Physiology Refresher

by Catherine Logan, MSPT

Personal Training 101: When was the last time you brushed up on a few basics about the human body?

You can probably remember studying for your certification exam: What is the difference between a strain and a sprain? a tendon and a ligament? an artery and a vein? the sympathetic and the parasympathetic nervous systems? After the exam was over, you probably used or heard these words yet forgot the exact medical definitions, the precise functions or even the distinctions between one term and another. This physiology review will revisit terms commonly used by your healthcare referral sources and even your clients. If you maintain familiarity with this vocabulary, you will feel more confident and effective while working with postrehab and medical fitness clientele or just answering everyday questions.

Respiratory and Circulatory Systems

The respiratory system is composed of the oral and nasal cavities, the lungs and the series of tubes leading to the lungs. In addition to providing oxygen and eliminating carbon dioxide, this system defends the body against microbes, toxic chemicals and other foreign matter. The respiratory system works with the circulatory system to oxygenate the blood and prepare it for transport to the tissues of the body (Widmaier, Raff & Strang 2006).

The circulatory system is made up of the heart, blood vessels and blood itself. **Arteries** are thick-walled large muscular blood vessels that carry blood *away* from the heart and distribute it to the body, while **veins** are thin-walled blood vessels that carry blood from the body back *toward* the heart. The smaller blood vessels that branch off from arteries are called **arterioles.** Veins often contain valves to help prevent backflow and facilitate the return of blood against gravity. The coronary arteries also carry blood away from the heart, but only as far as the exterior of it, where they supply the heart muscle (myocardium) (Beasley 2003). Circulation is the movement of blood from the heart to the body and then back to the heart. Blood pumps out of the heart through its left ventricle and enters the **aorta,** the largest artery found in the body. The aorta acts as the blood's exit route from the heart, and arteries branch off the aorta to take blood throughout the body. The arterial system carries *oxygenated* blood to the body. Arterioles then transport oxygen-rich blood into the **capillaries,** the thinnest blood vessels in the body. Capillaries allow for the exchange of nutrients, oxygen and waste products between the blood and the body's tissues. The smallest veins, the **venules,** receive this now *deoxygenated* blood for transport back to the heart via the venous system (Beasley 2003).

The deoxygenated blood returns to the heart's right atrium, passes into the right ventricle and enters the lungs through the pulmonary artery. The blood is then oxygenated in the lungs and carried back through the pulmonary veins to the heart's left atrium before continuing on to the left ventricle (Beasley 2003).

Blood flow between any two points in the circulatory system is directly proportional to the pressure difference between those two points, but inversely proportional to the resistance to flow [flow = change in pressure/resistance]. Additionally, the resistance to flow is directly proportional to the viscosity (thickness) of the blood times the length of the tube (artery or vein), but inversely proportional to the fourth power of the tube's radius [resistance to flow = viscosity x length of vessel / vessel's radius^4].

So if the pressure difference between two points is high and yet the resistance to flow is low, the vessel will have a high flow rate. At rest, the abdominal organs receive the highest percentage of blood flow, yet during exercise the largest amount of blood flow is delivered to the skeletal muscles (Widmaier, Raff & Strang 2006). At rest there is less blood flow to the skin than there is during exercise. When we exercise, more blood flows to our skin to help us dissipate heat; more blood also flows to the heart for the additional work it performs in increasing its cardiac output.

Cardiac output is the amount of blood pumped out of the left ventricle in 1 minute and is a product of stroke volume (volume of blood pumped per contraction) and heart rate (number of contractions per minute). A normal cardiac output value is approximately 5 liters per minute. Blood pressure is a product of cardiac output and **peripheral vascular resistance** (PVR). PVR is the degree of opposition to blood flow in the arterioles. Vasoconstriction or vasodilation determines PVR (Beasley 2003).

Musculoskeletal System

There are three different types of muscle—skeletal, smooth and cardiac. **Skeletal muscle** attaches to bones; it produces movement and supports our skeletal system. **Smooth muscle** lines body cavities and vessels. The heart is composed of **cardiac muscle.**

This review will focus on skeletal muscle, which has a repeating, striated pattern owing to its thick and thin filaments. Skeletal muscle is attached to bone by **tendons.** The skeletal muscle may *assist* in providing stability to a joint, but other soft-tissue structures (including ligaments, the joint capsule and the congruency of the bones) contribute to joint stability. **Ligaments** attach bone to bone, supplying stability at rest and during motion by creating an active and passive soft-tissue restraint (Brotzman & Wilk 2003).

Skeletal muscles are often called "voluntary" because we usually control them voluntarily, the exception being reflexes. A skeletal muscle fiber can produce four different types of contraction (development of muscle tension): isometric, isotonic, isokinetic and eccentric. An **isometric** contraction generates tension, but no movement occurs at the joint. An **isotonic** contraction occurs when the muscle shortens and movement is produced at a constant tension. An **isokinetic** contraction generates tension at a fixed speed of contraction. And an **eccentric** contraction occurs when the muscle lengthens during a contraction (Widmaier, Raff & Strang 2006). ("Eccentric contraction" is not a contradiction in terms—the lowering phase of a push-up is an example of this type of contraction.)

Most skeletal muscles have two attachment points: origin and insertion. Since some muscles may act in both directions, it is sometimes easier to refer to *proximal* and *distal* attachments instead of origin and insertion. For example, the proximal attachment of the hamstrings muscle is on the ischial tuberosity (pelvis), and there are three distal attachment sites: the medial and posterior tibia and the lateral fibula (Moore 1992).

The Nervous System

The nervous system is made up of two components: the **central nervous system (CNS)** and the **peripheral nervous system (PNS).** The CNS consists of the brain and spinal cord, while the PNS is composed of the nerves that connect the CNS to muscles, glands and sensory organs. The PNS consists of 43 paired nerves that mostly contain the axons (nerve fibers) of both efferent and afferent neurons—meaning they relay and receive information to and from the periphery. Incoming and outgoing neural signals (information) are integrated and organized by the CNS (Widmaier, Raff & Strang 2006).

The basic unit of the entire nervous system is the nerve cell, known as a **neuron.** Nerve cells can be broken down into three classes based on their function: **afferent neurons,** which convey information from the periphery (tissues/organs/muscles) into the CNS; **efferent neurons,** which convey information from the CNS to the periphery; and **interneurons,** which connect neurons within the CNS itself.

The efferent division of the PNS can be further broken down into the somatic and autonomic nervous systems. Although the somatic and autonomic divisions are called "nervous systems," they are just *components* of the efferent division of the PNS. The **somatic nervous system** comprises the nerves traveling from the CNS to skeletal muscle. Activity of the somatic neurons within the brain stem and spinal cord leads to contraction of the skeletal muscle that it innervates (supplies with nerves). Damage to this pathway may result in reduction or elimination of the muscle's ability to produce a contraction. The **autonomic nervous system** innervates heart and smooth muscles, our gastrointestinal system and other glands. You may remember the parasympathetic "flight" and sympathetic "fight" responses. The fight-or-flight mechanism is a function of the autonomic nervous system (Widmaier, Raff & Strang 2006).

Effects of sympathetic stimulation include increases in heart rate, constriction of skin vessels, dilation of the bronchi of the lungs and inhibition of gastric juices for digestion. Conversely, reduction in the strength of a contraction of the heart, constriction of the bronchi and stimulation of digestive juices result from parasympathetic stimulation (Moore 1992).

As our population continues to live longer and the Baby Boomers advance in age, fitness professionals will be inundated with clients suffering from chronic conditions, heart disease, orthopedic concerns and postrehabilitation problems. Having a working knowledge of the physiology of the major systems of the body will enable us to serve our clients' best interests and feel comfortable designing exercise programs for a diverse population.

SIDEBAR: Clinical Notes: Respiratory and Circulation Systems

1. Inadequate blood flow, and therefore lack of oxygen supply, to the myocardium owing to an occlusion of a coronary artery may cause a myocardial infarct (MI), also known as a heart attack. A coronary bypass surgical procedure uses a coronary bypass graft to shunt blood to an area of the myocardium affected by the occlusion to increase flow. Essentially this procedure creates a *detour* so that blood can reach the compromised area of the heart (Moore 1992).
2. Since the arteries carry blood away from the heart, they transport oxygenated blood. There is one exception, however: the pulmonary arteries carry deoxygenated blood from the right ventricle to the lungs. Similarly, while veins usually function to transport deoxygenated blood, the pulmonary veins carry oxygenated blood from the lungs to the left atrium.
3. During exercise, cardiac output may increase from the typical resting value of 5 liters per minute to as high as 35 liters per minute in a trained athlete. The majority of the increase in cardiac output is directed to the exercising muscles. The increase in cardiac output is due to a large increase in heart rate and only a small increase in stroke volume [cardiac output = heart rate x stroke volume]. Training, however, can increase a person's maximal oxygen consumption by increasing maximal stroke volume and therefore cardiac output (Widmaier, Raff & Strang 2006).
4. Inadequate cardiac output may be indicated by any combination of the following signs and symptoms: shortness of breath, dizziness, decreased blood pressure, chest pain and cool, clammy skin (Beasley 2003).

SIDEBAR: Clinical Notes: Musculoskeletal System

1. Hamstrings injuries are common in athletes who perform quick starts, run hard or run quickly with great force. The intense muscular exertion required to perform these activities may

result in a tear or avulsion (in which a bone fragment tears away with the tendon) of part of the proximal tendinous attachment (Moore 1992).

2. The terms *sprain* and *strain* are often used interchangeably, but each refers to a distinct condition. A **sprain** refers to the excessive stretch of a ligament and may or may not include tearing of the ligamentous tissue. A **strain** occurs when a muscle or tendon that attaches to bone is overstretched or torn (Brotzman & Wilk 2003).

SIDEBAR: Clinical Notes: Nervous System

1. When neurons in the brain are deprived of their blood supply, and thus do not receive oxygen or nutrients, they can die. Neuronal death, which results in a stroke, can occur after only a few minutes without oxygen (Widmaier, Raff & Strang 2006).
2. Diabetes can cause degeneration of peripheral neurons, meaning people who are diabetic might not receive and relay sensory information as efficiently as those who are not (Widmaier, Raff & Strang 2006).

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