condemnation. Revisit your compelling reason and reaffirm your commitment to change. The health, peace, and sense of wellbeing inherent in the highest level of your own personal wellness is more than worth the effort required to change

CHAPTER 2 - FITNESS PRINCIPLES

Objectives

1. Describe the origins of exercise
2. Define physical activity and exercise
3. Discuss principles of adaptation to stress
4. Provide guidelines for creating a successful fitness program
5. Identify safety concerns

Terminology

- **Physical activity –** any activity that requires skeletal muscle and requires energy aimed at improving health.
- **Exercise –** a subset of physical activity that is planned and structured aimed at improving fitness.
- **Health related components of fitness –** types of activities dedicated to improving physical fitness categorized as cardiorespiratory endurance, muscular strength and endurance, flexibility, and body composition.
- **Skills related components of fitness –** types of activities dedicated to improving physical skills categorized as speed, agility, coordination, balance, power, and reaction time.
- **Principles of adaptations to stress –** guidelines related to managing the application of stress during physical activity/exercise.
- **Overload Principle –** a principle of adaptation to stress

suggesting the amount of stress applied during exercise must exceed a threshold level to stimulate adaptation.

- **Volume –** the term used to describe "how much" stress is being applied by combining the duration and frequency of exercise.
- **Progression principle –** a principle relating to how much additional stress that can safely be introduced to gradually improve fitness without risking injury or overuse.
- **Specificity –** the principle of stress suggesting activities should be closely centered around the primary outcome goal, i.e. train the way you want to adapt.
- **Reversibility –** the principle that adaptations to stress can be lost over time if training is modified or stopped.
- **Principle of rest and recovery –** the concept that adaptation not only requires overload but also requires rest to avoid overstressing the body.
- **Periodization –** a method of organizing workouts into blocks or periods. These cycles consist of work/stress periods and rest periods.
- **Overtraining syndrome –** a condition of chronic stress from physical activity affecting the physical and psychological states of an individual or athlete.
- **Detraining –** the act of no longer training at all or decreasing the amount of training.

Exercise: Not a Passing Fad

DAWN MARKELL AND DIANE PETERSON

The benefits of physical activity and exercise are universally recognized—and have been for far longer than one might think. Our Paleolithic ancestors regularly engaged in physical activity to survive. Rather than chasing after a soccer ball to win a game or taking a leisurely stroll down a tree-lined path, they "worked out" by chasing after their next meal. For them, no exercise meant no food. How's that for a health benefit!

With the advent of sedentary agriculture some 10,000 years ago, that same level of peak performance was no longer necessary. As our ancestors continued to devise more advanced means of acquiring food, physical activity declined. It wasn't until the fourth century BCE, that the Greek physician Herodicus, recognized the importance of being physically active outside of a hunter-gatherer society. He practiced gymnastic medicine, a branch of Greek medicine that relied on vigorous exercise as a treatment. During that same time period, Hippocrates, who is often referred to as the Father of Modern Medicine, asserted, "If we could give every individual the right amount of nourishment and exercise, not too little and not too much, we would have found the safest way to health." In the 12 century CE, the Jewish philosopher Rabbi Moses ben Maimon, a physician to the Sultan of Egypt, stated, "Anyone who lives a sedentary life and does not exercise, even if he eats good foods and takes care of himself according to proper medical principles, all his days will be painful ones and his strength will wane." The 15th century theologian and scholar Robert Burton went so far as to declare that *not* exercising, or "idleness" as he referred to it in his widely read tome, *The Anatomy of Melancholy*, was the "bane of body and mind." Burton also warned that the lack of exercise was the sole cause of melancholy (the name given depression at that time) and “many other maladies.” Burton claimed that idleness was one of the seven deadly sins, as well as “the nurse of naughtiness,” and the “chief author of mischief.” For Burton, exercise was not only essential for good health, but a means of avoiding eternal damnation.

By the 16th century, the benefits of exercise were widely accepted, at least among the wealthy and the educated, who had access to leisure. During this time period, H. Mercuralis defined exercise as “the deliberate and planned movement of the human frame, accompanied by breathlessness, and undertaken for the sake of health or fitness.” This definition is still widely used today.

Beyond the physical health benefits, there are affective benefits associated with group games and activities. Ancient Mayans organized the first team game called the Ball Game. It consisted of two teams trying to get a ball through a hoop mounted approximately 23 feet on a wall. The rules were to get the ball through the hoop using certain parts of the body. In some cases the captain of the losing team gave himself as a human sacrifice to the winning team, an act that was believed by the Mayans to be a vital part of prosperity.

American Indians are thought to have founded the modern game of lacrosse, as well as other stick games. Lacrosse, which received its name from French settlers, was more than a form of recreation. It was a cultural event used to settle disputes between tribes.

Figure 1. Ball Players. George Catlin. Date unknown.

The outcome of the game, as well as the choosing of teams, was thought to be controlled supernaturally. As such, game venues and equipment were prepared ritualistically.

From Ancient History to Modern Times

In retrospect, the perceived benefits of exercise have changed very little since Herodicus or the American Indians. Mounting research supports historical assertions that exercise is vital to sustaining health and quality of life. Culturally, sports play a huge role in growth and development of youth and adults. Physically, there is indisputable evidence that regular exercise promotes healthy functioning of the brain, heart, and the skeletal and muscular systems. Exercise also reduces risk for chronic diseases, such as cancer, diabetes, and obesity. Regular exercise can even improve emotional health and overall wellbeing.

What are Physical Activity and Exercise?

DAWN MARKELL AND DIANE PETERSON

Physical activity is defined as any movement carried out by skeletal muscle that requires energy and is focused on building health. Health benefits include improved blood pressure, blood-lipid profile, and heart health. Acceptable physical activity includes yard work, house cleaning, walking the dog, or taking the stairs instead of the elevator. Physical activity does not have to be done all it once. It can be accumulated through various activities throughout the day. Although typing on a phone or laptop or playing video games does involve skeletal muscle and requires a minimal amount of energy, the amount required is not sufficient to improve health.

Despite the common knowledge that physical activity is tremendously beneficial to one's health, rates of activity among Americans continue to be below what is needed. According to the Center for Disease Control (CDC), only 1 in 5 (21%) of American adults meet the recommended physical activity guidelines from the Surgeon General. Less than 3 in 10 high school students get 60 minutes or more of physical activity per day. Non-Hispanic whites (26%) are more active than their Hispanic (16%) and Black counterparts (18%) as is the case for males (54%) and females (46%). Those with more education and those whose household income is higher than poverty level are more likely to be physically active.

The word *exercise*, although often used interchangeably with the phrase *physical activity*, denotes a sub-category of physical activity. **Exercise** is a planned, structured, and repetitive movement pattern intended to improve fitness. As a positive side-effect, it significantly improves health as well. Fitness improvements include the heart's ability to pump blood, increased muscle size, and improved flexibility.

Components of Health-Related Fitness

DAWN MARKELL; DIANE PETERSON; AND AMANDA SHELTON

In order to carry out daily activities without being physically overwhelmed, a minimal level of fitness is required. To perform daily activities without fatigue, it is necessary to maintain health in five areas: cardiorespiratory endurance, muscular strength and endurance, flexibility, and body composition. These five areas are called the components of health-related fitness. Development of these areas will improve your quality of life, reduce your risk of chronic disease, and optimize your health and well-being. Each of these 5 areas will be explored in depth at a later time. Below is a brief description of each.

1. **Cardiorespiratory endurance** is the ability to carry out prolonged, large muscle, dynamic movements at a moderate to high level of intensity. This relates to your heart's ability to pump blood and your lungs' ability to take in oxygen.

2. **Muscular strength** is the ability of the muscles to exert force over a single or maximal effort.

3. **Muscular endurance** is the ability to exert a force over a period of time or repetitions.

4. **Flexibility** is the ability to move your joints through a full range of motion.

5. **Body Composition** is the relative amount of fat mass to fat-free mass.

As previously stated, these areas are significant in that they influence your quality of life and overall health and wellness.

Skill-Related Components of Fitness

In addition to the 5 health-related components, there are 6 skill-related components that assist in developing optimal fitness: speed, agility, coordination, balance, power, and reaction time. Although important, these areas do not directly affect a person's health. A person's ability to perform ladder drills (also known as agility drills) is not related to his/her long term heart health. However, coordination of muscle movements may be helpful in developing muscular strength through resistance training. As such, they may indirectly affect the 5 areas associated with health-related fitness. Skill-related components are more often associated with sports performance and skill development.

Dawn Markell & Diane Peterson, Health and Fitness for Life. MHCC Library Press. Sept 4, 2019. https://mhcc.pressbooks.pub/hpe295

Amanda Shelton, *Introduction to Exercise Science for Fitness Professionals*. MHCC Library Press.

1. **Speed** is the relationship between time an distance or the rate at which someone can travel over a given distance.
2. **Agility** relates to speed but in more-so to change of direction and position of the body while maintaining control throughout the movement.
3. **Coordination** involves the efficiency of movements in relation to various aspects of the body working together to create smooth and efficient movement.
4. **Balance** is the ability to maintain your body's position, which may occur at rest or in motion.
5. **Power** is a type of fitness that connects *muscular strength* or *muscular endurance*, two of our health-related components, to *speed*, one of our other skill-related components, by seeing

how fast you can exert a force over a single or maximal effort or repeatedly over time or repetitions.

6. **Reaction Time** refers to the ability of someone to act quickly in response to some type of stimuli (auditory, visual, kinesthetic, etc.)

As we look at how we want to develop and facilitate a well-rounded fitness program, we will look at how these skill-related components of fitness can be coordinated specifically to different types of training. Often times when developing a training program, we will combine various health-related and skill-related components of fitness into a single activity, drill, or programming.

Principles of Adaptation to Stress

DAWN MARKELL AND DIANE PETERSON

The human body adapts well when exposed to stress. The term *stress*, within the context of exercise, is defined as an exertion above the normal, everyday functioning. The specific activities that result in stress vary for each individual and depend on a person's level of fitness. For example, a secretary who sits at a desk all day may push his/her cardiorespiratory system to its limits simply by walking up several flights of stairs. For an avid runner, resistance training may expose the runner's muscles to muscular contractions the athlete is not accustomed to feeling. Although stress is relative to each individual, there are guiding principles in exercise that can help individuals manage how much stress they experience to avoid injury and optimize their body's capacity to adapt. Knowing a little about these principles provides valuable insights needed for organizing an effective fitness plan.

Overload Principle

Consider the old saying, "No pain, no gain." Does exercise really have to be painful, as this adage implies, to be beneficial? Absolutely not. If that were true, exercise would be a lot less enjoyable. Perhaps a better way to relay the same message would be to say that improvements are driven by stress. Physical stress, such as walking at a brisk pace or jogging, places increased stress on the regulatory systems that manage increased heart rate and blood pressure, increased energy production, increased breathing, and even increased sweating for temperature regulation. As these subsequent adaptations occur, the stress previously experienced during the same activity, feels less stressful in future sessions. As a result of the adaptation, more stress must be applied to the system in order to stimulate improvements, a principle known as the **overload principle**.

For example, a beginning weightlifter performs squats with 10 repetitions at 50 pounds. After 2 weeks of lifting this weight, the lifter notices the 50 pounds feels easier during the lift and afterwards causes less fatigue. The lifter adds 10 pounds and continues with the newly established stress of 60 pounds. The lifter will continue to get stronger until his/her maximum capacity has been reached, or the stress stays the same, at which point the lifter's strength will simply plateau. This same principle can be applied, not only to gain muscular strength, but also to gain flexibility, muscular endurance, and cardiorespiratory endurance.

FITT

DAWN MARKELL AND DIANE PETERSON

In exercise, the amount of stress placed on the body can be controlled by four variables: **F**requency, **I**ntensity, **T**ime (duration), and **T**ype, better known as FITT. The FITT principle, as outlined by the American College of Sports Medicine (ACSM) falls under the larger principle of overload.

Frequency and Time

Each variable can be used independently or in combination with other variables to impose new stress and stimulate adaptation. Such is the case for frequency and time.

Frequency relates to how often exercises are performed over a period of time. In most cases, the number of walking or jogging sessions would be determined over the course of a week. A beginner may determine that 2–3 exercise sessions a week are sufficient enough to stimulate improvements. On the other hand, a seasoned veteran may find that 2–3 days is not enough to adequately stress the system. According to the overload principle, as fitness improves, so must the stress to ensure continued gains and to avoid plateauing.

The duration of exercise, or time, also contributes to the amount of stress experienced during a workout. Certainly, a 30-minute brisk walk is less stressful on the body than a 4-hour marathon.

Although independent of one another, frequency and time are often combined into the blanket term, **volume**. The idea is that volume more accurately reflects the amount of stress experienced. This can be connected to the **progression principle**. For example, when attempting to create a jogging plan, you may organize 2 weeks like this:

- Week 1: three days a week at 30 minutes per session
- Week 2: four days a week at 45 minutes per session

At first glance, this might appear to be a good progression of frequency and time. However, when calculated in terms of volume, the aggressive nature of the progression is revealed. In week 1, three days at 30 minutes per session equals 90 minutes of total exercise. In week two, this amount was doubled with four days at 45 minutes, equaling 180 minutes of total exercise. Doing too much, too soon, will almost certainly lead to burnout, severe fatigue, and injury. The progression principle relates to an optimal overload of the body by finding an amount that will drive adaptation without compromising safety.

Intensity

Intensity, the degree of difficulty at which the exercise is carried out, is the most important variable of FITT. More than any of the other components, intensity drives adaptation. Because of its importance, it is imperative for those beginning a fitness program to quantify intensity, as opposed to estimating it as hard, easy, or somewhere in between. Not only will this numeric value provide a better understanding of the effort level during the exercise session, but it will also help in designing sessions that accommodate individual goals.

How then can intensity be measured? Heart rate is one of the best ways to measure a person's effort level for cardiorespiratory fitness. Using a percentage of maximum lifting capacity would be the measure used for resistance training.

Type of Exercise

Simply put, the type of exercise performed should reflect a person's goals. In cardiorespiratory fitness, the objective of the exercise is to stimulate the cardiorespiratory system. Other activities that accomplish the same objective include swimming, biking, dancing, cross country skiing, aerobic classes, and much more. As such, these activities can be used to build lung capacity and improve cellular and heart function.

Specificity

DAWN MARKELL AND DIANE PETERSON

The more specific the exercise to individual training goals, the better. While vigorous ballroom dancing will certainly help develop the cardiorespiratory system, it will unlikely improve a person's 10k time. To improve performance in a 10k, athletes spend the majority of their time training by running, as they will have to do in the actual 10k. Cyclists training for the Tour de France, spend up to six hours a day in the saddle, peddling feverishly. These athletes know the importance of training the way they want their body to adapt. This concept, called the **principle of specificity**, should be taken into consideration when creating a training plan.

In this discussion of the principle of specificity, a few additional items should be considered. Stress, as it relates to exercise, is very specific. There are multiple types of stress. The three main stressors are metabolic stress, force stress, and environmental stress. Keep in mind, the body will adapt based on the type of stress being placed on it.

Metabolic stress results from exercise sessions when the energy systems of the body are taxed. For example, sprinting short distances requires near maximum intensity and requires energy (ATP) to be produced primarily through anaerobic pathways, that is, pathways not requiring oxygen to produce ATP. Anaerobic energy production can only be supported for a very limited time (10 seconds to 2 minutes). However, distance running at steady paces requires aerobic energy production, which can last for hours. As a result, the training strategy for the distance runner must be different than the training plan of a sprinter, so the energy systems will adequately adapt.

Likewise, **force stress** accounts for the amount of force required during an activity. In weightlifting, significant force production is required to lift heavy loads. The type of muscles being developed, fast-twitch muscle fibers, must be recruited to support the activity. In walking and jogging, the forces being absorbed come from the body weight combined with forward momentum. Slow twitch fibers, which are unable to generate as much force as the fast twitch fibers, are the type of muscle fibers primarily recruited in this activity. Because the force requirements differ, the training strategies must also vary to develop the right kind of musculature.

Environmental stress, such as exercising in the heat, places a tremendous amount of stress on the thermoregulatory systems. As an adaptation to the heat, the amount of sweating increases as does plasma volume, making it much easier to keep the body at a normal temperature during exercise. The only way to adapt is through heat exposure, which can take days to weeks to properly adapt.

In summary, to improve performance, being specific in your training, or training the way you want to adapt, is paramount.

Rest, Recovery, and Periodization

DAWN MARKELL AND DIANE PETERSON

For hundreds of years, athletes have been challenged to balance their exercise efforts with performance improvements and adequate rest. The **principle of rest and recovery (or principle of recuperation)** suggests that rest and recovery from the stress of exercise must take place in proportionate amounts to avoid too much stress. One systematic approach to rest and recovery has led exercise scientists and athletes alike to divide the progressive fitness training phases into blocks, or periods. As a result, optimal rest and recovery can be achieved without overstressing the athlete. This training principle, called **periodization**, is especially important to serious athletes but can be applied to most exercise plans as well. The principle of periodization suggests that training plans incorporate phases of stress followed by phases of rest.

Training phases can be organized on a daily, weekly, monthly, and even multi-annual cycles, called micro-, meso-, and macrocycles, respectively. An example of this might be:
[table id=1 /]
As this table shows, the volume and intensity changes from week 1 to week 3. But, in week 4, the volume and intensity drops significantly to accommodate a designated rest week. If the chart were continued, weeks 5-7 would be “stress” weeks and week 8 would be another rest week. This pattern could be followed for several months.

Without periodization, the stress from exercise would continue indefinitely eventually leading to fatigue, possible injury, and even a condition known as **overtraining syndrome**. Overtraining syndrome is not well understood. However, experts agree that a decline in performance resulting from psychological and physiological factors cannot be fixed by a few days' rest. Instead, weeks, months, and sometimes even years are required to overcome the symptoms of overtraining syndrome. Symptoms include the following: weight loss, loss of motivation, inability to concentrate or focus, feelings of depression, lack of enjoyment in activities normally considered enjoyable, sleep disturbances, change in appetite.

Reversibility

DAWN MARKELL AND DIANE PETERSON

Chronic adaptations are not permanent. As the saying goes, “Use it or lose it.”

The **principle of reversibility** suggests that activity must continue at the same level to keep the same level of adaptation. As activity declines, called **detraining**, adaptations will recede.

In cardiorespiratory endurance, key areas, such as VO_{2max}, stroke volume, and cardiac output all declined with detraining while submaximal heat rate increased. In one study, trained subjects were given bed rest for 20 days. At the end of the bed rest phase, VO_{2max} had fallen by 27% and stroke volume and cardiac output had fallen by 25%. The most well-trained subjects in the study had to train for nearly 40 days following bed rest to get back into pre-rest condition. In a study of collegiate swimmers, lactic acid in the blood after a 2-minute swim more than doubled after 4 weeks of detraining, showing the ability to buffer lactic acid was dramatically affected.

Not only is endurance training affected, but muscular strength, muscular endurance, and flexibility all show similar results after a period of detraining.

Training Volume

AMANDA SHELTON

Exercise volume is a valuable component of a fitness training program to consider as you start to look at the bigger picture of physical activity and exercise. **Training volume** looks at the overall load of activity you complete within a given time frame. Training volume can be examined based on a given exercise, a day of activity, across a week's activities, or a full training cycle. The type of training you are participating in will change how you can measure and define training volume on a small scale.

When we explore volume and identify ways to measure volume, we can identify a few specific common units in the literature. Typically for aerobic activities, volume is measured as: kilocalories per week ($kcal \cdot wk^{-1}$), MET-minutes per week ($MET \cdot min \cdot wk^{-1}$), or MET-hours per week ($MET \cdot h \cdot wk^{-1}$). This volume would be measure based on the relationship between the total time of activity and the intensity of the activity over the course of the week. This measure can change over time as it is also influenced across a lifespan or training cycle based on individual adaptations to exercise. That is to say that over time as you are following a running training program, your training load may be the same but you can travel a further distance utilizing the same amount of energy as your body adapts to maintain a lower intensity at the same speed (or the same intensity at a faster speed).

If you are participating in muscular strength based activity, instead of using a kilocalories per week based measure, you may instead want to use a measure of total weight moved by taking the (sets · repetitions · weight used).

Training Volume Examples

If you were performing a dumbbell biceps curl for 3 sets of 10 repetitions with 25 pounds in each hand (50 total pounds), that means you had a **total daily exercise volume** of:

- (3 sets · 10 reps · 50 pounds) = 1,500 pounds for your biceps curls

If you performed dumbbell biceps curls twice per week within your program, that means your **total weekly exercise volume** of biceps curls would be 3,000 pounds.

When it comes to training volume, the common question that arises is – **how much is enough?** and **what is too much?** Finding this balance is an essential component of developing an individualized, progressive, and meaningful program.

How much is enough?[8]

When looking specifically at health related benefits, we see large scale studies that are identifying the rate of 1000 kcal · wk^{-1} through a combination of moderate and vigorous intensity activity are related to lowered risk of cardiovascular disease and premature mortality. We see this relating directly to the recommendations listed in the *Physical Activity Guidelines for Americans*, American

Heart Association (AHA), and American College of Sports Medicine (ACSM) recommendations discussed in the earlier.

What is too much?[8]

Typically, when the conversation of "too much" exercise comes into play, it is not necessarily the actual participation in exercise that is the root cause of the problem or even the individual's total training volume. "Too much" often relates more directly to the *type of exercise* being performed and *the intensity of that exercise*. Highly strenuous activity, particularly that the individual is not accustomed to, is often the cause of potential injury/illness related to exercise which include coronary heart disease (including acute myocardial infarction and sudden cardiac death) and musculoskeletal complications (such as soft tissue injuries).

Higher intensity activities such as running, competitive sports, and exercise that your body is not physically accustomed to increase the risk of potential complications including musculoskeletal injury, muscle soreness, and a loss of strength (attrition). In extreme cases it can lead to a condition called **rhabdomyolysis** (or "rhabdo") which is a condition where the damage to the skeletal muscles is so great that the tissue begins to break down and impact vital organs in the body which can occasionally lead to kidney failure, cardiac arrhythmias, and in rare cases, death. While the occurrence of rhabdomyolysis is very rare, it can occur in both experience and novice individuals who participate in eccentric exercise that they are not accustomed to, particularly in hot environments.

Low- to moderate- intensity activities have a relatively low risk of complication associated with participation. For this reason, the development of initial fitness and maintaining good balance within a program of low- to moderate-intensity and manageable higher intensity activities are key to identifying a starting point for total volume and progression through a fitness program.

Carol Garber, Bryan Blissmer, Michael Deschenes, et al. Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory, Musculoskeletal, and Neuromotor Fitness in Apparently Healthy Adults. *Medicine & Science in Sports & Exercise*: July 2011, 43(7), 1334-1359. doi: 10.1249/MSS.0b013e318213fefb

Individual Differences

DAWN MARKELL AND DIANE PETERSON

While the principles of adaptation to stress can be applied to everyone, not everyone responds to stress in the same way. In the HERITAGE Family study, families of 5 (father, mother, and 3 children) participated in a training program for 20 weeks. They exercised 3 times per week, at 75% of their VO_{2max}, increasing their time to 50 minutes by the end of week 14. By the end of the study, a wide variation in responses to the same exercise regimen was seen by individuals and families. Those who saw the most improvements saw similar percentage improvements across the family and vice versa. Along with other studies, this has led researchers to believe individual differences in exercise response are genetic. Some experts estimate genes to contribute as much as 47% to the outcome of training.

In addition to genes, other factors can affect the degree of adaptation, such as a person's age, gender, and training status at the start of a program. As one might expect, rapid improvement is experienced by those with a background that includes less training, whereas those who are well trained improve at a slower rate.

Activity Guidelines

Below is a link to the physical activity guidelines provided by the US Department of Health and Human Services. As you review these recommendations, notice how closely they follow the FITT pattern described earlier in the chapter.

NIH Recommendations for Physical Activity

Fitness Guidelines

The recommendations linked above pertain to physical activity only. While they can be applied to fitness, more specific guidelines have been set to develop fitness. As stated previously, physical activity is aimed at improving health; exercise is aimed at improving health and fitness. These guidelines will be referenced often as each health-related component of fitness is discussed.

Creating a Successful Fitness Plan

DAWN MARKELL AND DIANE PETERSON

Often, the hardest step in beginning a new routine is simply starting the new routine. Old habits, insufficient motivation, lack of support, and time constraints all represent common challenges when attempting to begin a new exercise program. Success, in this case, is measured by a person's ability to consistently participate in a fitness program and reap the fitness benefits associated with a long-term commitment.

Think Lifestyle

Beginning a fitness program is a daunting task. To illustrate the concept of lifestyle, consider attendance at fitness centers during the month of January. Attendance increases dramatically, driven by the number 1 New Year's resolution in America: losing weight. Unfortunately, as time marches on, most of these new converts do not. By some estimates, as many as 80% have stopped coming by the second week in February. As February and March approach, attendance continues to decline, eventually falling back to pre-January levels.

Why does this occur? Why aren't these new customers able to persist and achieve their goal of a healthier, leaner body? One possible explanation: patrons fail to view their fitness program as a lifestyle. The beginning of a new year inspires people to make resolutions, set goals, as they envision a new and improved version of themselves. Unfortunately, most of them expect this transformation to occur in a short period of time. When this does not happen, they become discouraged and give up.

Returning to teen level weight and/or fitness may be an alluring, well-intended goal, but one that is simply unrealistic for most adults. The physical demands and time constraints of adulthood must be taken into consideration for any fitness program to be successful. Otherwise, any new fitness program will soon be abandoned and dreams of physical perfection fade, at least until next January.

Like any other lifestyle habit, optimal health and fitness do not occur overnight. Time and, more importantly, consistency, drive successful health and fitness outcomes. The very term *lifestyle* refers to changes that are long term and become incorporated into a person's daily routine. Unlike many fad diets and quick fixes advertised on television, successful lifestyle changes are also balanced and reasonable. They do not leave you feeling depressed and deprived after a few days. Find a balance between what you want to achieve and what you are realistically able to do. Finally, you must do more than simply change your behaviors. You must also modify your mental perception to promote long-term health. Find a compelling reason for incorporating healthier behaviors into your daily routine.

The steps below will guide you through this process. Before beginning a fitness program, you should understand the safety concerns associated with exercise.

Safety First: Assessing Your Risk

The physical challenges of beginning a new exercise program increase the risk of injury, illness, or even death. Results from various studies suggest vigorous activity increases the risk of acute cardiac heart attacks and/or sudden cardiac death. While that cautionary information appears contradictory to the previously identified benefits of exercise, the long-term benefits of exercise unequivocally outweigh its risks. In active young adults (younger than 35), incidence of cardiac events are still rare, affecting 1 in 133,000 in men and 1 in 769,000 in women. In older individuals, 1 in 18,000 experience a cardiac event.

Of those rare cardiac incidents that do occur, the presence of preexisting heart disease is the common thread, specifically, atherosclerosis. **Atherosclerosis** causes arteries to harden and become clogged with plaque, which can break apart, move to other parts of the body, and clog smaller blood vessels. As such, it is important to screen individuals for risk factors associated with heart disease before they begin an exercise program.

The American College of Sports Medicine recommends a thorough pre-screening to identify any risk of heart disease. The 7 major risk factors associated with increased risk of heart disease are identified below.

1. **Family history** – Having a father or first-degree male relative who has experienced a cardiac event before the age of 55, or a mother or first-degree female relative who has experienced a cardiac event before age 65, could indicate a genetic predisposition to heart disease.
2. **Cigarette smoking** – The risk of heart disease is increased for those who smoke or have quit in the past 6 months.
3. **Hypertension** – Having blood pressure at or above 140 mm/HG systolic, 90 mm/Hg diastolic is associated with increased risk of heart disease.
4. **Dyslipidemia** – Having cholesterol levels that exceed recommendations (LDL above 130 mg/dL, HDL below 40 mg/dL), or total cholesterol of greater than 200 mg/dL increases risk.
5. **Impaired fasting glucose (diabetes)** – Blood sugar should be

within the recommended ranges.

6. **Obesity** – Body mass index greater than 30, waist circumference of larger than 102 cm (40”) for men and larger than 88 cm (34.5”) for women, or waist to hip ratio of greater than 0.95 for men, or greater than 0.86 for women increases risk of heart disease.
7. **Sedentary lifestyle** – Persons not meeting physical activity guidelines set by US Surgeon General’s Report have an increased risk of heart disease.

In addition to identifying your risk factors, you should also complete a Physical Activity Readiness Questionnaire (PAR-Q) before beginning an exercise program. The PAR-Q asks yes or no questions about symptoms associated with heart disease. Based on your responses on the PAR-Q, you will be placed into a risk category: low, moderate, high.

- **Low risk persons** include men younger than 45, and women younger than 55, who answer no to all of the PAR-Q questions and have one or no risk factors. Although further screening is a good idea, such as getting physician’s approval, it isn’t necessary.
- **Moderate risk persons** are men of or greater than 45, women 55 or those who have two or more risk factors. Because of the connection between cardiac disease, the seven risk factors, and risk during exercise, it is recommended you get a physician’s approval before beginning an exercise program.
- **High risk persons** answer yes to one or more of the questions on the PAR-Q. Physician’s approval is required before beginning a program.

Once you have determined your ability to safely exercise, you are ready to take the next steps in beginning your program. Additional safety concerns, such as where you walk and jog, how to be safe during your workout, and environmental conditions, will be addressed at a later time.

As you review the remaining steps, a simple analogy may help to better conceptualize the process.

Imagine you are looking at a map because you are traveling to a particular location and you would like to determine the best route for your journey. To get there, you must first determine your current location and then find the roads that will take you to your desired location. You must also consider roads that will present the least amount of resistance, provide a reasonably direct route, and do not contain any safety hazards along the way. Of course, planning the trip, while extremely important, is only the first step. To arrive at your destination, you must actually drive the route, monitoring your car for fuel and/or malfunction, and be prepared to reroute should obstacles arise.

Preparing yourself for an exercise program and ultimately, adopting a healthier lifestyle, requires similar preparation. You will need to complete the following steps:

1. **Assess your current fitness:** Where are you on the map?
2. **Set goals:** What is your destination's location?
3. **Create a plan:** What route will you choose?
4. **Follow through:** Start driving!

Assess Your Condition

To adequately prepare, you will need to take a hard look at your current level of fitness. With multiple methods of assessing your fitness, you should select the one that most closely applies to you. Obtaining a good estimate will provide you a one-time glance at your baseline fitness and health and provide a baseline measurement for gauging the efficacy of your fitness program in subsequent reassessments.

Assessments are specific to each health-related component of fitness. You will have the opportunity to assess each one in the near future.

Set Goals

Using the map analogy, now that you know your current location, you must determine your destination and the best route for getting there. You can start by setting goals.

In his bestselling book, *The 7 Habits of Highly Effective People*, author Stephen Covey suggests you should "Begin with the end in mind."[7] While Covey's words may not be directly aimed at those seeking to complete a fitness program, his advice is useful to anyone making a significant lifestyle change. To be successful, you must develop a clear vision of your destination. Setting specific goals about how you want to feel and look, increases your chances of success. Without specific goals to measure the success of your efforts, you could possibly exceed your target and believe you failed.

The art of setting goals includes stating them in a clearly defined and measurable way. Consider exactly what you would like to accomplish, make certain your goals can be measured, and establish a reasonable timeframe in which to achieve your goals. Goals that meet these guidelines are referred to as S.M.A.R.T. goals.

> **Specific:** Be as specific and detailed as possible in creating your goal.
>
> **Measurable**: If your goal cannot be measured, you will not know when you have successfully completed the goal.

Attainable: Consider whether you have the resources—such as time, family support, and financial means—to obtain your goal.

Realistic: While your goal should be challenging, it should not exceed reasonable expectations.

Timeframe: Set a deadline to accomplish your goal.

Well-Stated Goals

A well-stated goal contains all of the SMART components listed above. Take a look at the well-stated example: *I will improve my 12-minute distance by 10% within 2 months of the first assessment.*

Note, all the ingredients of a well-stated goal are present. It is specific (improve 12-minute distance by 10%), measurable (10% improvement), attainable and realistic (the degree of improvement is reasonable in that time frame), and includes a time frame (a clear deadline of 2 months).

Less Effective Goals

Less effective goals would be stated like this: *I will run farther next time I assess my fitness*; *I want to jog faster*; *I will lose weight.*

And a common one: *I will exercise 3 days a week at 60% max heart rate for 45 minutes per session for 2 months.*

At a closer glance, none of these examples contain all of the ingredients of a well-stated goal. How can "faster" be measured? "Farther" is not specific enough, nor is "lose weight." In the last example, this is not a goal at all. It is a plan to achieve a goal that has not been stated.

In the end, setting up well-stated goals will give you the best chance to convert good intentions into a healthier lifestyle.

To complete this step, write down 2-3 personal goals, stated in the SMART format, and put them in a place you will see them frequently.

Create a Plan

Once you know exactly what you want to achieve, generate a strategy that will help you reach your goals. As you strategize, your goal is to determine the frequency, the intensity, and the duration of your exercise sessions. While doing this, it is imperative to keep in mind a few key principles.

First, use your goals as the foundation for your program. If your goal is related to weight loss, this should drive the frequency, duration, and intensity of your daily workouts as these variables will influence your body's use of fat for fuel and the number of calories burned. If you feel more interested in improving your speed, you will need to dedicate more workout time to achieving those results.

Another key principle is the importance of safety. The importance of designing a program that is safe and effective cannot be overstated. You can minimize any risks by relying on the expert recommendations of the US Department of Health and Human Services previously outlined and linked here. These highly reputable organizations have conducted extensive research to discover the optimal frequency, intensity, and duration for exercise.

Follow Through

Once you have assessed your current fitness levels, set goals using the SMART guidelines, and created your personalized fitness plan, you should feel very proud of yourself! You have made significant progress toward achieving a healthier lifestyle. Now is when the "rubber hits the road." (Literally so, if your plan includes walking or jogging.) Now that you have invested time and energy to develop a thoughtful, well-designed fitness program, it is time to reap the returns of good execution. The assessment, planning and preparation are really the hardest parts. Once you know what to do and how to do it, success is simply a matter of doing it.

Unfortunately, the ability to stick with a program proves difficult for most. To prevent getting derailed from your program, identify barriers that may prevent you from consistently following through. One of the most common challenges cited is a shortage of time. Work schedules, school, child care, and the activities of daily living can leave you with little time to pursue your goals. Make a list of the items that prevent you from regularly exercising and then analyze your schedule and find a time for squeezing in your exercise routine. Regardless of when you schedule your exercise, be certain to exercise consistently. Below are a few additional tips for achieving consistency in your daily fitness program:

- **Think long term; think lifestyle.** The goal is to make exercise an activity you enjoy every day throughout your life. Cultivating a love for exercise will not occur overnight and developing your ideal routine will take time. Begin with this knowledge in mind and be patient as you work through the challenges of making exercise a consistent part of your life.

- **Start out slowly.** Again, you are in this for the long haul. No need to overdo it in the first week. Plan for low intensity activity, for 2–3 days per week, and for realistic periods of time

(20–30 minutes per session).

- **Begin with low Intensity/low volume.** As fitness improves, you will want to gradually increase your efforts in terms of quantity and quality. You can do this with more time and frequency (called volume) or you can increase your intensity. In beginning a program, do not change both at the same time.

- **Keep track.** Results from a program often occur slowly, subtly, and in a very anti-climactic way. As a result, participants become discouraged when immediate improvements are not visible. Keeping track of your consistent efforts, body composition, and fitness test results and seeing those subtle improvements will encourage and motivate you to continue.

- **Seek support.** Look for friends, family members, clubs, or even virtual support using apps and other online forums. Support is imperative as it provides motivation, accountability, encouragement, and people who share a common interest, all of which are factors in your ability to persist in your fitness program.

- **Vary your activities from time to time.** Your overall goals are to be consistent, build your fitness, and reap the health benefits associated with your fitness program. Varying your activities occasionally will prevent boredom. Instead of walking, play basketball or ride a bike. Vary the location of your workout by discovering new hiking trails, parks or walking paths.

- **Have fun.** If you enjoy your activities, you are far more likely to achieve a lasting lifestyle change. While you cannot expect to be exhilarated about exercising every day, you should not dread your daily exercise regimen. If you do, consider varying your activities more, or finding a new routine you find more enjoyable.

- **Eat healthier.** Nothing can be more frustrating than being consistent in your efforts without seeing the results on the scale. Eating a balanced diet will accelerate your results and allow you to feel more successful throughout your activities.

Additional Safety Concerns

DAWN MARKELL AND DIANE PETERSON

As activity rates among Americans increase, specifically outdoor activities, safety concerns also rise. Unfortunately, the physical infrastructure of many American cities does not accommodate active lifestyles. Limited financial resources and de-emphasis on public health means local and state governments are unlikely to allocate funds for building roads with sidewalks, creating walking trails that surround parks, or adding bike lanes. In addition, time constraints and inconvenience make it challenging for participants to travel to areas where these amenities are available. As a result, exercise participants share roads and use isolated trails/pathways, inherently increasing the safety risks of being active.

A key principle in outdoor safety is to recognize and avoid the extremes. For example, avoid roads that experience heavy traffic or are extremely isolated. Avoid heavy populated areas as well as places where no one is around. Do not exercise in the early morning or late at night, during extreme cold or extreme heat. To minimize safety risks during these types of environmental conditions, do not use headphones that could prevent you from hearing well and remaining alert, do not exercise alone, prepare for adequate hydration in the heat, and use warm clothing in extreme cold to avoid frostbite. Extreme conditions require extra vigilance on your part.

A second key principle, whether outdoor or indoor, is to simply use common sense. While this caveat seems obvious, it gets ignored far too often. Always remember the purpose of your exercise is for enjoyment and improved health. If these objectives could be compromised by going for a run at noon in 95-degree heat, or lifting large amounts of weight without a spotter, you should reconsider your plan. Before exercising in what could be risky conditions, ask yourself, “Is there a safer option available?”

Lastly, be aware of the terrain and weather conditions. Walking or jogging on trails is a wonderful way to enjoy nature, but exposed roots and rocks present a hazard for staying upright. Wet, muddy, or icy conditions are additional variables to avoid in order to complete your exercise session without an accident.

Environmental Conditions

When exercising outdoors, you must consider the elements and other factors that could place you at increased risk of injury or illness.

Heat-Related Illness

Heat-related illnesses, such as heat cramps, heat exhaustion, and heat stroke, contributed to 7,233 deaths in the United States between 1999 and 2009. A 2013 report released by the Center for Disease Control stated that about 658 deaths from heat-related illnesses occurred every year which account for more deaths than tornadoes, hurricanes, and lightning combined. Of those deaths, most were male, older adults.

The number one risk factor associated with heat-related illness is hydration, the starting point of all heat-related illness. Unfortunately, sweat loss can occur at a faster rate than a person can replace with fluids during exercise, especially at high intensities. Even when trying to hydrate, ingestion of large amounts of fluids during exercise can lead to stomach discomfort. What does this mean? Hydration must begin before exercise and must become part of your daily routine.

Several practical methods of monitoring hydration levels can assist in preventing illness. One simple method, while not fool proof, is to simply monitor the color of your urine. In a hydrated state, urination will occur frequently (every 2–3 hours) and urine will have very little color. In a dehydrated state, urination occurs infrequently in low volume and will become more yellow in color.

Another simple method involves weighing yourself before and after a workout. This is a great way to see firsthand how much water weight is lost during an exercise session primarily as a result of sweat. Your goal is to maintain your pre- and post-body weight by drinking fluids during and after the workout to restore what was lost. This method, when combined with urine-monitoring, can provide a fairly accurate assessment of hydration levels.

The best preventative measure for maintaining a hydrated state is simply drinking plenty of water throughout the day. In previous years, recommendations for the amount of water to drink were a one size fits all of about 48–64 oz. per day, per person. In an effort to individualize hydration, experts now recommend basing fluid intake on individual size, gender, activity levels, and climate. Generally, half an ounce (fluid ounces) to 1 ounce per pound of body weight is recommended.[9] For a 150-pound individual, this would mean 75–150 ounces of water per day (½ gallon to one gallon)! While there is still considerable debate over the exact amounts, no one disputes the importance of continually monitoring your hydration using one of the techniques described previously. Insufficient hydration leads to poor performance, poor health, and potentially serious illness.

It should be noted that electrolyte “sport” drinks, such as Gatorade and PowerAde, are often used to maintain hydration. While they can be effective, these types of drinks were designed to replace electrolytes (potassium, sodium, chloride) that are lost through sweating during physical activity. In addition, they contain carbohydrates to assist in maintaining energy during activities of long duration. If the activity planned is shorter than 60 minutes in duration, water is still the recommended fluid. For activities beyond 60 minutes, a sports drink should be used.

Cold-Related Illnesses

Much like extremely hot environmental conditions, cold weather can create conditions equally as dangerous if you fail to take proper precautions. To minimize the risk of cold-related illness, you must prevent the loss of too much body heat. The three major concerns related to cold-related illnesses are hypothermia, frost-nip, and frost bite.

As with heat-related illness, the objective of preventing cold-related illness is to maintain the proper body temperature of between 98.6 and 99.9 degrees Fahrenheit. If body temperature falls below 98.6 F, multiple symptoms may appear, indicating the need to take action. Some of those symptoms include:

- shivering
- numbness and stiffness of joints and appendages
- loss of dexterity and/or poor coordination
- peeling or blistering of skin, especially to exposed areas
- discoloration of the skin in the extremities

When walking or jogging in the cold, it is important to take the necessary steps to avoid problems that can arise from the environmental conditions.

- **Hydration is key.** Cold air is usually drier air, which leads to moisture loss through breathing and evaporation. Staying hydrated is key in maintaining blood flow and regulating temperature.

- **Stay dry.** Heat loss occurs 25x faster in water than on dry land. As such, keeping shoes and socks dry and clothing from accumulating too much sweat will allow for more effective body temperature regulation.
- **Dress appropriately.** Because of the movement involved, the body will produce heat during the exercise session. Therefore, the key point is to direct moisture (sweat) away from the skin. This is controlled most effectively by layering your clothing. A base layer of moisture-wicking fabric should be used against the skin while additional layers should be breathable. This will channel moisture away from the skin, and any additional layers of clothing, without it becoming saturated in sweat. If exercising on a windy day, use clothing that protects from the wind and is adjustable so you can breathe.
- **Cover the extremities.** Those parts of the body farthest away from the heart (toes, fingers, and ears) tend to get coldest first. Take the appropriate steps to cover those areas by using gloves, moisture-wicking socks, and a winter cap to cover your head.

CHAPTER 3: EXERCISE METABOLISM

Introduction to Bioenergetics and Metabolism

HEATHER KETCHUM AND ERIC BRIGHT

Metabolism[4]

Metabolism

This photo shows a woman working out at a gym.

Figure 1: Metabolism is the sum of all energy-requiring and energy-consuming processes of the body. Many factors contribute to overall metabolism, including lean muscle mass, the amount and quality of food consumed, and the physical demands placed on the human body. (credit: "tableatny"/flickr.com)

Eating is essential to life. Many of us look to eating as not only a necessity, but also a pleasure. You may have been told since childhood to start the day with a good breakfast to give you the energy to get through most of the day. You most likely have heard about the importance of a balanced diet, with plenty of fruits and vegetables. But what does this all mean to your body and the physiological processes it carries out each day? You need to absorb a range of nutrients so that your cells have the building blocks for metabolic processes that release the energy for the cells to carry out their daily jobs, to manufacture new proteins, cells, and body parts, and to recycle materials in the cell.

There are certain chemical reactions essential to life, the sum of which is referred to as **metabolism**. The focus of these discussions will be **anabolic reactions** and **catabolic reactions**. You will examine the various chemical reactions that are important to sustain life, including why you must have oxygen, how mitochondria transfer energy, and the importance of certain "metabolic" hormones and vitamins.

Metabolism varies, depending on age, gender, activity level, fuel consumption, and lean body mass. Your own metabolic rate fluctuates throughout life. By modifying your diet and exercise regimen, you can increase both lean body mass and metabolic rate. Factors affecting metabolism also play important roles in controlling muscle mass. Aging is known to decrease the metabolic rate by as much as 5 percent per year. Additionally, because men tend have more lean muscle mass than women, their basal metabolic rate (metabolic rate at rest) is higher; therefore, men tend to burn more calories than women do. Lastly, an individual's inherent metabolic rate is a function of the proteins and enzymes derived from their genetic background. Thus, your genes play a big role in your metabolism. Nonetheless, each person's body engages in the same overall metabolic processes.

Heather Ketchum & Eric Bright, OU Human Physiology Textbook. OpenStax CNX. Jun 18, 2015. Download for free at http://cnx.org/contents/e4f804ec-103f-4157-92e1-71eed7aa8584@1

Overview of Metabolic Reactions

HEATHER KETCHUM AND ERIC BRIGHT

Metabolic Reactions[4]

Metabolic processes are constantly taking place in the body. **Metabolism** is the sum of all of the chemical reactions that are involved in catabolism and anabolism. The reactions governing the breakdown of food to obtain energy are called catabolic reactions. Conversely, anabolic reactions use the energy produced by catabolic reactions to synthesize larger molecules from smaller ones, such as when the body forms proteins by stringing together amino acids. Both sets of reactions are critical to maintaining life.

Because catabolic reactions produce energy and anabolic reactions use energy, ideally, energy usage would balance the energy produced. If the net energy change is positive (catabolic reactions release more energy than the anabolic reactions use), then the body stores the excess energy by building fat molecules for long-term storage. On the other hand, if the net energy change is negative (catabolic reactions release less energy than anabolic reactions use), the body uses stored energy to compensate for the deficiency of energy released by catabolism.

Catabolic Reactions

Catabolic reactions break down large organic molecules into smaller molecules, releasing the energy contained in the chemical bonds. These energy releases (conversions) are not 100 percent efficient. The amount of energy released is less than the total amount contained in the molecule. Approximately 40 percent of energy yielded from catabolic reactions is directly transferred to the high-energy molecule adenosine triphosphate (ATP). ATP, the energy currency of cells, can be used immediately to power molecular machines that support cell, tissue, and organ function. This includes building new tissue and repairing damaged tissue. ATP can also be stored to fulfill future energy demands. The remaining 60 percent of the energy released from catabolic reactions is given off as heat, which tissues and body fluids absorb.

Structurally, ATP molecules consist of an adenine, a ribose, and three phosphate groups (Figure). The chemical bond between the second and third phosphate groups, termed a high-energy bond, represents the greatest source of energy in a cell. It is the first bond that catabolic enzymes break when cells require energy to do work. The products of this reaction are a molecule of adenosine diphosphate (ADP) and a lone phosphate group (P_i). ATP, ADP, and P_i are constantly being cycled through reactions that build ATP and store energy, and reactions that break down ATP and release energy.
Structure of ATP Molecule

This diagram shows the chemical structure of adenosine triphosphate, and how different reactions add or remove phosphate groups.
Adenosine triphosphate (ATP) is the energy molecule of the cell.
During catabolic reactions, ATP is created and energy is stored until needed during anabolic reactions.

The energy from ATP drives all bodily functions, such as contracting muscles, maintaining the electrical potential of nerve cells, and absorbing food in the gastrointestinal tract. The metabolic reactions that produce ATP come from various sources (Figure).

QR Code
representing a URL

Watch this video to learn more about adenosine triphosphate (ATP).
Sources of ATP

This flowchart shows how food is modified into lipids, carbohydrates, and protein, and the various catabolic reactions which convert food into energy.
During catabolic reactions, proteins are broken down into amino acids, lipids are broken down into fatty acids, and polysaccharides are broken down into monosaccharides. These building blocks are then used for the synthesis of molecules in anabolic reactions.

Of the four major macromolecular groups (carbohydrates, lipids, proteins, and nucleic acids) that are processed by digestion, carbohydrates are considered the most common source of energy to fuel the body. They take the form of either complex carbohydrates, polysaccharides like starch and glycogen, or simple sugars (monosaccharides) like glucose and fructose. Sugar catabolism breaks polysaccharides down into their individual monosaccharides. Among the monosaccharides, glucose is the most common fuel for ATP production in cells, and as such, there are a number of endocrine control mechanisms to regulate glucose concentration in the bloodstream. Excess glucose is either stored as an energy reserve in the liver and skeletal muscles as the complex polymer glycogen, or it is converted into fat (triglyceride) in adipose cells (adipocytes).

Among the lipids (fats), triglycerides are most often used for energy via a metabolic process called β-oxidation. About one-half of excess fat is stored in adipocytes that accumulate in the subcutaneous tissue under the skin, whereas the rest is stored in adipocytes in other tissues and organs.

Proteins, which are polymers, can be broken down into their monomers, individual amino acids. Amino acids can be used as building blocks of new proteins or broken down further for the production of ATP. When one is chronically starving, this use of amino acids for energy production can lead to a wasting away of the body, as more and more proteins are broken down.

Nucleic acids are present in most of the foods you eat. During digestion, nucleic acids including DNA and various RNAs are broken down into their constituent nucleotides. These nucleotides are readily absorbed and transported throughout the body to be used by individual cells during nucleic acid metabolism.

Anabolic Reactions

In contrast to catabolic reactions, anabolic reactions involve the joining of smaller molecules into larger ones. Anabolic reactions combine monosaccharides to form polysaccharides, fatty acids to form triglycerides, amino acids to form proteins, and nucleotides to form nucleic acids. These processes require energy in the form of ATP molecules generated by catabolic reactions. Anabolic reactions, also called biosynthesis reactions, create new molecules that form new cells and tissues, and revitalize organs.

Hormonal Regulation of Metabolism

Catabolic and anabolic hormones in the body help regulate metabolic processes. **Catabolic hormones** stimulate the breakdown of molecules and the production of energy. These include **cortisol**, **glucagon**, adrenaline/**epinephrine**, and **cytokines**. All of these hormones are mobilized at specific times to meet the needs of the body. **Anabolic hormones** are required for the synthesis of molecules and include **growth hormone**, **insulin-like growth factor**, **insulin**, **testosterone**, and **estrogen**. Table summarizes the function of each of the catabolic hormones and Table summarizes the functions of the anabolic hormones. Please note that not all of the information in these tables may be clear to you at this point in your studies. The information will be much clearer after we study the Endocrine and Nervous systems.

Catabolic Hormones

Hormone	Function
Cortisol	Released from the adrenal gland in response to stress; its main role is to increase blood glucose levels by gluconeogenesis (breaking down fats and proteins)
Glucagon	Released from alpha cells in the pancreas either when starving or when the body needs to generate additional energy; it stimulates the breakdown of glycogen in the liver to increase blood glucose levels; its effect is the opposite of insulin; glucagon and insulin are a part of a negative-feedback system that stabilizes blood glucose levels
Adrenaline/ epinephrine	Released in response to the activation of the sympathetic nervous system; increases heart rate and heart contractility, constricts blood vessels, is a bronchodilator that opens (dilates) the bronchi of the lungs to increase air volume in the lungs, and stimulates gluconeogenesis

Anabolic Hormones

Hormone	Function
Growth hormone (GH)	Synthesized and released from the pituitary gland; stimulates the growth of cells, tissues, and bones
Insulin-like growth factor (IGF)	Stimulates the growth of muscle and bone while also inhibiting cell death (apoptosis)
Insulin	Produced by the beta cells of the pancreas; plays an essential role in carbohydrate and fat metabolism, controls blood glucose levels, and promotes the uptake of glucose into body cells; causes cells in muscle, adipose tissue, and liver to take up glucose from the blood and store it in the liver and muscle as glucagon; its effect is the opposite of glucagon; glucagon and insulin are a part of a negative-feedback system that stabilizes blood glucose levels
Testosterone	Produced by the testes in males and the ovaries in females; stimulates an increase in muscle mass and

Anabolic Hormones	
Hormone	**Function**
	strength as well as the growth and strengthening of bone
Estrogen	Produced primarily by the ovaries, it is also produced by the liver and adrenal glands; its anabolic functions include increasing metabolism and fat deposition

Oxidation-Reduction Reactions

The chemical reactions underlying metabolism involve the transfer of electrons from one compound to another by processes catalyzed by enzymes. The electrons in these reactions commonly come from hydrogen atoms, which consist of an electron and a proton. A molecule gives up a hydrogen atom, in the form of a hydrogen ion (H^+) and an electron, breaking the molecule into smaller parts. The loss of an electron, or **oxidation**, releases a small amount of energy; both the electron and the energy are then passed to another molecule in the process of reduction, or the gaining of an electron. These two reactions always happen together in an **oxidation-reduction reaction** (also called a redox reaction)—when an electron is passed between molecules, the donor is oxidized and the recipient is **reduced**. To help you remember which is which—remember the acronym OIL RIG (<u>O</u>xidized <u>I</u>s <u>L</u>osing, <u>R</u>educed <u>I</u>s <u>G</u>ained). Oxidation-reduction reactions often happen in a series, so that a molecule that is reduced is subsequently oxidized, passing on not only the electron it just received but also the energy it received. As the series of reactions progresses, energy accumulates that is used to combine P_i and ADP to form ATP, the high-energy molecule that the body uses for fuel.

Oxidation-reduction reactions are catalyzed by enzymes that trigger the removal of hydrogen atoms. Coenzymes work with enzymes and accept hydrogen atoms. The two most common coenzymes of oxidation-reduction reactions are **nicotinamide**

adenine dinucleotide (NAD) and **flavin adenine dinucleotide (FAD)**. Their respective reduced coenzymes are **NADH** and **$FADH_2$**, which are energy-containing molecules used to transfer energy during the creation of ATP.

NAD^+ and FAD^+ Oxidation-Reduction Reactions

This diagram shows the chemical structure of NAD+,NADH, FAD, and FADH2 and the oxidation and reduction reactions for them.

NAD^+ and FAD^+ are coenzymes that are used to transfer energy via oxidation-reduction reactions to create ATP.

Chapter Review

Metabolism is the sum of all catabolic (break down) and anabolic (synthesis) reactions in the body. The metabolic rate measures the amount of energy used to maintain life. An organism must ingest a sufficient amount of food to maintain its metabolic rate if the organism is to stay alive for very long.

Catabolic reactions break down larger molecules, such as carbohydrates, lipids, and proteins from ingested food, into their constituent smaller parts. They also include the breakdown of ATP, which releases the energy needed for metabolic processes in all cells throughout the body.

Anabolic reactions, or **biosynthetic reactions**, synthesize larger molecules from smaller constituent parts, using ATP as the energy source for these reactions. Anabolic reactions build bone, muscle mass, and new proteins, fats, and nucleic acids. Oxidation-reduction reactions transfer electrons across molecules by oxidizing one molecule and reducing another, and collecting the released energy to convert P_i and ADP into ATP. Errors in metabolism alter the processing of carbohydrates, lipids, proteins, and nucleic acids, and can result in a number of disease states.

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Metabolic States of the Body

HEATHER KETCHUM AND ERIC BRIGHT

Metabolic States of the Body[4]

You eat periodically throughout the day; however, your organs, especially the brain, need a continuous supply of glucose. How does the body meet this constant demand for energy? Your body processes the food you eat both to use immediately and, importantly, to store as energy for later demands. If there were no method in place to store excess energy, you would need to eat constantly in order to meet energy demands. Distinct mechanisms are in place to facilitate energy storage, and to make stored energy available during times of fasting and starvation.

The Absorptive State

The **absorptive state**, or the fed state, occurs after a meal when your body is digesting the food and absorbing the nutrients (catabolism exceeds anabolism). Digestion begins the moment you put food into your mouth, as the food is broken down into its constituent parts to be absorbed through the intestine. The digestion of carbohydrates begins in the mouth, whereas the digestion of proteins and fats begins in the stomach and small intestine. The constituent parts of these carbohydrates, fats, and proteins are transported across the intestinal wall and enter the bloodstream (sugars and amino acids) or the lymphatic system (fats). From the intestines, these systems transport them to the liver, adipose tissue, or muscle cells that will process and use, or store, the energy.

Depending on the amounts and types of nutrients ingested, the absorptive state can linger for up to 4 hours. The ingestion of food and the rise of glucose concentrations in the bloodstream stimulate pancreatic beta cells to release **insulin** into the bloodstream, where it initiates the absorption of blood glucose by liver hepatocytes, and by adipose and muscle cells. Once inside these cells, glucose is immediately converted into glucose-6-phosphate. By doing this, a concentration gradient is established where glucose levels are higher in the blood than in the cells. This allows for glucose to continue moving from the blood to the cells where it is needed. Insulin also stimulates the storage of glucose as glycogen in the liver and muscle cells where it can be used for later energy needs of the body. Insulin also promotes the synthesis of protein in muscle. As you will see, muscle protein can be catabolized and used as fuel in times of starvation.

If energy is exerted shortly after eating, the dietary fats and sugars that were just ingested will be processed and used immediately for energy. If not, the excess glucose is stored as **glycogen** in the liver and muscle cells, or as fat in adipose tissue; excess dietary fat is also stored as triglycerides in adipose tissues.

Figure summarizes the metabolic processes occurring in the body during the absorptive state.
Absorptive State

This figure shows how nutrients are absorbed by the body. The diagram shows digested nutrients entering the blood stream and being absorbed by liver cells, muscle cells, and adipose cells. Underneath each panel, text details the process taking place in each cell type.
During the absorptive state, the body digests food and absorbs the nutrients.

The Post-absorptive State

The **post-absorptive state**, or the fasting state, occurs when the food has been digested, absorbed, and stored. You commonly fast overnight, but skipping meals during the day puts your body in the post-absorptive state as well. During this state, the body must rely initially on stored **glycogen**. Glucose levels in the blood begin to drop as it is absorbed and used by the cells. In response to the decrease in glucose, insulin levels also drop. Glycogen and triglyceride storage slows. However, due to the demands of the tissues and organs, blood glucose levels must be maintained in the normal range of 80–120 mg/dL. In response to a drop in blood glucose concentration, the hormone glucagon is released from the alpha cells of the pancreas. **Glucagon** acts upon the liver cells, where it inhibits the synthesis of glycogen and stimulates the breakdown of stored glycogen back into glucose. This glucose is released from the liver to be used by the peripheral tissues and the brain. As a result, blood glucose levels begin to rise. Gluconeogenesis will also begin in the liver to replace the glucose that has been used by the peripheral tissues.

After ingestion of food, fats and proteins are processed as described previously; however, the glucose processing changes a bit. The peripheral tissues preferentially absorb glucose. The liver, which normally absorbs and processes glucose, will not do so after a prolonged fast. The gluconeogenesis that has been ongoing in the liver will continue after fasting to replace the glycogen stores that were depleted in the liver. After these stores have been replenished, excess glucose that is absorbed by the liver will be converted into triglycerides and fatty acids for long-term storage. Figure summarizes the metabolic processes occurring in the body during the postabsorptive state.
Postabsorptive State

This figure shows the postabsorptive stage where no nutrients enter the blood stream from the digestive system and its effects of liver cells, muscle cells, and adipose cells.
During the postabsorptive state, the body must rely on stored glycogen for energy.

Starvation

When the body is deprived of nourishment for an extended period of time, it goes into “survival mode.” The first priority for survival is to provide enough glucose or fuel for the brain. The second priority is the conservation of amino acids for proteins. Therefore, the body uses ketones to satisfy the energy needs of the brain and other glucose-dependent organs, and to maintain proteins in the cells (see [link]). Because glucose levels are very low during starvation, glycolysis will shut off in cells that can use alternative fuels. For example, muscles will switch from using glucose to fatty acids as fuel. As previously explained, fatty acids can be converted into acetyl CoA and processed through the Krebs cycle to make ATP. Pyruvate, lactate, and alanine from muscle cells are not converted into acetyl CoA and used in the Krebs cycle, but are exported to the liver to be used in the synthesis of glucose. As starvation continues, and more glucose is needed, glycerol from fatty acids can be liberated and used as a source for gluconeogenesis.

After several days of starvation, ketone bodies become the major source of fuel for the heart and other organs. As starvation continues, fatty acids and triglyceride stores are used to create ketones for the body. This prevents the continued breakdown of proteins that serve as carbon sources for gluconeogenesis. Once these stores are fully depleted, proteins from muscles are released and broken down for glucose synthesis. Overall survival is dependent on the amount of fat and protein stored in the body.

Metabolic Rate

The **metabolic rate** is the amount of energy consumed minus the amount of energy expended by the body. The **basal metabolic rate (BMR)** describes the amount of daily energy expended by humans at rest, in a neutrally temperate environment, while in the postabsorptive state. It measures how much energy the body needs for normal, basic, daily activity. About 70 percent of all daily energy expenditure comes from the basic functions of the organs in the body. Another 20 percent comes from physical activity, and the remaining 10 percent is necessary for body thermoregulation or temperature control. This rate will be higher if a person is more active or has more lean body mass. As you age, the BMR generally decreases as the percentage of less lean muscle mass decreases.

Chapter Review

There are three main metabolic states of the body: absorptive (fed), postabsorptive (fasting), and starvation. During any given day, your metabolism switches between **absorptive** and **post-absorptive states**. Starvation states happen very rarely in generally well-nourished individuals. When the body is fed, glucose, fats, and proteins are absorbed across the intestinal membrane and enter the bloodstream and lymphatic system to be used immediately for fuel. Any excess is stored for later fasting stages. As blood glucose levels rise, the pancreas releases insulin to stimulate the uptake of glucose by hepatocytes in the liver, muscle cells/fibers, and adipocytes (fat cells), and to promote its conversion to glycogen. As the postabsorptive state begins, glucose levels drop, and there is a corresponding drop in insulin levels. Falling glucose levels trigger the pancreas to release glucagon to turn off glycogen synthesis in the liver and stimulate its breakdown into glucose. The glucose is released into the bloodstream to serve as a fuel source for cells throughout the body. If glycogen stores are depleted during fasting, alternative sources, including fatty acids and proteins, can be metabolized and used as fuel. When the body once again enters the absorptive state after fasting, fats and proteins are digested and used to replenish fat and protein stores, whereas glucose is processed and used first to replenish the glycogen stores in the peripheral tissues, then in the liver. If the fast is not broken and starvation begins to set in, during the initial days, glucose produced from gluconeogenesis is still used by the brain and organs. After a few days, however, ketone bodies are created from fats and serve as the preferential fuel source for the heart and other organs, so that the brain can still use glucose. Once these stores are depleted, proteins will be catabolized first from the organs with fast turnover, such as the intestinal lining. Muscle will be spared to prevent the wasting of muscle tissue; however, these proteins will be used if alternative stores are not available.

Heather Ketchum & Eric Bright, OU Human Physiology Textbook. OpenStax CNX. Jun 18, 2015. Download for free at http://cnx.org/contents/e4f804ec-103f-4157-92e1-71eed7aa8584@1

ATP in Living Systems

AMANDA SHELTON

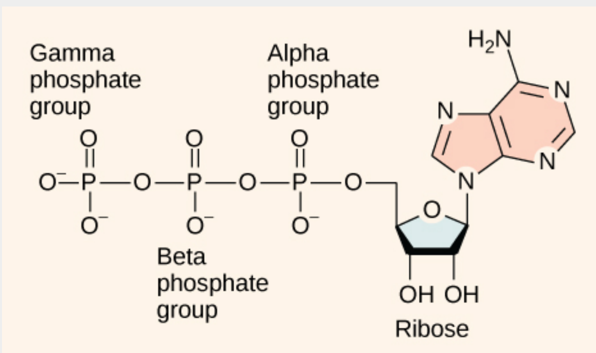
Energy in Living Systems[6]

A living cell cannot store significant amounts of free energy. Excess free energy would result in an increase of heat in the cell, which would result in excessive thermal motion that could damage and then destroy the cell. Rather, a cell must be able to handle that energy in a way that enables the cell to store energy safely and release it for use only as needed. Living cells accomplish this by using the compound adenosine triphosphate (ATP). **ATP** is often called the "*energy currency*" of the cell, and, like currency, this versatile compound can be used to fill any energy need of the cell. How? It functions similarly to a rechargeable battery.

When ATP is broken down, usually by the removal of its terminal phosphate group, energy is released. The energy is used to do work by the cell, usually by the released phosphate binding to another molecule, activating it. For example, in the mechanical work of muscle contraction, ATP supplies the energy to move the contractile muscle proteins. Recall the active transport work of the sodium-potassium pump in cell membranes. ATP alters the structure of the integral protein that functions as the pump, changing its affinity for sodium and potassium. In this way, the cell performs work, pumping ions against their electrochemical gradients.

ATP Structure and Function

At the heart of ATP is a molecule of adenosine monophosphate (AMP), which is composed of an adenine molecule bonded to a ribose molecule and to a single phosphate group (Figure). Ribose is a five-carbon sugar found in RNA, and AMP is one of the nucleotides in RNA. The addition of a second phosphate group to this core molecule results in the formation of adenosine diphosphate (ADP); the addition of a third phosphate group forms adenosine triphosphate (ATP).



ATP (adenosine triphosphate) has three phosphate groups that can be removed by hydrolysis to form ADP (adenosine diphosphate) or AMP (adenosine monophosphate).The negative charges on the phosphate group naturally repel each other, requiring energy to bond them together and releasing energy when these bonds are broken.

The addition of a phosphate group to a molecule requires energy. Phosphate groups are negatively charged and thus repel one another when they are arranged in series, as they are in ADP and ATP. This repulsion makes the ADP and ATP molecules inherently unstable. The release of one or two phosphate groups from ATP, a process called **dephosphorylation**, releases energy.

Energy from ATP

Hydrolysis is the process of breaking complex macromolecules apart. During hydrolysis, water is split, or *lysed*, and the resulting hydrogen atom (H^+) and a hydroxyl group (OH^-) are added to the larger molecule. The hydrolysis of ATP produces ADP, together with an inorganic phosphate ion (P_i), and the release of free energy. To carry out life processes, ATP is continuously broken down into ADP, and like a rechargeable battery, ADP is continuously regenerated into ATP by the reattachment of a third (*terminal*) phosphate group. Water, which was broken down into its hydrogen atom and hydroxyl group during ATP hydrolysis, is regenerated when a third phosphate is added to the ADP molecule, reforming ATP.

Obviously, energy must be infused into the system to regenerate ATP. Where does this energy come from? In nearly every living thing on earth, the energy comes from the metabolism of glucose. In this way, ATP is a direct link between the limited set of exergonic pathways of glucose catabolism and the multitude of endergonic pathways that power living cells.

Phosphorylation

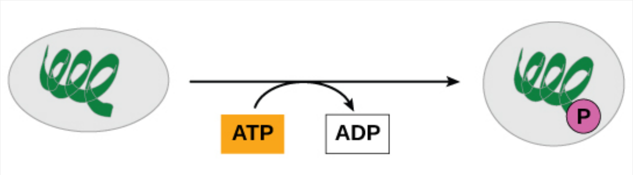
Recall that, in some chemical reactions, enzymes may bind to several substrates that react with each other on the enzyme, forming an intermediate complex. An intermediate complex is a temporary structure, and it allows one of the substrates (such as ATP) and reactants to more readily react with each other; in reactions involving ATP, ATP is one of the substrates and ADP is a product. During an endergonic chemical reaction, ATP forms an intermediate complex with the substrate and enzyme in the reaction. This intermediate complex allows the ATP to transfer its third phosphate group, with its energy, to the substrate, a process called phosphorylation. **Phosphorylation** refers to the addition of the phosphate (~P). This is illustrated by the following generic reaction:

$$\text{A + enzyme + ATP} \rightarrow [\text{ A} - \text{enzyme } - \sim\text{P }] \rightarrow \text{B + enzyme + ADP + phosphate ion}$$

When the intermediate complex breaks apart, the energy is used to modify the substrate and convert it into a product of the reaction. The ADP molecule and a free phosphate ion are released into the medium and are available for recycling through cell metabolism.

Substrate Phosphorylation

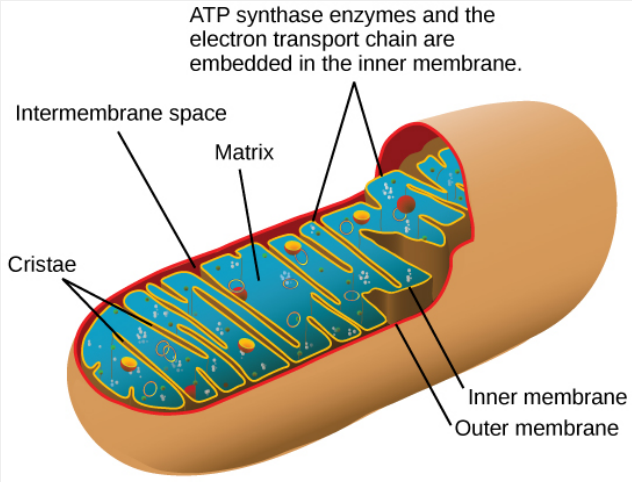
ATP is generated through two mechanisms during the breakdown of glucose. A few ATP molecules are generated (that is, regenerated from ADP) as a direct result of the chemical reactions that occur in the catabolic pathways. A phosphate group is removed from an intermediate reactant in the pathway, and the free energy of the reaction is used to add the third phosphate to an available ADP molecule, producing ATP (Figure). This very direct method of phosphorylation is called **substrate-level phosphorylation.**



In phosphorylation reactions, the terminal phosphate of ATP is attached to a protein.

Oxidative Phosphorylation

Most of the ATP generated during glucose catabolism, however, is derived from a much more complex process, chemiosmosis, which takes place in mitochondria (Figure) within a eukaryotic cell or the plasma membrane of a prokaryotic cell. **Chemiosmosis**, a process of ATP production in cellular metabolism, is used to generate 90 percent of the ATP made during glucose catabolism and is also the method used in the light reactions of photosynthesis to harness the energy of sunlight. The production of ATP using the process of chemiosmosis is called **oxidative phosphorylation** because of the involvement of oxygen in the process.



In eukaryotes, oxidative phosphorylation takes place in mitochondria. In prokaryotes, this process takes place in the plasma membrane. (Credit: modification of work by Mariana Ruiz Villareal)

OpenStax. "Energy in Living Systems." *Biology*, https://www.oercommons.org/courseware/lesson/56966/overview?section=7. Accessed 26 July 2021.

Muscular Physiology

DAWN MARKELL AND DIANE PETERSON

Muscles are used for movement in the body. The largest portion of energy expenditure in the body happens in muscles while helping us perform daily activities with ease and improving our wellness. Muscular strength is the amount of force that a muscle can produce one time at a maximal effort, and muscular endurance is the ability to repeat a movement over an extended period of time. Resistance training is the method of developing muscular strength and muscular endurance, which in turns improves wellness. This chapter explores many ways to resistance train. However, achieving the best muscular performance requires the assistance of a trained professional.

Muscles are highly specialized to contract forcefully. Muscles are powered by muscle cells, which contract individually within a muscle to generate force. This force is needed to create movement.

There are over 600 muscles in the human body; they are responsible for every movement we make, from pumping blood through the heart and moving food through the digestive system, to blinking and chewing. Without muscle cells, we would be unable to stand, walk, talk, or perform everyday tasks.

Types of Muscle

There are three types of muscle:

1. **Skeletal Muscle:** Responsible for body movement.
2. **Cardiac Muscle:** Responsible for the contraction of the heart.
3. **Smooth Muscle:** Responsible for many tasks, including

movement of food along intestines, enlargement and contraction of blood vessels, size of pupils, and many other contractions.

Note – a description of Cardiac and Smooth muscles can be found in ***Chapter 3 – Types of Muscle Fibers.*** *The remainder of this chapter will focus solely on Skeletal muscles.*

Skeletal Muscle Structure and Function

Skeletal muscles are attached to the skeleton and are responsible for the movement of our limbs, torso, and head. They are under conscious control, which means that we can consciously choose to contract a muscle and can regulate how strong the contraction actually is. Skeletal muscles are made up of a number of **muscle fibers**. Each muscle fiber is an individual muscle cell and may be anywhere from 1 mm to 4 cm in length. When we choose to contract a muscle fiber—for instance we contract our bicep to bend our arm upwards—a signal is sent from our brain via the spinal cord to the muscle. This signals the muscle fibers to contract. Each nerve will control a certain number of muscle fibers. The nerve and the fibers it controls are called a **motor unit**. Only a small number of muscle fibers will contract to bend one of our limbs, but if we wish to lift a heavy weight then many more muscles fibers will be recruited to perform the action. This is called muscle fiber recruitment. As seen in ***Chapter 3 – Types of Muscle Fibers,*** Skeletal muscle fibers fall under three classifications: a) **Slow oxidative (SO)**, b) **Fast oxidative**, and c) **Fast glycolytic.** As a reminder, the terms Slow vs Fast refer to the motor unit's speed of recruitment/the fibers' speed of contraction, while the terms Oxidative vs Glycolytic refer to whether the fiber mainly produces ATP in **Aerobic** or **Anaerobic conditions.** As this topic was covered in Chapter 3, it will not be further elaborated in this Chapter.

Each muscle fiber is surrounded by connective tissue called an **external lamina**. A group of muscle fibers are encased within more connective tissue called the **endomysium**. The group of muscle fibers and the endomysium are surrounded by more connective tissue called the **perimysium**. A group of muscle fibers surrounded by the perimysium is called a **muscle fascicule**. A muscle is made up of many muscle fasciculi, which are surrounded by a thick collagenous layer of connective tissue called the epimysium. The epimysium covers the whole surface of the muscle.

Muscle fibers also contain many mitochondria, which are energy powerhouses that are responsible for the aerobic production of energy molecules, or ATP molecules. Muscle fibers also contain glycogen granules as a stored energy source, and **myofibrils**, which are threadlike structures running the length of the muscle fiber. Myofibrils are made up of two types of protein:

1. **Actin myofilaments**
2. **Myosin myofilaments**

The Actin and Myosin filaments form the contractile part of the muscle, which is called the sarcomere. Myosin filaments are thick and dark when compared with actin filaments, which are much thinner and lighter in appearance. The actin and myosin filaments lie on top of one another; it is this arrangement of the filaments that gives muscle its striated or striped appearance. When groups of actin and myosin filaments are bound together by connective tissue they make the myofibrils. When groups of myofibrils are bound together by connective tissue, they make up muscle fibers.

The ends of the muscle connect to bone through a **tendon**. The muscle is connected to two bones in order to allow movement to occur through a **joint**. When a muscle contracts, only one of these bones will move. The point where the muscle is attached to a bone that moves is called the **insertion**. The point where the muscle is attached to a bone that remains in a fixed position is called the **origin**.

How Muscles Contract

Muscles are believed to contract through a process called the **Sliding Filament Theory**. In this theory, the muscles contract when actin filaments slide over myosin filaments resulting in a shortening of the length of the sarcomeres, and hence, a shortening of the muscle fibers. During this process the actin and myosin filaments do not change length when muscles contract, but instead they slide past each other. As a result, the muscle fiber becomes shorter and fatter in appearance. As a number of muscle fibers shorten at the same time, the whole muscle contracts and causes the tendon to pull on the bone it attaches to. This creates movement that occurs at the point of insertion.

For the muscle to return to normal (i.e., to lengthen), a force must be applied to the muscle to cause the muscle fibers to lengthen. This force can be due to gravity or due to the contraction of an opposing muscle group.

Skeletal muscles contract in response to an electric signal called an **action potential**. Action potentials are conducted along nerve cells before reaching the muscle fibers. The nerve cells regulate the function of skeletal muscles by controlling the number of action potentials that are produced. The action potentials trigger a series of chemical reactions that result in the contraction of a muscle.

When a nerve impulse stimulates a motor unit within a muscle, all of the muscle fibers controlled by that motor unit will contract. When stimulated, these muscle fibers contract on an all-or-nothing basis. The all-or-nothing principle means that muscle fibers either contract maximally along their length or not at all. Therefore, when stimulated, muscle fibers contract to their maximum level and when not stimulated there is no contraction. In this way, the force generated by a muscle is not regulated by the level of contraction by individual fibers, but rather it is due to the number of muscle fibers that are recruited to contract. This is called **muscle fiber recruitment**. When lifting a light object, such as a book, only a small number of muscle fibers will be recruited. However, those that are recruited will contract to their maximum level. When lifting a heavier weight, many more muscle fibers will be recruited to contract maximally.

When one muscle contracts, another opposing muscle will relax. In this way, muscles are arranged in pairs. An example is when you bend your arm at the elbow: you contract your bicep muscle and relax your tricep muscle. This is the same for every movement in the body. There will always be one contracting muscle and one relaxing muscle. If you take a moment to think about these simple movements, it will soon become obvious that unless the opposing muscle is relaxed, it will have a negative effect on the force generated by the contracting muscle.

A muscle that contracts, and is the main muscle group responsible for the movement, is called the **agonist** or prime mover. The muscle that relaxes is called the **antagonis**t. One of the effects that regular strength training has is an improvement in the level of relaxation that occurs in the opposing muscle group. Although the agonist/antagonist relationship changes, depending on which muscle is responsible for the movement, every muscle group has an opposing muscle group.

Below are examples of agonist and antagonist muscle group pairings:

[table id=2 /]

Smaller muscles may also assist the agonist during a particular movement. The smaller muscle is called the **synergist**. An example of a synergist would be the deltoid (shoulder) muscle during a press-up. The front of the deltoid provides additional force during the push-up; however, most of the force is applied by the pectoralis major (chest). Other muscle groups may also assist the movement by helping to maintain a fixed posture and prevent unwanted movement. These muscle groups are called fixators. An example of a **fixator** is the shoulder muscle during a bicep curl or tricep extension.

Types of Muscular Contraction

Isometric: This is a static contraction where the length of the muscle, or the joint angle, does not change. An example is pushing against a stationary object such as a wall. This type of contraction is known to lead to rapid rises in blood pressure.

Isotonic: This is a moving contraction, also known as **dynamic contraction**. During this contraction the muscle fattens, and there is movement at the joint.

Types of Isotonic Contraction

Concentric: This is when the muscle contracts and shortens against a resistance. This may be referred to as the lifting or positive phase. An example would be the lifting phase of the bicep curl.

Eccentric: This occurs when the muscle is still contracting and lengthening at the same time. This may be referred to as the lowering or negative phase.

Types of Muscle Fibers

HEATHER KETCHUM; ERIC BRIGHT; DAWN MARKELL; AND DIANE PETERSON

Types of Muscle Fibers[4]

Two criteria to consider when classifying the types of muscle fibers are how fast some fibers contract relative to others, and how fibers produce ATP. Using these criteria, there are three main types of skeletal muscle fibers. Slow oxidative (SO) fibers contract relatively slowly and use aerobic respiration (oxygen and glucose) to produce ATP. Fast oxidative (FO) fibers have fast contractions and primarily use aerobic respiration, but because they may switch to anaerobic respiration (glycolysis), can fatigue more quickly than SO fibers. Lastly, fast glycolytic (FG) fibers have fast contractions and primarily use anaerobic glycolysis. The FG fibers fatigue more quickly than the others. It is worth noting that many references classify types of muscle fibers as:

Type I: Slow Twitch or Highly Oxidative muscle fibers (equivalent to SO fibers above) and

Type II: Fast Twitch or Low Oxidative muscle fibers. Type II is further subdivided into Type IIa (equivalent to FO fibers above) and Type IIb (or Type IIx – equivalent to the FG fibers above).

The speed of contraction is dependent on how quickly myosin's ATPase hydrolyzes ATP to produce cross-bridge action. Fast fibers hydrolyze ATP approximately twice as quickly as slow fibers, resulting in much quicker cross-bridge cycling (which pulls the thin filaments toward the center of the sarcomeres at a faster rate). The primary metabolic pathway used by a muscle fiber determines whether the fiber is classified as oxidative or glycolytic. If a fiber primarily produces ATP through aerobic pathways it is oxidative. More ATP can be produced during each metabolic cycle, making the fiber more resistant to fatigue. Glycolytic fibers primarily create ATP through anaerobic glycolysis, which produces less ATP per cycle. As a result, glycolytic fibers fatigue at a quicker rate.

The oxidative fibers contain many more mitochondria than the glycolytic fibers, because aerobic metabolism, which uses oxygen (O_2) in the metabolic pathway, occurs in the mitochondria. The SO fibers possess a large number of mitochondria and are capable of contracting for longer periods because of the large amount of ATP they can produce, but they have a relatively small diameter and do not produce a large amount of tension. SO fibers are extensively supplied with blood capillaries to supply O_2 from the red blood cells in the bloodstream, and use this in combination with fats and carbohydrates to produce ATP (primary fuel sources). The SO fibers also possess myoglobin, an O_2-carrying molecule similar to O_2-carrying hemoglobin in the red blood cells. The myoglobin stores some of the needed O_2 within the fibers themselves (and gives SO fibers their red color). All of these features allow SO fibers to produce large quantities of ATP, which can sustain muscle activity without fatiguing for long periods of time.

The fact that SO fibers can function for long periods without fatiguing makes them useful in maintaining posture, producing isometric contractions, stabilizing bones and joints, and making small movements that happen often but do not require large amounts of energy. They do not produce high tension, and thus they are not used for powerful, fast movements that require high amounts of energy and rapid cross-bridge cycling.

FO fibers are sometimes called intermediate fibers because they possess characteristics that are intermediate between fast fibers and slow fibers. They produce ATP relatively quickly, more quickly than SO fibers, and thus can produce relatively high amounts of tension. They are oxidative because they produce ATP aerobically, possess high amounts of mitochondria, and do not fatigue quickly. However, FO fibers do not possess significant myoglobin, giving them a lighter color than the red SO fibers. FO fibers are used primarily for movements, such as walking, that require more energy than postural control but less energy than an explosive movement, such as sprinting. FO fibers are useful for this type of movement because they produce more tension than SO fibers but they are more fatigue-resistant than FG fibers.

FG fibers primarily use anaerobic glycolysis as their ATP source (meaning carbohydrates are their primary fuel source). They have a large diameter and possess high amounts of glycogen, which is used in glycolysis to generate ATP quickly to produce high levels of tension. Because they do not primarily use aerobic metabolism, they do not possess substantial numbers of mitochondria or significant amounts of myoglobin and therefore have a white color. FG fibers are used to produce rapid, forceful contractions to make quick, powerful movements. These fibers fatigue quickly, permitting them to only be used for short periods. Most muscles possess a mixture of each fiber type. The predominant fiber type in a muscle is determined by the primary function of the muscle, although most skeletal muscles in a human contain(s) all three types in varying proportions.

Numbers of Slow (SO) and Fast-Twitch Fibers (FO, FG) (Dawn Markell, Diane Peterson)

The number of slow and fast-twitch fibers contained in the body varies greatly between individuals and is determined by a person's genetics. People who do well at endurance sports tend to have a higher number of slow-twitch fibers, whereas people who are better at sprint events tend to have higher numbers of fast-twitch muscle fibers. Both the slow twitch and fast-twitch fibers can be influenced by training. It is possible through sprint training to improve the power generated by slow twitch fibers, and through endurance training, it is possible to increase the endurance level of fast-twitch fibers. The level of improvement varies, depending on the individual, and training can never make slow-twitch fibers as powerful as fast-twitch, nor can training make fast-twitch fibers as fatigue resistant as slow-twitch fibers. That being said, it has been observed that following a period of endurance training, FO fibers will start to strongly resemble SO fibers, but following a period of strength training they will start to strongly resemble FG fibers. In fact, following several years of endurance training they may end up being almost identical to SO muscle fibers.

Cardiac Muscle Structure and Function (Dawn Markell, Diane Peterson)

Cardiac muscle cells are only found in the heart. They are elongated and contain actin and myosin filaments, which form sarcomeres; these join end to end to form myofibrils. The actin and myosin filaments give cardiac muscle a striated appearance. The striations are less numerous than in skeletal muscle. Cardiac muscles contain high numbers of mitochondria, which produce energy through aerobic metabolism. An extensive capillary network of tiny blood vessels supply oxygen to the cardiac muscle cells. Unlike the skeletal muscle cells, the cardiac cells all work as one unit, all contracting at the same time. In short, the sinoatrial node at the top of the heart sends an impulse to the atrioventricular node, which sends a wave of polarization that travels from one heart cell to another causing them all to contract at the same time.

Smooth Muscle Structure and Function (Dawn

Markell, Diane Peterson)

Smooth muscle cells are variable in function and perform numerous roles within the body. They are spindle shaped and smaller than skeletal muscle and contain fewer actin and myosin filaments. The actin and myosin filaments are not organized into sarcomeres, so smooth muscles do not have a striated appearance. Unlike other muscle types, smooth muscle can apply a constant tension. This is called smooth muscle tone. Smooth muscle cells have a similar metabolism to skeletal muscle, producing most of their energy aerobically. As such, they are not well adapted to producing energy anaerobically.[1]

Chapter Review

ATP provides the energy for muscle contraction. The three mechanisms for ATP regeneration are creatine phosphate, anaerobic glycolysis, and aerobic metabolism. Creatine phosphate provides about the first 15 seconds of ATP at the beginning of muscle contraction. Anaerobic glycolysis produces small amounts of ATP in the absence of oxygen for a short period. Aerobic metabolism utilizes oxygen to produce much more ATP, allowing a muscle to work for longer periods. Muscle fatigue, which has many contributing factors, occurs when muscle can no longer contract. An oxygen debt is created as a result of muscle use. The three types of muscle fiber are slow oxidative (SO), fast oxidative (FO) and fast glycolytic (FG). SO fibers use aerobic metabolism to produce low power contractions over long periods and are slow to fatigue. FO fibers use aerobic metabolism to produce ATP but produce higher tension contractions than SO fibers. FG fibers use anaerobic metabolism to produce powerful, high-tension contractions but fatigue quickly.

Glossary

fast glycolytic (FG)
muscle fiber that primarily uses anaerobic glycolysis

fast oxidative (FO)
intermediate muscle fiber that is between slow oxidative and fast glycolytic fibers

slow oxidative (SO)
muscle fiber that primarily uses aerobic respiration

Heather Ketchum & Eric Bright, OU Human Physiology Textbook. OpenStax CNX. Jun 18, 2015. Download for free at http://cnx.org/contents/e4f804ec-103f-4157-92e1-71eed7aa8584@1

Nutrition, Performance, and Recovery

AMANDA SHELTON

Putting Value into the Diet

There are a variety of components of the average daily diet that contribute to an effective nutrition strategy for improving exercise performance including optimizing your **macronutrient, micronutrient, and fluid intake and timing** of consumption to help provide a more effective and individualized dietary intake pattern. But first I want to give a little brief introduction to our essential nutrients for those who have never taken a nutrition course before.

Macronutrients

Energy-yielding Macronutrients include the nutrients that many people have at least heard of before:

1. Carbohydrates
2. Proteins
3. Lipids (fats)

Carbohydrates[4]

Carbohydrates are organic molecules composed of carbon, hydrogen, and oxygen atoms. Include our simple sugars such as glucose and fructose and complex sugars such as starch, glycogen, and cellulose. The complex sugars are also called polysaccharides and are made of multiple monosaccharide molecules. Polysaccharides serve as energy storage (e.g., starch and glycogen) and as structural components (e.g., chitin in insects and cellulose in plants).

Our simple sugars can be digested and absorbed quickly to provide energy via ATP to the cells during higher intensity activity. While our complex carbohydrates require a bit more time for digestion and absorption and can provide the body with a longer, slower release of energy over time.

Protein[4]

Much of the body is made of protein, and these proteins take on a myriad of forms. They represent cell signaling receptors, signaling molecules, structural members, enzymes, intracellular trafficking components, extracellular matrix scaffolds, ion pumps, ion channels, oxygen and CO_2 transporters (hemoglobin). That is not even the complete list! There is protein in bones (collagen), muscles, and tendons; the hemoglobin that transports oxygen; and enzymes that catalyze all biochemical reactions. Protein is also used for growth and repair. Amid all these necessary functions, proteins also hold the potential to serve as a metabolic fuel source. Proteins are not stored for later use, so excess proteins must be converted into glucose or triglycerides, and used to supply energy or build energy reserves. Although the body can synthesize proteins from amino acids, food is an important source of those amino acids, especially because humans cannot synthesize all of the 20 amino acids used to build proteins.

Lipids[4]

Fats (or triglycerides) within the body are ingested as food or synthesized by adipocytes or hepatocytes from carbohydrate precursors (Figure). Lipid metabolism entails the oxidation of fatty acids to either generate energy or synthesize new lipids from smaller constituent molecules. Lipid metabolism is associated with carbohydrate metabolism, as products of glucose (such as acetyl CoA) can be converted into lipids.

Dietary Strategies for Performance[7]

There are several strategies that have been used to help improve an athlete's performance during different activities. The most effective use of these strategies will depend on the individual, the type(s) of activity they participate in (both exercise and physical activity), and their dietary consumption outside of activity specific needs.

Carbohydrate Loading

This is one of the most popular strategies for improving performance, one that you may have done before! Ever have a Team Pasta Feed? Night before the event Team Dinner? These are common tactics for how we can maximize our muscle glycogen stores prior to an activity or event.

Why do we do it? To maximize the glycogen stores in our muscles prior to endurance exercise lasting longer than 90 minutes.

What's the benefit? Delay the onset of fatigue and improve performance.

When do we do it? Best practices for this is a bit more involved than just eating pasta the night before.

- *For events lasting longer than* 90 *minutes*: Ideally, we are consuming **~10-12 grams of carbohydrates per kg of body mass per day** in the 36-48 hours prior to the activity/event.
- *For events lasting* 60-90 *minutes*: **~7-12 grams of carbohydrates per kg of body mass during the 24 hours leading up to the activity/event**.

Case Study

Suzie Cue is running in her first half marathon this weekend. Suzie has been practicing her in race food and hydration strategy throughout her training but is trying to figure out what meals to have leading up to the event.

> **About Suzie:**
>
> Height: 5'6″
>
> Body Mass: 140 lbs.
>
> Goal Race Time: 1 hour and 59 minutes

Since she expects the race to take more than 90 minutes she uses the recommendation listed above to determine her carbohydrate intake on Friday and Saturday before her Sunday race.

First, we need to convert lbs to kg:

- = (140 lbs)/ (2.2 lb/kg) = **63.6 kg**

Then we need to figure out how many grams of carbohydrate per day Suzie should consume based on her body mass:

- = 10 g * 63.6 kg = **636 g/day**
- = 12 g * 63.6 kg = **763 g/day**

For reference, in a typical 2000 kcal/day diet, we are typically looking at 225-325g of carbohydrates per day

For Suzie, what might this look like in a regular days consumption?

Breakfast: 132 g of carbohydrates

- Maple and Brown Sugar Instant Oatmeal (2 packets) = 66 g
- Banana (medium) = 27 g
- Orange Juice (12 oz) = 39 g

Mid Morning Snack: 47 g of carbohydrates

- Apple (medium) = 25 g
- Gatorade (1 bottle) = 22 g

Lunch: 223 g of carbohydrates

- Steak Burrito = 116 g
- 1 20 oz bottle of lemon-lime soda = 64 g
- Tortilla Chips and Salsa = 43 g

Mid Afternoon Snack: 60 g of carbohydrates

- 1 cup of Skim Milk = 12 g
- Graham Crackers (4 full crackers) = 48 g

Dinner: 147 g of carbohydrates

- Spaghetti with Meatballs = 99 g
- Garlic Bread (2 slices) = 36 g
- 1 cup Skim Milk = 12 g

Dessert: 54 g of carbohydrates

- Vanilla Ice Cream (1 cup) = 31 g
- Caramel Sauce (2 Tbsp) = 23 g

Total Carbohydrates for the day: **663 g of carbohydrates**

With Carbohydrate Loading it is important to note that it is not necessarily what we would consider a "well-balanced" diet since it is significantly more carbohydrates than what would be recommended in the typical dietary pattern based on body mass. This is not a pattern that should be maintained throughout training and should only be used in situations where the length of endurance activity will be extended and performance is the intent. In our example with Suzie above, during her training if she had a "long run" midway through her training cycle that was a 7.0 mile run that she expected to take ~65 minutes, she would not necessarily need to go through the same intensive carbohydrate loading as dictated above.

In addition to the day(s) leading up to the event, with endurance activities specifically, it is important that we look to “fill” those stores as much as possible in the hours leading up to the activity/event.

- For events lasting longer than 60 minutes: **1-4 grams of carbohydrates per kg of body mass in the 1-4 hours prior to the activity/event**.

Mid-Event Carbohydrate Intake

Similarly as with Carbohydrate Loading, when we have longer duration endurance events (particularly those that last longer than 60 minutes) it is important that we begin to consider consumption of carbohydrates DURING the activity.

Benefits of carbohydrates during activity:

- Prevent hypoglycemia (low blood sugar)
- Maintains high level of carbohydrate oxidation for utilization of energy
- Improves performance of long-duration activity (especially multiple hours of activity)

Exercise Duration	Example Exercise Type	Carbohydrate Intake Per Hour
30-75 minutes	5k or 10k race	Small amounts or carbohydrate rinse
1-2 hours	Soccer Game (90 minutes long)	30 g
2-3 hours	Half to Full Marathon	60 g
>2.5 hours	Half Ironman Triathlon, Ultra-races	90 g

“Train Low, Compete High” Method

Within this particular method, different strategies exist. This method is sometimes also referred to as “fasted training” where you are restricting carbohydrate or total into prior to participation in your training activities. This may occur by participating in your training session after an overnight fast or by having a several hour fast prior to participating in a second training session in the day. With this, you would follow a similar carbohydrate loading strategy identified above immediately preceding your competition.

***Intended/Speculated Benefits:**

- Enhanced cell-signaling pathways
- Increased mitochondrial enzyme content and activity
- Enhanced lipid oxidation rates
- Improved exercise capacity

**Not supported through scientific literature, further research is needed.*

Unfortunately, this strategy has no clear evidence in the scientific literature to support these benefit claims and further research is necessary to identify the optimal strategy for this particular method.

Heather Ketchum & Eric Bright, OU Human Physiology Textbook. OpenStax CNX. Jun 18, 2015. Download for free at: http://cnx.org/contents/e4f804ec-103f-4157-92e1-71eed7aa8584@1

Beck K, Thomson JS, Swift RJ, von Hurst PR. Role of nutrition in performance enhancement and postexercise recovery. *Open Access J Sports Med.* 2015;6:259-267 https://doi.org/10.2147/OAJSM.S33605

Carbohydrate Metabolism

HEATHER KETCHUM AND ERIC BRIGHT

Carbohydrate Metabolism[4]

During digestion, carbohydrates are broken down into simple, soluble sugars that can be transported across the intestinal wall into the circulatory system to be transported throughout the body. Carbohydrate digestion begins in the mouth with the action of salivary amylase on starches and ends with monosaccharides being absorbed across the epithelium of the small intestine. Once the absorbed monosaccharides are transported to the tissues, the process of cellular respiration begins (Figure). This section will focus first on glycolysis, a process where the monosaccharide glucose is oxidized, releasing the energy stored in its bonds to produce ATP.
Cellular Respiration

This figure shows the different pathways of cellular respiration. The pathways shown are glycolysis, the pyruvic acid cycle, the Krebs cycle, and oxidative phosphorylation.
Cellular respiration oxidizes glucose molecules through glycolysis, the Krebs cycle, and oxidative phosphorylation to produce ATP.
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Watch this video to learn about cellular respiration.

Glycolysis

Glucose is the body's most readily available source of energy. After digestive processes break polysaccharides down into monosaccharides, including glucose, the monosaccharides are transported across the wall of the small intestine and into the circulatory system, which transports them to the liver. In the liver, hepatocytes either pass the glucose on through the circulatory system or store excess glucose as glycogen in a process called glycogenesis. Cells in the body take up the circulating glucose in response to insulin and, through a series of reactions called glycolysis, transfer some of the energy in glucose to ADP to form ATP (Figure). The last step in glycolysis produces the product pyruvate.

Glycolysis Overview

This flowchart shows the different steps in glycolysis in detail. The top panel shows the energy-consuming phase, the middle panel shows the coupling of phosphorylation with oxidation, and the bottom panel shows the energy-releasing phase.

During the energy-consuming phase of glycolysis, two ATPs are consumed, transferring two phosphates to the glucose molecule. The glucose molecule then splits into two three-carbon compounds, each containing a phosphate. During the second phase, an additional phosphate is added to each of the three-carbon compounds. The energy for this endergonic reaction is provided by the removal (oxidation) of two electrons from each three-carbon compound. During the energy-releasing phase, the phosphates are removed from both three-carbon compounds and used to produce four ATP molecules. Please note that each purple arrow indicates an enzyme catalyzed reaction.

Glycolysis begins with the phosphorylation of glucose by the enzyme hexokinase to form glucose-6-phosphate. This step uses one ATP, which is the donor of the phosphate group. Under the action of phosphofructokinase, glucose-6-phosphate is converted

into fructose-6-phosphate. At this point, a second ATP donates its phosphate group, forming fructose-1,6-bisphosphate. This six-carbon sugar is split to form two phosphorylated three-carbon molecules, glyceraldehyde-3-phosphate and dihydroxyacetone phosphate, which are both converted into glyceraldehyde-3-phosphate. The glyceraldehyde-3-phosphate is further phosphorylated with groups donated by dihydrogen phosphate present in the cell to form the three-carbon molecule 1,3-bisphosphoglycerate. The energy of this reaction comes from the oxidation of (removal of electrons from) glyceraldehyde-3-phosphate. In a series of reactions leading to pyruvate, the two phosphate groups are then transferred to two ADPs to form two ATPs. Thus, glycolysis uses two ATPs but generates four ATPs, yielding a net gain of two ATPs and two molecules of pyruvate. In the presence of oxygen, pyruvate is oxidized (in a linking step) and then continues on to the Krebs cycle (also called the citric acid cycle or tricarboxylic acid cycle (TCA), where additional energy is extracted and passed on. (see Figure)
Glycolysis Reactions

This flowchart shows the different reactions in glycolysis along with intermediates in detail.
The glycolysis pathway including intermediates of the reaction.
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Watch this video to learn about glycolysis.

Glycolysis can be divided into two phases: energy consuming (also called chemical priming) and energy yielding. The first phase is the energy-consuming phase, so it requires two ATP molecules to start the reaction for each molecule of glucose. However, the end of the reaction produces four ATPs, resulting in a net gain of two ATP energy molecules.

Glycolysis can be expressed as the following equation:

<span id="MathJax-Element-1-Frame" class="MathJax" style="font-style: normal;font-weight: normal;line-height: normal;font-size: 14px;text-indent: 0px;text-align: center;text-transform: none;letter-spacing: normal;float: none;direction: ltr;max-width: none;max-height: none;min-width: 0px;min-height: 0px;border: 0px;padding: 0px;margin: 0px" role="presentation" data-mathml="

$$\text{Glucose} + 2\text{ATP} + 2\text{NAD}^{+} + 4\text{ADP} + 2\text{P}_{i} \rightarrow 2\text{ Pyruvate} + 4\text{ATP} + 2\text{NADH} + 2\text{H}^{+}$$

“>Glucose + 2ATP + 2NAD+ + 4ADP + 2Pi → 2 Pyruvate + 4ATP + 2NADH + 2H+

This equation states that glucose, in combination with ATP (the energy source), NAD^{+} (a coenzyme that serves as an electron acceptor), and inorganic phosphate, breaks down into two pyruvate molecules, generating four ATP molecules—for a net yield of two ATP—and two energy-containing NADH coenzymes. The NADH that is produced in this process will be used later to produce ATP in the mitochondria. Importantly, by the end of this process, one glucose molecule generates two pyruvate molecules, two high-energy ATP molecules, and two electron-carrying NADH molecules.

The following discussions of glycolysis include the enzymes responsible for the reactions and the intermediates in the reaction. The names of the enzymes and intermediates are not important, but understanding the oxidation-reduction and hydrolysis reactions as well as the reactants and products of the overall reaction is very important. When glucose enters a cell, the enzyme hexokinase (or glucokinase, in the liver) rapidly adds a phosphate to convert it into glucose-6-phosphate. A kinase is a type of enzyme that adds a phosphate molecule to a substrate (in this case, glucose, but it can be true of other molecules also). This conversion step requires one ATP and essentially traps the glucose in the cell, preventing it from passing back through the plasma membrane, thus allowing glycolysis to proceed. It also functions to maintain a concentration gradient with higher glucose levels in the blood than in the tissues. By establishing this concentration gradient, the glucose in the blood will be able to flow from an area of high concentration (the blood) into an area of low concentration (the tissues) to be either used or stored. Hexokinase is found in nearly every tissue in the body. Glucokinase, on the other hand, is expressed in tissues that are active when blood glucose levels are high, such as the liver. Hexokinase has a higher affinity for glucose than glucokinase and therefore is able to convert glucose at a faster rate than glucokinase. This is important when levels of glucose are very low in the body, as it allows glucose to travel preferentially to those tissues that require it more.

In the next step of the first phase of glycolysis, the enzyme glucose-6-phosphate isomerase converts glucose-6-phosphate into fructose-6-phosphate. Like glucose, fructose is also a six carbon-containing sugar. The enzyme phosphofructokinase-1 then adds one more phosphate to convert fructose-6-phosphate into fructose-1-6-bisphosphate, another six-carbon sugar, using another ATP molecule. Aldolase then breaks down this fructose-1-6-bisphosphate into two three-carbon molecules, glyceraldehyde-3-phosphate and dihydroxyacetone phosphate. The triosephosphate isomerase enzyme then converts dihydroxyacetone phosphate into a second glyceraldehyde-3-phosphate molecule. Therefore, by the end of this chemical-priming or energy-consuming phase, one glucose molecule is broken down into two glyceraldehyde-3-phosphate molecules.

The second phase of glycolysis, the energy-yielding phase, creates the energy that is the product of glycolysis. Glyceraldehyde-3-phosphate dehydrogenase converts each three-carbon glyceraldehyde-3-phosphate produced during the energy-consuming phase into 1,3-bisphosphoglycerate. This reaction releases an electron that is then picked up by NAD^+ to create an NADH molecule. NADH is a high-energy molecule, like ATP, but unlike ATP, it is not used as energy currency by the cell. Because there are two glyceraldehyde-3-phosphate molecules, two NADH molecules are synthesized during this step. Each 1,3-bisphosphoglycerate is subsequently dephosphorylated (i.e., a phosphate is removed) by phosphoglycerate kinase into 3-phosphoglycerate. Each phosphate released in this reaction can convert one molecule of ADP into one high-energy ATP molecule, resulting in a gain of two ATP molecules.

The enzyme phosphoglycerate mutase then converts the 3-phosphoglycerate molecules into 2-phosphoglycerate. The enolase enzyme then acts upon the 2-phosphoglycerate molecules to convert them into phosphoenolpyruvate molecules. The last step of glycolysis involves the dephosphorylation of the two phosphoenolpyruvate molecules by pyruvate kinase to create two pyruvate molecules and two ATP molecules.

In summary, glycolysis takes one glucose molecule and breaks it down into two pyruvate molecules yielding a net gain of two ATPs and two NADH molecules. Therefore, glycolysis generates energy for the cell and creates pyruvate molecules that can be oxidized and continue on to the aerobic Krebs cycle (also called the citric acid cycle or tricarboxylic acid cycle (TCA)); converted into lactic acid or alcohol (in yeast) by fermentation; or used later for the synthesis of glucose through gluconeogenesis.

Anaerobic Respiration

When oxygen is limited or absent, pyruvate enters an anaerobic pathway. In these reactions, pyruvate can be converted into lactic acid. In addition to generating an additional ATP, this pathway serves to keep the pyruvate concentration low so glycolysis continues, and it oxidizes NADH into the NAD^+ needed by glycolysis. In this reaction, lactic acid replaces oxygen as the final electron acceptor. Anaerobic respiration occurs in most cells of the body when oxygen is limited or mitochondria are absent or nonfunctional. For example, because erythrocytes (red blood cells) lack mitochondria, they must produce their ATP from anaerobic respiration. This is an effective pathway of ATP production for short periods of time, ranging from seconds to a few minutes. The lactic acid produced diffuses into the plasma and is carried to the liver, where it is converted back into pyruvate or glucose via the Cori cycle. Similarly, when a person exercises, muscles use ATP faster than oxygen can be delivered to them. They depend on glycolysis and lactic acid production for rapid ATP production.

Aerobic Respiration

In the presence of oxygen, pyruvate will be oxidized and can enter the Krebs cycle where additional energy is extracted as electrons are transferred from the pyruvate to the receptors NAD^+, GDP, and FAD, with carbon dioxide being a "waste product" (Figure). The NADH and $FADH_2$ pass electrons on to the electron transport chain, which uses the transferred energy to produce ATP. As the terminal step in the electron transport chain, oxygen is the terminal electron acceptor and creates water inside the mitochondria.
Aerobic versus Anaerobic Respiration

This flowchart shows the processes of anaerobic and aerobic respiration. The top image shows the energy consuming phase of glycolysis. This branches into aerobic respiration on the left and anaerobic respiration on the right.
The process of anaerobic respiration converts glucose into two lactate molecules in the absence of oxygen or within erythrocytes that lack mitochondria. During aerobic respiration, glucose is oxidized into two pyruvate molecules.

Krebs Cycle

The pyruvate molecules generated during glycolysis are transported across the mitochondrial membrane into the inner mitochondrial matrix, where they are first oxidized in the linking step and then metabolized by enzymes in a pathway called the Krebs cycle (Figure). The Krebs cycle is also commonly called the citric acid cycle or the tricarboxylic acid (TCA) cycle. During the Krebs cycle, high-energy molecules, including ATP, NADH, and $FADH_2$, are created. NADH and $FADH_2$ then pass electrons through the electron transport chain in the mitochondria to generate more ATP molecules.

Krebs Cycle

The top panel of this figure shows the transformation of pyruvate to acetyl-CoA, and the bottom panel shows the steps in Krebs cycle. During the Krebs cycle, each pyruvate that is generated by glycolysis is converted into a two-carbon acetyl CoA molecule. The acetyl CoA is systematically processed through the cycle and produces high-energy NADH, $FADH_2$, and ATP molecules. Please note that each gray arrow indicates an enzyme catalyzed reaction

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Watch this video to learn more about the Krebs cycle.

The three-carbon pyruvate molecules generated during glycolysis move from the cytoplasm into the mitochondrial matrix, where they are converted by the enzyme pyruvate dehydrogenase into a two-carbon acetyl coenzyme A (acetyl CoA) molecule. This reaction is an oxidative decarboxylation reaction and is often referred to as a linking step or pyruvate oxidation. It converts each three-carbon pyruvate into a two-carbon acetyl CoA molecule, releasing carbon dioxide and transferring two electrons that combine with NAD^+ to form NADH. Acetyl CoA enters the Krebs cycle by combining with a four-carbon molecule, oxaloacetate, to form the six-carbon molecule citrate, or citric acid, at the same time releasing the coenzyme A molecule.

The six-carbon citrate molecule is systematically converted to a five-carbon molecule and then a four-carbon molecule, ending with oxaloacetate, the beginning of the cycle. Along the way, each citrate molecule will produce one ATP, one $FADH_2$, and three NADH. The $FADH_2$ and NADH will enter the oxidative phosphorylation system located in the inner mitochondrial membrane. In addition, the Krebs cycle supplies the starting materials to process and break down proteins and fats.

To start the Krebs cycle, citrate synthase combines acetyl CoA and oxaloacetate to form a six-carbon citrate molecule; CoA is subsequently released and can combine with another pyruvate molecule to begin the cycle again. The aconitase enzyme converts citrate into isocitrate. In two successive steps of oxidative decarboxylation, two molecules of CO_2 and two NADH molecules are produced when isocitrate dehydrogenase converts isocitrate into the five-carbon α-ketoglutarate, which is then catalyzed and converted into the four-carbon succinyl CoA by α-ketoglutarate dehydrogenase. The enzyme succinyl CoA dehydrogenase then converts succinyl CoA into succinate and forms the high-energy molecule GTP, which transfers its energy to ADP to produce ATP. Succinate dehydrogenase then converts succinate into fumarate, forming a molecule of $FADH_2$. Fumarase then converts fumarate into malate, which malate dehydrogenase then converts back into oxaloacetate while reducing NAD^+ to NADH. Oxaloacetate is then ready to combine with the next acetyl CoA to start the Krebs cycle again (see Figure). For each turn of the cycle, three NADH, one ATP (through GTP), and one $FADH_2$ are created. Each carbon of pyruvate is converted into CO_2, which is released as a byproduct of oxidative (aerobic) respiration. Remember that for each glucose molecule, there are two pyruvates produced and therefore two turns of the Krebs cycle.

Oxidative Phosphorylation

Oxidative phosphorylation includes two parts; electron transport chain (ETC) and chemiosmotic coupling. The ETC and chemiosmotic coupling are part of oxidative phophorylation. The ETC uses electron carriers to pump protons across the cristae and into the intermembrane space. Chemiosmotic coupling then, generates ATP when protons are transported back into the matrix via ATP synthase. The electron transport chain (ETC) uses electrons from the oxidation of NADH (produced by glycolysis, pyruvate oxidation, and Krebs cycle) and $FADH_2$ (produced by Krebs cycle). These electrons are transferred through protein complexes embedded in the inner mitochondrial membrane by a series of enzymatic reactions. The electron transport chain consists of a series of four enzyme complexes (Complex I – Complex IV) and two coenzymes (ubiquinone and Cytochrome c), which act as electron carriers and proton pumps used to transfer H^+ ions into the space between the inner and outer mitochondrial membranes (Figure). The ETC couples the transfer of electrons between a donor (like NADH and $FADH_2$) and an electron acceptor (like O_2) with the transfer of protons (H^+ ions) across the inner mitochondrial membrane, enabling the process of oxidative phosphorylation. In the presence of oxygen, energy is passed, stepwise, through the electron carriers to collect gradually the energy needed to attach a phosphate to ADP and produce ATP. The role of molecular oxygen, O_2, is as the terminal electron acceptor for the ETC. This means that once the electrons have passed through the entire ETC, they must be passed to another, separate molecule. These electrons, O_2, and H^+ ions from the matrix combine to form new water molecules. This is the basis for your need to breathe in oxygen. Without oxygen, electron flow through the ETC ceases.

Electron Transport Chain

This image shows the mitochondrial membrane with proton pumps and ATP synthase embedded in the membrane. Arrows show the direction of flow of proteins and electrons across the membrane. The electron transport chain is a series of electron carriers and ion pumps that are used to pump H^+ ions out of the inner mitochondrial matrix.
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Watch this video to learn about the electron transport chain.
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Watch this video to learn about oxidative phosphorylation and chemiosmosis.

The electrons released from NADH and $FADH_2$ are passed along the chain by each of the carriers, which are reduced when they receive the electron and oxidized when passing it on to the next carrier. Each of these reactions releases a small amount of energy, which is used to pump H^+ ions across the inner membrane. The accumulation of these protons in the space between the membranes creates a proton gradient with respect to the mitochondrial matrix.

Also embedded in the inner mitochondrial membrane is an amazing protein pore complex called ATP synthase. Effectively, it is a turbine that is powered by the flow of H^+ ions across the inner membrane down a gradient and into the mitochondrial matrix. As the H^+ ions traverse the complex, the shaft of the complex rotates. This rotation enables other portions of ATP synthase to encourage ADP and P_i to create ATP. This process whereby ATP is produced by the transport of protons by ATP synthase is called chemiosmosis or chemiosmotic coupling. In accounting for the total number of ATP produced per glucose molecule through aerobic respiration, it is important to remember the following points:

- A net of two ATP are produced through glycolysis (four produced and two consumed during the energy-consuming stage).
- In all phases after glycolysis, the number of ATP, NADH, and $FADH_2$ produced must be multiplied by two to reflect how each glucose molecule produces two pyruvate molecules.
- In the ETC, about three ATP are produced for every oxidized NADH. However, only about two ATP are produced for every oxidized FADH2. The electrons from FADH2 produce less ATP, because they start at a lower point in the ETC (Complex II) compared to the electrons from NADH (Complex I) (see (Figure)).
- The ETC and chemiosmotic coupling are part of oxidative phosphorylation. The ETC uses electron carries to pump protons across the cristae and into the intermembrane space. Chemiosmotic coupling then, generates ATP when protons are transported back into the matrix via ATP synthase.

Therefore, for every glucose molecule that enters aerobic respiration, a net total of 36 ATPs are produced (Figure).
Carbohydrate Metabolism

This figure shows the different steps in which carbohydrates are metabolized and lists the number of ATP molecules produced in each step. The different steps shown are glycolysis, transformation of pyruvate to acetyl-CoA, the Krebs cycle, and the electron transport chain.
Carbohydrate metabolism involves glycolysis, the Krebs cycle, and the electron transport chain. The NADH Transport cost is associated with transporting NADH produced from glycolysis into the mitochondrial matrix. The cost for this transport is two ATPs.

Gluconeogenesis

Gluconeogenesis is the synthesis of new glucose molecules from pyruvate, lactate, glycerol, or the amino acids alanine or glutamine. This process takes place primarily in the liver during periods of low glucose, that is, under conditions of fasting, starvation, and low carbohydrate diets. So, the question can be raised as to why the body would create something it has just spent a fair amount of effort to break down? Certain key organs, including the brain, can use only glucose as an energy source; therefore, it is essential that the body maintain a minimum blood glucose concentration. When the blood glucose concentration falls below that certain point, new glucose is synthesized by the liver to raise the blood concentration to normal.

Gluconeogenesis is not simply the reverse of glycolysis. There are some important differences (Figure). Pyruvate is a common starting material for gluconeogenesis. First, the pyruvate is converted into oxaloacetate. Oxaloacetate then serves as a substrate for the enzyme phosphoenolpyruvate carboxykinase (PEPCK), which transforms oxaloacetate into phosphoenolpyruvate (PEP). From this step, gluconeogenesis is nearly the reverse of glycolysis. PEP is converted back into 2-phosphoglycerate, which is converted into 3-phosphoglycerate. Then, 3-phosphoglycerate is converted into 1,3 bisphosphoglycerate and then into glyceraldehyde-3-phosphate. Two molecules of glyceraldehyde-3-phosphate then combine to form fructose-1-6-bisphosphate, which is converted into fructose 6-phosphate and then into glucose-6-phosphate. Finally, a series of reactions generates glucose itself. In gluconeogenesis (as compared to glycolysis), the enzyme hexokinase is replaced by glucose-6-phosphatase, and the enzyme phosphofructokinase-1 is replaced by fructose-1,6-bisphosphatase. This helps the cell to regulate glycolysis and gluconeogenesis independently of each other.

As will be discussed as part of lipolysis, fats can be broken down into

glycerol, which can be phosphorylated to form dihydroxyacetone phosphate or DHAP. DHAP can either enter the glycolytic pathway or be used by the liver as a substrate for gluconeogenesis.
Gluconeogenesis

This figure shows the different steps in gluconeogenesis, where pyruvate is converted to glucose.
Gluconeogenesis is the synthesis of glucose from pyruvate, lactate, glycerol, alanine, or glutamate.

AGING AND THE…Body's Metabolic Rate

The human body's metabolic rate decreases nearly 2 percent per decade after age 30. Changes in body composition, including reduced lean muscle mass, are mostly responsible for this decrease. The most dramatic loss of muscle mass, and consequential decline in metabolic rate, occurs between 50 and 70 years of age. Loss of muscle mass is the equivalent of reduced strength, which tends to inhibit seniors from engaging in sufficient physical activity. This results in a positive-feedback system where the reduced physical activity leads to even more muscle loss, further reducing metabolism.

There are several things that can be done to help prevent general declines in metabolism and to fight back against the cyclic nature of these declines. These include eating breakfast, eating small meals frequently, consuming plenty of lean protein, drinking water to remain hydrated, exercising (including strength training), and getting enough sleep. These measures can help keep energy levels from dropping and curb the urge for increased calorie consumption from excessive snacking. While these strategies are not guaranteed to maintain metabolism, they do help prevent muscle loss and may increase energy levels. Some experts also suggest avoiding sugar, which can lead to excess fat storage. Spicy foods and green tea might also be beneficial. Because stress activates cortisol release, and cortisol slows metabolism, avoiding stress, or at least practicing relaxation techniques, can also help.

Chapter Review

Metabolic enzymes catalyze catabolic reactions that break down carbohydrates contained in food. The energy released is used to power the cells and systems that make up your body. Excess or unutilized energy is stored as fat or glycogen for later use. Carbohydrate metabolism begins in the mouth, where the enzyme salivary amylase begins to break down complex sugars into monosaccharides. These can then be transported across the intestinal membrane into the bloodstream and then to body tissues. In the cells, glucose, a six-carbon sugar, is processed through a sequence of reactions into smaller sugars, and the energy stored inside the molecule is released. The first step of carbohydrate catabolism is glycolysis, which produces pyruvate, NADH, and ATP. Under anaerobic conditions, the pyruvate can be converted into lactate to keep glycolysis working. Under aerobic conditions, pyruvate enters the Krebs cycle, also called the citric acid cycle or tricarboxylic acid cycle. In addition to ATP, the Krebs cycle produces high-energy FADH2 and NADH molecules, which provide electrons to the oxidative phosphorylation process that generates more high-energy ATP molecules. For each molecule of glucose that is processed in glycolysis, a net of 36 ATPs can be created by aerobic respiration.

Under anaerobic conditions, ATP production is limited to those generated by glycolysis. While a total of four ATPs are produced by glycolysis, two are needed to begin glycolysis, so there is a net yield of two ATP molecules.

In conditions of low glucose, such as fasting, starvation, or low carbohydrate diets, glucose can be synthesized from lactate, pyruvate, glycerol, alanine, or glutamate. This process, called gluconeogenesis, is almost the reverse of glycolysis and serves to create glucose molecules for glucose-dependent organs, such as the brain, when glucose levels fall below normal.

Glossary

acetyl coenzyme A (acetyl CoA)
: starting molecule of the Krebs cycle

ATP synthase
: protein pore complex that creates ATP

cellular respiration
: production of ATP from glucose oxidation via glycolysis, the Krebs cycle, and oxidative phosphorylation

citric acid cycle
: also called the Krebs cycle or the tricarboxylic acid cycle; converts pyruvate into CO_2 and high-energy $FADH_2$, NADH, and ATP molecules

electron transport chain (ETC)
: ATP production pathway in which electrons are passed through a series of oxidation-reduction reactions that forms

water and produces a proton gradient

energy-consuming phase
first phase of glycolysis, in which two molecules of ATP are necessary to start the reaction

energy-yielding phase
second phase of glycolysis, during which energy is produced

glucokinase
cellular enzyme, found in the liver, which converts glucose into glucose-6-phosphate upon uptake into the cell

gluconeogenesis
process of glucose synthesis from pyruvate or other molecules

glucose-6-phosphate
phosphorylated glucose produced in the first step of glycolysis

glycolysis
series of metabolic reactions that breaks down glucose into pyruvate and produces ATP

hexokinase
cellular enzyme, found in most tissues, that converts glucose into glucose-6-phosphate upon uptake into the cell

Krebs cycle
also called the citric acid cycle or the tricarboxylic acid cycle, converts pyruvate into CO_2 and high-energy $FADH_2$, NADH, and ATP molecules

monosaccharide
smallest, monomeric sugar molecule

oxidative phosphorylation
process that converts high-energy NADH and $FADH_2$ into ATP

polysaccharides
complex carbohydrates made up of many monosaccharides

pyruvate
three-carbon end product of glycolysis and starting material that is converted into acetyl CoA that enters the Krebs cycle

salivary amylase
digestive enzyme that is found in the saliva and begins the digestion of carbohydrates in the mouth

terminal electron acceptor
: oxygen, the recipient of the free hydrogen at the end of the electron transport chain

tricarboxylic acid cycle (TCA)
: also called the Krebs cycle or the citric acid cycle; converts pyruvate into CO_2 and high-energy $FADH_2$, NADH, and ATP molecules

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Protein Metabolism

HEATHER KETCHUM AND ERIC BRIGHT

Protein Metabolism[4]

The digestion of proteins begins in the stomach. When protein-rich foods enter the stomach, they are greeted by a mixture of the enzyme pepsin and hydrochloric acid (HCl; 0.5 percent). The latter produces an environmental pH of 1.5–3.5 that denatures proteins within food. Pepsin cuts proteins into smaller polypeptides and their constituent amino acids. When the food-gastric juice mixture (chyme) enters the small intestine, the pancreas releases sodium bicarbonate to neutralize the HCl. This helps to protect the lining of the intestine. The small intestine also releases digestive hormones, including secretin and CCK, which stimulate digestive processes to break down the proteins further. Secretin also stimulates the pancreas to release sodium bicarbonate. The pancreas releases most of the digestive enzymes, including the proteases trypsin, chymotrypsin, and carboxypeptidase, which aid protein digestion. Together, all of these enzymes break complex proteins into smaller individual amino acids (Figure), which are then transported across the intestinal mucosa to be used to create new proteins, or to be converted into fats or acetyl CoA and used in the Krebs cycle.

Digestive Enzymes and Hormones

The left panel shows the main organs of the digestive system, and the right panel shows a magnified view of the intestine. Text callouts indicate the different protein digesting enzymes produced in different organs.

Enzymes in the stomach and small intestine break down proteins into amino acids. HCl in the stomach aids in proteolysis, and hormones secreted by intestinal cells direct the digestive processes.

In order to avoid breaking down the proteins that make up the pancreas and small intestine, pancreatic enzymes are released as inactive proenzymes that are only activated in the small intestine. In the pancreas, vesicles store trypsin, chymotrypsin, and procarboxypeptidase as trypsinogen, chymotrypsinogen, and carboxypeptidase, respectively. Once released into the small intestine, an enzyme found in the wall of the small intestine, called enterokinase, binds to trypsinogen and converts it into its active form, trypsin. Trypsin then binds to chymotrypsinogen to convert it into the active chymotrypsin. Trypsin and chymotrypsin break down large proteins into smaller peptides while carboxypeptidase cleaves individual amino acids, a process called proteolysis. These smaller peptides are catabolized into their constituent amino acids, which are transported across the apical surface of the intestinal mucosa in a process that is mediated by sodium-amino acid co-transporters. These transporters bind sodium and then bind the amino acid to transport it across the membrane. At the basal surface of the mucosal cells, the sodium and amino acid are released. The sodium can be reused in the transporter, whereas the amino acids are transferred into the bloodstream to be transported to the liver and cells throughout the body for protein synthesis.

Freely available amino acids are used to create proteins. If amino acids exist in excess, the body has no capacity or mechanism for their storage; thus, they are converted into glucose or ketones, or they are decomposed. Amino acid decomposition results in hydrocarbons and nitrogenous waste, which includes ammonia which is converted to urea in the liver via the urea cycle. This process produces a keto group that may be used in the Krebs cycle and hence is used as a source of energy.

Amino acids can also be used as a source of energy, especially in times of starvation. Because the processing of amino acids results in the creation of metabolic intermediates, including pyruvate, acetyl CoA, acetoacyl CoA, oxaloacetate, and α-ketoglutarate, amino acids can serve as a source of energy production through the Krebs cycle (Figure). Figure summarizes the pathways of catabolism and anabolism for carbohydrates, lipids, and proteins.

Energy from Amino Acids

This figure shows the different reactions in which products of carbohydrate breakdown are converted into different amino acids.

Amino acids can be broken down into precursors for glycolysis or the Krebs cycle. Amino acids (in bold) can enter the cycle through more than one pathway.

Catabolic and Anabolic Pathways

This diagram shows the different metabolic pathways, and how they are connected.

Nutrients follow a complex pathway from ingestion through anabolism and catabolism to energy production.

Chapter Review

Digestion of proteins begins in the stomach, where HCl and pepsin begin the process of breaking down proteins into their constituent amino acids. As the chyme enters the small intestine, it mixes with bicarbonate and digestive enzymes. The bicarbonate neutralizes the acidic HCl, and the digestive enzymes break down the proteins into smaller peptides and amino acids. Digestive hormones secretin and CCK are released from the small intestine to aid in digestive processes, and digestive proenzymes are released from the pancreas (trypsinogen and chymotrypsinogen). Enterokinase, an enzyme located in the wall of the small intestine, activates trypsin, which in turn activates chymotrypsin. These enzymes liberate the individual amino acids that are then transported via sodium-amino acid transporters across the intestinal wall into the cell. The amino acids are then transported into the bloodstream for dispersal to the liver and cells throughout the body to be used to create new proteins. When in excess, the amino acids are processed and stored as glucose or ketones. The nitrogen waste that is liberated in this process is converted to urea in the urea acid cycle and eliminated in the urine. In times of starvation, amino acids can be used as an energy source and processed through the Krebs cycle.

Glossary

carboxypeptidase
pancreatic enzyme that digests protein

chymotrypsin
pancreatic enzyme that digests protein

chymotrypsinogen
: proenzyme that is activated by trypsin into chymotrypsin

enterokinase
: enzyme located in the wall of the small intestine that activates trypsin

inactive proenzymes
: forms in which proteases are stored and released to prevent the inappropriate digestion of the native proteins of the stomach, pancreas, and small intestine

pepsin
: enzyme that begins to break down proteins in the stomach

procarboxypeptidase
: proenzyme that is activated by trypsin into carboxypeptidase

proteolysis
: process of breaking proteins into smaller peptides

secretin
: hormone released in the small intestine to aid in digestion

sodium bicarbonate
: anion released into the small intestine to neutralize the pH of the food from the stomach

trypsin
: pancreatic enzyme that activates chymotrypsin and digests protein

trypsinogen
: proenzyme form of trypsin

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Lipid Metabolism

HEATHER KETCHUM AND ERIC BRIGHT

Lipid Metabolism[4]

Lipid metabolism begins in the intestine where ingested triglycerides are broken down into smaller chain fatty acids and subsequently into monoglyceride molecules (see Figure) by pancreatic lipases, enzymes that break down fats after they are emulsified by bile salts. When food reaches the small intestine in the form of chyme, a digestive hormone called cholecystokinin (CCK) is released by intestinal cells in the intestinal mucosa. CCK stimulates the release of pancreatic lipase from the pancreas and stimulates the contraction of the gallbladder to release stored bile salts into the intestine. CCK also travels to the brain, where it can act as a hunger suppressant.

Triglyceride Broken Down into a Monoglyceride

The top image shows the chemical formula for a triglyceride, and the bottom panel shows the formula for a monoglyceride.

A triglyceride molecule (a) breaks down into a monoglyceride (b)

Together, the pancreatic lipases and bile salts break down triglycerides into free fatty acids. These fatty acids can be transported across the intestinal membrane. However, once they cross the membrane, they are recombined to again form triglyceride molecules. Within the intestinal cells, these triglycerides are packaged along with cholesterol molecules in phospholipid vesicles called chylomicrons (Figure). The chylomicrons enable fats and cholesterol to move within the aqueous environment of your lymphatic and circulatory systems. Chylomicrons leave the enterocytes by exocytosis and enter the lymphatic system via lacteals in the villi of the intestine. From the lymphatic system, the chylomicrons are transported to the circulatory system. Once in the circulation, they can either go to the liver or be stored in fat cells (adipocytes) that comprise adipose (fat) tissue found throughout the body.
Chylomicrons

This figure shows a chylomicron containing triglycerides and cholesterol molecules as well as other lipids.
Chylomicrons contain triglycerides, cholesterol molecules, and other apolipoproteins (protein molecules). They function to carry these water-insoluble molecules from the intestine, through the lymphatic system, and into the bloodstream, which carries the lipids to adipose tissue for storage.

Lipolysis

To obtain energy from fat, triglycerides must first be broken down by hydrolysis into their two principal components, fatty acids and glycerol. This process, called lipolysis, takes place in the cytoplasm. The resulting fatty acids are oxidized by β-oxidation or fatty acid oxidation into acetyl CoA, which is used by the Krebs cycle (Figure). The glycerol that is released from triglycerides after lipolysis directly enters the glycolysis pathway as dihydrooxyacetone phosphate (DHAP). Because one triglyceride molecule yields three fatty acid molecules with as much as 16 or more carbons in each one, fat molecules yield more energy than carbohydrates and are an important source of energy for the human body. Triglycerides yield more than twice the energy per unit mass when compared to carbohydrates and proteins. Therefore, when glucose levels are low, triglycerides can be converted into acetyl CoA molecules and used to generate ATP through aerobic respiration.

Breakdown of Fatty Acids

This figure shows the reactions that break down fatty acids.

During fatty acid oxidation, triglycerides can be broken down into acetyl CoA molecules and used for energy when glucose levels are low. In addition,excess acetyl CoA is converted to ketones via ketogenesis.

Ketogenesis

If excessive acetyl CoA is created from the oxidation of fatty acids and the Krebs cycle is overloaded and cannot handle it, the acetyl CoA is diverted to create ketone bodies (see Figure). These ketone bodies can serve as a fuel source if glucose levels are too low in the body. Ketones serve as fuel in times of prolonged starvation or when patients suffer from uncontrolled diabetes and cannot utilize most of the circulating glucose. In both cases, fat stores are liberated to generate energy through the Krebs cycle and will generate ketone bodies when too much acetyl CoA accumulates. However, ketones are acids which at high levels can cause the pH of the plasma to become acidic; a condition called ketoacidosis.

Ketone Body Oxidation

Organs that have classically been thought to be dependent solely on glucose, such as the brain, can actually use ketones as an alternative energy source. This keeps the brain functioning when glucose is limited. When ketones are produced faster than they can be used, they can be broken down into CO_2 and acetone. The acetone is removed by exhalation. One symptom of ketogenesis is that the patient's breath smells sweet like alcohol. This effect provides one way of telling if a diabetic is properly controlling the disease. The carbon dioxide produced can acidify the blood, leading to diabetic ketoacidosis, a dangerous condition in diabetics.

Lipogenesis

When glucose levels are plentiful, the excess acetyl CoA generated by glycolysis can be converted into fatty acids, triglycerides, cholesterol, steroids, and bile salts. This process, called lipogenesis, creates lipids (fat) from the acetyl CoA and takes place in the cytoplasm of adipocytes (fat cells) and hepatocytes (liver cells). When you eat more glucose or carbohydrates than your body needs, your system uses acetyl CoA to turn the excess into fat. Although there are several metabolic sources of acetyl CoA, it is most commonly derived from glycolysis. Acetyl CoA availability is significant, because it initiates lipogenesis. Lipogenesis begins with acetyl CoA and advances by the subsequent addition of two carbon atoms from another acetyl CoA; this process is repeated until fatty acids are the appropriate length. Because this is a bond-creating anabolic process, ATP is consumed. However, the creation of triglycerides and lipids is an efficient way of storing the energy available in carbohydrates. Triglycerides and lipids, high-energy molecules, are stored in adipose tissue until they are needed.

Although lipogenesis occurs in the cytoplasm, the necessary acetyl CoA is created in the mitochondria and cannot be transported across the mitochondrial membrane. To solve this problem, pyruvate is converted into both oxaloacetate and acetyl CoA. Two different enzymes are required for these conversions. Oxaloacetate forms via the action of pyruvate carboxylase, whereas the action of pyruvate dehydrogenase creates acetyl CoA. Oxaloacetate and acetyl CoA combine to form citrate, which can cross the mitochondrial membrane and enter the cytoplasm. In the cytoplasm, citrate is converted back into oxaloacetate and acetyl CoA. Oxaloacetate is converted into malate and then into pyruvate. Pyruvate crosses back across the mitochondrial membrane to wait for the next cycle of lipogenesis. The acetyl CoA is converted into malonyl CoA that is used to synthesize fatty acids. Figure summarizes the pathways of lipid metabolism.

Lipid Metabolism

This figure shows the different reactions that take place for lipid metabolism.

Lipids may follow one of several pathways during metabolism. Glycerol and fatty acids follow different pathways.

Chapter Review

Lipids are available to the body from three sources. They can be ingested in the diet, stored in the adipose tissue of the body, or synthesized in the liver. Fats ingested in the diet are digested in the small intestine. The triglycerides are broken down into monoglycerides and free fatty acids, then imported across the intestinal mucosa. Once across, the triglycerides are resynthesized and transported to the liver or adipose tissue. Fatty acids are oxidized through fatty acid or β-oxidation into two-carbon acetyl CoA molecules, which can then enter the Krebs cycle to generate ATP. If excess acetyl CoA is created and overloads the capacity of the Krebs cycle, the acetyl CoA can be used to synthesize ketone bodies. When glucose is limited, ketone bodies can be oxidized and used for fuel. Excess acetyl CoA generated from excess glucose or carbohydrate ingestion can be used for fatty acid synthesis or lipogenesis. Acetyl CoA is used to create lipids, triglycerides, steroid hormones, cholesterol, and bile salts. Lipolysis is the breakdown of triglycerides into glycerol and fatty acids, making them easier for the body to process.

Glossary

beta (β)-oxidation
: fatty acid oxidation

bile salts
: salts that are released from the liver in response to lipid ingestion and surround the insoluble triglycerides to aid in their conversion to monoglycerides and free fatty acids

cholecystokinin (CCK)
: hormone that stimulates the release of pancreatic lipase and the contraction of the gallbladder to release bile salts

chylomicrons
: vesicles containing cholesterol and triglycerides that transport lipids out of the intestinal cells and into the lymphatic and circulatory systems

fatty acid oxidation
: breakdown of fatty acids into smaller chain fatty acids and acetyl CoA

ketone bodies
: alternative source of energy when glucose is limited, created when too much acetyl CoA is created during fatty acid oxidation

lipogenesis
: synthesis of lipids that occurs in the liver or adipose tissues

lipolysis
: breakdown of triglycerides into glycerol and fatty acids

monoglyceride molecules
: lipid consisting of a single fatty acid chain attached to a glycerol backbone

pancreatic lipases
: enzymes released from the pancreas that digest lipids in the diet

triglycerides
: lipids, or fats, consisting of three fatty acid chains attached to a glycerol backbone

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CHAPTER 4 - CARDIORESPIRATORY FITNESS

Objectives

1. Define the cardiovascular and respiratory system
2. Describe how the cardiorespiratory system works
3. Identify the benefits of cardiorespiratory fitness
4. What is the importance of this system?
5. Identify methods for assessing and improving the CR system

Terminology

- **Cardiorespiratory system:** The term used to describe the relationship between the cardiovascular system (heart and blood vessels) and respiratory system (lungs).
- **Calorie:** A term used to describe food energy. Scientifically, it is the amount of energy needed to raise one kilogram of water, 1 degree Celsius. More accurately, it is one kilocalorie.
- **Adenosine Triphosphate (ATP):** The basic unit of energy used by the cells.
- **Aerobic energy system:** The term used to describe the way cells produce ATP. In this case, the cells require oxygen to assist in ATP production.
- **Mitochondria:** The area (organelle) of the cell where ATP is produced.

- **Creatine phosphate:** a compound found in the cells and used by the immediate energy system that can be used to produce ATP.
- **Non-oxidative energy system:** a term used to describe the way cells produce ATP. In this case, cells do not require oxygen to produce ATP.
- **Glucose:** The simplest form of sugars found in the blood.
- **Tidal volume:** The amount of air measured during inspiration or expiration.
- **Diffusion capacity:** The amount of air that is transferred from the lungs to the blood.
- **Arterial-vein difference (aVO2diff):** The difference between the oxygen found in arterial blood and venous blood.
- **Principle of Reversibility:** The fitness principle describing how fitness is lost while detraining.
- **Maximal oxygen consumption (VO2max):** The maximum amount of oxygen the body can take in and utilize.
- **Specificity:** A fitness principle describing how fitness improvements or adaptations to exercise stress are specific to the type of training that is performed.
- **Overload:** The fitness principle describing how adaption to exercise stress is driven by progressively increasing the workload during training.
- **Target Heart Rate (THR):** A term describing heart rate zones that represent an intensity range—a low end heart rate and a high end rate—used as a guide for exercise intensity.
- **Max heart rate (MHR):** The maximum number of beats per minute the heart can contract.
- **Resting Heart Rate (RHR):** The minimum number of beats per minute the heart contracts.
- **Heart Rate Reserve (HRR):** The difference between the maximum heart rate and the resting heart rate. This term is also used to describe a method for calculating target heart rate.
- **Rating of Perceived Exertion (RPE):** A self-assessment used

during exercise used to estimate the intensity of the work being performed. The scale used, called the Borg Scale, ranges from 6 to 20.

- **Talk-test:** A self-assessment used during exercise to estimate the intensity of the work being performed. The assessment is based on the degree of breathlessness observed while attempting to talk during exercise.

What are the cardiovascular and respiratory systems?

DAWN MARKELL AND DIANE PETERSON

Imagine for a moment climbing to the top of Mt. Everest, a challenging feat very few have accomplished. In the process, you gradually ascend from base camp, which sits at about 17,500 feet above sea level, to the peak at over 29,000 feet. At this elevation, the pressure of oxygen is so low, you struggle to take in a satisfying breath. Although you strive to breathe deeply, you are unable to get enough air. Your heart rate increases and you might even develop nausea and a headache. Unless your body has a chance to acclimate itself to higher elevations or you gain access to supplemental oxygen, your symptoms will persist or worsen.

These are the sensations many people with cardiovascular or respiratory illnesses, such as asthma, chronic bronchitis, or mild cardiovascular disease, experience on a daily basis. Climbing up a flight of steps may leave them gasping for air, as would walking briskly or even breathing in cold air. Regardless of the cause, being unable to take in sufficient air can create a sense of panic and cause serious physical discomfort.

From this simple example, hopefully, you feel an appreciation for the simple act of breathing and ensuing satisfaction that comes with each life-sustaining breath. For most people, unless they engage in strenuous physical activity sufficient to get them breathing hard, their **cardiovascular and respiratory system** (heart, blood vessels, and lungs) operates efficiently enough to go relatively unnoticed. However, does that mean their cardiorespiratory (CR) system is functioning at optimal capacity? Or, could it be operating at a minimum level and experiencing problems that go undetected? This chapter defines cardiorespiratory fitness, examines the benefits of a healthy CR system, and explores how to effectively assess and improve the CR system.

The Benefits of Good Cardiorespiratory Health

The link below provides a list of specific benefits:

- Benefits of Cardiorespiratory Fitness

The article linked below describes how exercise protects against Cardiovascular Disease (CVD):

- Preventing CVD

How the CR System Works

The cardiorespiratory system operates to obtain and circulate vital compounds throughout the body—specifically, oxygen and nutrients, such as food energy, vitamins, and minerals. Both oxygen and nutrients, which are imperative for cellular energy production, must be taken in from the lungs and digestive system. Because the heart and lungs are so interlocked in this process, the two systems are often labeled together as the cardiorespiratory system. Without a healthy respiratory system, the body would struggle to bring in enough oxygen, release carbon dioxide (the chemical waste product of cellular metabolism) and eliminate unwanted particles that enter the respiratory tract when inhaling. Without a healthy heart, transporting oxygen from the lungs and nutrients from the digestive system to the body's cells would be impossible. If the health of the CR system were compromised enough, survival would be impossible. Additionally, both must be healthy or the function of one or the other will be compromised.

Below are several videos explaining how the cardiovascular and respiratory systems operate and function together:

- The CR System and Exercise
- Effects of exercise on the circulatory and respiratory systems
- Circulatory & Respiratory Systems
- The circulatory system
- The respiratory system

The CR System and Energy Production

DAWN MARKELL AND DIANE PETERSON

Clearly the cardiovascular and respiratory systems function as one, but why is the CR system so important? What makes the distribution of oxygen throughout the body so vital to existence? The answer is simple: ENERGY. While oxygen in and of itself does not contain any energy (**calories**), it does combine with fuel extracted from food once it has been introduced into the cell to help produce **adenosine triphosphate** (ATP). ATP is the basic form of cellular energy found in the body. Because the body stores very little ATP, it must constantly be regenerated. For this reason, people must continue eating and breathing to live.

Within the context of fitness, the purpose of the cardiorespiratory system is not only to produce energy but to also adapt in a way so that energy production can be optimized. For example, a high school cross country runner wants to be fit enough to compete in the state cross country meet. Unfortunately, this athlete's current mile time is 6 minutes per mile. In other words, that is the maximum work rate possible for this athlete. However, the goal is to improve to 5 minutes per mile, or improve the maximum work rate. To do so, more energy must be produced. According to the principles of adaptation, it is possible for this athlete to become more efficient at producing energy, enabling him to run a mile in less time. An example of this adaptation comes from the world record mile time of 3 minutes and 43 seconds. The world record marathon time (26.2 miles) is 2 hours, 1 minutes, and 39 seconds. That equates to 4 minutes and 38 seconds per mile over the 26-mile course. That is some serious ATP production!

Oxidative Energy System (Aerobic)

As oxygen and nutrients are delivered to the cells, they are utilized to produce ATP. The workhorses of the cell for oxidative metabolism are the **mitochondria**. This form of energy production is contingent on the ability of the CR system to deliver oxygen and nutrients and the cell's ability to process that oxygen. Because of the importance of oxygen in this particular energy-producing pathway, it is called the oxidative energy system, or **aerobic system**.

Oxidative energy production is the primary means of ATP production during rest and for activities that last for 2 minutes or longer. Although other forms of energy production assist in ATP production at any given time, long duration exercise sessions rely on this aerobic pathway. Also, in contrast to other forms of ATP production, the oxidative energy system uses both carbohydrates and fats for fuel sources.

To consider: What activities would emphasize development of this energy pathway?

Immediate/Explosive Energy System

While the oxidative system is the primary source of ATP production, it does require a few minutes for the system to begin operating at full capacity during exercise. How then could the body immediately produce enough energy to perform a strenuous activity, such as sprinting 50 meters? Clearly, another energy system must drive ATP production. The immediate or explosive energy system utilizes the storage of **creatine phosphate** (CP) and the storage of **adenosine diphosphate**, which is stored in very small amounts, to generate ATP. When needed, this energy system provides enough ATP to sustain a short-duration, explosive activity, approximately 10–20 seconds or less. Once CP is depleted, other energy systems must assist in the ATP generating process.

Non-Oxidative or Anaerobic Energy System

As the name implies, the **non-oxidative energy system** does not require oxygen to generate ATP. Instead, the cells where the ATP is produced require **glucose** (carbohydrates that have been broken down) as the fuel source. Like the immediate energy system, this system is associated with high intensity and short duration movements. While it is possible for some elite athletes to maintain exercise at "anaerobic" levels for several minutes, even they will eventually fatigue as a result of the non-oxidative system's ability to sustain ATP production for events lasting longer than approximately 2 minutes.

As glucose is processed to produce ATP, the natural byproduct of this process, lactic acid, also begins to accumulate. The result of excessive lactic acid accumulation contributes to muscle fatigue, making it impossible to continue exercise at a high intensity.

Energy Systems Combine

It is important to understand that energy systems do not operate in a compartmental fashion, but rather operate simultaneously, each carrying some of the burden of ATP production. For example, a professional soccer player would spend most of the match "cruising" at a light/moderate intensity level, thus primarily utilizing the oxidative energy system. However, during the match, he or she may sprint for several hundred meters, utilizing the explosive and non-oxidative system, or he or she may jump, requiring use of the explosive system. Thus, both energy systems are utilized simultaneously throughout the match. To improve performance, this player would need to develop the energy system which is utilized the most during the match.

Here's a video that goes over all 3 systems, but with a slightly different nomenclature for the Immediate Energy System (ATP-PCR Sytem) and the Non-Oxidative System (Glycolitic System): Energy Systems

Changes in the CR System

DAWN MARKELL AND DIANE PETERSON

An improvement in CR functioning, or fitness level, requires adaptation of the system. Remember, the point is to more effectively generate ATP so more work can be accomplished. In order to process more oxygen and deliver more oxygenated blood to the cells, the overall system must undergo changes to make this possible. Here is a list of adaptations that occur to the CR system as a result of consistent aerobic exercise:

- Resting heart rate may decrease. The average resting heart rate hovers around 70–75 beats per minute. Elite athletes may have resting heart rates in the high 30s. Generally, resting heart rate may decrease by approximately 10 beats per minute with chronic exercise.
- Pulmonary adaptations, such as increased **tidal volume** (the amount of oxygen entering the lungs with each breath) and increased **diffusion capacity** (the amount of oxygen that enters the blood stream from the lungs). This allows for more oxygen to enter the pulmonary circulation en route to the left side of the heart.
- The heart muscles, specifically the left side of the heart, increase in size making it possible to contract more forcefully. As a result, more blood can be pumped with each beat meaning more oxygen can be routed to the systemic circulation.
- More oxygen is delivered and transported into the cells where ATP production can occur. This is called the **arterial-vein difference** (a-VO_{2diff})

These changes in the system are not permanent due to the **principle of reversibility**. Following a period of inactivity, the benefits from chronic aerobic exercise will be reversed.

Assessing CR Fitness

To adequately prepare for starting a personal fitness program, it is important to first assess your current level of fitness. There are multiple methods for assessing a person's level of fitness. Each of the walking/jogging assessments discussed here attempts to estimate a key physiological marker of the heart's and lungs' functioning capacity and maximal oxygen consumption. **Maximal oxygen consumption**, or $VO_{2\ max}$, measures the body's maximum ability to take in and utilize oxygen, which directly correlates to overall health and fitness. A good estimate of $VO_{2\ max}$ provides a one-time glance at a person's health and fitness level and a baseline measurement for reassessment at future dates to gauge improvements.

Some of the most common walking/jogging assessments used to estimate $VO_{2\ max}$ include the 12-Minute Walk, 1.5-Mile Run/Walk Test, the 20m Leger Shuttle Run, 3-Minute Step Test, and 1-Mile Walk Test. Unfortunately, these field assessments, although practical and inexpensive, only provide estimations. More accurate assessments require a lab-based $VO_{2\ max}$ test using equipment that measures the volume of oxygen and carbon dioxide being moved in and out of the air passages during exercise. Although this test is more accurate, the expense and availability make it impractical for most. Unlike the lab test, the field assessments are relatively cost free, user-friendly and require very little expertise to conduct or perform. In addition, the key point of the assessment is measuring differences rather than absolute values, and the field tests accurately meet that objective.

Several examples of tests that assess cardiorespiratory endurance can be found in the Fitness and Stress Assessments chapter at the end of this textbook.

Measuring Heart Rate

DAWN MARKELL AND DIANE PETERSON

Those starting the $VO_{2\ max}$ assessments must first measure their heart rate, an important component used in the calculations.

Here is a video describing how to determine heart rate:

- How to Check Your Pulse

Creating a Plan to Develop CR Fitness

Once the assessments have been completed, the next step is to develop a plan for maintaining or improving your current level of fitness. This fitness plan should include activities that are safe and adapted to meet your personal goals. Once these fitness goals have been identified, the principles of adaptation to change can be utilized to achieve those goals. These principles include **specificity**, targeting specific areas in a workout, and **overload**, the practice of increasing exertion as the body adapts to ensure continued gains in fitness levels. Specifically, you need to apply the FITT principle (**F**requency, **I**ntensity, **T**ime, and **T**ype) described in detail in the previous chapter, "Fitness Principles":

- **Frequency**: 3–5 days per week for healthy adults.
- **Intensity**: moderate to vigorous intensity, which equals 40–85% of heart rate reserve, or 55–90% of percentage of max heart rate. (More information about intensity will be provided later.)
- **Time/duration**: 20–60 minutes per session or accumulation of 150 minutes per week. Sessions must be continuous for 10

minutes or more.
- **Type/mode**: Use large muscle groups and exercises specific to cardiorespiratory exercise.

Click on the link below for ACSM's latest recommendations on the quantity and quality of exercise for adults:

- ACSM's Official News Release

Measuring Intensity

DAWN MARKELL AND DIANE PETERSON

Intensity may be the most important aspect of the FITT principle. Engaging in a “cardio” program that does not stress the CR system to the recommended levels will be ineffective. Engaging in a program that overstresses the system can lead to injury and pose unnecessary risks. So how do you know if you are in the right range?

Heart rate is one of the best ways to measure effort level. Walking and jogging increase a person’s heart rate. Based on the function of the heart, this is no surprise. The heart rate directly correlates with the amount of oxygen being taken in by the lungs. As activity increases in intensity, oxygen demands increase and so does heart rate.

Because of this relationship, heart rate can be used in the design of an effective walking and jogging program by creating target heart rate zones. Heart rate zones represent an intensity range—a low end heart rate and a high end rate—within which a person’s heart rate would fall during a walking or jogging session.

The first step in determining your **target heart rate (THR)**, is to determine your **maximum heart rate (MHR)**, both measured in beats per minute (bpm). Generally, MHR is estimated to be your age subtracted from 220 beats per minute. In other words, your heart rate should theoretically stop increasing once it reaches the calculated maximum. While helpful, it is not uncommon to see variances in the laboratory tested maximum heart rate versus the calculated method.

The next step in calculating THR is to calculate a specific percentage of your MHR. This is done using two different methods.

Keep in mind, finding the THR is the objective in both methods, even though slightly different numbers are used.

The first method, called Max Heart Rate Method, is more commonly used.

Max Heart Rate Method

1. Calculate MHR;
   MHR = 220 – age.
2. Calculate high and low THR by plugging in a percentage range. In this example, 60 and 80% are being used.
   MHR x .60 = THR_{Low}
   MHR x .80 =THR_{High}
3. The resulting low and high THR numbers represent the range, or target intensity.

The target intensity signifies an optimal training zone for that particular walking or jogging session. By keeping the heart rate within that range, you will drive adaptation specific to that intensity. By using real, but random numbers, and plugging them into the above equation this becomes apparent.

Female, aged 20:

1. MHR = 220 -20
   MHR = 200 bpm;
2. THR_{low} = 200 x .60
   THR_{low} = 120 bpm
   THR_{high} =200 x .80
   THR_{high} = 160 bpm
3. THR = 120 – 160 bpm

To achieve her self-established goals, the female in the example above will need to stay within the range of 120 and 160 bpm. If her efforts are intense enough that she begins to exceed 160 bpm during her session, or easy enough that her heart rate falls below 120 bpm, she would need to change her intensity mid-session to get the optimal results.

The Karvonen Formula or Heart Rate Reserve Method

1. Calculate MHR; MHR = 220 − age.
2. Determine your **resting heart rate (RHR)**.
3. Find the **heart rate reserve (HRR)**; HRR = MHR − RHR
4. Calculate high and low THR by plugging in a percentage range and then adding in the RHR. In this example, 60 and 80% are being used.
   THR_{low} = HRR x .60 + RHR
   THR_{high} = HRR x .80 + RHR
5. The resulting low and high THR numbers represent the range, or target intensity.

Clearly, the Karvonen formula requires a few more steps, specifically, the incorporation of the resting heart rate. Using the same female in the example above, along with a randomly selected RHR, the THR looks like this:

1. MHR = 220 − 20
   MHR = 200
2. RHR = 72 bpm (randomly selected)
3. HRR = MHR − RHR
   HRR = 200 − 72
   HRR = 128
4. THR_{low} = HRR x .60 + RHR
   THR_{low} = 128 x .60 + 72

THR_{low} = 149 bpm

THR_{high} = HRR x .80 + RHR

THR_{high} = 128 x .80 + 72

THR_{high} = 174 bpm

5. THR = 149 – 174 bpm

A comparison of the two methods, reveals that the low and high end of the Karvonen formula is much higher than the Max Heart Rate method, even though the exact same percentages have been used. If the female in this example used the Karvonen Formula, she would find herself at a much higher intensity, especially at the low end of the range (120 vs. 149 bpm). How can this be? Aren't these formulas supposed to have the same objective?

While it is true that both equations are used to estimate a target heart rate range, only the Karvonen Formula takes into account the RHR, the lowest possible heart rate that can be measured for that individual. The Max Heart Rate method assumes the lowest heart rate possible is "0," a number to be avoided if at all possible! Because of the difference between 0 and the maximum heart rate, the calculated percentages result in a much lower number. In terms of accuracy, the Karvonen method is superior. It simply is a better representation of true target ranges.

Other Ways to Determine Intensity

Since not everyone owns a heart rate monitor, or wishes to pause during training to take pulse, other methods of determining exercise intensity have been developed. One particular method, called the **rating of perceived exertion (RPE)**, uses subjective measurement to determine intensity. The method is as simple as asking the question, Overall, how hard do I feel I am working? The answer is given based on a scale of 6 to 20 with 6 being almost no effort and 20 being maximum effort. Studies have indicated that when subjects are asked to exercise at a moderate or heavy intensity level, subjects can accurately do so, even without seeing their heart rate. As a result, using the RPE scale can be an effective way of managing intensity.

- The original RPE scale or **Borg Scale**, designed by Dr. Gunnar Borg, was developed to mimic generalized heart rate patterns. The starting and ending point of the scale are less intuitive than a typical scale of 1-10. By design, the 6 represents a resting heart rate of 60 bpm and the 20 an exercise heart rate of 200 bpm, a beat count someone might experience at maximum effort. Over time, a modified Borg Scale was developed using a simple 1–10 scale, with 1 being resting effort and 10 being maximum effort. Even though the modified scale is more intuitive, the traditional scale is still used more frequently. Follow this link to see both the original and modified scales.
- Walking and jogging not only benefit physical health, but many enjoy the social benefits realized by exercising with friends. When walking or jogging with friends, intensity can easily be measured by monitoring your ability to carry on a conversation. With the **Talk Test**, if you are only able to say short phrases or give one word responses when attempting to converse during an exercise session, this would suggest you are working at a high enough intensity that your breathing rate makes conversation difficult. Certainly, if you can speak in full sentences without getting winded, the intensity would be very light. Just like RPE, the Talk Test is yet another way to subjectively measure intensity, which can then be correlated with heart rates.

CHAPTER 5 - TRAINING FOR MUSCULAR STRENGTH AND ENDURANCE

Objectives

1. Describe muscular structure and function
2. Identify types of muscles
3. Describe an effective resistance exercise program
4. Assess your muscular strength and endurance
5. Understand the dangers of supplements

Terminology

- **Muscles**– organ in the body that causes movement
- **Skeletal Muscle**– Responsible for body movement
- **Cardiac Muscle**– Responsible for the contraction of the heart
- **Muscle Fiber**– individual muscle cell
- **Motor unit**– a nerve controlling a group of muscle fibers
- **Myofibrils-** threadlike structures running the length of the muscle fiber
- **Insertion**– point where the muscle is attached to a bone that moves
- **Origin**– point where the muscle is attached to a bone that remains in a fixed position
- **Action Potential**– the electrical current that cause a muscle to contract
- **Sliding Filament Theory**– the theory of how our muscles move

- **Dynamic contraction**– muscle movements that cause bodily movements
- **Repetition**– One movement pattern
- **Set**– a group of repetitions
- **Periodization**– Breaking resistance training into different training phases
- **Strength**– the maximal amount a force that can produced one time
- **Hypertrophy**– muscle fibers getting bigger
- **Atrophy**– muscle fibers getting smaller
- **Isokinetic**– muscle is contracted at a constant tempo
- **Isometric**– muscle contraction that causes no change in muscle length/no bodily movement

Exercise and Muscle Performance

HEATHER KETCHUM AND ERIC BRIGHT

Exercise and Muscle Performance[4]

Physical training alters the appearance of skeletal muscles and can produce changes in muscle performance. Conversely, a lack of use can result in decreased performance and muscle appearance. Although muscle cells can change in size, new cells are not formed when muscles grow. Instead, structural proteins are added to muscle fibers in a process called hypertrophy, so cell diameter increases. The reverse, when structural proteins are lost and muscle mass decreases, is called atrophy. Age-related muscle atrophy is called sarcopenia. Cellular components of muscles can also undergo changes in response to changes in muscle use.

Endurance Exercise

Slow fibers are predominantly used in endurance exercises that require little force but involve numerous repetitions. The aerobic metabolism used by slow-twitch fibers allows them to maintain contractions over long periods. Endurance training modifies these slow fibers to make them even more efficient by producing more mitochondria to enable more aerobic metabolism and more ATP production. Endurance exercise can also increase the amount of myoglobin in a cell, as increased aerobic respiration increases the need for oxygen. Myoglobin is found in the sarcoplasm and acts as an oxygen storage supply for the mitochondria.

The training can trigger the formation of more extensive capillary networks around the fiber, a process called angiogenesis, to supply oxygen and remove metabolic waste. To allow these capillary networks to supply the deep portions of the muscle, muscle mass does not greatly increase in order to maintain a smaller area for the diffusion of nutrients and gases. All of these cellular changes result in the ability to sustain low levels of muscle contractions for greater periods without fatiguing.

The proportion of SO muscle fibers in muscle determines the suitability of that muscle for endurance, and may benefit those participating in endurance activities. Postural muscles have a large number of SO fibers and relatively few FO and FG fibers, to keep the back straight (Figure). Endurance athletes, like marathon-runners also would benefit from a larger proportion of SO fibers, but it is unclear if the most-successful marathoners are those with naturally high numbers of SO fibers, or whether the most successful marathon runners develop high numbers of SO fibers with repetitive training. Endurance training can result in overuse injuries such as stress fractures and joint and tendon inflammation.

Marathoners

This photograph shows some runners in a race.

Long-distance runners have a large number of SO fibers and relatively few FO and FG fibers. (credit: “Tseo2”/Wikimedia Commons)

Resistance Exercise

Resistance exercises, as opposed to endurance exercise, require large amounts of FG fibers to produce short, powerful movements that are not repeated over long periods. The high rates of ATP hydrolysis and cross-bridge formation in FG fibers result in powerful muscle contractions. Muscles used for power have a higher ratio of FG to SO/FO fibers, and trained athletes possess even higher levels of FG fibers in their muscles. Resistance exercise affects muscles by increasing the formation of myofibrils, thereby increasing the thickness of muscle fibers. This added structure causes hypertrophy, or the enlargement of muscles, exemplified by the large skeletal muscles seen in body builders and other athletes (Figure). Because this muscular enlargement is achieved by the addition of structural proteins, athletes trying to build muscle mass often ingest large amounts of protein.

Hypertrophy

This photograph shows a man flexing his muscles.

Body builders have a large number of FG fibers and relatively few FO and SO fibers. (credit: Lin Mei/flickr)

Except for the hypertrophy that follows an increase in the number of sarcomeres and myofibrils in a skeletal muscle, the cellular changes observed during endurance training do not usually occur with resistance training. There is usually no significant increase in mitochondria or capillary density. However, resistance training does increase the development of connective tissue, which adds to the overall mass of the muscle and helps to contain muscles as they produce increasingly powerful contractions. Tendons also become stronger to prevent tendon damage, as the force produced by muscles is transferred to tendons that attach the muscle to bone.

For effective strength training, the intensity of the exercise must continually be increased. For instance, continued weight lifting without increasing the weight of the load does not increase muscle size. To produce ever-greater results, the weights lifted must become increasingly heavier, making it more difficult for muscles to move the load. The muscle then adapts to this heavier load, and an even heavier load must be used if even greater muscle mass is desired.

If done improperly, resistance training can lead to overuse injuries of the muscle, tendon, or bone. These injuries can occur if the load is too heavy or if the muscles are not given sufficient time between workouts to recover or if joints are not aligned properly during the exercises. Cellular damage to muscle fibers that occurs after intense exercise includes damage to the sarcolemma and myofibrils. This muscle damage contributes to the feeling of soreness after strenuous exercise, but muscles gain mass as this damage is repaired, and additional structural proteins are added to replace the damaged ones. Overworking skeletal muscles can also lead to tendon damage and even skeletal damage if the load is too great for the muscles to bear.

Performance-Enhancing Substances

Some athletes attempt to boost their performance by using various agents that may enhance muscle performance. Anabolic steroids are one of the more widely known agents used to boost muscle mass and increase power output. Anabolic steroids are a form of testosterone, a male sex hormone that stimulates muscle formation, leading to increased muscle mass.

Endurance athletes may also try to boost the availability of oxygen to muscles to increase aerobic respiration by using substances such as erythropoietin (EPO), a hormone normally produced in the kidneys, which triggers the production of red blood cells. The extra oxygen carried by these blood cells can then be used by muscles for aerobic respiration. Human growth hormone (hGH) is another supplement, and although it can facilitate building muscle mass, its main role is to promote the healing of muscle and other tissues after strenuous exercise. Increased hGH may allow for faster recovery after muscle damage, reducing the rest required after exercise, and allowing for more sustained high-level performance.

Although performance-enhancing substances often do improve performance, most are banned by governing bodies in sports and are illegal for nonmedical purposes. Their use to enhance performance raises ethical issues of cheating because they give users an unfair advantage over nonusers. A greater concern, however, is that their use carries serious health risks. The side effects of these substances are often significant, nonreversible, and in some cases fatal. The physiological strain caused by these substances is often greater than what the body can handle, leading to effects that are unpredictable and dangerous. Anabolic steroid use has been linked to infertility, aggressive behavior, cardiovascular disease, and brain cancer.

Similarly, some athletes have used creatine to increase power output. Creatine phosphate provides quick bursts of ATP to muscles in the initial stages of contraction. Increasing the amount of creatine available to cells is thought to produce more ATP and therefore increase explosive power output, although its effectiveness as a supplement has been questioned.

EVERYDAY CONNECTION

Aging and Muscle Tissue

Although atrophy due to disuse can often be reversed with exercise, muscle atrophy with age, referred to as sarcopenia, is irreversible. This is a primary reason why even highly trained athletes succumb to declining performance with age. This decline is noticeable in athletes whose sports require strength and powerful movements, such as sprinting, whereas the effects of age are less noticeable in endurance athletes such as marathon runners or long-distance cyclists. As muscles age, muscle fibers die, and they are replaced by connective tissue and adipose tissue (Figure). Because those tissues cannot contract and generate force as muscle can, muscles lose the ability to produce powerful contractions. The decline in muscle mass causes a loss of strength, including the strength required for posture and mobility. This may be caused by a reduction in FG fibers that hydrolyze ATP quickly to produce short, powerful contractions. Muscles in older people sometimes possess greater numbers of SO fibers, which are responsible for longer contractions and do not produce powerful movements. There may also be a reduction in the size of motor units, resulting in fewer fibers being stimulated and less muscle tension being produced.

Atrophy
This image shows muscle atrophy. The left panel shows normal muscle and the right panel shows atrophied muscle.

Muscle mass is reduced as muscles atrophy with disuse. Sarcopenia can be delayed to some extent by exercise, as training adds structural proteins and causes cellular changes that can offset the effects of atrophy. Increased exercise can produce greater numbers of cellular mitochondria, increase capillary density, and increase the mass and strength of connective tissue. The effects of age-related atrophy are especially pronounced in people who are sedentary, as the loss of muscle cells is displayed as functional impairments such as trouble with locomotion, balance, and posture. This can lead to a decrease in quality of life and medical problems, such as joint problems because the muscles that stabilize bones and joints are weakened. Problems with locomotion and balance can also cause various injuries due to falls.

Chapter Review

Hypertrophy is an increase in muscle mass due to the addition of structural proteins. The opposite of hypertrophy is atrophy, the loss of muscle mass due to the breakdown of structural proteins. Endurance exercise causes an increase in cellular mitochondria, myoglobin, and capillary networks in SO fibers. Endurance athletes have a high level of SO fibers relative to the other fiber types. Resistance exercise causes hypertrophy. Power-producing muscles have a higher number of FG fibers than of slow fibers. Strenuous exercise causes muscle cell damage that requires time to heal. Some athletes use performance-enhancing substances to enhance muscle performance. Muscle atrophy due to age is called sarcopenia and occurs as muscle fibers die and are replaced by connective and adipose tissue.

Glossary

angiogenesis
: formation of blood capillary networks

atrophy
: loss of structural proteins from muscle fibers

hypertrophy
: addition of structural proteins to muscle fibers

sarcopenia
: age-related muscle atrophy

Heather Ketchum & Eric Bright, OU Human Physiology Textbook. OpenStax CNX. Jun 18, 2015. Download for free at http://cnx.org/contents/e4f804ec-103f-4157-92e1-71eed7aa8584@1

Resistance Exercise Programming

DAWN MARKELL AND DIANE PETERSON

Designing a resistance exercise program can seem like a daunting task. However, the basics are very simple. The table below provides instructions for designing an effective resistance exercise program.

Resistance Exercise Program

F	Frequency of Exercise	How Often	Beginner	2–3 days per week Full-body workout of all 6 body areas 48–72 hours of rest in-between workouts	
			Intermediate to High	4–5 days per week; often perform split workouts (example: Monday and Thursday, work chest, shoulders, triceps, abdominals; Tuesday and Friday, work back, legs, biceps) 48–72 hours of rest in-between workouts	
I	Intensity of Exercise	How Hard	Beginner	60%–70% of maximum strength	
			Intermediate to High	70%–90% of maximum strength	
T	Time of Exercise	–How many reps –How many sets –How much time between sets	Beginner	1–3 Sets 8–12 repetitions	30 sec to 1 minute
			Intermediate to High	Endurance – 12–20+ Reps 2–3 Sets	30 sec to 1 minute
				Strength – 2–6 Reps 3–5 Sets	2 to 5 minutes
T	Type of Exercise	Which Exercises	Weight machines, free weights, resistance tubing, medicine ball, own body weight		

Note: Specificity Principle — you must work each muscle group to have strength gains in that particular part of the body.

Recommendations for Resistance Training Exercise

- **Perform a minimum of 8 to 10 exercises that train the major muscle groups.**
    - Workouts should not be too long. Programs longer than one hour are associated with higher dropout rates.
    - Choose more compound, or multi-joint exercises, which involve more muscles with fewer exercises.
- **Perform one set of 8 to 12 repetitions to the point of fatigue.**
    - More sets may elicit slightly greater strength gains, but additional improvement is relatively small.
- **Perform exercises at least 2 days per week.**
    - More frequent training may elicit slightly greater strength gains, but additional improvement is relatively small since progress is made during the recuperation between workouts.
- **Perform exercises using proper form.**
- **Perform exercises through a full range of motion.**
    - Elderly trainees should perform the exercises in the maximum range of motion that does not elicit pain or discomfort.
- **Perform exercises in a controlled manner.**
- **Maintain a normal breathing pattern or breathe out during the power phase of the exercise.**
- **If possible, exercise with a training partner.**

- Partners can provide feedback, assistance, and motivation.

Position Stand on Progression Models in Resistance Training for Healthy Adults[2]

- **Utilize both concentric and eccentric muscle actions.**
- **Utilize single and multiple joint exercises.**
- **Exercise sequence:**
  - large before small muscle group exercises
  - multiple-joint exercises before single-joint exercises
  - higher intensity before lower intensity exercises
- **When training at a specific load:**
  - 2-10% increase in load if one to two repetitions over the desired number
- **Training frequency**:
  - 2-3 days per week for novice and intermediate training
  - 4-5 days per week for advanced training
- **Novice training:**
  - 8-12 repetition maximum (RM)
- **Intermediate to advanced training:**
  - 1-12 RM using periodization* (strategic implementation of specific training phases alternating between phases of stress and phases of rest)
  - eventual emphasis on heavy loading (1-6 RM)
  - at least 3-min rest periods between sets
  - moderate contraction velocity

    - 1-2 s concentric, 1-2 s eccentric

- **Power training (two general loading strategies):**
    - **Strength training**
        - use of light loads
        - 30-60% of 1 RM
        - fast contraction velocity
        - 2-3 min of rest between sets for multiple sets per exercise
        - emphasize multiple-joint exercises especially those involving the total body
    - **Local muscular endurance training**
        - light to moderate loads
        - 40-60% of 1 RM
        - high repetitions (> 15)
        - short rest periods (< 90 seconds)

Recommendations should be viewed within the context of an individual's target goals, physical capacity, and training status.

For more information on using periodization for weight training, click on the link below:

Periodization for Weight Training

Six Types of Resistance Training

Each type of resistance training benefits muscles in a different way. While these types of resistance training are not new, they could be unique sources of resistance that you have not considered in your quest to add muscle to your frame. Using these forms of resistance alone, in combination with one another, or in combination with the more traditional resistance apparatus, can enable you to diversify your efforts to produce valuable and improved results.

In each type of training, you may use an apparatus to create an environment for resistance. The uniqueness of these sources is found in the way they are implemented. You might use a dumbbell for a particular exercise in some of these alternative resistance methods, but the way you use the resistance through a range of motion may be altogether different.

1. Dynamic Constant Training

As the name suggests, the most distinctive feature of dynamic constant training (DCT) is that the resistance is constant. A good example of DCT occurs when you use free weights or machines that do not alter resistance, but redirect it instead. The emphasis shifts to different planes along the muscle group being worked. When you work on a shoulder-press machine, for example, the resistance remains constant over the entire range of motion. It is identical from the bottom of the movement to the top and back down again. Only the direction of the resistance varies. The resistance redirects itself through the arc and then redirects itself again when the shoulders let the weight come back down to the starting position.

2. Dynamic Progressive Training

In dynamic progressive training (DPT), resistance increases progressively as you continue to exercise. DPT is often used as a rehabilitative measure and offers the sort of resistance that builds gradually while remaining completely within the control of the person using it. Equipment includes rubber bands and tubing, springs, and an apparatus controlled by spring-loaded parts. They are low-cost items that are easily accessible and can be used anywhere. Though commonly employed for rehabilitation of torn ligaments, joints, muscles, and broken bones, it is also convenient for travelers on either vacation or business trips. When combined with traditional forms of resistance, this training creates a better-balanced program and provides the muscles with a welcome alternative from time to time.

3. Dynamic Variable Training

This form of resistance exercise takes up where dynamic constant training leaves off. Whereas DCT employs constant resistance, never varying to accommodate the body's mechanics, DVT can be adapted to the varying degrees of strength of a muscle group throughout a range of motion. Some specialized machines use the DVT principle most effectively by allowing user to increase resistance at the beginning, middle or end of the range of motion. If your joints are stronger at the end of a movement (the top) or the beginning (the bottom), you can set the resistance accordingly.

4. Isokinetic Training

In isokinetic training (IKT), the muscle is contracted at a constant tempo. Speed determines the nature of this resistance training, not the resistance itself; however, the training is based on movement carried out during a condition of resistance. IKT can be performed with the body's own weight.

In isokinetic training, resistance is steady while velocity remains constant. For example, isokinetics are at work with any machine that is hydraulically operated. The opposing forces mirror each other throughout the range of motion. A good example would be pressing down for triceps on a hydraulic machine and having to immediately pull up (the resistance is constant in both directions) into a biceps curl while maintaining the same speed. IKT often involves opposing body parts. Trainers can use a variety of apparatus with their clients to achieve isokinetic stasis between muscle groups.

5. Isometric Training

Familiar to most people, isometric training (IMT) is an excellent way to build strength with little adverse effect on joints and tendons commonly associated with strength training and lifting heavy weights. Though it appears simple in comparison to traditional resistance training, IMT should not be underrated in its effectiveness. IMT is a method in which the force of contraction is equal to the force of resistance. The muscle neither lengthens nor shortens. You may be wondering how any training occurs without lengthening and shortening the muscles. In IMT, the muscles act against each other or against an immovable object.

Isometric training is used when performing planks or wall sits. Another common IMT exercise is pressing the hands together to strengthen the pectorals and biceps. Isometric training has been proven very effective for gaining strength, but this method usually strengthens only the muscles at the point of the isometric contraction. If the greatest resistance and force are acting upon the mid-portion of the biceps, that is where most of the benefit will occur.

6. Isotonic Training

This method demands constant tension, typically with free weights. Though this approach may sound a lot like dynamic constant training, it differs because it does not necessarily redirect the resistance through a range of motion, but rather, keeps tension constant as in the negative portion of an exercise. Complete immobility of the muscle being worked is required. For example, in the preacher curl, the biceps are fixed against the bench. They lift (positive), then release the weight slowly downward (negative), keeping the same tension on the muscles in both directions. This is one reason that free-weight exercise is considered the best form of isotonic training. Merely lifting a dumbbell or barbell, however, is not necessarily enough to qualify as isotonic. The true essence of isotonic training is keeping resistance constant in both the positive and negative portions of each repetition.

Exercise Order for Resistance Training

The general guidelines for exercise order when training all major muscle groups in a workout is as follows:

- Large muscle group exercises (i.e., squat) should be performed before smaller muscle group exercises (i.e., shoulder press).

- Multiple-joint exercises should be performed before single-joint exercises.

- For power training, total body exercises (from most to least complex) should be performed before basic strength exercises. For example, the most complex exercises are the snatch (because the bar must be moved the greatest distance) and related lifts, followed by cleans and presses. These take precedence over exercises such as the bench press and squat.

- Alternating between upper and lower body exercises or opposing (agonist–antagonist relationship) exercises can allow some muscles to rest while the opposite muscle groups are trained. This sequencing strategy is beneficial for maintaining high training intensities and targeting repetition numbers.

- Some exercises that target different muscle groups can be staggered between sets of other exercises to increase workout efficiency. For example, a trunk exercise can be performed between sets of the bench press. Because different muscle groups are stressed, no additional fatigue would be induced prior to performing the bench press. This is especially effective when long rest intervals are used.[3]

Resistance Training Conclusion

The most effective type of resistance-training routine employs a variety of techniques to create a workout program that is complete and runs the gamut, from basic to specialized. Learning different methods of training, different types of resistance, and the recommended order can help you acquire a balanced, complete physique. That does not mean that these training methods will help everybody to win competitions, but they will help you learn how to tune in to your body and understand its functions through resistance and movement. This knowledge and understanding develops a valuable skill, allowing you to become more adept at finding what works best for you on any given day.

For additional information on resistance exercises, click on the link below:

Exercise and Muscle Directory

Basics of Form during Resistance Training

AMANDA SHELTON

Basics of Form

Form during resistance training will look like a lot of components of proper form discussed elsewhere in this textbook because the key concepts of proper for are relatively consistent. *Please note that there will be exceptions to these general guidelines for form that will be lift specific to different activities.*

Core Stability – we need to focus on protecting our spine and ensuring that our transfer of force between the upper and lower body is optimized. There are varied strategies for what core stability to will look like and that may also depend on the type of resistance training being performed.

Knees following over toes – the knees should follow over the direction of the toes to avoid knee valgus or adduction at the hips.

Scapular Retraction and Depression – retraction and depression of the scapula can help to optimize the position of the shoulder joint during general lifting. *Considerations*: There are some lifts that are specifically involving additional or different position of the scapula where this position may be inappropriate.

Neutral head position – maintaining a head position that is in alignment with the spine and in a neutral position will help to protect the cervical spine and avoid neck injuries.

Loading through the heel during strength or stability exercises –

this provides a stable surface for producing force while also ensuring that major muscle groups are involved in lower body activities instead of being limited by smaller muscle groups. *Considerations:* Loading through the toes will be appropriate technique for power types of activities with more explosive movement patterns.

Resistance Training Systems

AMANDA SHELTON

Resistance Training Systems

When creating a resistance training program, there are several training systems that can be used with different benefits associated with them.

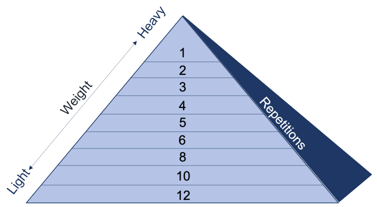
Single Set

In a single set system, you are completing **one set of each exercise**. Benefits of a single set system: this is a great option for beginners to complete a variety of exercises without overloading beyond their abilities. This is also a good starting point for progression into a higher intensity program while the initial adaptations to resistance training occur.

Multi-Set

The multi-set system includes **multiple sets of each exercise**. The number of sets that are selected should be based on the training goals of the individual and the type of resistance training they are participating in (muscular endurance vs. muscular hypertrophy vs. muscular strength vs. muscular power). Benefits of a multi-set system: better for more advanced clients who are looking to increase their load to optimize the adaptations of their program.

Pyramid



The pyramid system involves multiple sets, just like the multi-set system, but in the pyramid system there are **varied levels of repetitions throughout the multiple sets along with changing the intensity of the weights used**. You can go "up" or "down" in the pyramid system. Remember, repetitions and intensity (the amount of weight used in this case) follow an inverse relationship meaning that as you increase the repetitions the weight decreases while if you decreased the number of repetitions the weight increases.

Superset

In the superset system, you are performing two exercises in rapid succession from one another. There are many variations of the superset system and how it is implemented within a program. It can be completed through varying the body area being loaded by a superset of upper body + lower body exercises (*i.e., biceps curls and calf raises*) or a superset of push + pull in the same body area but opposing muscle groups (*i.e., dumbbell bench press and bent over rows*). Other variations of a superset can include a **tri-set**, where three exercises are superset together, or a **giant-set**, where more than 3 exercises are superset together. Benefits of the superset system: you may have the opportunity to shorten rest times because while you are resting for one muscle group you are performing another exercise on a different muscle group which can either optimize time-management during resistance training or the benefit of minimizing rest time to increase cardiovascular load while still allowing for muscle recovery between compounding sets.

Circuit Training

For circuit training, you are performing a series of exercises in sequence with minimal rest. Circuit training sometimes can be confused with a giant-set from our superset system, although there are some distinct differences. Typically, in circuit training you will have all major muscle groups addressed within the variety of exercises within the circuit and have built in “rest” stations. You will likely only have one circuit within the workout session, whereas with giant-sets you may have multiple giant-sets within the workout session. Circuit training will also sometimes have cardiorespiratory exercises built in to the system to increase cardiovascular loading during the activity.

Drop Set

The drop set system is a more advanced training technique that involves completing a set to failure, decreasing the weight, and repeating a set to failure. This can be repeated for as many sets as desired. Typically during this type of system, the dropped set involves decreasing weight by 5~20%. Drop sets can be performed as a standalone training strategy or incorporated into other systems (such as the multi-set or superset systems) where your final set is a drop set performed to failure. This strategy allows you to overload the muscle to fatigue without adding additional weight that can sometimes help to overcome performance plateaus.

Supplements and Performance Enhancing Substances

DAWN MARKELL AND DIANE PETERSON

Performance-Enhancing Substances

Some athletes attempt to boost their performance by using various agents that may enhance muscle performance. Anabolic steroids are one of the more widely known agents used to boost muscle mass and increase power output. Anabolic steroids are a form of testosterone, a male sex hormone that stimulates muscle formation, leading to increased muscle mass.

Endurance athletes may also try to boost the availability of oxygen to muscles to increase aerobic respiration by using substances such as erythropoietin (EPO), a hormone normally produced in the kidneys, which triggers the production of red blood cells. The extra oxygen carried by these blood cells can then be used by muscles for aerobic respiration. Human growth hormone (hGH) is another supplement, and although it can facilitate building muscle mass, its main role is to promote the healing of muscle and other tissues after strenuous exercise. Increased hGH may allow for faster recovery after muscle damage, reducing the rest required after exercise, and allowing for more sustained high-level performance.

Although performance-enhancing substances often do improve performance, most are banned by governing bodies in sports and are illegal for nonmedical purposes. Their use to enhance performance raises ethical issues of cheating because they give users an unfair advantage over nonusers. A greater concern, however, is that their use carries serious health risks. The side effects of these substances are often significant, nonreversible, and in some cases fatal. The physiological strain caused by these substances is often greater than what the body can handle, leading to effects that are unpredictable and dangerous. Anabolic steroid use has been linked to infertility, aggressive behavior, cardiovascular disease, and brain cancer.

Similarly, some athletes have used creatine to increase power output. Creatine phosphate provides quick bursts of ATP to muscles in the initial stages of contraction. Increasing the amount of creatine available to cells is thought to produce more ATP and therefore increase explosive power output, although its effectiveness as a supplement has been questioned.

Bottom Line: Many active people use nutritional supplements and drugs in the quest for improved performance and appearance. Most of these substances are ineffective and expensive, and many are dangerous. A balanced diet should be your primary nutritional strategy.

Below are links that provide additional information about the use of supplements during exercise:

Benefits and Side Effects of Steroid Use
Protein Powders
Creatine Supplements

CHAPTER 6 - FLEXIBILITY

Objectives

1. Define flexibility
2. Examine the benefits of flexibility
3. Identify ways to increase flexibility
4. Create an effective stretching program
5. Assess your own flexibility

Terminology

- **Static Flexibility**: the outermost limit of a stretched muscle measured while holding a stretch in place. This can also refer to a technique used to improve the outermost limit of a stretched muscle performed by holding stretches for 15-60 seconds.
- **Dynamic Flexibility:** the relative degree of ease a muscle can move through a normal range of motion. The can also refer to a technique used to improve static flexibility and ease of motion done by performing exaggerated movements.
- **Elasticity:** the ability of the muscle to return to its resting length after being stretched.
- **Plasticity:** the tendency of a muscle to assume a greater length after stretching.
- **Proprioceptors:** sensors within muscles that send feedback to the central nervous system conveying muscular length and tension. The two primary sensors related to flexibility are Golgi Tendon Organs (GTO's) and muscle spindles.
- **Joint Structure:** the fixed arrangement of a joint that is a

determining factor for range of motion. An example would be ball-in-socket joint or modified hinge joint.

- **Myotatic Reflex:** a reflexive stimulus of the muscle to contract as a muscle is being stretched.
- **Reciprocal Inhibition:** the principle that when one muscle is stimulated to contract the opposing muscle is will relax.
- **Autogenic Inhibition:** an inhibitory reflex that allows one sensor in the muscle to override the signals of another sensor. Also called the inverse myotatic reflex.
- **Active stretching:** a mode for stretching that is unassisted or involves no internal stimulus.
- **Passive stretching:** a mode for stretching that uses an external source such as a partner or gravity to assist in the movements.
- **Ballistic stretching:** a technique used to improve range of motion performed by gently bouncing back and forth to stretch and relax the muscle.
- **Proprioceptive Neuromuscular Facilitation (PNF):** a technique used to improve range of motion performed by a sequence of stretching and contracting muscles. These sequences target the neuromuscular structures to facilitate relaxation of reflexive activity.

What is Flexibility?

DAWN MARKELL AND DIANE PETERSON

One of the five health-related components of fitness is flexibility. Flexibility relates to the ability to move a joint through its full range of motion (ROM). Developing a complete fitness program requires taking time to emphasize this component by stretching. Unfortunately, as the American Council on Exercise points out, "Most people neglect flexibility training, limiting freedom of movement, physical and mental relaxation, release of muscle tension and soreness, and injury prevention."[1]

Perhaps the reason it is so easy for people to overlook flexibility is because its benefits, while significant, are felt more than seen. However, failing to address this component of fitness can have serious consequences, especially as a person ages. Without flexibility, everyday tasks, such as sweeping the floor or even getting out of bed, become difficult. Reduced mobility of joints increases the risk of injury during an exercise routine, as well as the risk of occasional and chronic back pain. This chapter will provide a greater understanding of this vitally important component of a complete fitness program and demonstrate why flexibility shouldn't be overlooked.

Types of Flexibility

Flexibility is classified into two types: static and dynamic.

1. Static flexibility

This type of flexibility is a measure of the limits of a joint's overall range of motion. It is measured by stretching and holding a joint in the position of its maximum range while using a measuring instrument to quantify that range. To achieve the maximum range, **passive forces**, the force generated from an external source, are required.

2. Dynamic flexibility

This type of flexibility is a measure of overall joint stiffness during movement. Unlike static flexibility, dynamic flexibility requires active force production, or your own muscles contracting. Because quantifying "stiffness," is difficult, dynamic flexibility is measured more subjectively. Assessment is based on how easy or difficult it is to perform certain tasks, such as swinging a tennis racket, climbing steps, or getting in and out of a car.

The aim of any good stretching program is to improve both static and dynamic flexibility so that normal ROM can be achieved. The definition of *normal* in this context is one developed from population studies that measured various areas of the body and established an average degree of movement for a particular joint.

Benefits of Flexibility and Stretching

DAWN MARKELL AND DIANE PETERSON

Regular stretching provides many benefits, the most important of which is simple: flexibility provides freedom of movement and the ability to complete activities with greater ease.

Healthy Joints and Pain Management

As many as 26 percent of all adults report pain and stiffness in joints. That number increases dramatically with age, and women are more likely to develop joint symptoms.[2] For adults, arthritis is one of the most common conditions, with 54% of people 75 years and older having been diagnosed with arthritis.[3] Regular exercise, including regular stretching, is essential for people with arthritis to maintain function and manage joint pain. Even for those not affected by joint conditions, stretching increases joint mobility and function, and decreases joint stiffness and pain.

Imbalances in the muscles can cause discomfort and pain. For example, if the front of a person's thighs and hips gets too tight from a lack of flexibility, the tension will pull on the hips, where the muscles are attached. The result is the pelvis may be pulled forward and cause greater sway in your lower back. This affects posture and can eventually lead to pain and stiffness in the neck, shoulders, and lower back. Stretching all major muscle groups and joint areas regularly promotes good alignment and balance.

Muscle Relaxation and Stress Relief

Staying in one position for long periods of time, repetitive movements, and other everyday stressors can result in stiff muscles and knots, also called trigger points. Regular stretching decreases anxiety, blood pressure, and breathing rate, which help to relax muscles and aches and pains related to neuromuscular tension (stress). Flexibility has also been prescribed successfully to treat dysmenorrhea, which is painful menstruation. It also relieves muscle cramps that can occur during exercise or participation in sports.

Other Benefits

In addition to the benefits listed above, research has documented additional benefits that provide good reasons for maintaining a routine of stretching:

- **Increased blood flow:** Blood carries vital nutrients and oxygen to muscles and tissues. Stretching increases blood flow to the muscles being stretched, which helps them recover from exercise faster.[4]
- **Reduced risk of developing future lower back pain:** Although research is still inconclusive, most experts agree that muscle fitness and stretching exercises reduce the risk of developing lower back pain by counteracting the natural loss in muscle and connective tissue elasticity that occurs with aging.

Flexibility and Aging

For many college students, maintaining long- term flexibility is not a concern. For young adults, bending over to tie their shoes is painless. Walking around campus with a backpack requires minimal effort. However, ROM declines with age. Simple activities like rotating the head and neck to glance over the shoulders, getting in and out of a vehicle, or carrying groceries can become painful. Therefore, flexibility is critical in maintaining a high quality of life throughout the aging process.

The Inactivity-Mobility Cycle

Anyone who has suffered an injury and had to wear a splint, cast, or brace to immobilize a joint knows how important mobility is to overall health. Unfortunately, when the joints' ROM becomes restricted by arthritis or other injuries, activity declines. As activity declines, the ROM continues to diminish as a result of inactivity, and a vicious cycle ensues. A simple stretching program can help alleviate this problem and break the cycle.

Improving Range of Motion

DAWN MARKELL AND DIANE PETERSON

Joint ROM results from a combination of factors, which are classified as either internal or external. Internal structures relate to the physical structures of body materials and tissue. External factors are non-structural and include gender, age, excess fat mass, muscle mass, environmental temperature, and restrictions in clothing or equipment.

Internal factors include joint structure/joint mechanics and the connective and soft tissue surrounding the joint. Because muscular actions, such as muscular contractions and stretching, are controlled by the nervous system, another internal factor can be attributed to the neuromuscular system and how the stretching and tension is managed.

Joint Structure

A joint is defined as a location on the skeletal system where two or more bones intersect and interact. For example, the humerus (upper arm) intersects with the radius and ulna (lower arm) at the point of the elbow. The bony formation of each joint structurally limits its ROM. For example, the shoulder joint, which is structurally a ball-in-socket joint, can rotate in multiple directions, giving it a wide range of motion. However, the knee joint is a modified hinge joint, which is limited to essentially a forward-backward direction of movement.

Additionally, ROM may be limited by excessive fat mass or even large muscle mass surrounding a particular joint. Although the amount of muscle mass and fat mass surrounding a joint can be altered by diet and activity levels, joint structure is permanent. As a result, little can be done to improve flexibility in this area.

Not only is range of motion related to the joint structure, but flexibility exercises are joint-specific. Stretching the hamstring will not improve flexibility in the shoulders. Likewise, flexibility in the shoulders may be excellent while fingers or ankles remain "stiff." As such, a complete and effective stretching program includes multiple stretches for various joints.

Connective and Muscle Tissue

Joints are surrounded and connected by muscles, tendons, ligaments, and skin. The head of the humerus fits into a small cavity to create the shoulder joint. However, those bones cannot remain in that position without the muscles, tendons, and ligaments that keep the joint tight and hold it in place. In addition, muscle tissue is surrounded with connective tissue, primarily collagen and elastin. As a joint moves through its normal range of motion, all of this soft tissue must stretch to accommodate the movement. Therefore, static and dynamic flexibility is probably most limited by the flexibility of the surrounding soft tissue, specifically the connective tissue.

While the exact biomechanics of how flexibility is changed is not well understood, they do appear to be related to the elastic and plastic properties of the connective tissue. **Elasticity** is defined as the ability to return to resting length after **passive stretching** (i.e., elastic recoil). Like a spring, soft tissues stretch and then recoil to their resting position. **Plasticity** is the tendency to assume a greater length after passive stretching (i.e., plastic deformation). Stretching that spring composed of soft tissues will change its resting position to a new longer length. The goal of a flexibility program is to repeatedly overload the elastic properties of the muscle to elicit plastic deformation over time. Experts suggest that a slow, sustained stretch for 30–90 seconds is necessary to produce chronic plastic deformation.

Neuromuscular System

Modern cars come equipped with a central computer and sensors to troubleshoot problems with the vehicle. Sensors in the engine monitor temperature. Sensors on the wheels gauge tire pressure while sensors in the gas tank alert the driver when fuel is low. Much like a car, our bodies are equipped with sensors, called **proprioceptors**, that help us manage movement and prevent injury.

Muscles have two specific types of proprioceptors that determine the length and tension of the muscle. These proprioceptors are called muscle spindles and Golgi tendon organs (GTOs).

Muscle spindles lie parallel to the regular muscle and help determine the length of muscles when they are being stretched. When a muscle is stretched, it sends signals to the central nervous system causing the stretched muscle to contract. This resistance to the stretch, called the **myotatic** or **stretch reflex** is generated by the nervous system's reflexive stimulus sent to the stretching muscle. That same signal also causes the antagonist, or opposing muscle to relax, called **reciprocal inhibition**. As such, when the upper thigh muscles (quadriceps) are stretched, the hamstrings (antagonist to the quadriceps) relax.

The GTOs are located near the **musculotendon junction**, the end points of the muscle, and relay messages to the central nervous system regarding muscle lengthening and tension of the muscle. When activated, these signals will override the stretch reflex causing a sudden relaxation of the stretching muscle. This is called

autogenic inhibition or the **inverse myotatic reflex**. This inhibitory reflex can only occur after the muscle has been stretched for 5 seconds or longer. This is why, to effectively stretch, movements must be sustained for long, slow increments of time. Otherwise, the resistance encountered from the stretch reflex will not be overridden and lengthening cannot occur. Whether signaling the muscles to contract or relax, the neuromuscular system manipulates the stretched muscle, presumably as a protective mechanism to prevent injury.

Improving Flexibility

DAWN MARKELL AND DIANE PETERSON

Research has identified multiple stretching techniques that aid in improving ROM. Regardless of the specific technique or specific mode used, each technique can be performed using either active or passive mode. **Active stretching**, also called unassisted stretching, is done individually without an external stimulus. **Passive stretching**, or assisted stretching, is when a partner or trainer is used as the stimulus in the stretching exercise. Both modes are effective and can be applied to each of the techniques described below.

Static Stretching

The technique most commonly prescribed and used to improve flexibility is the static stretch. A static stretch involves slow, gradual, and controlled movements. The muscle group is stretched toward the end of the joint's ROM until the point of mild discomfort is reached. Once that point is reached, the stretch is held in a "static" position for 30 to 90 seconds. After the prescribed time, the stretch can be repeated. Common ways in which static stretching is applied would be performing Yoga routines or stretching after a workout or an athletic event. Some of the major advantages of static stretching are as follows:

1. It is generally considered safe (see "Stretches to Avoid" on the next page).
2. It is simple to perform.
3. It is effective at increasing ROM.

The only major disadvantage comes from doing it too much, which can reduce strength and may make joints unstable. Of course, this potential risk applies to all of the techniques.

Ballistic Stretching

Ballistic stretching involves forceful bouncing or ball-like movements that quickly exaggerate the joint's ROM without holding the position for any particular duration. This type of stretching involves dynamic movements like those done by athletes during sports events. In that regard, ballistic stretching is seen as being very specific to and beneficial for athletes. However, one criticism of ballistic stretching is that because of the short duration of the stretch and the forceful nature of ballistic movements, the muscular contraction from the stretch reflex may cause muscle soreness or even injury. For that reason, many coaches regard ballistic stretching as unsafe. Also, many researchers contend that it is less effective at improving ROM. Nonetheless, the American College of Sports Medicine (ACSM) still recommends ballistic stretching as one method to effectively increase flexibility.

Dynamic Stretching

Ballistic stretching is a form of dynamic stretching. However, when referring to dynamic stretching routines, most fitness professionals are referring to dynamic movements that do not involve forceful bouncing motions. Instead, dynamic stretching, in this context, suggests performing exaggerated sports movements in a slower, more controlled manner. For example, a sprinter may use several exaggerated stride lengths before a race to improve hip ROM.

An advantage of dynamic stretching is its ability to target and improve dynamic flexibility, which in turn may improve performance. A disadvantage comes from the movements involved, which often require good balance and coordination. Since mastering the correct form requires time and a certain level of athleticism, dynamic stretching may not be suitable for certain populations.

Proprioceptive Neuromuscular Facilitation (PNF) Stretching

This type of exercise usually involves a partner. The partner will passively stretch the person's muscle. This movement is immediately followed by an isometric muscle contraction against resistance. This contraction is then followed by another passive stretch. This type of stretch is also named contract-relax stretch because of the sequence of movements involved. Other types of PNF stretching involve contract-relax-antagonist contraction, also describing the sequence of movements involved but adding an additional step.

As the name of the technique implies, PNF stretching emphasizes the natural interaction of the proprioceptors with the muscles to increase the ROM during the stretch. Remember that during the stretch, the muscle spindles cause two responses: the stretch reflex and the reciprocal inhibition (the relaxing of the antagonist muscle). After 5 seconds, the GTOs then override the muscle spindle's signals causing autogenic inhibition. Because the muscle is relaxed, it can be stretched more easily. To reiterate, the stretch either uses the activity of the antagonist muscle to get the target muscle to relax or the target muscle itself relaxes as a result of the contraction of the antagonist muscle.

While many experts assert that PNF stretching is the most effective technique, studies that compare static and PNF stretching are inconclusive. Regardless, it does appear to be very effective at increasing static flexibility. Some disadvantages to PNF are that it generally requires a knowledgeable partner, it is somewhat complicated, and it can cause soreness as a result of the contractions.

Creating an Effective Stretching Program

DAWN MARKELL AND DIANE PETERSON

First evaluate your current flexibility status by assessing various joints' ROM. Specifically, performing the sit-and-reach test will assess your hamstring and lower back flexibility while using a goniometer can be used to assess your ankles, knees, hips, neck and shoulders. Instructions on how to perform these assessments will follow later.

Setting Goals

Once you determine which of your joints are the most and least flexible, you can set some realistic goals to improve or maintain your ROM. Be specific when you set goals. Instead of just saying, "I want to increase my flexibility," identify the specific area of the body you intend to improve. You will also want to make sure your goal can be measured. A better way to state your goal is, "I will improve my sit-and-reach score by 4 cm by the end of the semester." Notice this goal, as stated, includes a specific area, is measurable, and includes a deadline. By stating your goal properly, you will increase the likelihood of achieving it.

Applying the FITT Principle

When designing a flexibility program use the FITT Principle (**F**requency, **I**ntensity, **T**ime and **T**ype). Your flexibility program should include multiple stretching exercises that target all major joints, including the neck, shoulders, elbows, wrists, trunk, hips, knees, and ankles.

After selecting your exercises, follow the recommendations below when performing your routine:

- **Frequency:** Stretch a minimum of 2-3 days per week, ideally 5-7 days per week.
- **Intensity:** Stretch to the point of tightness or mild discomfort.
- **Time (duration of each stretch):** Stretch for a minimum of 10 seconds for very tight muscles with an emphasis on progressing to 30-90 seconds. Complete two to four repetitions of each stretch.
- **Type (mode):** Select the technique that best suits your circumstances: static, dynamic, ballistic, or proprioceptive neuromuscular facilitation.

When to Stretch

Although stretching can be done any time, the ACSM traditionally recommends that flexibility training be incorporated into the warm up or cool down phase of an exercise session. Recent studies suggests that stretching before an exercise session will compromise the force-producing capabilities of muscles and should be avoided. Therefore, it is recommended that stretching be restricted to *after* the warm-up or workout, when the temperature of the body and muscles has increased. Additional evidence pertaining to this concept shows that applying heat packs for 20 minutes to increase muscle temperature can increase hamstring flexibility more so than 30 seconds of static stretching. These findings confirm that temperature also plays a significant role in muscle ROM.

Stretching Safely

In addition to warming up your muscles before performing stretching exercises, additional precautions can be taken to ensure the safety of your routine. When muscles are stretched quickly and forcefully, the stretch reflex can be activated. This creates significant tension because the muscle fibers will not only be stretching but also attempting to contract. As mentioned previously, this is one of the reasons ballistic stretching may not be suitable for everyone. To avoid this, stretch slowly and in a controlled fashion while holding the stretch for 10 seconds or more.

Stretches to Avoid

Research indicates that some stretches are **contraindicated**, which means they are not recommended because they provide little to no benefit and may cause injury. A list of stretches to avoid, as well as safer, alternate stretches, can be found by clicking on the link below. However, this is not a comprehensive list of potentially risky stretches. To avoid injury, it is important to consider personal limitations before performing a stretch exercise.

Contraindicated Stretches

CHAPTER 7: CORE AND BALANCE TRAINING PRINCIPLES (AMANDA SHELTON)

What is "the core"?

So often, the term "core" gets thrown around within the realm of exercise without clear knowledge of what its components are. In this chapter, we will examine the different components of the lumbo-pelvic-hip complex (LPHC), the body's center of gravity, the role of the core in the kinetic chain, and developing core training.

The LPHC is named after its primary components:

- lumbar spine
- pelvic girdle
- abdomen
- hip joint

Balance

LAWRENCE DAVIS

Warning sign indicating a rough walking surface, which isn't a problem for animals with more stable body types, such as cats and dogs. Image Credit: National Park Service

[1]

As an RN on MED floor, Jolene assesses each patient's fall risk according to the Morse Fall Scale, provide a nursing diagnosis (ND)

1. "Rough Surface Warning"National Park Service is in the Public Domain

for fall risk, and implement fall precautions based on the ND. The human body typically operates in many positions that are not very stable and we must constantly use our muscles to adjust our body position and counteract the tendency of our bodies to fall over. We often refer to this skill as *balance*. For the most part balance is subconscious, but watching a toddler who has just learned to walk will provide an amplified idea of how much actual **work** is required for humans to stay upright. Toddlers are especially unstable due to their disproportionately massive heads, and after this unit we will understand exactly why that feature so greatly affects their **stability**.

Davis, Lawrence. *Body Physics: Motion to Metabolism.* Open Oregon Educational Resources. https://openoregon.pressbooks.pub/bodyphysics

Center of Gravity

LAWRENCE DAVIS

Finding the Center of Gravity

You may have heard the term **center of gravity** in reference to balance and you might intuitively know that a toddler's big head raises their center of gravity, which makes them less stable than adults. We already know that the **force of gravity** is what gives an object **weight**, but what is the center of gravity? Think about which body part you feel gravity pulling on. Do you feel it pulling on just your leg, or your arm, or what? Actually, the force of gravity acts on all of your mass in the same way, according to **Newton's Universal Law of Gravitation** down to every single molecule and atom. If we break up your body into many many small chunks of equal mass we could calculate the tiny force of gravity on each one. If we add up all those tiny forces we get your total weight. If we average the locations of all those equal tiny forces, the resulting location would be the **center of gravity**. If we averaged the location of all the equal chunks of mass that would be the **center of mass**. Everyday objects, like humans, are small enough that gravity acts **uniformly** on all parts of the object and the center of gravity and the center of mass are essentially the same location. Check out the following video to learn how to experimentally find the center of gravity (mass) of an irregular object.

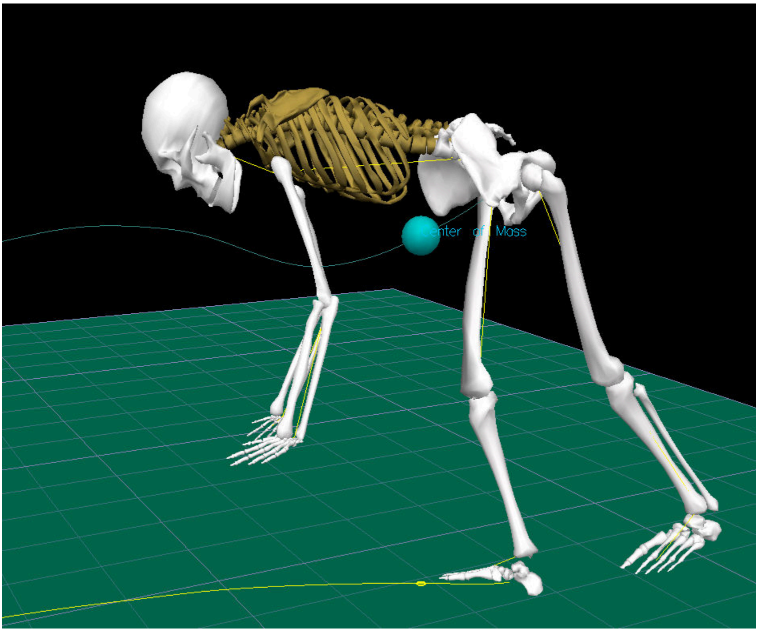
One or more interactive elements has been excluded from this version of the text. You can view them online *here: https://ecampusontario.pressbooks.pub/paramedicfitness/?p=275#oembed-1*

Reinforcement Exercises

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://ecampusontario.pressbooks.pub/paramedicfitness/?p=275#h5p-1

Balance

Being out of balance means that your **center of gravity** is no longer above your **support base** (usually the space between your feet). When that happens you either fall down or take a step to widen your support base (regain your balance). Let's examine why those are the only two options you have.



The center of gravity of an object (blue dot) is the average location of all gravitational forces. This average location does not necessarily have to be on the object. Image Credit: D. Gordon E. Robertson via wikimedia commons

1

Freely rotating objects tend to rotate around their **center of mass**. The following video shows a neat demonstration of that phenomenon:

https://youtu.be/DY3LYQv22qY

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1. "COM" by D. Gordon E. Robertson, Wikimedia Commons is licensed under CC BY-SA 3.0

Davis, Lawrence. *Body Physics: Motion to Metabolism.* Open Oregon Educational Resources. https://openoregon.pressbooks.pub/bodyphysics

Supporting the Body

LAWRENCE DAVIS

Support Force (Normal Force)

When standing on the ground **gravity** is pulling you down, but you aren't falling. In fact you are in **static equilibrium** so the ground must be providing a supporting **force** that balances your weight. The ground provides that force in response to **compression** caused by your weight. When solid objects push back against forces that are deforming them we call that responsive push-back the **Normal Force**.

Reinforcement Activity

Push your finger down into your palm and feel the resistance from your palm.

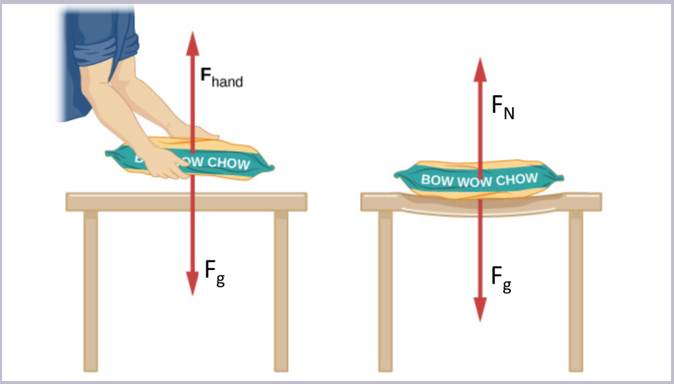
That resistance is the **normal force**.

When you pull your finger away from your palm, the normal force from your palm goes away.

Everyday Example[1]

In the diagram below, we see a person placing a bag of dog food on a table. When the bag of dog food is placed on the table, and the person lets go, how does the table exert the **force** necessary to balance the **weight** of the bag? While you wouldn't see it with your naked eye, the table sags slightly under the load (weight of the bag). This would be noticeable if the load were placed on a thin plywood table, but even a sturdy oak table deforms when a force is applied to it. That resistance to deformation causes a **restoring force** much like a deformed spring (or a trampoline or diving board). When the load is placed on the table, the table sags until the restoring force becomes as large as the weight of the load, putting the load in **equilibrium**. The table sags quickly and the sag is slight, so we do not notice it, but it is similar to the sagging of a trampoline or a hammock when you climb on.

1. OpenStax University Physics, University Physics Volume 1. OpenStax CNX. Jul 11, 2018 http://cnx.org/contents/d50f6e32-0fda-46ef-a362-9bd36ca7c97d@10.18



The person holding the bag of dog food must supply an upward force equal in size and opposite in direction to the force of gravity on the food. The card table sags when the dog food is placed on it, much like a stiff trampoline. Elastic restoring forces in the table grow as it sags until they supply a normal force equal in size to the to the weight of the load. Image credit: University Physics

Normal Force and Weight

If you place an object on a table the **normal force** from the table supports the **weight** of the object. For this reason normal force is sometimes called support force. However, normal is another word for **perpendicular**, so we will stick with normal force because it reminds us of the important fact that the normal force always acts at an angle of 90° to the surface. That does not mean the normal force always point vertically, nor is it always equal to an object's weight. If you push horizontally on the wall, the wall pushes back (keeping your hand from moving through the wall). The force from the wall is a normal force, but it acts horizontally and is not equal to your weight.

Situations where normal force is not equal to the weight of the object. Adapted from Garscon Plancher" by Obiwancho, and "Trek on the Viedma Glacier" by Liam Quinn "U.S. Air Force Chief Master Sgt. Suzan Sangster"released by the United States Armed Forces with the ID 090815-F-3140L-048

234

In each situation pictured above the **normal force** is not equal to body **weight**. In the left image the normal force is less than body weight, and acting horizontally. In the middle image the normal force is less than body weight and acting at an angle. In the right image the normal force on the drill is more than it's own weight

2. "Garscon Plancher" by Obiwancho , Wikimedia Commons is licensed under CC BY-SA 3.0
3. "U.S. Air Force Chief Master Sgt. Suzan Sangster", Wikimedia Commons is in the Public Domain,
4. "Trek on the Viedma Glacier" by Liam Quinn , Wikimedia Commons is licensed under CC BY-SA 2.0

because Master Sgt. Sangster is also pushing down on the drill. The normal force on Master Sgt. Sangster's feet is less than her weight because she is also receiving an upward normal force from the drill handle.

Often (N) is used as a symbol for normal force, but we are using **N** to abbreviate for the **SI** force unit **Newtons**, so instead we will use F_N. The normal force comes up so often students often accidentally begin to refer to normal force as "natural force" instead, so watch out for that possible source of confusion.

Reinforcement Exercises: Normal Force

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://ecampusontario.pressbooks.pub/paramedicfitness/?p=279#h5p-2

Davis, Lawrence. *Body Physics: Motion to Metabolism.* Open Oregon Educational Resources. https://openoregon.pressbooks.pub/bodyphysics

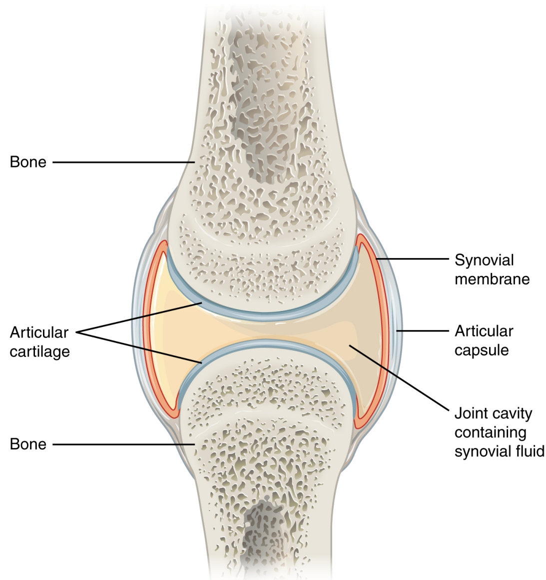
Friction in Joints

LAWRENCE DAVIS

Synovial Joint Friction

Static and kinetic friction are both present in joints. **Static friction** must be overcome, by either muscle **tension** or **gravity**, in order to move. Once moving, **kinetic friction** acts to oppose motion, cause wear on joint surfaces, generate **thermal energy**, and make the body less efficient. (We will examine the **efficiency** of the body later in this textbook.) The body uses various methods to decrease friction in joints, including synovial fluid, which serves as a lubricant to decrease the **friction coefficient** between bone surfaces in synovial joints (the majority of joints in the body). Bone surfaces in synovial joints are also covered with a layer of articular cartilage which acts with the synovial fluid to reduce friction and provides something other than the bone surface to wear away over time[1]. We ignored friction when analyzing our forearm as a lever because the frictional forces are relatively small and because they acted inside the joint, very close to the pivot point so they caused **negligible** torque.

1. OpenStax, Anatomy & Physiology. OpenStax CNX. Jun 25, 2018 http://cnx.org/contents/14fb4ad7-39a1-4eee-ab6e-3ef2482e3e22@10.1.



Synovial joints allow for smooth movements between the adjacent bones. The joint is surrounded by an articular capsule that defines a joint cavity filled with synovial fluid. The articulating surfaces of the bones are covered by a thin layer of articular cartilage. Ligaments support the joint by holding the bones together and resisting excess or abnormal joint motions. Image Credit: OpenStax Anatomy & Physiology

Reinforcement Exercises

Find a value for the kinetic **coefficient of friction** between ends of a bone in a synovial joint lubricated by synovial fluid. State your value and your source.

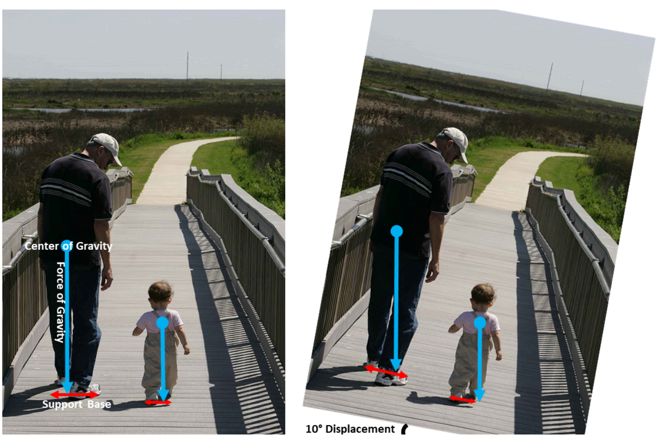
If the **normal force** between bones in the knee is 160 **lbs**, what is the kinetic frictional force between the surfaces of the knee bones?

Davis, Lawrence. *Body Physics: Motion to Metabolism.* Open Oregon Educational Resources. https://openoregon.pressbooks.pub/bodyphysics

Human Stability

LAWRENCE DAVIS

When asking what makes a structure more or less stable, we find that a high **center of gravity** or a small **support base** makes a structure less stable. In these cases a small **displacement** is need in order to move the center of gravity outside the area of support. Structures with a low center of gravity compared to the size of the support area are more stable. One way to visualize stability is to imagine **displacement** of the center of gravity caused by placing the object on a slope. For example, a 10° displacement angle might displace the center of gravity of a toddler beyond the support base formed by its feet, while an adult would still be in equilibrium.



Compared to an adult, a smaller displacement will move a toddlers center of gravity outside the base of support. Image adapted from A man and a toddler take a leisurely walk on a boardwalk by Steve Hillibrand via Wikimedia Commons.

1

The **center of gravity** of a person's body is above the **pivots** in the hips, which is relatively high compared to the size of the **support base** formed by the feet, so **displacements** must be quickly controlled. This control is a **nervous system** function that is developed when we learn to hold our bodies erect as infants. For increased stability while standing, the feet should be spread apart, giving a larger base of support. Stability is also increased by bending the knees, which lowers the center of gravity toward the base of support. A cane, a crutch, or a walker increases the stability of the user by widening the base of support. Due to their disproportionately large heads, young children have their center of gravity between the shoulders, rather than down near the hips, which decreases their stability and increases the likelihood of reaching a **tipping point**.[2]

1. " A man and toddler take a leisurely walk on a boardwalk" by Steve Hillebrand, U.S. Fish and Wildlife Service, Wikimedia Commons, is in the Public Domain
2. OpenStax, College Physics. OpenStax CNX. Aug 3, 2018 http://cnx.org/contents/031da8d3-b525-429c-80cf-6c8ed997733a@12.1.

Warning label on a bucket indicating the danger of children falling into a bucket and drowning. This danger is caused by the inherent instability of the toddler body. Image Credit: GodsMoon via Wikimedia Commons.

3

3. "Drowning Child Warning" by GodsMoon, Wikimedia Commons is licensed under CC BY-SA 2.0

Reinforcement Exercises

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://ecampusontario.pressbooks.pub/paramedicfitness/?p=286#h5p-3

Davis, Lawrence. *Body Physics: Motion to Metabolism.* Open Oregon Educational Resources. https://openoregon.pressbooks.pub/bodyphysics

Guidelines for Core and Balance Training

AMANDA SHELTON

Progressional Training

When it comes to general training progression there are a few key steps you can take to meaningfully progress a program.

1. **Start off simple.** When first getting started in a program, you want the individual to work on something they are capable of doing. This is an opportunity to check in on form and movement patterns to ensure that their base is strong. **Progress to complex.** As you continue a program, you can progress to more complex movement patterns or positions within your exercise to continue to challenge the individual.
2. **Start with the expected.** The individual should know exactly what to expect with the exercise when they are first starting out, the movement should be consistent and expected. **Progress to the unexpected.** Progression through a program can begin to add in unexpected, reactive types of exercises and drills to create more functional activities that would be similar to real-world or sport-specific movements.
3. **Start off stable**. Their stability focus when first starting should be within their body. **Progress to unstable.** Instability can be added into a program in a variety of ways, this might be changing the surface that they are standing or bearing weight on (i.e., a folded up towel, a stability pad or stability ball) or changing their body position to create more instability through balance (i.e., going from a two-foot stance to a

tandem stance to a single a single leg stance).

A Functional Core

As with any type of exercise programming, it is always important to focus on the individual's needs based on their goals, activity, and base of training. When it comes to identifying and developing the basis for a core training program, there are three key functions that should be the focus of the program:

1. Producing force
2. Reducing force
3. Stabilization

Producing Force

In order to create movement within the body, particularly movements that cross the core musculature, the core muscles need to be able to efficiently produce force and transfer that force from the upper and lower extremities. While we often think of core more singularly within our trunk, many of our full body movements (i.e., throwing, kicking, running, jumping, etc.) all have force that is transferred between the upper and lower body through the core.

Reducing Force

Similarly to our force transmission discussed with force production, we also have to consider how our efficient force reduction plays into our whole body movements. We need to be able to control the force production and reduce ineffective movements through force reduction in our core to maintain form, slow down, change of direction, and other reactive and sports-specific movements. Reducing forces through our core can help to accomplish this variety of tasks as well as reduce our risk of injury through uncontrolled movements.

Stabilization

As with many of our different types of training, being able to stabilize within a given body area is what helps us to maintain an optimal kinetic chain whether that be during stationary stabilization to address postural needs while sitting at a desk or while carrying an object overhead. Maintaining stabilization through the core is essential for protecting our valuable vertebral column and spine from potential strain and injury during static positions or dynamic movements.

Core Training

With core training more specifically we have three progressive components to focus on for beginning a program:

1. **Intervertebral stability** – maintaining stability through the spine to ensure this key component of your body is protected and safe.
2. **Lumbopelvic stability** – maintaining stability where the lumbar spine articulates with the pelvis. This helps to maintain proper alignment in the lumbar spine which will help to maintain intervertebral stability throughout the rest of the core system.

3. **Movement efficiency** – creating movement through the core system that are efficient at force production, force reduction, and stabilization throughout the system.

Balance Training Development

During balance training, the focus becomes more specific to the stability component of your exercises. With this, balance training can very easily be incorporated into other types of training but can also be done as a standalone exercise program. When developing a balance training the program should involve:

1. **All planes of motion** – whether it is static or dynamic balance development, it is important to consider that all planes of motion are involved in order to create consistency in different positions and movement patterns.
2. **Functional movement patterns** – encourage development of balance in movement patterns that are meaningful to the individual's needs. For example, a runner who experiencing single leg loading through a sagittal plane flexion and extension of at the hip, knee, ankle, and shoulder where weight transfers from posterior to anterior should participate in balance training that addresses the needs of that specific force transfer while maintaining upright body positioning.
3. **Proprioceptively challenging** – progressing the level of instability, similarly to what was discussed above with progressing to a less stable environment can help promote continued balance development. In addition to instability as a proprioceptive challenge you can also think of varying speeds of movement or inclusion of reactivity to enrich the environment and improve progression.

CHAPTER 8: PLYOMETRICS, SPEED, AGILITY, AND QUICKNESS TRAINING PRINCIPLES

Plyometric Exercises

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What are Plyometric Exercises?

Plyometric exercises are a type of training that was developed initially to address the gap between strength training and speed training with activity that involve explosive types of activities such as sprinting activities, jumping activities, etc.[10] There are several strategies at play that help with the development of plyometric training that include the utilization of the stretch reflex, the stretch-shortening cycle, and neural adaptations that occur during increased central nervous system activation due to the eccentric and concentric components of plyometrics.

The Stretch-Shortening Cycle

The stretch-shortening cycle refers to the preparatory movement that places a stretch on a muscle before the movement occurs. During the stretch-shortening cycle there are three distinct stages:

1. Eccentric movement
2. Amortization
3. Concentric movement

During the eccentric movement the muscles at play are stretched while they are loading which is sometimes referred to as the countermovement. The amortization stage is the transition moment between the eccentric and concentric movement where the change of movement direction occurs. The concentric movement is when the muscles utilized in the primary movement shorten as they contract. In order for a plyometric activity to be optimized and successful, the timing of the movement is essential. If there is any delay in the timing of any of these stages individually there will be a collective disfunction in the overall success of the movement as any stored or potential energy is lost in the delayed movement. The timing of these phases will have external variables that may influence the optimization of performance including added weight or drop heights.

The Role of Strength and Power

Strength is a key component of effective plyometric programming and development. Developing strength prior to progressing into plyometrics exercise is essential for creating maximal loading and force during the eccentric movement stage and the concentric movement stage. Continuing to develop strength can also help to provide further benefits to explosive power in plyometric activities. While developing strength can help to promote power improvements, fewer benefits are seen in the opposite strategy with regard to strength improvements being seen with exclusively power focused training development.

Heinecke, Marc. Literature Review: Neuromuscular Response to Plyometric Training. *International Journal of Strength and Conditioning*: 2021. https://journal.iusca.org/index.php/Journal/article/view/53/116

Variables of Plyometric Training

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When developing a plyometric training program there are few key considerations to incorporate.

Program Variables

Safety should always be the #1 priority of any program, but with the explosive nature of plyometrics it becomes even more essential.

What makes a program or exercise safe?

1. **The individual is prepared through appropriate strength development prior to beginning a plyometric program.** A based of strength will prepare the individual for the force development and form stabilization needs associated with the stretch-shortening cycle and movement patterns of plyometrics.
2. **The environment is appropriate for the individual's skill level.** This may include use of appropriate footwear or gear in association with the surface the activity it being performed on. For example, if using a grass surface cleated shoes would be more appropriate than flat shoes or if using a court, shoes built for jumping and change of direction would be more appropriate than cushioned or unstable shoes.
3. **The equipment being used is functional and not damaged or unsecured.** Damaged or improper use of equipment can create and unsafe space for exercise that can lead to an increased risk

of injury.

4. **The progression of the program is appropriate to the individual's development.** This may include developing plyometric activities that progress from single plane to multi-plane activities, changing the type of implement being used (i.e., taped lines, cones, hurdles, plyo boxes, etc.), or the amplitude of the movement (i.e., higher drop height, quicker movement transition, added weight, etc.)

Progressing a Plyometric Program

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Beginning Plyometrics

The initial focus of the activity should be:

1. Stabilizing the movement within the joints so that their is control and minimal extraneous movements within the joints during the activity
2. Optimal landing mechanics
3. Alignment within the body system as it relates to overall posture
4. The efficiency of the movement (neuromuscular efficiency)

Intermediate Plyometrics

As the program progresses, the focus should as well. In an intermediate program the focus should shift to:

1. Increasing the dynamic components of the movement and rate of contraction through the concentric movement.
2. Transition from double leg to single leg activities to increase more focused single limb force production more similar to sport specific movements.

Advanced Plyometrics

Continued progression is essential for further fitness and performance development. As an individual progresses from an intermediate plyometric program the program can progress to include:

1. More dynamic contraction through functional and varied planes of motion and ranges of motion. This is a great opportunity to include functional and sport specific movements based on the individuals' goals.
2. More focus on speed of movement and explosive power for force production.

Speed, Agility, and Quickness

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Speed, Agility, and Quickness (SAQ) are important for performance development. By developing speed, agility, and quickness an individual will enhance their ability to accelerate, decelerate, and stabilize their body through that movement. This ability may sound familiar to other types of performance development that we have discussed previously as we have learned about force production, force reduction, and stabilizing through the body during movement. These are all essential components of exercise and sport performance.

Speed

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Speed

During speed based activities we are practicing move the body in *one direction* as quickly as possible. With speed training, there is no change of direction – you are working on going directly from point A to point B in as little time as possible.

Speed = (stride rate) x (stride length)

We can quantify speed as a relationship between your **stride rate** (the amount of time between steps you take) and your **stride length** (the distance between steps). Changes to either one of these variables will have a direct impact on your speed, though there is a point of diminishing returns when it comes to your stride length. For example, if the length is too long the load on the lower body can change, putting you at risk for injury.

Sprint Mechanics

“Indoor Track and Field – Bishop Loughlin Games” by Steven Pisano is licensed under CC BY 2.0

When examining proper sprint mechanics, we are looking for the lumbar spine to be in a neutral position along with a distinct patter for the two contralateral lower limbs to follow a specific pattern of movement to maintain optimal form.

Triple Extension

The back leg will be in what we call *triple extension*. When looking at the image above, you can see that the hip is in extension, the knee is in extension, and the ankle is in plantar flexion.

Triple Flexion

The front leg will be in what we call *triple flexion*. When looking at the image above, you can see that the hip is in flexion, the knee is in flexion, and the ankle is in dorsiflexion.

The Transition

As the sprint pattern occurs, front leg will extend back while making contact with the ground at the foot and *pushing* forward into hip extension, knee extension, and ankle plantar flexion as the back leg drives the knee forward with hip flexion, knee flexion, and ankle dorsiflexion. Alternating triple extension and triple flexion on opposing limbs to propel the body forward.

Agility

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Agility

Agility takes speed to the next level. While speed only looks at the rate you can move in one direction from point A to point B, agility will include your ability to *change directions*. When it comes to agility, your speed will play a factor in your agility but there is much more involved in change directions.

The Components of Changing Directions

There are four main components in changing directions that are important to consider when it comes to training agility:

1. **The acceleration** – the ability to start the movement and pick up speed.
2. **The deceleration** – the ability to stop the movement and decrease speed.
3. **Stabilization** – the ability to maintain balance and posture as the transition between acceleration and deceleration occurs.
4. **Changing direction** – the ability to transition between acceleration, deceleration, stabilization, and back to acceleration in a different plane of motion while maintaining your center of gravity.

Agility development is comprised of several types of fitness training that we have already discussed throughout this textbook including:

strength, speed, plyometrics/power, balance, and core training. Development through these types of training will help to support development of agility as well.

Quickness

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Quickness

So we have our speed and our agility, but where does our quickness come into play for developing fitness?

While speed is our ability to move from point A to point B in one direction as quickly as possible and agility is our ability to accelerate and decelerate through a change in direction, quickness is our ability to react and change positions/direction as fast as possible with a maximal rate of force production. Therefore, quickness is the combination of speed and agility.

Functional Quickness

What does it mean to have functional quickness? To explore this we need to think about when quickness might be used in real world or sport experiences.

Quickness in Action

If you are running down the soccer field, dribbling the ball in an attack toward the goal what are some reasons you might need to change directions quickly?

- You *see* a defender coming toward you to block your line to the goal
- You *hear* a teammate who is open across the field call for the ball
- You *feel* the ball move further with your dribble than you expected

These different types of visual, auditory, and kinesthetic feedback that you receive during your attack will help you make decisions on your body position, changing directions, and speed or acceleration changes you might need to make in order to be successful in your attack to the goal. Incorporating this type of feedback into quickness training can help the individual be more functional in how they develop their quickness to be more meaningful as it transitions to sport-specific activities.

CHAPTER 9 - BODY COMPOSITION

Objectives

1. What is body composition?
2. How does body composition affect a person's health?
3. What are the health risks and costs associated with overweight and obesity?
4. What is the significance of body fat distribution?
5. What is Body Mass Index (BMI) and why is it important?

Terminology

- **Body Composition:** The measurement of the body's proportion of fat mass to fat free mass.
- **Fat Mass:** The amount of fat tissue in the body often expressed as a percentage of total body mass.
- **Fat Free Mass (FFM):** not fat tissue in the body such as bones, muscles, ligaments, and blood.
- **Essential Fat:** the amount of fat needed for vital body functions.
- **Non-essential fat:** the amount of fat that exceeds the necessary fat needed for vital body functions. This fat is considered energy storage.
- **Overweight:** the accumulation of non-essential body fat to the point that it adversely affects health.
- **Obesity:** is characterized by excessive accumulation of body fat

and can be defined as a more serious degree of being overweight.

- **Adipose Tissue:** another term for fat. More specifically it is loose connective tissue composed of adipocytes.
- **Subcutaneous fat:** fat tissue stored below the skin's surface.
- **Visceral Fat:** fat tissue stored around central organs.
- **Android shape**: a body shape used to help characterize body fat distribution in which fat is stored in the abdominal region. The android shape is also called the "apple" shape.
- **Gynoid shape**: a body shape used to help characterize body fat distribution in which fat is stored in the hips, buttocks, and thighs. It is also called the pear shape.
- **Body Mass Index (BMI):** an index based on concept that weight and height should be proportionate. It is calculated by dividing weight by the height squared (weight/height2).
- **Hydrodensitometry**: This method attempts to measure the density of the body by using water displacement.
- **Dual Energy X-ray Absorbtiometry (DEXA):** A method of measuring body composition that uses low energy x-rays that also measure bone density.
- **Air Displacement Plethysmography**: A method of measuring body composition that measures the density of the body by using air displacement.
- **Bio-electrical impedance analysis (BIA):** A method of measuring body composition by emitting a small electrical current through the body and using the amount of resistance encountered by this current to predict body fat content.
- **Skinfold Analysis**: A method of measuring body composition by measuring the diameter of pinched skin at various sites on the body.

Body Weight versus Body Composition

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According to surveys, the top reason American females exercise is for weight control. For males, the top reason is to improve muscle tone while weight control ranks as the fourth most important reason.[1] Levels of attractiveness based on weight and visible musculature are significant points of emphasis in American culture. As such, individuals with well-toned muscles and low body weight are marketed as *superior* within the context of attractiveness, financial success, and multiple other traits. Unfortunately, this emphasis, as seen in mainstream media, can result in unrealistic ideals and potentially harmful behaviors, such as eating disorders.

Unlike the mainstream outlets, which focus on the association between fat levels and physical attractiveness, this chapter focuses on the health-related consequences related to good and bad body composition. **Body composition** is defined as the body's relative amount of fat-free mass (FFM) and fat mass (FM) and is generally expressed as a percentage of total body weight. FFM includes bones, muscles, ligaments, body fluids and other organs, while FM is limited to fat tissue.

The Importance of Measuring Body Composition Rather Than Just Tracking Body Weight

Tracking weight can be helpful, but body composition measurements help separate a person's actual weight from the weight that could be unhealthy.

For example, an individual who weighs 200 pounds and has 8% body fat, such as an athlete, only carries around 16 pounds of FM. However, a 200-pound person who has a sedentary lifestyle and a body composition of 20%, carries 40 pounds of FM. Weight alone, in this case, does not distinguish between FFM and FM and would suggest both individuals have similar health. As body fat percentage increases, the potential for various diseases also increases significantly.

Diseases Associated with Excessive Body Fat

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According to the National Institute of Health (NIH), a wide array of diseases can be linked to excessive body fat.[2] Some of them are:

- Type II Diabetes Mellitus
- Hypertension
- Cancer
- Cerebrovascular Disease (Stroke)
- Cardiovascular Disease
- Metabolic Syndrome
- Lung Disorders
- Sleep Apnea
- Asthma
- Musculoskeletal Diseases
- Osteoarthritis
- Gout
- Gallbladder Disease
- Pancreatitis
- Non-Alcohol Fatty Liver Disease
- Dementia
- Psychological Problems and Quality of Life
- Kidney Disease
- Pregnancy Problems

How Much Fat is Needed?

Fat is a necessary component of daily nutrition. It is needed for healthy cellular function, energy, cushioning for vital organs, insulation, and for food flavor.

Fat storage in the body consists of two types of fat: essential and nonessential fat. **Essential fat** is the minimal amount of fat necessary for normal physiological function. For males and females, essential fat values are typically considered to be 3% and 12%, respectively. Fat above the minimal amount is referred to as **nonessential fat**. It is generally accepted that an overall range of 10-22 percent for men and 20-32 percent for women is considered satisfactory for good health. A body composition within the recommended range suggests a person has less risk of developing obesity-related diseases, such as diabetes, high blood pressure, and even some cancers.

A woman's essential fat range is naturally greater than a man's because of fat deposits in breasts, uterus and sex-specific sites. In both males and females, non-essential fat reserves can be healthy, especially in providing substantial amounts of energy.

Excessive body fat is categorized by the terms overweight and obesity. These terms do not implicate social status or physical attractiveness, but rather indicate health risks. **Overweight** is defined as the accumulation of non-essential body fat to the point that it adversely affects health. According to the American College of Sports Medicine (ACSM), the threshold for being characterized as overweight is having a body composition of FM greater than 32% and 19% for females and males, aged 20-39, respectively.[3]

Obesity is characterized by excessive accumulation of body fat and can be defined as a more serious degree of being overweight. Classifications of obesity begin at body composition of FM greater than 39% and 25% in females and males ages 20-39, respectively. [4]

Other Health Risks

Diseases are not the only concern with an unhealthy body fat percentage. Several others are listed below.

Performance of physical activity

An important component of a healthy lifestyle and weight management is regular physical activity and exercise. To the contrary, those who live a sedentary lifestyle will find it more difficult to maintain a healthy body weight or develop adequate musculature, endurance, and flexibility. Unfortunately, additional body weight makes it more difficult to be active because it requires more energy and places a higher demand on weak muscles and the cardiovascular system. The result is a self-perpetuating cycle of inactivity leading to more body weight, which leads to more inactivity.

Emotional wellness

Studies indicate obesity is associated with a 25% increase in anxiety and mood disorders, regardless of age or gender. Other studies suggest increases in BMI significantly increase the incidence of personality disorders and anxiety and mood disorders. Additional studies have been able to associate a higher incidence of psychological disorders and suicidal tendencies in obese females compared with obese males.[5]

Pre-mature death

The association between obesity and diseases, such as cancer, CVD, and diabetes, suggests that people with more body fat generally have shorter lifespans. The Center for Disease Control (CDC) estimates up to 365,000 deaths each year can be linked with obesity, representing nearly 15% of all deaths. Other studies have tied the Years of Life Lost to body mass index measurements, estimating anywhere from 2 to 20 years can be lost, depending on ethnicity, age at time of obese classification, and gender.[6]

Economic impact

The physical harm caused by obesity and overweight is mirrored by its economic impact on the health care system. The CDC has estimated the medical costs to be about $147 billion in 2008, which includes preventative, diagnostic, and treatments. Overweight and obesity also contribute to loss of productivity at work through absenteeism and *presenteeism*, defined as being less productive while working. The annual nationwide productive costs fall within the range of from $3.38 to $6.38 billion.[7]

Body Fat Distribution

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Body composition measurements can help determine health risks and assist in creating an exercise and nutrition plan to maintain a healthy weight. However, the presence of unwanted body fat is not the only concern associated with an unhealthy weight. Where the fat is stored, or fat distribution, also affects overall health risks.

Non-essential fat is primarily stored in **adipose tissue**, or fat cells, located on the surface of the body and surrounding the body's organs. Surface fat, located just below the skin, is called **subcutaneous fat**. Fat that lies deeper in the body surrounding the body's organs is called **visceral fat**. Unlike subcutaneous fat, visceral fat is more often associated with abdominal fat. Researchers have found that excessive belly fat decreases insulin sensitivity, making it easier to develop type II diabetes. It may also negatively impact blood lipid metabolism, contributing to more cases of cardiovascular disease and stroke in patients with excessive belly fat.[8]

Body fat distribution can easily be determined by simply looking in the mirror. The outline of the body, or body shape, would indicate the location of where body fat is stored. Abdominal fat storage patterns are generally compared to the shape of an apple, called the **android shape**. This shape is more commonly found in males and post-menopausal females. In terms of disease risk, this implies males and post-menopausal females are at greater risk of developing health issues associated with excessive visceral fat. Individuals who experience chronic stress tend to store fat in the abdominal region.

A pear-shaped body fat distribution pattern, or **gynoid shape**, is more commonly found in pre-menopausal females. Gynoid shape is characterized by fat storage in the lower body such as the hips and buttocks. This shape may be connected to females' child-bearing abilities as enzymes associated with fat-storage and mobilization are activated during certain times of pregnancy and post-partum.

Besides looking in the mirror to determine body shape, people can use an inexpensive tape measure to measure the diameter of their hips and waist. Many leading organizations and experts currently believe a waist circumference of 40″ or greater for males and 35″ or greater for females significantly increases risk of disease.[9]

In addition to measuring waist circumference, measuring the waist and the hips and using a waist-to-hip ratio (waist circumference divided by the hip circumference) is equally effective at predicting body fat-related health outcomes. According to the National Heart, Lung, and Blood Institute, a ratio of greater than 0.82 for females and 0.94 for males is associated with a higher risk of developing heart disease, diabetes, and hypertension. [10]

Body Mass Index

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In addition to body composition and waist/hip circumferences, measuring body mass has also been used as an effective method to assess health risks. **Body mass index (BMI)** is a measurement of height (m^2) and weight (kg) suggesting that a person's weight should be proportional to his or her height. For example, based on the BMI scale, a female with a height of 5'6" should not weigh more than 155 lbs. If her weight exceeded 155 lbs., she would be categorized as "overweight."

BMI = Weight (kg) / Height (m^2)

Among several criticisms, the BMI method has been faulted for not distinguishing between FM and FFM, since only the overall weight is taken into account. For athletes, who may be more massive as a result of larger muscles, this criticism holds true. For example, a professional football player who weighs 215 pounds and stands at 6'3" would have the exact same BMI as a relatively sedentary arm-chair quarterback who also weighs 215 pounds with the same height. This discrepancy also exists when applying BMI to the senior population. As age increases, muscle mass declines. Seniors who have experienced years of muscle mass decline but increased body fat may maintain a constant weight despite having a very different body composition.

Other criticisms of using BMI as a health risk assessment tool include its failure to take age or gender into account. As discussed previously, females naturally have more body fat yet are classified in the same context as males. Because this measurement is so widely used by physicians, patients continue to express concerns about the validity of BMI as an indication of fatness.

Regardless of the criticisms, BMI as used for the general population, has been shown to be a reasonable predictor of health outcomes. At its core, it is not intended to be an estimate of body composition, i.e., measure Fat Mass and Fat-Free Mass. Instead, it is intended to be used as an estimate of healthy/unhealthy levels of body fat. When used as a means of tracking weight changes over time it can be a valuable tool in predicting health and for recommending lifestyle modifications.[11]

Waist-to-Hip Ratio

An alternative measurement which some studies have found to be more accurate than BMI is waist-to-hip ratio.

Unlike body mass index (BMI), which calculates the ratio of your weight to your height, waist-to-hip ratio takes into account the differences in body structure. So the very fit football lineman who might have a BMI rating of obese, may have a much healthier WHR rating. WHR measures the ratio of your waist circumference to your hip circumference. It determines how much fat is stored on your waist, hips, and buttocks.

How to Measure Body Composition

DAWN MARKELL AND DIANE PETERSON

Multiple methods exist to estimate body composition. Remember, body composition is the ratio of Fat Mass and Fat-Free Mass used to help determine health risks. Of the other methods already mentioned (waist, waist-to-hip ratio, and BMI), none provide estimates of body composition but do provide measurements of other weight-related health markers, such as abdominal fat. Experts have designed several methods to estimate body composition. While they are not flawless, they do provide a fairly accurate representation of body composition. The most common are:

Hydrostatic Weighing (Underwater Weighing)

At one time, hydrostatic weighing (also and maybe more accurately called **hydrodensitometry**) was considered the criterion for measuring body composition. Many other methods are founded on this model, in one form or another.

This method attempts to measure the density of the body by applying Archimedes' principle: density = mass/volume.

The mass and volume components are measured by using dry weight and then weight while being submerged in a water tank. Since fat is less dense than muscle tissue, a person with more body fat will weigh less in the water than a similar person with more lean mass. Using the measurements, the density can be determined and converted into body fat percentage. With a small margin of error (around 1-2%) this method is very accurate. Unfortunately, the expense and practicality of building and maintaining a water tank limits access for most. Also, for those with a fear of water, this would obviously not be the preferred method.

Dual Energy X-Ray Absorptiometry (DEXA)

Replacing underwater weighing as the new "gold standard," is DEXA. While underwater weighing accurately compartmentalizes FM and FFM, DEXA adds a third compartment by using low-radiation X-rays to distinguish bone mineral. This addition slightly increases the accuracy of DEXA by eliminating some of the guess work associated with individual differences, such as total body water and bone mineral density.Originally, DEXA scanners were designed to determine and help diagnose bone density diseases. As a result, they can be found in many physicians' offices. However, a full body scan, which takes only a few minutes, is all that is needed to also determine body fat percentage. Major disadvantages to this method are its high cost and the need for a well-trained professional to operate the equipment and analyze the results.

Air Displacement (Plethysmography)

A good alternative to more expensive methods, air displacement determines body density using the same principle as underwater weighing, by measuring mass and volume. Clearly, the main difference is that mass and volume are being determined by air displacement rather than water displacement. Using a commercial device (the Bod Pod is most commonly referenced), a person sits in a chamber that varies the air pressure allowing for body volume to be assessed. Air displacement provides a viable alternative for those with a fear of water. Like many other methods, the expense, availability, and training of personnel Air Displacement requires limit accessibility. Additionally, its accuracy is slightly less than underwater weighing.

Bio-electrical Impedance Analysis (BIA)

BIA takes a slightly different approach to measuring FFM. The premise behind BIA is that FFM will be proportional to the electrical conductivity of the body. Fat-tissue contains little water, making it a poor conductor of electricity; whereas, lean tissue contains mostly water and electrolytes, making it an excellent conductor. BIA devices emit a low-level electrical current through the body and measure the amount of resistance the current encounters. Based on the level of impedance, a pre-programed equation is used to estimate body fat percentage. The most accurate BIA devices use electrodes on the feet and hands to administer the point-to-point electrical current. The margin of error for these devices falls in the range of 3–5%. Portable or handheld BIA devices that only measure lower or upper body conductivity have a higher margin of error (4–8%). Because BIA devices primarily measure hydration, circumstances that may influence hydration status at the time of measurement must be taken into account. Recent exercise, bladder content, hydration habits, and meal timing can cause wide measurement variations and influence accuracy. However, this method is generally inexpensive, often portable, and requires limited training to use, making it a very practical option.

Skinfold Analysis

Skinfold analysis is a widely used method of assessing body composition because of its simplicity, portability, and affordability.

It is also fairly accurate when administered properly. Margins of error are about 4–7%, depending on the quality of the skinfold calipers and skill of the administrator/technician. The assumption of skinfold measurement is that the amount of subcutaneous fat is proportionate to overall body fat. As such, a technician pinches the skin at various sites and uses calipers to measure and record the diameter of the skin folds. These numbers can then be plugged into an equation to generate an estimate of body fat percentage. The proportionality of subcutaneous fat and overall body fat depends on age, gender, ethnicity, and activity rates. As such, technicians should use the skinfold technique specific to the equation that accounts for those variables to improve accuracy.

Weighing in on the U.S.

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Despite the well-known health concerns implicated in overweight and obesity and the availability of multiple methods for assessment and tools to improve body composition, current trends in the United States and around the world are moving in the wrong direction. The unprecedented number of obese Americans has led experts to label it an epidemic, much like they would a disease in a developing country. According to the CDC, the number of American adults (>20 years) that fall into the overweight classification based on BMI are 70.7%. Of those, 37.9% fall within the obese classification. In 1962, the overweight and obesity rates for adults in the U.S. were 32% and 13%, respectively. In other words, overweight trends have more than doubled and obesity rates have almost tripled over the past 50+ years.[12]

Of more concern are the increasing number of obese children ages 6-11 and adolescents ages 12-19, amounting to 17.4% and 20.6%, respectively.[13] While those numbers have stabilized over the past decade, this has led to a dramatic increase in insulin resistance, a form of diabetes formerly known as adult onset diabetes.

With such a diverse population in the U.S. and with an understanding of how BMI is calculated, it is only natural to question the high number of overweight and obese citizens based on BMI alone. However, it is generally believed this is an accurate portrayal of weight status. In a study attempting to compare BMI measurements to actual body fat percentage, it was determined that the total number of obese citizens may be underestimated, and its current prevalence may be worse than is currently being reported.

What Can Be Done?

With the available tools to identify health risks associated with body fat, anyone concerned about their health should gather as much data about body composition and body fat distribution as possible. Compiling multiple measurements and analyzing them provides a better idea of a person's current health status and will help determine the next course of action. For example, BMI alone can be beneficial. But when combined with waist circumference, a greater understanding of risk can be achieved. Likewise, when combining BMI and waist circumference with body fat percentage, an ideal conclusion of health status can be made.

In a lab activity that your instructor may assign for this chapter, you will be guided through the process of assessing your BMI, waist circumference, waist-to-hip ratio, and body fat percentage.

The next course of action is to set goals and formulate a plan to get to a healthy range of weight and body fat percentage. Where weight loss is needed, the plan should include a balance of calorie restriction and physical activity/exercise. This might also include tracking your current eating and activity habits. More specific information on weight management strategies will be discussed in a later chapter.

Low Body Composition

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Because more people experience excess body fat, the focus up to this point has been on health concerns related to overweight and obesity. However, fat is an essential component to a healthy body, and in rare cases, individuals have insufficient fat reserves, which can also be a health concern. The range of essential body fat for males is 3-5% and 8-12% for females. Attempting to, or intentionally staying in those ranges, through excessive exercise or calorie restriction is not recommended. Unfortunately, low body fat is often associated with individuals struggling with eating disorders, the majority of whom are females.

The main concern of low body fat relates to the number and quality of calories being consumed. Foods not only provide energy but also provide the necessary nutrients to facilitate vital body functions. For example, low amounts of iron from a poor diet can result in anemia. Potassium deficiencies can cause hypokalemia leading to cardiovascular irregularities. If adequate calcium is not being obtained from foods, bone deficiencies will result. Clearly, having low body fat, depending on the cause, can be equally as detrimental to health as having too much.

The health concerns most often linked to low body fat are:

- Reproductive disorders
- Infrequent or missing menstrual cycles
- Respiratory disorders
- Immune System disorders
- Circulatory disorders
- Premature death

In some cases, despite attempts to gain weight, individuals are unable to gain the pounds needed to maintain a healthy weight. In these cases, as in the case of excess fat, a holistic approach should be taken to determine if the low levels of body fat are adversely affecting health. These individuals should monitor their eating habits to assure they are getting adequate nutrition for their daily activity needs. Additionally, other lifestyle habits should be monitored or avoided, such as smoking, which may suppress hunger.

Additional reading on low body fat and its impact can be found on the Livestrong.com website, on this page: At what body fat percent do you start losing your period?.

CHAPTER 10 - NUTRITION

Objectives

1. Summarize the basics of nutrition
2. Define macronutrients and micronutrients
3. Categorize and describe the body's sources of energy
4. Analyze intake of nutrition and make appropriate changes

Terminology

- **Nutrition:** The science of food and how the body uses it in health and disease
- **Essential nutrients:** Substances the body must get from foods because it cannot manufacture at all, or fast enough to meet needs.
- **Macronutrient:** An essential nutrient required in relatively large amounts.
- **Micronutrient:** An essential nutrient required in minute amounts.
- **Kilocalorie:** A measure of energy content in food; 1 kilocalorie represents the amount of energy needed to raise 1 liter of water 1°C
- **Carbohydrates:** The word *carbohydrate* literally means "hydrated carbon," or carbon with water. Can be either simple or complex.
- **Fats:** Lipids consist of fatty acids, triglycerides, phospholipids, and sterols (cholesterol). Can be either Saturated or Unsaturated.

- **Proteins:** Protein is another major macronutrient that, like carbohydrates, consists of small repeating units. But instead of sugars, proteins are made up of amino acids. Can be either complete or incomplete.
- **Soluble Fiber:** Fiber that is found to lower cholesterol levels.
- **Insoluble Fiber:** Fiber that binds to water and allows for soft fecal matter
- **Vitamins:** Organic substances found in food that can either be fat or water soluble.
- **Minerals:** Inorganic substances found in food or spices.

The Basics

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Nutrition can be defined as the science of the action of food, beverages, and their components in biological systems. A nutrient is a compound that provides a needed function in the body. Nutrients can be further classified based on the amount needed in the body. **Macronutrients** are the nutrients the body needs in larger amounts. **Micronutrients** are also important nutrients, but ones the body needs in smaller amounts.

[table id=3 /]

Macronutrients

Carbohydrates

The word *carbohydrate* literally means "hydrated carbon," or carbon with water. Thus, it is no surprise that carbohydrates are made up of carbon, hydrogen, and oxygen. Sucrose (table sugar) is an example of a commonly consumed carbohydrate. Some dietary examples of carbohydrates are whole-wheat bread, oatmeal, rice, sugary snacks/drinks, and pasta.

Proteins

Like carbohydrates, proteins are comprised of carbon, hydrogen, and oxygen, but they also contain nitrogen. Several dietary sources of proteins include nuts, beans/legumes, skim milk, egg whites, and meat.

Lipids

Lipids consist of fatty acids, triglycerides, phospholipids, and sterols (cholesterol). Lipids are also composed of carbon, hydrogen, and oxygen. Some dietary sources of lipids include, oils, butter, and egg yolks.

Water

Water is made up of hydrogen and oxygen and is the only macronutrient that provides no energy.

Micronutrients

Vitamins

These compounds are essential for normal physiologic processes in the body.

Minerals

Minerals are the elements (think periodic table) that are essential for normal physiologic processes in the body.

Carbohydrates

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Carbohydrates have become, surprisingly, quite controversial. However, it is important to understand that carbohydrates are a diverse group of compounds that have a multitude of effects on bodily functions. Thus, trying to make blanket statements about carbohydrates is not a good idea.

Carbohydrates provide energy for the body as well as fiber for digestive health and blood sugar regulation. Many natural carbohydrates such as fruits, vegetables and whole grains provide essential vitamins and minerals. Carbohydrates can be broken into 2 categories:

Simple carbohydrates: found naturally in fruits and milk and are added to candy and sweetened beverages. Simple carbohydrates provide quick energy.

Complex carbohydrates: found in grains and legumes provide sustained energy.

High-Fructose Corn Syrup

Food manufacturers are always searching for cheaper ways to produce their products. One extremely popular method for reducing costs is the use of high-fructose corn syrup as an alternative to sucrose. High-fructose corn syrup is approximately 50% glucose and 50% fructose, which is the same as sucrose. Nevertheless, because increased consumption of high-fructose corn syrup has coincided with increased obesity in the United States, a lot of controversy surrounds its use.

The New York Times article linked below discusses the growing popularity of sugar compared to high fructose corn syrup: “Sugar is Back on Food Labels, This Time as a Selling Point”

Fiber

The simplest definition of fiber is indigestible matter. Indigestible means that it survives digestion in the small intestine and reaches the large intestine. There are three major fiber classifications:

1. Dietary fiber

This type of fiber contains both nondigestible carbohydrates and lignin and is always intrinsic and intact in plants.

2. Functional fiber

This type of fiber contains nondigestible carbohydrates only and can be isolated, extracted, or synthesized. Functional fiber can be from plants or animals and produces beneficial physiological effects in humans.

3. Total Fiber

Fiber that contains both dietary fiber and functional fiber.

Proteins

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Protein is another major macronutrient that, like carbohydrates, consists of small repeating units. But instead of sugars, proteins are made up of amino acids.

Proteins can be classified as either complete or incomplete. Complete proteins provide adequate amounts of all nine essential amino acids. Animal proteins, such as meat, fish, milk, and eggs, are good examples of complete proteins. Incomplete proteins do not contain adequate amounts of one or more of the essential amino acids. For example, if a protein does not provide enough of the essential amino acid leucine it would be considered incomplete. Leucine would be referred to as the limiting amino acid because there is not enough of it for the protein to be complete. Most plant foods are incomplete proteins, with a few exceptions, such as soy. The following link discusses limiting amino acids and protein complementation: https://nutrition.org/protein-complementation/

Self Magazine's Nutrition Data website is a useful resource for determining protein quality and identifying complementary proteins. To use the site, go to www.nutritiondata.com, type the name of the food you want information on in the search bar and hit Enter. When you have selected your food from the list of possibilities, you will be given information about this food. Included in this information is the Protein Quality section. This will give you an amino acid score and a figure that illustrates which amino acid(s) is limiting. If your food is an incomplete protein, you can click "Find foods with a complementary profile." This will take you to a list of dietary choices that will provide complementary proteins for your food.

Fats (Lipids)

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Fats (lipids) are the most concentrated source of energy at 9 calories per gram. Fats provide long term stored energy, insulation, cushion and help the body absorb fat-soluble vitamins. Depending on the fatty acid structure a lipid may be monounsaturated, polyunsaturated, or saturated.

Linoleic acid (omega 6) and alpha-linoleic acid (omega 3) are examples of polyunsaturated fats and are essential components of a healthy diet. These healthy fats have an interactive roll in cell metabolism as well as overall vascular health which reduces risk of certain types of heart disease.

Trans-Fats

When unsaturated fats go through a process of hydrogenation some fatty acids are changed to trans-fats. This hydrogenation process makes liquid fats (such as oils) solid at room temperature and resistant to spoilage. Many food manufacturers used hydrogenated oils in processed foods to give these foods a longer shelf-life. However, trans-fats have a negative impact on health by raising levels of bad cholesterol (LDL) and lowering good cholesterol (HDL). Trans-fats are associated with increased risk of heart disease, stroke and type-2 diabetes.

Cholesterol

Cholesterol is a fat-like (lipid-like) substance that your body uses as a building block to produce hormones, vitamin D, and digestive juices that help you break down fats in your diet. HDL (high-density lipoprotein, or "good" cholesterol) and LDL (low-density lipoprotein, or "bad" cholesterol) are two types of lipoproteins that carry cholesterol to and from the body's cells in the blood.The body needs some cholesterol to function, but when levels get too high, fatty deposits can accumulate in blood vessels, which causes them to narrow. This narrowing of the blood passageways by these lipids can lead to heart attacks, coronary artery disease, strokes, or other vascular diseases.

Vitamins

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Vitamins are organic compounds found in foods and are a necessary part of the biochemical reactions in the body. They are involved in a number of processes, including mineral and bone metabolism, and cell and tissue growth, and they act as cofactors for energy metabolism.

You get most of your vitamins through your diet, although some can be formed from the precursors absorbed during digestion. For example, the body synthesizes vitamin A from the β-carotene in orange vegetables like carrots and sweet potatoes. Vitamins are either fat-soluble or water-soluble. Fat-soluble vitamins A, D, E, and K, are absorbed through the intestinal tract with lipids. Vitamin D is also synthesized in the skin through exposure to sunlight. Because they are carried in lipids, fat-soluble vitamins can accumulate in the lipids stored in the body. If excess vitamins are retained in the lipid stores in the body, hypervitaminosis can result.

Water-soluble vitamins, including the eight B vitamins and vitamin C, are absorbed with water in the gastrointestinal tract. These vitamins move easily through bodily fluids, which are water based, so they are not stored in the body. Excess water-soluble vitamins are excreted in the urine. Therefore, hypervitaminosis of water-soluble vitamins rarely occurs, except with an excess of vitamin supplements.

Minerals

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Minerals in food are inorganic compounds that work with other nutrients to ensure the body functions properly. Minerals cannot be made in the body; they come from the diet. The amount of minerals in the body is small—only 4 percent of the total body mass—and most of that consists of the minerals that the body requires in moderate quantities: potassium, sodium, calcium, phosphorus, magnesium, and chloride.

The most common minerals in the body are calcium and phosphorous, both of which are stored in the skeleton and necessary for the hardening of bones. Most minerals are ionized, and their ionic forms are used in physiological processes throughout the body. Sodium and chloride ions are electrolytes in the blood and extracellular tissues, and iron ions are critical to the formation of hemoglobin. There are additional trace minerals that are still important to the body's functions, but their required quantities are much lower.

Like vitamins, minerals can be consumed in toxic quantities (although it is rare). A healthy diet includes most of the minerals your body requires, so supplements and processed foods can add potentially toxic levels of minerals. The Major Minerals table provides a summary of minerals and their function in the body.

Calories (Food Energy)

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Food energy is measured in kilocalories (kcals), commonly referred to as calories. Although technically incorrect, this terminology is so familiar that it will be used throughout this course. A kilocalorie is the amount of energy needed to raise 1 kilogram of water 1 degree Celsius.

The number of kilocalories per gram for each nutrient is shown below:

[table id=4 /]

As the table above illustrates, only carbohydrates, protein, and lipids provide energy. However, there is another dietary energy source that is not a nutrient—alcohol. To emphasize, alcohol is *not* a nutrient, but it does provide 7 kilocalories of energy per gram.

Knowing the number of calories in each nutrient allows a person to calculate/estimate the amount of calories contained in any food consumed.

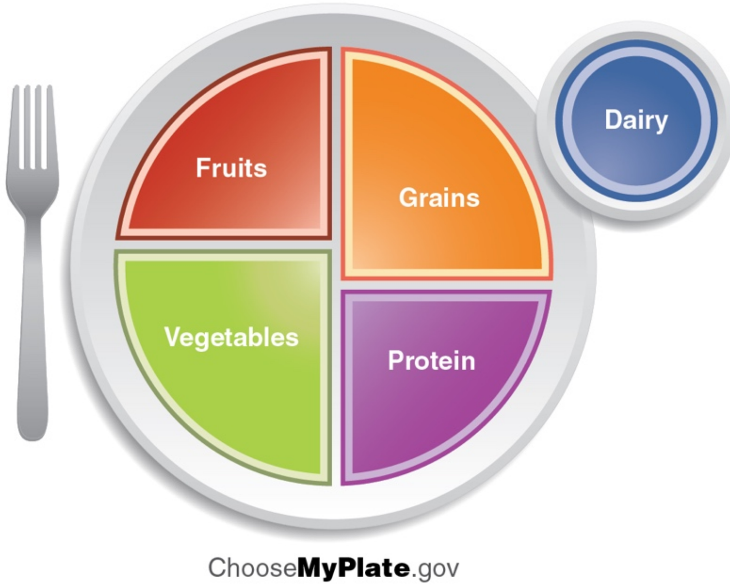
My Plate

On average, a person needs 1500 to 2000 calories per day to sustain (or carry out) daily activities. The total number of calories needed by one person is dependent on their body mass, age, height, gender, activity level, and the amount of exercise per day. If exercise is a regular part of one's day, more calories are required. As a rule, people underestimate the number of calories ingested and overestimate the amount they burn through exercise. This can lead to ingestion of too many calories per day. The accumulation of an extra 3500 calories adds one pound of weight. If an excess of 200 calories per day is ingested, one extra pound of body weight will be gained every 18 days. At that rate, an extra 20 pounds can be gained over the course of a year. Of course, this increase in calories could be offset by increased exercise. Running or jogging one mile burns almost 100 calories.

The type of food ingested also affects the body's metabolic rate. Processing of carbohydrates requires less energy than processing of proteins. In fact, the breakdown of carbohydrates requires the least amount of energy, whereas the processing of proteins demands the most energy. In general, the amount of calories ingested and the amount of calories burned determines the overall weight. To lose weight, the number of calories burned per day must exceed the number ingested. Calories are in almost everything you ingest, so when considering calorie intake, beverages must also be considered.

To help provide guidelines regarding the types and quantities of food that should be eaten every day, the USDA has updated their food guidelines from MyPyramid to MyPlate. They have put the recommended elements of a healthy meal into the context of a place setting of food. MyPlate categorizes food into the standard six food groups: fruits, vegetables, grains, protein foods, dairy, and oils. The accompanying website gives clear recommendations regarding quantity and type of each food that you should consume each day, as well as identifying which foods belong in each category. The accompanying graphic (Figure) gives a clear visual with general recommendations for a healthy and balanced meal. The guidelines recommend to "Make half your plate fruits and vegetables." The other half is grains and protein, with a slightly higher quantity of grains than protein. Dairy products are represented by a drink, but the quantity can be applied to other dairy products as well.

MyPlate



The U.S. Department of Agriculture developed food guidelines called MyPlate to help demonstrate how to maintain a healthy lifestyle.

Myplate.gov

Summary Video: Healthy Eating 101

CHAPTER 11 - WEIGHT MANAGEMENT

Objectives

1. Discuss how to manage weight through diet
2. Provide steps for starting a weight loss plan
3. Reinforce the importance of physical activity in weight management
4. Explain how to keep the weight off

Terminology

- **Binge Eating Disorder:** Eating large amounts (typically an entire day's worth) of calories in one sitting. Often done at night and alone.
- **Anorexia Nervosa:** A disorder where someone constricts caloric intake leading to extreme leanness.
- **Bulimia Nervosa:** Typically associated with large amounts of food, paired with a purge. This is what makes up the Binge-Purge cycle.

Weight Management Through Diet

DAWN MARKELL AND DIANE PETERSON

The majority of Americans are unhappy with their current weight. Almost everyone would like to lose at least 5 pounds. A growing percentage of Americans are carrying enough excess weight to put them at risk for many diseases and even death. Few people, however, know enough about their own bodies to successfully manage their weight. Anyone planning to start a weight loss program should begin by carefully considering the following factors:

- How many calories are being consumed daily? Myplate or HappyForks
- How many calories are being expended? BMR calculator
- How much fluids are being consumed?
- How well are electrolytes being managed?

Achieving one's ideal weight can be a challenge. But like most endeavors in life, knowledge is power. The more people know about their diet, the better equipped they will be to manage their weight. Most people focus on the number of calories consumed. However, it is also important for them to know how many macronutrients are in the foods they eat. The most effective way to do this is performing a 10-day nutritional intake analysis. These analyses are best done on consecutive days to account for the habitual ebb and flow of one's daily food intake.

Remaining healthy during any weight loss program is paramount. Fad diets that promise quick results do not consider the effects of rapid weight loss on the body. Restricting weight loss to 1 to 2 pounds a week is a far healthier approach. Slow weight loss also prevents the body from burning lean muscle since the body can only burn a certain amount of fat in a week. Dieters who experience steady declines in weight are more likely to keep the weight off. The term “diet” is often synonymous with strict routines that require drastic changes in one’s eating habits. In reality, the term “diet” simply describes the intake of food.

To lose weight, dieters need a clear understanding of how weight loss occurs. One pound of fat loss is going to require a reduction in caloric intake of 3,500 calories. When viewed in terms of daily food intake, to lose a pound a week, a dieter needs to reduce their daily food intake by 500 calories a day: 3,500 calories/7 days= 500 calories per day. To successfully lose 2 pounds per week, that reduction would have to be doubled to 1,000 calories per day. Attempting to lose 2 pounds or more per week would require a calorie reduction too drastic to be maintained and too restrictive to be healthy. Thus the recommendation of combining diet and exercise is the most effective method for experiencing weight loss. Subtracting 500 calories of food intake and exerting 500 calories in exercise will provide that same 1000 calorie reduction, but in a manner that is far easier to maintain, and certainly more enjoyable.

No matter what your weight loss goal is, even a modest weight loss, such as 5 to 10 percent of your total body weight, is likely to produce health benefits, such as improvements in blood pressure, blood cholesterol, and blood sugars.[1]

Getting Started with Weight Loss

On its website, the CDC explains the importance of including physical activity as part of any weight loss program. You can find information about the benefits of physical activity, recommended levels of physical activity, and the number of calories burned during common activities in this step-by-step guide to healthy weight loss. That same information is reprinted below for your convenience:

Step 1: Make a commitment.

Making the decision to lose weight, change your lifestyle, and become healthier is a big step to take. Start simply by making a commitment to yourself. Many people find it helpful to sign a written contract committing to the process. This contract may include things like the amount of weight you want to lose, the date you would like to lose the weight by, the dietary changes you will make to establish healthy eating habits, and a plan for getting regular physical activity.

Writing down the reasons why you want to lose weight can also help. It might be because you have a family history of heart disease, or because you want to see your kids get married, or simply because you want to feel better in your clothes. Post these reasons where they serve as a daily reminder of why you want to make this change.

Step 2: Take stock of where you are.

Consider talking to your health care provider. He or she can evaluate your height, weight, and explore other weight-related risk factors you may have. Ask for a follow-up appointment to monitor changes in your weight or any related health conditions.

Keep a “food diary” for a few days, in which you write down everything you eat. By doing this, you become more aware of what you are eating and when you are eating. This awareness can help you avoid mindless eating.

Next, examine your current lifestyle. Identify things that might pose challenges to your weight loss efforts. For example, does your work or travel schedule make it difficult to get enough physical activity? Do you find yourself eating sugary foods because that is what you buy for your kids? Do your coworkers frequently bring high-calorie items, such as doughnuts, to the workplace to share with everyone? Think through things you can do to help overcome these challenges.

Finally, think about aspects of your lifestyle that can help you lose weight. For example, is there an area near your workplace where you and some coworkers can take a walk at lunchtime? Is there a place in your community, such as a YMCA, with exercise facilities for you and child care for your kids?

Step 3: Set realistic goals.

Set some short-term goals and reward your efforts along the way. If your long-term goal is to lose 40 pounds and to control your high blood pressure, some short-term eating and physical activity goals might be to start eating breakfast, taking a 15-minute walk in the evenings, or having a salad or vegetable with supper.

Focus on two or three goals at a time. Great, effective goals are:

- Specific
- Realistic
- Forgiving (less than perfect)

For example, "Exercise more" is not a specific goal. But if you say, "I will walk 15 minutes, 3 days a week for the first week," you are setting a specific and realistic goal for the first week.

Remember, small changes every day can lead to big results in the long run. Also, remember that realistic goals are achievable goals. By achieving your short-term goals day by day, you will feel good about your progress and be motivated to continue. Setting unrealistic goals, such as losing 20 pounds in 2 weeks, can leave you feeling defeated and frustrated.

Being realistic also means expecting occasional setbacks. Setbacks happen when you get away from your plan for whatever reason—maybe the holidays, longer work hours, or another life change. When setbacks happen, get back on track as quickly as possible. Also, take some time to think about what you would do differently if a similar situation happens, to prevent setbacks.

Keep in mind everyone is different—what works for someone else might not be right for you. Just because your neighbor lost weight by taking up running, doesn't mean running is the best option for you. Try a variety of activities: walking, swimming, tennis, or group exercise classes, to see what you enjoy most and can fit into your life. These activities will be easier to stick with over the long term.

Step 4: Identify resources for information and support.

Find family members or friends who will support your weight loss efforts. Making lifestyle changes can feel easier when you have others you can talk to and rely on for support. You might have coworkers or neighbors with similar goals, and together you can share healthful recipes and plan group exercise. Joining a weight loss group or visiting a health care professional, such as a registered dietitian, can help.

Step 5: Continually "check in" with yourself to monitor your progress.

Revisit the goals you set for yourself in Step 3 and evaluate your progress regularly. If you set a goal to walk each morning but are having trouble fitting it in before work, see if you can shift your work hours or if you can get your walk in at lunchtime or after work.

Evaluate which parts of your plan are working well and which ones need tweaking. Then rewrite your goals and plan accordingly.

If you are consistently achieving a particular goal, add a new goal to help you continue on your pathway to success.

Reward yourself for your successes! Recognize when you are meeting your goals and be proud of your progress. Use non-food rewards, such as a new workout top or bottom or a new pair of running shoes, a sports outing with friends, or a relaxing bath. Rewards help keep you motivated on the path to better health.[2]

The Importance of Physical Activity in Maintaining a Healthy Weight

DAWN MARKELL AND DIANE PETERSON

Why is physical activity important?

Regular physical activity is important for good health, and it is especially important if you are trying to lose weight or to maintain a healthy weight.

When losing weight, more physical activity increases the number of calories your body uses for energy or "burns off." The burning of calories through physical activity, combined with reducing the number of calories you eat, creates a "calorie deficit" that results in weight loss.

Most weight loss occurs because of decreased caloric intake. However, evidence shows the only way to maintain weight loss is to be engaged in regular physical activity.

Most importantly, physical activity reduces risks of cardiovascular disease and diabetes beyond that produced by weight reduction alone.

Physical activity also helps to:

- Maintain weight.
- Reduce high blood pressure.
- Reduce risk for type 2 diabetes, heart attack, stroke, and several forms of cancer.

- Reduce arthritis pain and associated disability.
- Reduce risk for osteoporosis and falls.
- Reduce symptoms of depression and anxiety.

How much physical activity do I need?

When it comes to weight management, people vary greatly in how much physical activity they need. Here are some guidelines to follow:

To maintain your weight. Work your way up to 150 minutes of moderate-intensity aerobic activity, 75 minutes of vigorous-intensity aerobic activity, or an equivalent mix of the two each week. Strong scientific evidence shows that physical activity can help you maintain your weight over time. However, the exact amount of physical activity needed to do this is not clear since it varies greatly from person to person. It is possible that you may need to do more than the equivalent of 150 minutes of moderate-intensity activity a week to maintain your weight.

To lose weight and keep it off. You will need a high amount of physical activity unless you also adjust your diet and reduce the amount of calories you are eating and drinking. Getting to and staying at a healthy weight requires both regular physical activity and a healthy eating plan.

What do moderate- and vigorous-intensity mean?

Moderate: While performing physical activity, if your breathing and heart rate are noticeably faster but you can still carry on a conversation, it is probably moderately intense. Examples include:

- Walking briskly (a 15-minute mile).
- Light yard work (raking/bagging leaves or using a lawn mower).
- Light snow shoveling.
- Actively playing with children.
- Biking at a casual pace.

Vigorous: If your heart rate is increased substantially, and you are breathing too hard and fast to have a conversation, it is probably vigorously intense. Examples include:

- Jogging/running.
- Swimming laps.
- Rollerblading/inline skating at a brisk pace.
- Cross-country skiing.
- Most competitive sports (football, basketball, or soccer).
- Jumping rope.

This table provides a list of common physical activities and the average calories expended during those activities.

[table id=5 /]

1. Calories burned per hour will be higher for persons who weigh more than 154 lbs. (70 kg) and lower for persons who weigh less.

Source: Adapted from Dietary Guidelines for Americans 2005, page 16, Table 4.

Keeping the Weight Off

DAWN MARKELL AND DIANE PETERSON

On its website the CDC admonishes that permanent weight loss is a result of making changes to eating habits that become a long-term part of a healthier lifestyle. You may access that section on their website in the references at the end of this text. It is also reprinted below for your convenience.

Reflect, Replace, Reinforce: A process for improving your eating habits

Create a list of your eating habits.

Keeping a food diary for a few days, in which you write down everything you eat and the time of day you ate it, will help you uncover your habits. For example, you might discover that you always seek a sweet snack to get you through the mid-afternoon energy slump. Use this diary to help. It's good to note how you were feeling when you decided to eat, especially if you were eating when not hungry. Were you tired? Stressed out?

Highlight the habits on your list that may be leading you to overeat. Common eating habits that can lead to weight gain are:

- Eating too fast
- Always cleaning your plate
- Eating when not hungry
- Eating while standing up (may lead to eating mindlessly or too quickly)
- Always eating dessert

- Skipping meals (or maybe just breakfast)

Look at the unhealthy eating habits you have highlighted. Be sure you have identified all the triggers that cause you to engage in those habits. Identify a few you would like to work on improving first. Don't forget to pat yourself on the back for the things you are doing right. Maybe you almost always eat fruit for dessert, or you drink low-fat or fat-free milk. These are good habits! Recognizing your successes will help encourage you to make more changes.

Create a list of "cues."

Review your food diary to become more aware of when and where you are "triggered" to eat for reasons other than hunger. Note how you are typically feeling at those times. Often an environmental "cue," or a particular emotional state, is what encourages eating for non-hunger reasons.

Common triggers for eating when not hungry are:

- Opening up the cabinet and seeing your favorite snack food.
- Sitting at home watching television.
- Before or after a stressful meeting or situation at work.
- Coming home after work and having no idea what's for dinner.
- Having someone offer you a dish they made "just for you!"
- Walking past a candy dish on the counter.
- Sitting in the break room beside the vending machine.
- Seeing a plate of doughnuts at the morning staff meeting.
- Swinging through your favorite drive-through every morning.
- Feeling bored or tired and thinking food might offer a pick-me-up.

Circle the "cues" on your list that you face on a daily or weekly basis. Going home for the Thanksgiving holiday may be a trigger for you to overeat, and eventually, you want to have a plan for as many eating cues as you can. But for now, focus on the ones you face more often.

Ask yourself these questions for each "cue" you have circled:

- Is there anything I can do to avoid the cue or situation? This option works best for cues that don't involve others. For example, could you choose a different route to work to avoid stopping at a fast food restaurant on the way? Is there another place in the break room where you can sit so you are not next to the vending machine?
- For things I cannot avoid, can I do something differently that would be healthier? Obviously, you cannot avoid all situations that trigger your unhealthy eating habits, like staff meetings at work. In these situations, evaluate your options. Could you suggest or bring healthier snacks or beverages? Could you offer to take notes to distract your attention? Could you sit farther away from the food so it won't be as easy to grab something? Could you plan ahead and eat a healthy snack before the meeting?
- Replace unhealthy habits with new, healthy ones. For example, in reflecting upon your eating habits, you may realize that you eat too fast when you eat alone. So, make a commitment to share a lunch each week with a colleague, or have a neighbor over for dinner one night a week. Other strategies might include putting your fork down between bites or minimizing other distractions (i.e., watching the news during dinner) that might keep you from paying attention to how quickly—and how much—you are eating.

Here are more ideas to help you replace unhealthy habits:

- Eat more slowly. If you eat too quickly, you may "clean your plate” instead of paying attention to whether your hunger is satisfied.

- Eat only when you are truly hungry instead of when you are tired, anxious, or feeling an emotion besides hunger. If you find yourself eating when you are experiencing an emotion besides hunger, such as boredom or anxiety, try to find a non-eating activity to do instead. You may find a quick walk or phone call with a friend helps you feel better.
- Plan meals ahead of time to ensure that you eat a healthy well-balanced meal.
- Reinforce your new, healthy habits and be patient with yourself. Habits take time to develop. It doesn’t happen overnight. When you do find yourself engaging in an unhealthy habit, stop as quickly as possible and ask yourself: Why do I do this? When did I start doing this? What changes do I need to make?
- Be careful not to berate yourself or think that one mistake “blows” a whole day’s worth of healthy habits. You can do it! It just takes one day at a time![4]

Health Risks of Being Underweight

DAWN MARKELL AND DIANE PETERSON

The 2003–2006 National Health and Nutrition Examination Survey (NHANES) estimated that 1.8 percent of adults and 3.3 percent of children and adolescents in the United States are underweight. Centers for Disease Control and Prevention. "NCHS Health E-Stat. Prevalence of Underweight among Children and Adolescents: United States, 2003–2006." Accessed October 8, 2011. http://www.cdc.gov/nchs/data/hestat/underweight/underweight_children.htm.

Being underweight is linked to nutritional deficiencies, especially iron-deficiency anemia, and to other problems such as delayed wound healing, hormonal abnormalities, increased susceptibility to infection, and increased risk of some chronic diseases such as osteoporosis. In children, being underweight can stunt growth.

The most common underlying cause of being underweight in America is inadequate nutrition. Other causes are wasting diseases, such as cancer, multiple sclerosis, tuberculosis, and eating disorders. People with wasting diseases are encouraged to seek nutritional counseling, as a healthy diet greatly affects survival and improves responses to disease treatments. Eating disorders that result in underweight affect about eight million Americans (seven million women and one million men).

Anorexia Nervosa

Anorexia nervosa, more often referred to as "anorexia," is a psychiatric illness in which a person obsesses about their weight and about food that they eat. Anorexia results in extreme nutrient inadequacy and eventually to organ malfunction. The National Institute of Mental Health (NIMH) reports that 0.9 percent of females and 0.3 percent of males will develop anorexia according to The National Institute of Mental Health. Eating Disorders. But it is an extreme example of how an unbalanced diet can affect health. Anorexia frequently manifests during adolescence and it has the highest rate of mortality of all mental illnesses. People with anorexia consume, on average, fewer than 1,000 kilocalories per day and exercise excessively. They are in a tremendous caloric imbalance. Moreover, some may participate in binge eating, self-induced vomiting, and purging with laxatives or enemas. The very first time a person starves him- or herself may trigger the onset of anorexia. The exact causes of anorexia are not completely known, but many things contribute to its development including economic status, as it is most prevalent in high-income families. It is a genetic disease and is often passed from one generation to the next. Pregnancy complications and abnormalities in the brain, endocrine system, and immune system may all contribute to the development of this illness.

The primary signs of anorexia are fear of being overweight, extreme dieting, an unusual perception of body image, and depression. The secondary signs and symptoms of anorexia are all related to the caloric and nutrient deficiencies of the unbalanced diet and include excessive weight loss, a multitude of skin abnormalities, diarrhea, cavities and tooth loss, osteoporosis, and liver, kidney, and heart failure. There is no physical test that can be used to diagnose anorexia and distinguish it from other mental illnesses. Therefore, a correct diagnosis involves eliminating other mental illnesses, hormonal imbalances, and nervous system abnormalities. Eliminating these other possibilities involves numerous blood tests, urine tests, and x-rays. Coexisting organ malfunction is also examined. Treatment of any mental illness involves not only the individual, but also family, friends, and a psychiatric counselor. Treating anorexia also involves a dietitian, who helps to provide dietary solutions that often have to be adjusted over time. The goals of treatment for anorexia are to restore a healthy body weight and significantly reduce the behaviors associated with causing the eating disorder. Relapse to an unbalanced diet is high.

Bulimia

Bulimia, like anorexia, is a psychiatric illness that can have severe health consequences. The NIMH reports that 0.5 percent of females and 0.1 percent of males will have bulimia at some point in their lifetime. Bulimia is characterized by episodes of eating large amounts of food followed by purging, which is accomplished by vomiting and with the use of laxatives and diuretics. Unlike people with anorexia, those with bulimia often have a normal weight, making the disorder more difficult to detect and diagnose. The disorder is characterized by signs similar to anorexia such as fear of being overweight, extreme dieting, and bouts of excessive exercise. Secondary signs and symptoms include gastric reflux, severe erosion of tooth enamel, dehydration, electrolyte imbalances, lacerations in the mouth from vomiting, and peptic ulcers. Repeated damage to the esophagus puts people with bulimia at an increased risk for esophageal cancer. The disorder is also highly genetic, linked to depression and anxiety disorders, and most commonly occurs in adolescent girls and young women. Treatment often involves antidepressant medications and, like anorexia, has better results when both the family and the individual with the disorder participate in nutritional and psychiatric counseling.

Binge-Eating Disorder

Similar to those who experience anorexia and bulimia, people who have a binge-eating disorder have lost control over their eating. Binge-eating disorder is not currently diagnosed as a distinct psychiatric illness, although there is a proposal from the American Psychiatric Association to categorize it more specifically. People with binge-eating disorder will periodically overeat to the extreme, but their loss of control over eating is not followed by fasting, purging, or compulsive exercise. As a result, people with this disorder are often overweight or obese, and their chronic disease risks are those linked to having an abnormally high body weight such as hypertension, cardiovascular disease, and Type 2 diabetes. Additionally, they often experience guilt, shame, and depression. Binge-eating disorder is commonly associated with depression and anxiety disorders. According to the NIMH, binge-eating disorder is more prevalent than anorexia and bulimia, and affects 3.5 percent of females and 2.0 percent of males at some point during their lifetime. Treatment often involves antidepressant medication as well as nutritional and psychiatric counseling.

CHAPTER 12 - STRESS

Objectives

1. Define stress
2. Describe the effects of stress on wellbeing
3. Identify effective strategies for managing stress
4. Assess your own levels of stress

Terminology

- **Stress** – the body's physical, mental, and emotional response to a particular stimulus
- **Stressor** – Something that causes stress
- **Eustress** – Good Stress
- **Distress** – Bad stress
- **Adrenalin** – a hormone secreted by the adrenal glands, especially in conditions of stress, increasing rates of blood circulation and breathing
- **Homeostasis** – the default state in which the body functions normally
- **General adaptation syndrome (GAS)** – a pattern of stress responses consisting of three stages: alarm, resistance, and exhaustion

What Is Stress and How Does It Affect Wellness?

DAWN MARKELL AND DIANE PETERSON

In today's fast-paced society, most people complain about being stressed. However, when they use the term *stress*, they rarely know it's true meaning. The word carries many negative connotations and is associated with an unpleasant or traumatic event. As such, people mistakenly believe that stress is simply the nervousness and tension experienced prior to, during, or after a negative event. In fact, the effects of stress are physiological, emotional, *and* psychological.

Additionally, not all levels of stress are detrimental. The stress athletes experience right before a big game or college students feel right before an exam can enhance focus and increase their ability to concentrate. Stress is either good or bad depending on how long it persists and how it is perceived by the individual.

This chapter will provide a deeper understanding of what stress is and provide effective strategies for managing stress.

Stress is defined as the body's physical, mental, and emotional response to a particular stimulus, called a **stressor**. This adaption/coping-response helps the body prepare for challenging situations. It is the level of a person's response to a stressor that determines whether the experience is positive or negative. As a hardworking college student, you may feel as if you know the meaning of stress all too well. You may dream of a future where the demands on your time are diminished, so you can escape the high levels of stress you are feeling now. Unfortunately, regardless of their situation, everyone experiences stress on a regular basis. The good news is, not all stress is bad! Small levels of stress can enhance cognitive brain function. Stress may provide the motivation and concentration you need to write an essay, practice a speech, or prepare for a job interview. For most people, these types of stressors are manageable and not harmful. Stressors that have the potential for harm include the sudden loss of a loved one, the unexpected ending of a romantic relationship, or the unfair demands of an unreasonable boss.

Defining Stress

Stress, then, is more than simply the tension and apprehension generated by problems, obstacles, or traumatic events. Stress is the body's automatic response (physical, mental, and emotional) to any stressor. It is a natural and unavoidable part of life, and it can be empowering and motivating, or harmful and potentially dangerous.

For more information on stress click on the links below:

What is Stress?

What is stress and what causes it?

Effects of Stress on Wellness

As stated previously, not all stress is bad. In fact, the stress associated with riding a roller coaster, watching a scary movie, or scaling a cliff can enhance these experiences. Regardless of whether the stress experienced is negative or positive, the effects on the body are identical.

When a person senses that a situation demands action, the body responds by releasing chemicals into the blood. The hypothalamus signals the adrenal glands to release a surge of hormones that include adrenaline and cortisol. The physiological effects of those chemicals—enhanced focus, quicker reaction time, and increased heart rate, energy, and strength—are quite beneficial when faced with a potentially dangerous situation that is temporary.

Unfortunately, most of the stressors people face—work, school, finances, relationships—are a part of everyday life, and thus, inescapable. Experiencing ongoing, unavoidable stress can result in some very unpleasant and harmful effects, both mental and physical. Chronic stress can cause upset stomach, headaches, sleep problems, and heart disease. It can also cause depression, anxiety, and even memory loss.

To watch a video that describes the effects of stress in detail, click on the link below:

How Stress Affects Your Body and Mind

General Adaptation Syndrome

DAWN MARKELL AND DIANE PETERSON

Even if you know the physical effects of stress, you may be unaware of the different stages of stress, known as the general adaptation syndrome (GAS). The general adaptation syndrome is a universal and predictable response pattern to all stressors, whether good stress (called **eustress**) or bad stress (called **distress**).

Endocrinologist Hans Selye first described GAS in the 1930s and 1940s. He believed that when we are chronically exposed to stress, over time, the stress response causes aging and disease. During experiments with rats, Selye observed a series of physiological changes in the rats after they were exposed to stressful events.

After additional research, Selye concluded that these changes were not an isolated case, but rather the typical response to stress. He subsequently identified these stages as alarm, resistance, and exhaustion. Understanding these different responses and how they relate to each other may help you cope with stress. The sequence of physical responses associated with GAS is the same for eustress and distress and occurs in three stages.

Three Stages of GAS

1. Alarm reaction stage

In this stage, your body experiences the "fight or flight" response.

This natural reaction prepares you to either flee or protect yourself in dangerous situations. The **sympathetic branch** of the autonomic nervous system is activated and the adrenal glands secrete two hormones to stimulate your reactions to stress: epinephrine (also known as adrenalin) and norepinephrine (also known as noradrenalin).

Adrenalin mobilizes glucose and fatty acid release from fatty cells. The body is able to use both as energy to respond to stress. Adrenalin and noradrenalin also have powerful effects on the heart. Both the heart rate and stroke volume are increased, thereby increasing the body's cardiac output. They also help to shunt blood away from the other parts of the body and thereby push more blood to the heart, brain, and muscles as the body prepares to attack or flee. At the same time, the adrenal glands also release cortisol, to help meet the body's energy needs in times of stress.

2. Resistance stage

After the initial reaction to the stressor during the alarm reaction stage, the **parasympathetic branch** of the autonomic nervous system counteracts the changes that the stressful stimulus has produced, and attempts to restore a state of **homeostasis**, the default state in which the body functions normally.

During the resistance stage, the results of the hormonal changes which occurred in the previous stage are still apparent, including increased glucose levels in the blood and higher blood pressure, but stress hormone levels begin to return to normal, enabling the body's focus to shift from alertness to repair.

If the resistance stage continues for too long the body will stay in a state of alertness and continue to produce the stress hormones. Signs of the resistance stage include:

- Irritability
- Frustration
- Poor concentration

3. Exhaustion stage

After an extended period of stress, the body enters this final stage of GAS. At this stage, the body has depleted its physical, emotional, and mental resources and is unable to maintain normal function. Once the body is no longer equipped to fight stress and may experience these symptoms:

- Fatigue
- Depression
- Anxiety
- Feeling unable to cope

The Fight or Flight Response

When an individual perceives a potential stressor as dangerous, the body enters into a stress response termed "Fight or Flight". This is a natural physiological deviation from homeostasis designed to protect an individual from harm. When our ancestors lived among other animals out in the wild, it was important for survival that when faced with danger, an automatic "alarm" response would take over causing them to take immediate action (attack or run). This is still an important response mechanism in today's world. Imagine a bus speeding toward you, horn blasting, and you experienced no sense of danger or alarm. You would probably be killed. Luckily, your fight-or-flight response automatically steps in and takes over.

During the initial stress response, a person's brain sends messages to a part the nervous system called the autonomic nervous system. The autonomic nervous system has two branches: the sympathetic nervous system and the parasympathetic nervous system. The sympathetic nervous system is the fight-or-flight system which gets the body aroused and ready for action, and the parasympathetic nervous system returns the body to a normal, non-aroused state.

When activated, the sympathetic nervous system releases a chemical called adrenalin. Adrenalin is used as a messenger to continue sympathetic nervous system activity, so that once activity begins, it often continues and increases for some time. Adrenalin takes time to fully exit the blood stream so even after your sympathetic nervous system has stopped responding, you are likely to continue to feel "stressed". The parasympathetic nervous system takes over when the perceived danger is over (or the fight or run response took place).

Exercise and Fight or Flight

Physical activity or regular exercise serve to act as simulated "fight or flee" scenarios that trigger the parasympathetic nervous system and return the body to homeostasis.

What Are the Strategies for Managing Stress?

DAWN MARKELL AND DIANE PETERSON

Although stress in everyday life is unavoidable, there are ways to cope with it that will minimize or eliminate its harmful effects.

The Anxiety and Depression Association of America (ADAA) provides a list of effective strategies for coping with stress. That document is linked here: Tips: Coping Strategies. For your convenience, it is also reprinted below with the ADAA's permission.

When you are feeling anxious or stressed, these strategies will help you cope:

- **Take a time-out.** Practice yoga, listen to music, meditate, get a massage, or learn relaxation techniques. Stepping back from the problem helps clear your head.
- **Eat well-balanced meals.** Do not skip any meals. Do keep healthful, energy-boosting snacks on hand.
- **Limit alcohol and caffeine**, which can aggravate anxiety and trigger panic attacks.
- **Get enough sleep.** When stressed, your body needs additional sleep and rest.
- **Exercise daily** to help you feel good and maintain your health.
- **Take deep breaths**. Inhale and exhale slowly.
- **Count to 10 slowly**. Repeat, and count to 20 if necessary.
- **Do your best**. Instead of aiming for perfection, which isn't possible, be proud of however close you get.
- **Accept that you cannot control everything**. Put your stress in perspective: Is it really as bad as you think?
- **Welcome humor**. A good laugh goes a long way.
- **Maintain a positive attitude**. Make an effort to replace

negative thoughts with positive ones.

- **Get involved.** Volunteer or find another way to be active in your community, which creates a support network and gives you a break from everyday stress.
- **Learn what triggers your anxiety.** Is it work, family, school, or something else you can identify? Write in a journal when you're feeling stressed or anxious and look for a pattern.
- **Talk to someone.** Tell friends and family you're feeling overwhelmed, and let them know how they can help you. Talk to a physician or therapist for professional help.
- **Get help online.** Online programs guided by professional coaches to help you turn healthy anxiety management into a habit.
    - Listen to podcasts on a wide range of topics
    - Watch recorded webinars on topics ranging from how to worry less, coping with panic attacks, treatments for children, and helping suicidal families,and many more.

Fitness Tips: Stay Healthy, Manage Stress

To receive the greatest benefits from exercising, try to include at least 2½ hours of moderate-intensity physical activity (e.g., brisk walking) each week, 1¼ hours of a vigorous-intensity activity (such as jogging or swimming laps), or a combination of the two.

- **5 X 30:** Jog, walk, bike, or dance three to five times a week for 30 minutes.
- **Set small daily goals** and aim for daily consistency rather than perfect workouts. It is better to walk every day for 15–20 minutes than to wait until the weekend for a three-hour fitness marathon. Lots of scientific data suggests that frequency is most important.
- **Find forms of exercise** that are fun or enjoyable. Extroverted

people often like classes and group activities. People who are more introverted often prefer solo pursuits.

- **Distract yourself** with an iPod or other portable media player to download audiobooks, podcasts, or music. Many people find it is more fun to exercise while listening to material they enjoy.
- **Recruit** an “exercise buddy.” It is often easier to stick to your exercise routine when you have to stay committed to a friend, partner, or colleague.
- **Be patient** when you start a new exercise program. Most sedentary people require about four to eight weeks to feel coordinated and sufficiently in shape so that exercise feels easier.

Additional strategies for coping with stress are linked below:

Stress Management

10 Tips to Manage Stress

CHAPTER 13 - FITNESS AND STRESS ASSESSMENTS

Cardiorespiratory Fitness Assessment

MARTIN DUBUC

As was discussed in Chapter 4: Cardiorespiratory Fitness, Cardiorespiratory Assessments aim to assess an individual's capacity to accomplish two fundamental physiological processes:

1. Take in oxygen through the respiratory system and deliver it to the working tissues via the cardiovascular system (and conversely, remove metabolic waste and carbon dioxide from the working tissues and remove them from the body via metabolic processes and the respiratory system).
2. Use the delivered oxygen to produce Adenosine triphosphate (ATP), our body's energy currency, to power muscular contractions.

The greater their ability to accomplish the aforementioned processes, the greater an individual's Maximal Oxygen Consumption – VO2 max will be (i.e., the rate of oxygen uptake/consumption during maximal aerobic exercise). This directly translates to the body's ability to maintain higher intensities of aerobic exercise for extended periods of time. VO2 max is measured in ml/kg/min – in other words, how many millilitres of oxygen are consumed per kilogram of body weight per minute while exercising at the maximal aerobic intensity.

When assessing cardiorespiratory endurance, tests can be **Direct** (directly measuring the oxygen consumed by the body using masks and gas analysis software) or **Indirect** (using various variables such as workload, heart rate, distance, time, stage completion, etc. to **predict** what the oxygen consumption is). This course will specifically make use of Indirect protocols to allow you to estimate your VO2 max. In this chapter, you will find various tests that may be employed during your time as a PARA student to assess your current level of cardiorespiratory endurance.

Activity 1.1: 1.5 mile/ 2.4km Cooper Run

This test operates on the premise that the distance a subject can run in a specified time is determined by their ability to maintain a high level of oxygen consumption. *The principle is simple: fitter individuals will be able to run the 2.4km distance in less time.* Conversely, the 12-minute Cooper test works on the same premise, but subjects run the furthest distance possible in this case in 12 minutes.

Procedure:

This test should be conducted on a flat surface without risks of interruptions (traffic lights, etc.), which is why a 400m track is recommended (6 laps total – 6 x 400m = 2400m. The objective is to cover the 2.4km distance as quickly as possible *while maintaining the fastest steady exercise pace possible.* In other words, do not start too quickly or else you may be forced to slow down/walk later, but do not start too slowly where you end up running much faster in later laps. It is worth noting that participants tend to improve their performance on this test when re-testing, not due to training, but due to learning how to pace themselves from their previous trial. For this reason, a practice test is often recommended a few days before the official test. **A warm-up lap is also recommended, which includes light jogging, dynamic stretching, or other exercises to help increase your heart rate and warm up your muscles.**

Once you are ready, record how much time it takes you to travel the 2.4km distance in minutes and seconds. If your timing device provides lap times, use this feature to help you maintain a steady pace. Once you have completed the run, walk a lap / for 5 minutes at a slow pace to allow the body to cool down and recover.

VO2max calculation:

1. Take your recorded time (in minutes and seconds) and convert it to minutes by dividing the number of seconds by 60. For example, if a student runs the 2.4km in 12 minutes and 15 seconds, their exercise time is converted to 12 minutes and (15 / 60 = 0.25) – **12.25 minutes.**
2. Using your exercise time in minutes calculated in Step 1 above, insert it in the formula below (*It is worth noting that there are many variations of the formula below that can be used to estimate VO2max from a 2.4km run, including some that take biological gender and heart rate into consideration*):

$$(483 / \text{time in minutes}) + 3.5$$

Continuing with the example above, a student who completes the test in 12.25 minutes would be calculated as:

VO2*max* = (483/12.25) + 3.5 → 39.43 + 3.5 = 42.93 *ml/kg/min*

3. Once you have calculated your VO2max, you can refer to the reference table at the end of this chapter to find your Cardiorespiratory Endurance rating.

Activity 1.2: 20m Shuttle Run

This test is a requirement for the PARA *students' fitness testing and is described in detail in the* PARA *Fitness Test Descriptions chapter of this textbook (including the stages and equivalent grades).* As such, it will only be briefly covered here, particularly expanding on how the 20m Shuttle Run can also be used to estimate VO2max.

The 20m Shuttle Run, often referred to as the "Beep Test", the PACER test, or the Leger Shuttle Run, estimates a subject's VO2max by having them run a 20-meter distance back and forth at increasingly faster speeds with each stage (determined by audio cues, or “beeps” provided by an audio track). The premise is that a steady pace running speed would provide a similar VO2 score for different individuals. Those with higher cardiorespiratory endurance (or oxygen consumption capacity) will be able to maintain the required cadence into the later and faster stages of the test, while less fit subjects will be forced to quit the test sooner as they cannot keep the pace.

VO2max calculation:

Using the table below, determine your maximal attained running speed (MAS) based on the stage you were at when the test was terminated. Use the fastest speed you were running at, even if you did not successfully complete that stage. E.g., if a student quits the test after two shuttles into stage 7, their MAS would be 11.5 km/h.

Stage/ Level	Speed (km/h) *MAS*	Lap Time (s)	Level Time (s)	Level Distance (m)	Cumulative distance (m)	Cumulative Time (mm:ss)
1	8.5	6.35	63.5	150	150	1:04
2	9	6	60	150	300	2:04
3	9.5	5.68	62.5	165	465	3:06
4	10	5.4	64.8	180	645	4:11
5	10.5	5.14	61.7	180	825	5:13
6	11	4.91	63.8	195	1020	6:16
7	11.5	4.7	61	195	1215	7:17
8	12	4.5	63	210	1425	8:20
9	12.5	4.32	60.5	210	1635	9:21
10	13	4.15	62.3	225	1860	10:23
11	13.5	4	60	225	2085	11:23
12	14	3.86	61.7	240	2325	12:25
13	14.5	3.72	63.3	255	2580	13:28
14	15	3.6	61.2	255	2835	14:29
15	15.5	3.48	62.7	270	3105	15:32
16	16	3.38	60.8	270	3375	16:33
17	16.5	3.27	62.2	285	3660	17:35
18	17	3.18	60.4	285	3945	18:35
19	17.5	3.09	61.7	300	4245	19:37
20	18	3	60	300	4545	20:37
21	18.5	2.92	61.3	315	4860	21:38

Once you have determined your MAS, insert it in the formula below (*It is worth noting that there are many variations of the formula below that can be used to estimate VO2max from a 20m Shuttle Run Test based on your source, which may vary your final* VO2max *score by a few points*):

$$VO2max = -24.4 + (6 \times MAS)$$

Continuing with the example above, a student who reaches stage 7.5 would be calculated as:

VO2max = -24.4 + (6 x 11.5km/h) → -24.4 + 69 = 44.6 *ml/kg/min*

VO2 Max Ratings

Just as some of the formulas seen above may vary slightly based on the publication source, the ratings associated with VO2max scores can also vary depending on which reference you are using. The following rating table is established by the Canadian Society of Exercise Physiology (CSEP), which is considered the Gold Standard of Personal Training and Fitness Assessment in Canada.

Estimated VO_2max - Health Benefit Rating

AGE	ZONE	MALE	FEMALE
15–19	Excellent	57.4 +	49.0 +
	Very Good	52.4–57.3	43.7–48.9
	Good	48.8–52.3	39.5–43.6
	Fair	43.6–48.7	36.8–39.4
	Poor	< 43.6	< 36.8
20–29	Excellent	55.6 +	47.2 +
	Very Good	50.6–55.5	42.0–47.1
	Good	47.2–50.5	37.8–41.9
	Fair	41.6–47.1	35.0–37.7
	Poor	< 41.6	< 35.0
30–39	Excellent	48.8 +	45.4 +
	Very Good	45.4–48.7	40.1–45.3
	Good	40.1–45.3	36.0–40.0
	Fair	33.7–40.0	33.0–35.9
	Poor	< 33.7	< 33.0
40–49	Excellent	47.0 +	40.0 +
	Very Good	42.7–46.9	35.1–39.9
	Good	35.5–42.6	31.9–35.0
	Fair	31.9–35.4	27.1–31.8
	Poor	< 31.9	< 27.1
50–59	Excellent	41.8 +	36.6 +
	Very Good	36.5–41.7	34.0–36.5
	Good	30.1–36.4	31.0–33.9
	Fair	26.0–30.0	24.6–30.9
	Poor	< 26.0	< 24.6
60–69	Excellent	38.4 +	35.8 +
	Very Good	32.8–38.3	32.8–35.7
	Good	28.7–32.7	29.6–32.7
	Fair	23.5–28.6	23.5–29.5
	Poor	< 23.5	< 23.5

Taken from CSEP Physical Activity Training for Health® (CSEP-PATH®) Resource Manual, 3rd Edition

Reflection Questions

A. Based on the completion of either the 1.5 mile/2.4km Cooper Run OR the 20m Shuttle Run, answer the following:

1. What is your VO2max and associated Rating? Show your times/stage and calculations.

2. Is this result what you were expecting? Justify your answer.
3. Are you satisfied with your VO2max and Rating? Based on your response, how do you plan on improving or maintaining your current result?

B. If you have completed BOTH the 1.5 mile/2.4km Cooper Run AND the 20m Shuttle Run this semester, answer the following:

1. What is your VO2max and associated Rating for each test? Show your times/stage and calculations. Is this result what you were expecting? Justify your answer.
2. In your opinion, which test is more challenging to complete and why? Is this the test that gave you a lower or a higher score?
3. Which of these two tests do you believe to be more representative of your current state of cardiorespiratory endurance? Explain why.

Muscular Strength and Endurance Assessment

MARTIN DUBUC

Muscular Strength is typically defined as the maximum amount of force a muscle (or muscles) can generate in a single contraction (i.e., 1 Repetition Maximum or 1-RM), while **Muscular Endurance** tends to reflect a muscle's (or muscles') ability to provide multiple repetitions or remain contracted for an extended period of time. Our muscles' ability to generate force or endure repeated strain extends beyond their size and is in fact, a reflection of a combination of factors. As is discussed in Chapter 5 of this textbook, our muscles are composed of various muscle fiber types that differ in their characteristics and capacities, which will impact how much force or endurance they provide. Other factors, such as the nervous systems' ability to recruit large amounts of muscle fibers, synchronize their firing, or the resistance of connective tissues to the strain they are placed under, all play important roles in determining an individual's muscular strength and endurance. The following activities will help you assess your current level of muscular strength and endurance, as well as track your improvements as you progress through the program.

Activity 2.1 – Dynamic Muscular Strength Battery

The following six exercises are often used as a test battery (i.e., a series of tests/exercises) to determine someone's overall **dynamic muscular strength** (i.e., strength through a range of motion where changes in muscle fibre length takes place). *Note – the Grip Strength test described further in this unit is an example of* ***isometric muscular strength*** *since there is no range of motion or change in muscle fibre length.* Given that attempting actual 1-RMs poses a significant injury risk, particularly when proper form is not adhered to, this activity requires predicting your 1-RM for the six exercises provided by producing a larger number of reps. It stands to reason that larger individuals tend to generate more strength **(absolute strength)**, which is why strength is often expressed in **relative terms (weight lifted by body weight)** in order to compare your performance to established norms. For example, rather than stating "*the average college-age male can bench press 200lbs*" norms have been established that determine "the average college-age mal can bench press their body weight. If you happen to weigh more, it is expected you would be able to bench press more weight as well. This allows us to compare individuals of various sizes against established norms, as you will be expected to do for this lab activity.

Procedure

After completing a thorough warm-up, including lifting light to moderate weights of the exercises in question, choose a weight with which you believe you can only achieve five to ten repetitions. If you cannot do five, the prediction equation will still work. However, if you complete more than ten repetitions, give yourself several minutes of recovery and try again with a heavier weight. You will need to record the weight lifted and the amount of repetitions for the following exercises:

1. Bench Press (barbell – flat bench)
2. Arm Curl (barbell)
3. Lat Pull Down
4. Leg Press
5. Leg Extension
6. Leg Curl

Calculations

Step 1: Use the following table, established by Baechle, Earle, and Wathen (2000), to see what percentage of 1-RM you lifted based on the number of repetitions. There is an example below the table for you to see how to complete the calculation required for all six exercises.

Repetitions	%1-RM[a]
1	100
2	95
3	93
4	90
5	87
6	85
7	83
8	80
9	77
10	75

[a]These values may vary slightly for different muscle groups and ages.

Data from Baechle, Earle, and Wathen 2000.

Example Calculation

If you managed to lift a weight of 125 lbs for five repetitions, it estimates you were only lifting 87% of your 1-RM. To predict your 1-RM, simply divide the weight lifted by the estimated percentage:

125lbs / 0.87 = 143.7lbs (or rounded to 148lbs)

<u>Step 2:</u> Establish your Strength-to-body-mass ratio by dividing your newly estimated 1-RM from Step 1 for all six exercises by your body mass. DO NOT divide the weight you actually lifted; since you were able to do multiple repetitions, this is not your 1-RM.

Example Calculation

If you weigh 175lbs, and had a predicted 1-RM of 148lbs (from the example above), you would calculation your Strength-to-body mass ratio as follows:

148lbs (weight lifted) / 175 lbs (body mass) = 0.85 (only 2 decimals needed)

__Step 3:__ Use the provided table below, developed by testing 250 college-age men and women, to see how many points your ratios give you for all six exercises. If your ratio is between two scores, use the lower score provided to determine how many points you've earned. Once you have added up your points for all six exercises, refer to the Total Points/Strength Fitness Category at the bottom of the table to determine your rating. There is an example below the table.

Bench press	Arm curl	Lat pull-down	Leg press	Leg extension	Leg curl	Points
MEN						
1.50	0.70	1.20	3.00	0.80	0.70	10
1.40	0.65	1.15	2.80	0.75	0.65	9
1.30	0.60	1.10	2.60	0.70	0.60	8
1.20	0.55	1.05	2.40	0.65	0.55	7
1.10	0.50	1.00	2.20	0.60	0.50	6
1.00	0.45	0.95	2.00	0.55	0.45	5
0.90	0.40	0.90	1.80	0.50	0.40	4
0.80	0.35	0.85	1.60	0.45	0.35	3
0.70	0.30	0.80	1.40	0.40	0.30	2
0.60	0.25	0.75	1.20	0.35	0.25	1
WOMEN						
0.90	0.50	0.85	2.70	0.70	0.60	10
0.85	0.45	0.80	2.50	0.65	0.55	9
0.80	0.42	0.75	2.30	0.60	0.52	8
0.70	0.38	0.73	2.10	0.55	0.50	7
0.65	0.35	0.70	2.00	0.52	0.45	6
0.60	0.32	0.65	1.80	0.50	0.40	5
0.55	0.28	0.63	1.60	0.45	0.35	4
0.50	0.25	0.60	1.40	0.40	0.30	3
0.45	0.21	0.55	1.20	0.35	0.25	2
0.35	0.18	0.50	1.00	0.30	0.20	1

Total points	Strength fitness category*
48-60	Excellent
37-47	Good
25-36	Average
13-24	Fair
0-12	Poor

*Based on data compiled by V. Heyward from 250 college-age men and women.

Example

If the ratio of 0.85 from Step 2 was during the Lat Pull Down (a male student who weighs 175lbs completed five repetitions of 125lbs of a Lat Pull Down), then that ratio has a value of three points (as seen in the right-most column). *Note that if a female student achieved the same ratio, she would earn 10 points.* ***Be careful that you are looking at the proper column for the exercise in question and the correct half (Men or Women) for the appropriate points.***

Activity 2.2 – Grip Strength

The grip strength test uses a hand-grip dynamometer to measure the isometric muscular strength (i.e, no change in range of motion or muscle fibre length) generated by the hand and forearm in kilograms (kg) of force. It is often used as an indicator of total body strength.

To perform the test, place the grip of the dynamometer between the fingers and palm (at the base of the thumb). The second joint of the fingers should fit snugly under the handle and can be adjusted as needed. Hold the dynamometer next to your thigh with the dial facing out and do not let it touch your body. When you are ready, squeeze the dynamometer as hard as you can for a few seconds (maximal force) while exhaling throughout the contraction. It should remain relatively still throughout the contraction and not move around or touch the body. Measure each hand twice and add up the best trial (i.e., highest kg rating) of each hand, then refer to the table below for your Fitness Rating.

Age	Rating	Male	Female	Age	Rating	Male	Female
15-19	Excellent	≥108	≥68	40-49	Excellent	≥108	≥69
	Very good	98-107	60-67		Very good	97-107	61-68
	Good	90-97	53-59		Good	88-96	54-60
	Fair	79-89	48-52		Fair	80-87	49-53
	Poor	≤78	≤47		Poor	≤79	≤48
20-29	Excellent	≥115	≥70	50-59	Excellent	≥101	≥61
	Very good	104-114	63-69		Very good	92-100	54-60
	Good	95-103	58-62		Good	84-91	49-53
	Fair	84-94	52-57		Fair	76-83	45-48
	Poor	≤83	≤51		Poor	≤75	≤44
30-39	Excellent	≥115	≥71	60-69	Excellent	≥100	≥54
	Very good	104-114	63-70		Very good	91-99	48-53
	Good	95-103	58-62		Good	84-90	45-47
	Fair	84-94	51-57		Fair	73-83	41-44
	Poor	≤83	≤50		Poor	≤72	≤40

Activity 2.3 – Muscular Endurance Battery

For this activity, you will be completing three muscular endurance tests and providing your results and ratings for each.

Forearm Plank Test

This test is a measure of the muscular endurance of a variety of muscle groups, including abdominals (transverse abdominis, internal and external obliques, rectus abdominis), postural muscles that stabilize the spine, hips, pelvis, lower limbs, as well as shoulders and arms. The standardized technique for this test is for you to lie prone on a mat/floor with your elbows touching the ground. Your upper arms should be lined up directly beneath your shoulders, and your forearms should be in a neutral position with hands in front of the elbows. Your feet should be close together but not touching each other.

To perform the test, once you have positioned yourself in the form above, raise your pelvis off the ground and start a stopwatch. It is imperative that you establish and maintain a straight spine and rigid body position with only your forearms and toes making contact with the mat/floor. Once you cannot maintain the proper position (you can use a partner to observe and give a maximum of two warnings), the test is terminated, and the stopwatch is stopped. Use your time in seconds and refer to the table below to establish your percentile. You can round to the closest value for your time, and use whichever status (Varsity or Non-Varsity) you most identify with.

Percentile Score for the forearm plank by sex and sport status									
Time to fatigue in the plank test (**all values in seconds**)									
Percentile	**10th**	**20th**	**30th**	**40th**	**50th**	**60th**	**70th**	**80th**	**90th**
Female Non-Varsity (n=227)	34	47	56	62	70	79	91	103	130
Female Varsity (n=50)	45	59	63	74	87	97	110	162	194
Male Non-Varsity (n=134)	49	72	83	95	103	115	125	142	189
Male Varsity (n=59)	74	84	94	117	125	140	157	183	228

Push-Up Test

This test is a measure of muscular endurance of the chest, shoulders, and arms and requires you to perform as many repetitions as possible (with no time limit) without taking breaks, straining forcibly, or the ability to maintain proper technique. Since push-ups can vary in form, this test employs "military push-ups", meaning the legs are together, hands are positioned under the shoulders with fingers pointed forwards, and the arms stay tucked near the side. Your chin must touch the ground for the repetition to count, so a thin mat or towel can be used to provide a softer surface. In order to use the comparative standards of the table below, men will be performing standard push-ups (with toes as a contact point), and women will be performing modified push-ups (with knees as a contact point).

Age	Rating	Male	Female	Age	Rating	Male	Female
15-19	Excellent	≥39	≥33	40-49	Excellent	≥25	≥24
	Very good	29-38	25-32		Very good	17-24	15-23
	Good	23-28	18-24		Good	13-16	11-14
	Fair	18-22	12-17		Fair	10-12	5-10
	Poor	≤17	≤11		Poor	≤9	≤4
20-29	Excellent	≥36	≥30	50-59	Excellent	≥21	≥21
	Very good	29-35	21-29		Very good	13-20	11-20
	Good	22-28	15-20		Good	10-12	7-10
	Fair	17-21	10-14		Fair	7-9	2-6
	Poor	≤16	≤9		Poor	≤6	≤1
30-39	Excellent	≥30	≥27	60-69	Excellent	≥18	≥17
	Very good	22-29	20-26		Very good	11-17	12-16
	Good	17-21	13-19		Good	8-10	5-11
	Fair	12-16	8-12		Fair	5-7	2-4
	Poor	≤11	≤7		Poor	≤4	≤1

Squat Endurance Test

This test is a measure of the muscular endurance of your lower limbs, particularly focusing on your quadriceps, glutes, and hamstrings. To perform this test, position yourself in an athletic stance (i.e., your feet slightly wider than shoulder width with toes faintly pointing out), with your hands on your hips or on opposite shoulders, and a neutral spine (i.e., head and back straight). Your weight should be over the arches of the feet or slightly towards the heels. When you are ready, squat down while maintaining the aforementioned form until your thighs are at 90 degrees (or parallel to the floor), then rise back up to the starting position (this is one repetition). Complete as many squats as you can without stopping, then use this number to refer to your rating in the table below.

Men - Number of Squats Performed

Age / Rating	Very Poor	Poor	Below Average	Average	Above Average	Good	Excellent
18 - 25	Less than 25	25 - 30	31 - 34	35 - 38	39 - 43	44 - 49	More than 49
26 - 35	Less than 22	22 - 28	29 - 30	31 - 34	35 - 39	40 - 45	More than 45
36 - 45	Less than 17	17 - 22	23 - 26	27 - 29	30 - 34	35 - 41	More than 41
46 - 55	Less than 9	13 - 17	18 - 21	22 - 24	25 - 38	29 - 35	More than 35
56 - 65	Less than 9	9 - 12	13 - 16	17 - 20	21 - 24	25 - 31	More than 31
65 +	Less than 7	7 - 10	11 - 14	15 - 18	19 - 21	22 - 28	More than 28

Women - Number of Squats Performed

Age / Rating	Very Poor	Poor	Below Average	Average	Above Average	Good	Excellent
18 - 25	Less than 18	18 - 24	25 - 28	29 - 32	33 - 36	37 - 43	More than 43
26 - 35	Less than 13	13 - 20	21 - 24	25 - 28	29 - 32	33 - 39	More than 39
36 - 45	Less than 7	7 - 14	15 - 18	19 - 22	23 - 26	27 - 33	More than 33
46 - 55	Less than 5	5 - 9	10 - 13	14 - 17	18 - 21	22 - 27	More than 27
56 - 65	Less than 3	3 - 6	7 - 9	10 - 12	13 - 17	18 - 24	More than 24
65 +	Less than 2	2 - 4	5 - 10	11 - 13	14 - 16	17 - 23	More than 23

Activity 2.4 – Dynamic Muscle Endurance Battery

The following seven exercises are often used as a test battery (i.e., a series of tests/exercises) to determine someone's overall dynamic muscular endurance. As with the Muscular Strength tests described previously, the term dynamic implies repetitions through a range of motion and changes in muscle fibre length (e.g., Push-ups, Squats), as opposed to isometric muscular endurance tests where the position is stationary and there is little change in fibre length (e.g., Plank Test).

As was seen in the Dynamic Muscular Strength Battery, the weight used in these exercises will be determined by a ratio relative to your body weight (see Activity 2.1 for a description of absolute vs relative). It is worth noting the seventh exercise (the Bent-Knee Sit-Ups) is bodyweight only.

Procedure

After completing a thorough warm-up, including light weights of the exercises in question, calculate the required weight to be lifted based on your biological gender and body weight for the seven exercises by referring to the table below. Once you have the correct weights, you will simply need to count the number of repetitions completed for each exercise, ensuring you do not complete more than 15 repetitions per exercise. An example demonstrating how to calculate the weight to be lifted is provided after the table.

	% BODY MASS TO BE LIFTED		
Exercise	Men	Women	Repetitions (max = 15)
Arm curl	0.33	0.25	______
Bench press	0.66	0.50	______
Lat pull-down	0.66	0.50	______
Triceps extension	0.33	0.33	______
Leg extension	0.50	0.50	______
Leg curl	0.33	0.33	______
Bent-knee sit-up			______
			Total repetitions (max = 105) = ______

Total repetitions	Fitness category[a]
91-105	Excellent
77-90	Very good
63-76	Good
49-62	Fair
35-48	Poor
<35	Very poor

[a]Based on data compiled by V. Heyward from 250 college-age men and women.

Example Calculation

If I am a female student who weighs 125lbs, I will be required to lift 25% of my body weight (0.25) for the Arm Curl exercise. To calculate that weight, multiply the body mass by the percentage to be lifted:

125lbs x 0.25 = 31.3lbs (you can round up or down as needed based on equipment)

I would then be required to Arm Curl 31lbs for as many repetitions as possible in a single set, without exceeding 15 repetitions.

Calculating Rating:

Follow the example calculation above for the required exercises, counting your repetitions for each. Once each exercise is complete, add up the sum of all your repetitions and refer to the bottom of the table to find your Fitness Rating.

Reflection Questions

A. Based on the completion of Activity 2.1 – Dynamic Muscular Strength Battery, answer the following:

1. Which of the six exercises gave you the lowest points, and which gave you the highest?
2. Is this the result you were expecting? Justify your answer.
3. Are you satisfied with your Total Points and Strength Fitness Rating? Based on your response, how do you plan on improving or maintaining your current result?

B. Based on the completion of Activity 2.2 – Grip Strength, answer the following:

1. What was the difference in kilograms (kg) between your left and right hands (use the best trial of each to compare). If it is significantly different (more than 5kg), how would you try to even them out?
2. What was your Grip Strength Rating according to the table? Is this the result you were expecting?
3. Given how important Grip Strength is for the Stair Chair test, how do you plan on improving or maintaining your result?

C. Based on the completion of Activity 2.3 – Muscular Endurance Battery, answer the following:

1. Which of the exercises gave you the lowest rating, and which gave you the highest? Are these also the exercises that felt the hardest and easiest, respectively?
2. Is this the result you were expecting? Justify your answer.

3. Are you satisfied with your Ratings for these three exercises? Based on your response, how do you plan on improving or maintaining your current result?

D. Based on the completion of Activity 2.1 – Dynamic Muscular Strength Battery, answer the following:

1. Which of the seven exercises did you perform the least repetitions?
2. Is this the result you were expecting? Justify your answer.
3. Are you satisfied with your Total Repetitions and associated Fitness Rating? Based on your response, how do you plan on improving or maintaining your current result?

References

DAWN MARKELL AND DIANE PETERSON

Chapter 1 – Healthy Behaviors and Wellness

1. The Nine Dimensions of Wellness, http://www.uh.edu/wellness/dimensions
2. American Psychological Association Help Center, https://www.apa.org/helpcenter

Chapter 2 – Fitness Principles

1. Center for Disease Control and Prevention, Retrieved April 2017, CDC: Physical Activity, Data and Statistics, https://www.cdc.gov/physicalactivity/data/facts.htm
2. Saltin, B., Blomqvist, G., Mitchell, J.H., Johnson, R.L., Jr., Wildenthal, K., Chapman, C.B. Response to submaximal and maximal exercise after bed rest and training. 1968 Nov, Vol. 38 (Suppl. 5)
3. Noakes, Timothy D.; Sudden Death and Exercise, Sportscience, 1998, retrieved Dec. 2017, http://www.sportsci.org/jour/9804/tdn.html
4. Van Camp SP, Boor CM, Mueller FO, et al. Non-traumatic Sports Death in High School and college Athletes, Medicine and Science of Sports and Exercise 1995; 27:641-647
5. American College of Sports Medicine, 7th Edition, ACSM's Guidelines for Exercise Testing and Prescription, Philadelphia, PA, Lippincott, Williams and Wilkins, p. 10
6. American College of Sports Medicine, 7th Edition, ACSM's Guidelines for Exercise Testing and Prescription, Philadelphia,

PA, Lippincott, Williams and Wilkins, p. 27
7. 7 Habits of Highly Effective People,2003, Covey, Stephen R. Habit 2, New York, Franklin Covey Co. p. 40-61
8. Center for Disease Control and Prevention, Retrieved April 2017, CDC: Quick Stats: Number of Heat-related Deaths, by Sex-National Vital Statistics System-United States, 1999-2010, https://www.cdc.gov/mmwr/preview/mmwrhtml/mm6136a6.htm
9. Mayo Clinic, retrieved April 2017, Water: How Much Should You Drink Each Day? http://www.mayoclinic.org/healthy-lifestyle/nutrition-and-healthy-eating/in-depth/water/art-20044256

Chapter 4 – Muscular Strength and Endurance

1. Information pulled from www.strengthandfitnessuk.com
2. (ACSM 2002)
3. Information is from the National Strength and Conditioning Association and LiveStrong.org
4. Bringing Together Top Strength and Fitness Professionals. (n.d.). Retrieved April 25, 2017, from https://www.nsca.com/
5. Home. (n.d.). Retrieved April 25, 2017, from https://www.livestrong.org/
6. Kraemer, W. J., Adams, K., Cafarelli, E., Dudley, G. A., Dooly, C., Feigenbaum, M. S., . . . American, M. E. (2002, February). https://www.ncbi.nlm.nih.gov/pubmed/11828249
7. American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. Retrieved April 25, 2017, from https://www.ncbi.nlm.nih.gov/pubmed/11828249

Chapter 5 – Flexibility

1. Gummelt, D, The Impact of Flexibility Training on Performance, 2015, ACE Fitness; https://www.acefitness.org/education-and-resources/professional/expert-articles/5598/the-impact-of-flexibility-training-on-performance
2. Neogi, T. (2013). The Epidemiology and Impact of Pain in Osteoarthritis. *Osteoarthritis and Cartilage / OARS, Osteoarthritis Research Society*, *21*(9), 1145–1153. http://doi.org/10.1016/j.joca.2013.03.018
3. Arthritis Foundation; arthritis.org, retrieved April 2018; https://www.arthritis.org/about-arthritis/understanding-arthritis/arthritis-statistics-facts.php
4. Kruse, NT, Sillete, CR, Scheuermann, BW; American Journal of Physiology; Heart and Circulatory Physiology, 2016, May 1; 310 (9): H1210-21.
5. Millar, L, American College of Sports Medicine, ACSM.org, retrieved April 2018, http://www.acsm.org/public-information/articles/2016/10/07/improving-your-flexibility-and-balance
6. Hindle, K. B., Whitcomb, T. J., Briggs, W. O., & Hong, J. (2012). Proprioceptive Neuromuscular Facilitation (PNF): Its Mechanisms and Effects on Range of Motion and Muscular Function. *Journal of Human Kinetics*, *31*, 105–113. http://doi.org/10.2478/v10078-012-0011-y

Chapter 6 – Body Composition

1. National Institute of Diabetes and Digestive and Kidney Diseases, Retrieved April 2018, NIH: Health Risks of Being Overweight, https://www.niddk.nih.gov/health-information/health-topics/weight-control/

health_risks_being_overweight/Pages/health-risks-being-overweight.aspx
2. Kravitz, L., Heward, V. Getting a Grip on Body Composition, Retrieved April 2017, https://www.unm.edu/~lkravitz/Article%20folder/underbodycomp.html
3. Knight, J.; Diseases and Disorders Associated with Excess Body Weight; Annals of Clinical Laboratory Science Spring 2011 vol. 41 no.2 107-121 http://www.annclinlabsci.org/content/41/2/107.full
4. Chang, S.-H., Pollack, L. M., & Colditz, G. A. (2013). Life Years Lost Associated with Obesity-Related Diseases for U.S. Non-Smoking Adults. *PLoS ONE*, 8(6), e66550. http://doi.org/10.1371/journal.pone.0066550
5. Centers for Disease Control and Prevention, Retrieved Jan 2018, CDC: Adult Obesity Causes and Consequences https://www.cdc.gov/obesity/adult/causes.html
6. Doheny, K. The Truth About Fat, WebMD, July 2009, http://www.webmd.com/diet/features/the-truth-about-fat#4
7. Harvard T.H. Chan School of Public Heatlh, Retrieved March 2018, HSPH: Waist Size Matters https://www.hsph.harvard.edu/obesity-prevention-source/obesity-definition/abdominal-obesity/
8. National Heart, Lung, and Blood Institute, Retrieved Jan 2018, NIH: Classification of Overweight and Obesity by BMI, Waist Circumference, and Associated Disease Risks https://www.nhlbi.nih.gov/health/educational/lose_wt/BMI/bmi_dis.htm
9. Jitnarin, N., Poston, W. S. C., Haddock, C. K., Jahnke, S. A., & Day, R. S. (2014). Accuracy of Body Mass Index-defined Obesity Status in US Firefighters. *Safety and Health at Work*, 5(3), 161–164. http://doi.org/10.1016/j.shaw.2014.06.003
10. National Institute of Diabetes and Digestive and Kidney Diseases, Retrieved March 2018, NIH: Overweight and Obesity Statistics https://www.niddk.nih.gov/health-information/

health-statistics/Pages/overweight-obesity-statistics.aspx#b
11. Center for Disease Control and Prevention, Retrieved Feb 2018, CDC: Obesity and Overweight, https://www.cdc.gov/nchs/fastats/obesity-overweight.htm

Chapter 7 – Nutrition

1. NHANES Food Frequency Questionnaire – http://riskfactor.cancer.gov/diet/FFQ.English.June0304.pdf Framingham Heart Study History – http://www.framinghamheartstudy.org/about/history.html.
2. Framingham Heart Study Research Milestones – http://www.framinghamheartstudy.org/about/milestones.html
3. The Nurses Health Study – http://www.channing.harvard.edu/nhs/?page_id=70
4. Health Professionals Follow-Up Study – http://www.hsph.harvard.edu/hpfs/
5. https://www.hsph.harvard.edu/nutritionsource/healthy-eating-plate/
6. Wardlaw GM, Hampl J. (2006) Perspectives in nutrition. New York, NY: McGraw-Hill.
7. Schaafsma G. (2000) The protein digestibility-corrected amino acid score. J Nutr 130(7): 1865S.
8. http://cnx.org/contents/14fb4ad7-39a1-4eee-ab6e-3ef2482e3e22@8.108.
9. https://www.medicinenet.com/hdl_vs_ldl_cholesterol_differences/article.htm#what_is_hdl_the_good_cholesterol_what_is_ldl_the_bad_cholesterol

Chapter 8 – Weight Management

1. CDC's step by step guide to losing weight: https://www.cdc.gov/healthyweight/losing_weight/getting_started.html.
2. CDC's page on physical activity for healthy weight: https://www.cdc.gov/healthyweight/physical_activity/index.html
3. CDC's page on improving your eating habits. https://www.cdc.gov/healthyweight/losing_weight/eating_habits.html

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References

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1. Tung-Wu L, Chu-Fen C. (2012, February). Biomechanics of human movement and its clinical applications. *The Kaohsiun Journal of Medical Sciences*, 28(2), S13-S25. https://doi.org/10.1016/j.kjms.2011.08.004
2. Gea-Banacloche J. (2019). University Physics I: Classical Mechanics. Open Educational Resources. Retrieved from https://scholarworks.uark.edu/oer/3
3. Davis L. *Body Physics: Motion to Metabolism.* Open Oregon Educational Resources. https://openoregon.pressbooks.pub/bodyphysics
4. Ketchum H & Bright E, OU Human Physiology Textbook. OpenStax CNX. Jun 18, 2015 http://cnx.org/contents/e4f804ec-103f-4157-92e1-71eed7aa8584@1
5. Steven Telleen, Human Anatomy. OpenStax CNX. Apr 3, 2018 http://cnx.org/contents/4effb4bf-fdbb-478f-be7b-ddcc60373b0f@6.24
6. Markell D & Peterson D. *Health and Fitness for Life.* MHCC Library Press. Sept 4, 2019. https://mhcc.pressbooks.pub/hpe295
7. OpenStax. "Energy in Living Systems." *Biology*, https://www.oercommons.org/courseware/lesson/56966/overview?section=7. Accessed 26 July 2021.
8. Beck K, Thomson JS, Swift RJ, von Hurst PR. Role of nutrition in performance enhancement and postexercise recovery. *Open Access J Sports Med*. 2015;6:259-267 https://doi.org/10.2147/OAJSM.S33605
9. Garber C, Blissmer B, Deschenes M, et al. Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory, Musculoskeletal, and Neuromotor Fitness in Apparently Healthy Adults. *Medicine & Science in Sports & Exercise*: July

2011, 43(7), 1334-1359. doi: 10.1249/MSS.0b013e318213fefb
10. Gridi-Papp M. Human Anatomy. OpenStax CNX. Mar 1, 2018 http://cnx.org/contents/c29920ff-cf11-4c44-a140-046fb0e6e1f0@2.57
11. Heinecke, M. Literature Review: Neuromuscular Response to Plyometric Training. *International Journal of Strength and Conditioning*: 2021. https://journal.iusca.org/index.php/Journal/article/view/53/116