Biomechanics

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Introduction

Biomechanics is an encompassing term that joins human anatomy and physiology with movement physics and mathematics to identify how both internal and external forces affect the body. Dynamic mechanics, or objects in accelerated motion, is sectioned into kinematics and kinetics. Kinematics describes the occurring motion, whereas kinetics describes the forces that cause or have a tendency to change the motion. As with movement descriptors, force applications also have descriptors that allow for precise identification of what occurs with the body or the objects that interact and consequently, affect the body in some fashion.

Laws of Motion

Common terms used to describe motion include momentum, power, force, inertia, mass, and weight. Length and time are also considered with movement or motion and aid in determining the force considerations. All of these terms will be practically applied and used to develop a better understanding of biomechanics as it relates to motion and physical activity. Sir Isaac Newton’s Laws of Motion assist in understanding motion through three basic laws. The first law suggests that if an object is static or motionless, it will remain that way unless a force acts upon it. Likewise, if an object is in motion, it will stay in motion unless something acts to change the motion. This concept is more easily understood when looked at from an outer space perspective where there is negligible gravity. If no force is applied, nothing exists to affect motion. Therefore, an object moving has nothing to slow it down or cause it to change its course. The same is true of a static object.

Newton’s second law states that if an external force is applied to an object, the object will accelerate directly proportionate to the net external force and inversely proportionate to its mass. A bulldozer exemplifies this law. If a bulldozer pushes dirt, the dirt will move in the same direction the bulldozer is moving and will accelerate at the speed it is being pushed. The same can be said with a baseball throw or a weight being lifted. The resistance will accelerate in the direction of the force, at a speed determined by the weight of the object and the force applied.

The third law states that if an object exerts a force on another object, the reacting force from the other object will be equal and opposite. This case might lead one to believe that, given equivalent forces acting upon them, both objects will respond to these forces in the same manner; however, each object’s mass determines its acceleration potential. For instance, if a car moving at thirty miles an hour hits a trash can, the trash can will be pushed in the direction the car is moving (2nd law), but the force the car and trash can both experience will be the same. Obviously the outcome, from a movement standpoint, will be different. The car’s mass enables it to continue in motion; whereas the trash can’s disproportionate mass causes it to move in the direction of the force.

Forces

Forces, including gravity, act on the body every day. Manipulating these forces allows for voluntary movement and the maintenance of a desired static position. If the body could not control force, it would not be able to move efficiently, or even stand or sit in an upright position. In general, forces are often defined as a push or a pull, with the ability to start, speed up, slow down, stop or change the direction of an object. Force is
universally measured using the Newton, but a more common expression is the pound. By identifying or quantifying the force, it is possible to manipulate the event using other forces.

Forces are often classified as internal forces and external forces. Internal forces act within the object or system, while external forces are those that act on an object through some interaction. Internal forces in the body are produced by the actions of tissues, which exert forces upon each other. Inside the body, the forces are categorized as tensile forces, those in which tension results in a pulling force, and compressive forces, those that exert a pushing force. The two types of forces interact everyday for human function.

Even though the body can produce internal forces, it cannot change the motion of the center of mass without external forces, such as the ground. The tension created from muscle contractions can move the limbs of the body, but the body’s center mass will remain the same unless the body can push or pull against another object in a force/counter-force relationship. Picture yourself floating in outer space and trying to run somewhere. Your legs may perform the actions used to propel the body on earth, but without the ground reaction forces to push against, you would not be able to go anywhere. Thus, external forces are required to change the body’s center of mass, allowing for locomotion and enabling living things to run, swim, and jump. External forces do not have to contact the body to apply force to it. Gravity is a non-contact force that in many cases, determines the acceleration requirements of the body to perform tasks, as gravity determines terrestrial weight. Contact forces, on the other hand, occur when two objects contact one another. These objects include wind, water, the ground, or anything else that contacts the body. Contact in this sense means an interaction between “forces” not only solid objects.

Contact forces are further described as normal contact force, which acts equally and opposite to the interacting objects, and frictional force, which runs parallel to the two surfaces of the object. A runner will be able to accelerate using ground reaction forces by 1) the normal contact pushing down against the ground, and 2) the forward frictional force between the shoe’s surface and the ground surface. The normal force applies the vertical component so the foot leaves the ground, and the frictional force applies the horizontal component, which allows the runner to move forward. When internal and external forces work synergistically, they allow for stability, while also producing movement.

~Key Terms~

**Newton** - The unit of force required to accelerate a mass of one kilogram one meter per second squared.

**Internal forces** – A force exerted by one part of a system on another part within the same system.

**External forces**- A force exerted on a system or on some of its components by a source outside the system.

**Tensile forces**- A stretching force (tension) pulling at both ends of a component or structure along its length.

**Compressive force**- A pushing force whose direction and point of application would tend to shorten or squeeze an object along the dimension coinciding with the line of action of the force.

**Contact force**- a force between two objects (or an object and a surface) that are in contact with each other.

**Frictional force**- the force acting on a body when the body is not in motion, but when a force is acting on it.

**Stabilizer**- A muscle whose torque prevents movement at a joint.

**Neutralizer**- Role of a muscle whose torque cancels or eliminates the undesired effect of the torque produced by another muscle at that joint to allow a desired movement only.

**Prime mover**- The muscle that causes an action.

**Asymmetrical load**- A single sided or unbalanced load or weight distribution.

**Action and Reaction Forces**

Newton’s third law identified that forces come in pairs or couples, illustrating the concept of action and reaction forces, which act on different parts of the body. This explains why the more complex an activity becomes, the more difficult it is to perform. Chest pressing 50 lbs. using a machine is relatively easy because of the stable environment. The body contributes external force beyond the quantity of the resistance, but has limited other responsibilities to manage the environment. Essentially, forces contribute to the acceleration of the resistance in a single plane. When the same person performs a 50 lb. bench press, additional force requirements are added to stabilize the
bar and prevent undesirable actions while exerting the forces to accelerate the weight against gravity. In this case, the stabilizer and neutralizer forces used to control the bar are added to the prime mover force, identifying an increase in total force requirements. Performing the same lifting movement on a physioball using a pair of 25 lb. dumbbells further adds difficulty due to the addition of greater force requirements to stabilize the body on the ball, while stabilizing the resistance, and concurrently producing the necessary force to move the weight. Making the resistance asymmetrically loaded increases the force requirements even more dramatically (5).

**Balance**

When the body is able to manage the sum of all external forces so that the net forces acting on the body equal zero, the body will be in static equilibrium. Static equilibrium determines a person’s ability to balance. The ability of the body to manage force determines its voluntary capabilities and consequently, the efficiency of the movement or non-movement depending on the desired effect.

**Measuring Motion**

When the body is in motion, it is measured using space and time. The body will move through a quantifiable space in a period of time. The motion that is accomplished will either be linear, angular, or both. Linear motion, or translation, occurs when the body or body segment moves the same distance, in the same direction, and at the same time. Angular, or rotary motion, occurs when all points on a body move in circles around a fixed axis. Together, the two classifications of motion combine to produce general motion. General motion is the most common motion used in physical activities because angular motion of the joints move the distal portion of the limb linearly. If the starting position is known, the motion can be quantified into speed and velocity at defined points. The rate of change in velocity is defined as acceleration. Acceleration explains why things move.

**Gravity and Motion**

Remember Newton’s second law of motion? The change of motion of an object is proportional to the external force applied to it. If the internal and external forces do not balance, then an object will be accelerated in the direction defined by the greater of the two forces. This explains why a person can lift a resistance. When a person rises up from a chair the internal forces apply adequate force to the ground to lift the body upward. When the same person performs a squat with resistance, the same rules apply. The force produced must be greater than the gravitational pull on the mass. If the internal and external acceleration forces are not greater than the external force of gravity, the person will not be able to rise from the chair or lift the weight upward.

What if the mass of the object is greater than the mass of the body? The reason a person can lift more than his or her body weight is due to contact reaction forces. When a 200 lb. man bench presses 250 lbs., the body’s internal forces exert enough force to lift the weight because the internal forces combine with the external forces that the bench and ground supply. Together, the forces combine to produce an acceleration force greater than the mass of the man and the resistive force of the object; in this case, the weight. In space this scenario would not be possible. Based on Newton’s third law, the body could only push things away from it if the mass of the object were less than the body’s mass. If the mass was the 250 lb. weight, the man could not push the weight off the body, but the weight would push the man away from it due to its greater mass. So, in effect, the body would move in the direction of the force produced by the weight.

In some cases, the acceleration of a mass is greater than the acceleration forces produced by the body. When this occurs, the object may be decelerated but not accelerated.

**~Key Terms~**

- **Static equilibrium**- Sum of all forces and torque acting on a body are equal.
- **Balance**- A stable state characterized by the cancellation of all forces by equal opposing forces.
- **Linear motion**- Change in position that occurs when all points on an object move the same distance, in the same direction, and at the same time.
- **Angular motion**- occurs when all points on a body move in circles around a fixed axis.
- **General motion**- When an object displays a combination of both rotary and translatory movement.
- **Speed**- The time rate of change of position of a body without regard to direction.
- **Velocity**- Rate of motion or performance.
- **Acceleration**- A change in the velocity of an object.
- **Linear momentum**- Mass of an object times the linear velocity of the object.
For example, if a person with a maximum bench press of 200 lbs. performed a bench press with 210 lbs. of resistance, he would be able to lower the bar to the chest in a controlled manner but would not be able to return the bar in the opposite direction because the downward acceleration force is greater than the upward acceleration force. The deceleration concept must also be considered when objects are thrown. For instance, if a 20 lb. medicine ball was thrown to a 150 lb. person seated on a bench at 10 mph, the force required to decelerate and stop the ball when caught would be substantially more than the 20 lb. mass itself due to the medicine ball’s linear momentum. Linear momentum is the product of the mass and its linear velocity. If the sum of forces created by the body were not enough to attenuate the forces acting on the medicine ball, the 150 lb. person could be knocked off the bench. But because humans can produce internal force and apply external forces to achieve force sums greater than their mass, projectile objects with a sum of force that would normally disrupt equilibrium can be managed. This case illustrates the importance of understanding forces and motion when prescribing or performing activity.

**Energy and Work**

The body produces forces for all types of purposes. To do so requires energy. Before we can explain mechanical energy however, we must first define work, since this term is used in the description of energy. Work, in mathematical terms, and as defined by Webster’s dictionary, is the product of force and the amount of displacement in the direction of that force \( (W = F \times d) \). Work can be either positive or negative as long as there is movement. If a weight is pressed overhead this action is positive work; when the weight is lowered back down, the work is considered negative. Positive work suggests the displacement is in the direction of the force, whereas negative work occurs when the displacement is opposite the direction of the force: think concentric vs. eccentric contractions. The body can actually produce more negative force than it can positively. Going back to the bench press example, the weight lifter was able to decelerate the 210 lbs. down to the chest by performing negative work but did not have the force capabilities to move the resistance in the direction of the force to produce the positive work required to raise it back to its starting point. Both negative and positive work contribute to improvements in strength.

**Kinetic and Potential Energy**

To perform work, the body uses energy. Although energy has many meanings, in the mechanical sense, energy is defined as the capacity to do work. Although the body uses heat, electric, chemical, and mechanical energy, for the purposes of this chapter we will focus on mechanical energy. Mechanical energy has two forms, kinetic and potential. Kinetic energy implies motion, whereas potential energy suggests no movement, but does imply energy due to position, such as with a stretched rubber band or muscle. Kinetic energy or energy in motion is easily illustrated by the dynamics of a wrecking ball. When the heavy ball is swung from a crane, its energy is obvious when it hits a building. The ball displaces the building, knocking it apart. The kinetic energy of the object is affected by its mass and velocity. In this case, the bigger the wrecking ball and greater the velocity in which it is swung, the more energy it maintains and exerts on objects it contacts.

When energy is in a potential state, it is able to do work due to its position. For instance, a weight held off the roof of a building has potential energy. If it is released, it will accelerate at the rate of gravity. With gravity, the object’s location in relationship to the earth determines its potential energy. If the object is high enough to reach terminal velocity it will maximize its potential energy. On the other hand, if it is only four feet off the ground its potential energy will be less. As kinetic energy increases, potential energy proportionately decreases. The rubber band example also demonstrates the role of position in potential energy. The further the rubber band is stretched, the more energy it possesses upon release. Again, as the stretch in the band decreases, so does the potential energy, but as the band stretch decreases, the potential energy is turned into kinetic energy in equal and opposite proportion. The human body has systems in place that work very similarly to the rubber band. One mechanism we will visit later in this text is called the stretch-shortening cycle, which uses kinetic energy transferred into potential energy and back into kinetic energy for increased force output. A difference in living tissue is that potential energy may be gained or lost depending on certain neural factors.

Since work is always done when kinetic energy is produced, it is obvious a relationship exists between the two (energy ~ work). When potential energy is employed, there is no work, but forces are still being applied to maintain the potentiality of the energy. Remember, energy was defined as the capacity to do work. This explains why the human body burns calories to remain in a static position. Without movement, technically no work is being done. But to produce the
Mechanically speaking, energy can be increased or decreased by the performance of work. For instance, if a bow is drawn halfway back, the arrow will have less kinetic energy when released than if it were pulled back the full distance. In this case, the more work performed, the more energy produced. On the other hand, work can be done to decrease energy. When a medicine ball is thrown, the person throwing it creates kinetic energy through positive work. The person catching the medicine ball reduces the ball’s energy by performing negative work in the process of decelerating it. In both cases, the energy referred to is the energy of the moving object, not the energy of the accelerating object. When the body does work to manage energy, it increases its own energy usage. So energy can be viewed as external or internal depending on what is being analyzed. Internal energy will be covered under the section on bioenergetics (Chapter 5).

Power

Since work is the product of force and displacement, it can be accomplished in any variable of time. For instance, a 25 lb. object moved four feet requires the same amount of work no matter how long it takes to move it the full distance. The faster the rate of work is performed, the more power produced by the movement. Power is work divided by time ($P = \frac{F \times d}{t}$). This is illustrated by a race between two cars that have the same mass. If both cars weigh the same and drive the same distance in the race, they produced the same amount of work. The car that wins the race though, is the more powerful of the two vehicles. Power is an extremely important component of performance-related fitness, as it contributes to momentum, which assists in enabling the body to perform certain tasks, such as getting up from a chair. Power is expressed in watts, much like the power in a light bulb, which is why the electrical company is synonymous with the power company. Human power is also measured in watts. This can be seen on many pieces of aerobic equipment. The machines display the power output in watts and energy output in kilocalories.

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\text{Power} = \frac{\text{Work}}{\text{Time}} \\
P = \text{power} \\
W = \text{work} \\
T = \text{time taken to do the work}
\]

Power production characteristics of muscle can provide further insight as to how to maximize the performance of the human body. Power output depends upon the muscle’s contractile velocity. Interestingly, as a muscle’s contraction velocity increases, its maximal force output decreases. When velocity of a contraction is multiplied by the maximal force at that respective velocity, maximal power can be calculated for each contraction velocity. In general, a muscle’s maximal power occurs at a velocity that is approximately 50% of the muscle’s maximal contractile velocity. Using this information, the optimal method to perform tasks to maximize power can be calculated. Advanced training environments, such as those found in preparation for the Tour de France use this information to find the ideal gears, seat heights, and cranking speeds for the cyclist to optimize performance.

As stated earlier, power is a valuable tool for human performance, but the metabolic systems that generate the power fail to provide for the ability to sustain its output over a prolonged period of time. Power output is dependent upon the quantity of power and the time it is sustained. For instance, a sprinter uses high power outputs to generate great speeds in a short period of time, often referred to as burst power. Unfortunately, this power cannot be sustained. Therefore, beyond the point of peak power output, the sprinter’s speed will no longer increase, but rather begin to slow down. When power requirements are prolonged, the outputs are inversely related, meaning the longer the power is required the less power will be provided. This limitation is an inherent flaw in the metabolic systems of the body. Even when all systems are optimal, this limiting relationship still exists.

Torques

The body is constantly managing different types and applications of force. One of the most common applications within the body is the moment of force, or torque that causes change in angular motion. Simply put, torques cause rotation. The forces muscles produce move the limbs around their respective axis of rotation, as defined by the joint. But torques can also be applied without movement. Equilibrium, stability, and balance are attainable with the help of torques.

Since torque causes rotation, it changes the linear and angular motions of an object to cause general motion. If the external force is eccentric, meaning the force is directed through the center of gravity, it will not cause rotation, and therefore, remain linear. If the external force is directed against an object at a line other than the center of gravity, referred to as eccentric force (not to be confused with an eccentric contraction), some level of rotation will occur, thereby creating torque. This force can be easily demonstrated by placing a
pencil flat on a table. If the pencil is pushed in its center it will slide, or translate, across the table in the direction of the force without change in its orientation. However, if the pencil is pushed from the top or bottom, it will rotate away from the line of force. The closer the force is to the middle of the pencil, the less it will rotate; therefore, the closer a force is applied to the center of gravity, the less torque it will experience. On the contrary, the further the line of force is from the center of gravity the greater the torque created. When this occurs in the body, the more torque that is applied, the greater the internal force will need to be to manage the eccentric force. For instance, if a person performs an abdominal curl-up while holding a medicine ball on their chest they will experience an increase in torque and noticeable difficulty added to the movement when compared to performing the exercise without the resistance. When that same resistance is held with arms extended overhead, the torques increase by the magnitude of the distance the weight is located from the center of gravity. The same can be said for the side raise exercise. The further the resistance is held from the body, the longer the resistance arm, and consequently the greater the magnitude of torque applied. The more torque experienced during exercise, the greater the difficulty of the movement, even when the weight remains constant.

Torque is increased to an even greater degree when force couples act upon an object. Back to the pencil example, if a linear force is applied to the top of the pencil in one direction, while at the same time a similar force acts on the bottom of the pencil in the opposite direction, the pencil will experience the coupled torques and therefore rotate more easily. A see-saw works under the same premise. If two children of equal weight are on a see-saw, they can easily perform the up-down motion across the fulcrum of the board. One child applies upward force, while the gravitational force applied to the other child from the earth pulls downward to create the force couple. The force couple increases the torque to cause playful rotation. This can be accomplished even if the children have different weights due to the coupling effect of the forces. If one child tries to play on the see-saw alone, however, the same phenomenon will not be duplicated. The single child would produce some torque but not have the force capabilities to cause the torque in the way the two children’s force couple did. The child may get the see-saw to rise to a limited degree, but the low level of torque would limit the attainable motion.
~Key Terms~

**Energy** - The capacity to do work.

**Work** - Transfer of energy by a force acting to displace a body. Work is equal to the product of the force and the distance through which it produces movement.

**Kinetic energy** - The energy possessed by a body because of its motion.

**Potential energy** - Energy stored by an object by virtue of its position.

**Power** - Time rate of doing work.

**Watt** - A unit of power in the International System of Units equal to one joule per second.

**Torque** - The turning effect created by a force about an axis.

**Centric force** - Force whose line of action passes through the center of gravity of an object.

**Eccentric force** - Force whose line of action does not pass through the center of gravity of an object.

**Resistance arm** - The distance between the fulcrum and the resistance point.

**Force couples** - Torque created by a pair of oppositely directed forces about an axis.

The torques created by the muscles of the body are dependent upon the force and attachment location. This is called the line of action, or line of pull. The line of action is most often in the direction of the tendons. Tendon attachment locations cross joints to pull the limbs in the desired direction. Generally, the more distal the attachment, the more rotation or torque created. In most cases, the muscles work in pairs, so as rotation occurs from one muscle, other muscles aid in the production of torque or counter torque. For instance, when the elbow flexes, the bicep brachii crosses the elbow and pulls on the proximal radius, whereas the brachioradialis which crosses the elbow from the humerus and attaches to the distal portion of the radius, pulls from a different location. Together they act to enhance arm flexion capabilities. The hamstring muscle group and the gastrocnemius work in a similar fashion, which explains why many people feel contractile force in their calf on the leg curl.

With this in mind, the design concept behind weight training equipment and resisted movements becomes apparent. For instance, a leg extension or curl machine is designed to place the resistance at the distal end of the limb to create higher levels of torque. If the same machines had shorter swing arms, or if they were not properly adjusted to match a person’s limb length, the exercise would become easier. Likewise, the exercise machines with longer lever arms make it mechanically easier to move a respective resistance due to the lever advantage compared to the machines that have shorter levers like those that more closely resemble the free weight movement. The more cables and levers, the less resistance that is actually lifted.

**Determining Torque**

To determine the actual resistance, or torque, a muscle must overcome, some basic facts must be known. Algebraically, torque that produces movement is expressed as \( T = F \times FA \), or torque equals applied force, multiplied by the length of the force arm. Torque that resists movement is expressed as \( T = R \times RA \), or torque equals the resistance multiplied by the length of the resistance arm. The heavier the resistance or longer the resistance arm, the more difficult it is for the body to move the resistance. Holding a dumbbell close to the body is much easier than holding the dumbbell away from the body. The resistive torques increase as the
resistance arm lengthens. This is why a person can perform a lift with more weight on the bench press compared to the chest fly, or on the upright row compared to the side raise. The shortened resistance arm provides for mechanical advantage, particularly when the force arm is long.

From this, it follows that exercise difficulty can be manipulated by adjusting the factors that contribute to resistive torques or by changing the mechanical advantage of the lever system. If a person has difficulty with a movement, they can simply reduce the resistance, shorten the resistance arm, or lengthen the force arm to better perform the movement. In many cases with body weight exercises, shortening the resistance arm is the easiest variable to adjust. If a new exerciser has difficulty performing abdominal curl-ups from the ground, have them perform the exercise from an inclined bench with their feet on the ground. The muscle action and movement are the same, but the shortened resistance arm will make the movement easier. If they cannot do a push-up from the floor, have them perform the exercise from an elevated surface. Mild adjustments can make the difference between correct and successful performance and failure or poor movement technique and possible injury.

Stability

When the body is in general motion, torques are contributing to the angular motion while other forces are creating linear motion. As stated earlier, when all external forces and torques are accounted for so that the net sum of all forces and torques is equal, static equilibrium is attained. Static equilibrium means non-movement balance, but in exercise and physical activity non-movement would be contrary to the exercise’s purpose. So, with dynamic activities, balance and stability are more appropriate considerations for managing external forces and torques.

To understand balance and stability, it is important to first identify the major contributing factor that works against it: gravity. The constant 9.81 m/sec² applied to the body requires it to constantly manage the external force created by the gravitational pull. Gravity pulls on the center of mass of an object, commonly referred to as the center of gravity. The center of gravity, as defined by Webster’s dictionary is “that point in a body or system around which its mass or weight is evenly distributed or balanced, and through which the force of gravity acts.” With regard to Newton’s laws of motion, the center of gravity is the site by which the laws apply. The body rotates around its center of gravity.

The human body is slightly more complicated than a rigid mass when it comes to identifying the center of gravity. This is due to the fact that the body can be in different positions, which causes the center of gravity to migrate to the movement of the greatest mass. A shot put, for instance, always has the same center of gravity because it has no limbs. But humans have many joints which can move the center of gravity in all directions. When standing in anatomical position, the center of gravity is centrally located since most people are symmetrical from side to side. The same symmetry does not exist from front to back. A view of any person from the side will illustrate this fact. This is particularly true for individuals carrying excessive mass. The changes related to lean mass build up or fat storage may raise, lower, or shift the center of gravity forward or backward. Changes in the center of gravity may cause the body to work harder to establish static equilibrium, balance, or stability (4; 29). A pendulous belly for example, causes the center of gravity to shift anteriorly, increasing strain on lumbar joints as the soft tissues work to counteract the force. This identifies why added fat mass makes activity more difficult to perform, which can contribute to a decline in activity status.

Since stability is a key factor in the application of human force and the subsequent movement created by the force produced, its relationship with gravity must be
well understood. Webster’s dictionary says that an object is stable when it is not easily moved or thrown off balance. The ability of the body to stabilize its segments ultimately determines performance. This is true of lifting weights, running on a treadmill, or standing still. External force energy must be transferred through the body’s kinetic chain to effectively join it with internal force (11). It is very important that the force remains as close to its starting magnitude as possible. If any of the energy leaks out to unstable segments on the chain, the application of the internal force will be limited by the loss of the external force. This suggests a person completing a military press may not be able to reach their potential because part of the ground reaction force is lost due to instability in the trunk. The more stable the body becomes, the more efficiently external force can be applied.

**Components of Stability**

The body achieves stability by manipulating several variables. The mass of the object, height of the center of gravity, line of gravitational pull, and the base of support all affect the stability of the object (4; 13). Since the mass is constant, the three variables which can be managed are the base of support, the height of the center of gravity, and line of gravitational pull(14; 24). By manipulating these variables effectively, less internal and external force is required for stability.

The more central the line of gravity falls within the base of support, the more stable the object becomes. If the line of gravity migrates to the outer regions of the base, the object becomes less stable. If the line of gravitational pull exceeds the outer limits of the base of support, the object will no longer be able to maintain stability (13). This being said, the wider the base of support, the more stable an object will be as long as the line of gravitational pull is centered within the base. Again, moving the line of gravity toward the outer limits of the base of support will proportionally disrupt the object’s stability consistent with the distance from the center line of gravity (14). This is also true when the center of gravity is elevated. The degree of stability is indirectly proportional to the height of the center of gravity. If a person lies on the ground, they are difficult to move and therefore stable. A large pushing force would be required to disrupt their stability. When the same person stands up, the center of gravity is elevated with their elevated position. The pushing force required to disrupt an individual when they are standing is much less than the force needed to disrupt their stability when they are lying on the ground. If that same person stands
on one foot, even less external force would be needed to disrupt their stability because the base of support has been reduced.

Another key to stability is the width of the base of support as it applies to the direction of the external or disruptive force. For instance, in a tug-of-war, a wide stance in the direction of the pull would be more stable than a wide stance perpendicular to the line of pull. To enhance stability, the base of support width must be widest in the direction of the resistance. When objects are lifted overhead, the direction of the force is directly down, so a wide natural stance or wide split stance would each enhance stability.

In physical activities such as running, the base of support must constantly be changed to account for the movement of the centerline of gravitational pull (17). As the line of gravity moves outside the base of support, the person loses stability in the process to create mobility. This explains why a person will fall if one leg gets held up when running. Since the line of gravity is moving forward, the trip leg cannot swing through to re-establish a base of support outside of the line of gravity, stability is lost and the runner falls. If he or she trips, but can re-adjust and get the limb past the line of gravity in time, a stumble occurs but not a fall, since stability was lost and re-attained. Essentially, for activities where locomotion occurs, the body moves by constantly losing and regaining stability. The ability to regain stability helps define the efficiency by which the movement is performed.

This also explains why we may be able to accomplish a movement pattern with limited success but not in an efficient manner. If stability is disrupted or difficult to attain, or attained to a limited degree, the movement will suffer proportionate to the level of stability. If stability is lost, the movement will fail. But when complete stability is attained, the movement will become fluid. This supports the trend toward the inclusion of stability training in exercise programs. The more efficiently the body can attain stability and the more stable it can become, the better it will perform.

### Practical Application

#### The Body’s Stabilizing Units

The ability to stabilize its segments determines how effectively the body can manage forces to perform tasks. An inability to stabilize the body segments leads to dysfunction. Static and dynamic stability is achieved when passive, active, and control systems work together to manage forces and transfer load (5; 7). The ability to transfer force through a joint is dependent upon 1) the integrity, mechanics, and function of the tissue of the joint, often referred to as form closure, 2) the coordinated tensile and compression force produced by tissues to manage the other forces acting on the joint called force closure, and 3) the appropriate neural activity to orchestrate the pattern of motor control often referred to as kinesthetic awareness. Stability depends more upon accelerating force “harmony” than the independent factors such as the joint structure or strength of the attached tissue. This suggests that to become more stable, the objective should be to control motion as a whole, rather than addressing the independent parts, since it is the coordination of the parts that ultimately enhances stability.

Due to the fact that the stable segments of the body allow it to transfer external energy from the ground and other objects, the ability to recognize the areas of inefficiency is necessary to improve force transference through the kinetic chain (11). The multiple segments of the spine and pelvis need to transfer energy to and from the upper limb and lower limb segments. This suggests that the trunk is a key point of stability (5; 9). This is further demonstrated when increased limb velocities require the transfer of angular momentum. A motion segment must become stable to pass its angular momentum to another segment. If the trunk cannot attain an adequate level of stability, the force cannot be effectively transferred from the bottom to the top or from top down. Throwing, running, and jumping, as with most dynamic movements, require force transfer from the limbs through the trunk or the trunk through the limbs.

The body has two primary systems of stability for energy transfer at, and around, the lumbo-pelvic region. The inner unit, or local stabilizers, describes the tissues that stabilize the joints from deep within the body, while the outer unit, or global stabilizers, stabilizes and moves body segments using the more superficial prime mover musculature. The inner unit is comprised of the transverse abdominis, pelvic floor, multifidus, and the diaphragm. These muscles work together to create internal forces that support the spine (5; 8; 9). The outer unit is composed of groups of tissues that make up four independent systems, sometimes called sling systems, which work via the continuity of fascial attachment. They include the posterior oblique, the deep longitudinal, the anterior oblique, and the lateral oblique systems. Historians suggest that the ancient Egyptian theorists had an understanding of these relationships in the development of human stability and movement.
The Inner Unit
The inner unit features the hoop tension created by the transverse abdominis (TVA) and the multifidus muscles, which represent the primary stabilizers for the lumbo-pelvic region (5; 8; 9). It has a large attachment to the middle layer and the deep lamina of the posterior layer of the thoraco-dorsal fascia and is recruited prior to any upper or lower extremity movements (31). When the TVA contracts, tension increases in the thoraco-dorsal fascia called thoraco-lumbar fascia gain, and intra-abdominal pressure increases as the relatively non-compressible viscera pushes against the supportive structures of the diaphragm and pelvic floor. The collective effect of the thoracolumbar fascia gain, increased intra-abdominal pressure, and hydraulic amplifier effect caused by the spinal musculature, enhance stability in the lumbopelvic and upper spinal regions (9).

In upper body movements, TVA contractions should occur at least 30 milliseconds prior to the movement and 110 milliseconds before the initiation of a lower body movement for sufficient stability (9). TVA activation requirements seem to be consistent, regardless of the movement pattern or the plane in which the movement is performed (21). According to studies, individuals with a timing delay of TVA activation beyond the aforementioned requirements are more likely to suffer chronic low back pain (23). It is suggested that significant motor control deficit is present in people with chronic low back pain which is primarily associated with the control of the contraction of the transverse abdominis and is worsened by atrophy of the multifidus (6; 28).

The Outer Unit
The outer unit works in conjunction with the stability created by the inner unit. Each sling system is comprised of connective tissues, which act to stabilize or move body segments. The posterior oblique system is comprised of the latissimus dorsi, gluteus maximus, and intervening thoraco-dorsal fascia. When added to the superficial layer of the trapezius, transverse abdominis, and deep layer of the internal oblique, in conjunction with the hydraulic pump of the multifidus and erector spinae muscles, a structural force bridge is created. This bridge between the lumbar spine and pelvic girdle created by these active tissues is fundamental to safe exercise performance because these muscles are significant contributors to the transference of load through the pelvic girdle (31). The deep longitudinal system includes the deep lamina of the thoraco-dorsal fascia, the sacrotuberous ligament, and the biceps femoris muscle. This system serves as an extension of the inner unit by contributing to tension in the thoraco-dorsal fascia and facilitating compression through the sacroiliac joint. This support mechanism adds to dorsal and inferior lumbo-pelvic stabilization.

On the other side of the body, the anterior oblique system combines the abdominal obliques, the adductor muscles of the thigh and the intervening abdominal fascia. This system is considered important for phasic actions such as the initiation of movement and high load control activities (2). The oblique muscles are active whenever actions of the trunk, upper, and lower extremities occur (1; 22).

The final system to make up the outer unit is called the lateral system and includes the gluteus medius and minimis, the tensor fascia lata, and the adductors of the thigh. These muscles are important to bipedular motion and standing, providing frontal plane stability. As with all systems of the outer unit, the phasic actions of this system depend upon internal stabilizing force. If the inner unit cannot manage the forces produced by the outer unit, injury is a likely occurrence.

The relationship between the inner and outer unit is probably the best supporting evidence for the inclusion of functional-based activities for performance enhancement. The concept of harmonized movement suggests that stability is efficiently attained and forces are transferred effectively through body segments for desired outcomes. Training to emphasize improvements to inner unit stability, while utilizing resisted movements consistent with the natural functional systems of the outer unit, is well justified in an exercise program for optimal stability and function of the body (31).

Rotational Inertia
The necessity for harmonious interaction between the inner and outer units is even more evident when the body must manage dynamic forces at high velocities. Since the body has limb segments, forces and torques that cause rotation contribute to the disruption of stability as seen by the running example (18). People most often fall down when they move, not when they are standing still. The faster the rate of movement, the harder it is to manage the movement. Therefore, the faster a body segment moves, the greater the stability requirements assumed by the body. In the case of ballistic movements where the body segments are accelerated for power, such as throwing, running, or
swimming, it is important to recognize the additional contributing factors that affect stability. **Rotational inertia** and its product, **angular momentum** are created when the segments of the body move. The faster the movement, or the larger the segment, the more rotational inertia and subsequent angular momentum produced.

Rotational inertia, as it pertains to the body, is defined as the reluctance of the body segment to move around its axis. The distribution of mass and length of the swing arm dictate the amount of rotational inertia. A baseball bat has its proportionate mass toward the distal end when held correctly. In this position, it has less rotational inertia than if the bat were flipped around so the thin end is distal. This explains why the leg has greater rotational inertia around its joint than the arm. The longer length and greater mass proximal to the body makes it more reluctant to rotate. This is exemplified when running. The recovery leg is bent when it passes the hip. This way, it more efficiently re-establishes stability. The bent knee has less rotational inertia to overcome than a straight leg. This also explains why an overhead pitch used in baseball has greater velocity than the underhand pitch used in softball. The arm flexes during the overhand throw creating less rotational inertia than the straightened arm wind up of the softball throw.

### Angular Momentum

The amount of rotational inertia produced depends upon the total mass, distribution of the mass, and the angular velocity. Collectively, this product is the angular momentum. The force required to change angular momentum is proportionate to the quantity of momentum. Momentum is either desirable or completely undesirable, depending on the purpose of the movement. Desirable momentum would be that created in the hammer throw. In this case, the momentum can be built upon as the thrower rotates to throw the object further. In cases of resistance training, momentum may be less desirable because it applies less resistive force to the tissue being trained. Swinging the bar may allow for greater weight to be moved, but will likely place less stress on the targeted contractile tissues. This is commonly seen in many exercises when too much resistance is used. The lifter applies angular momentum, most often generated from hip extension or flexion to move greater resistance. Adaptations to the muscle are based on the force generated by the tissue and the duration those forces are applied for, not just the load moved. When using the hips to lift weight the prime movers perform less work and experience minimal training stress compared to the employment of proper lifting technique.

In other cases, it is desirable to use momentum to perform a lift or task. When momentum is employed to perform a task, it is usually transferred from one body segment to another. This is accomplished by stabilizing the initial moving part so the momentum transfers to the next segment. When Olympic weightlifters perform the clean and jerk exercise, they take advantage of the momentum forces to perform the lift. The lifter generates a powerful movement using hip extension, which causes the bar to accelerate upward. During the period of acceleration (caused by angular momentum) that is greater than gravity, the lifter has time to drop under the bar to catch it before it reaches neutral gravity. If the lifter does not get under the weight by the time it reaches neutral gravity, the lifter will have increasing difficulties successfully completing the lift because the bar will begin accelerating back to the ground at the rate of gravitational pull. Another example of the body’s ability to transfer momentum occurs when we run or jump. Humans can both run and jump without the use of arm movements, but the performance of the tasks will be compromised when the arms are employed during the movements. When we swing our arms during a forward or upward jumping motion, the angular momentum from the rotational inertia of the arm swing is transferred to the trunk to help propel the body in the direction the center of mass is moving (10; 30). Running works the same way. The alternating arm swing occurs contralaterally to the alternating leg movement for the purposes of balance and the generation of angular momentum. The arms are bent to accelerate more efficiently so as to mirror the speed of the recovery leg. The recovery leg is also flexed so the hip flexors can move it forward rapidly to regain stability.

### Agonist and Antagonists

Managing angular momentum is as important as generating it. Whenever the body produces angular momentum from rotational inertia, a force proportionate to the angular momentum is required to stop the movement. This is an important concept to apply in physical activity in order to prevent undesirable outcomes and injuries. The throwing example illustrates this concern. When a pitcher winds up during a pitch, additional angular momentum is supplied to further accelerate the baseball beyond the arm’s relative rotational force capabilities. The forward acceleration of the limb allows the ball to travel at a high velocity, but the limb must be decelerated using forces proportionate to the forces that caused the acceleration. If the deceleration muscles, or **antagonists**, are not comparable in force production capabilities (relative to
their role) to the acceleration producing muscles, or **agonist**, the joint and tissues of the movement segment they serve are at risk. In fact, other muscles may strain in support of deceleration, as they are not serving as antagonists to the prime movers but acting as assistive decelerators.

A pitcher who strains the muscles of the low back or rotator cuff during the follow-through of a pitch will do so because the acceleration was beyond the magnitude of the tissue’s eccentric deceleration capacity (25). When the prime antagonists cannot manage the deceleration requirements, they employ assistive musculature all the way down the kinetic chain to help slow the movement. This would explain a back strain that occurs when decelerating the throwing motion (20). If the sum of the deceleration forces does not equal acceleration, something has to give. Either a tissue will be compromised or stability will be lost. Individuals engaged in sports or activities where momentum forces are common should strengthen the muscles that aid in deceleration. In many cases, athletes and exercisers routinely focus on strengthening the muscles that accelerate movement without addressing the muscles that must slow the movement down. When the agonist muscle group surpasses the antagonist muscle group’s **strength balance** requirements, injuries will occur (12; 19; 26). This is actually the most common reason individuals suffer soft tissue strains.

A common example is seen in the frequency athletes “pull” or strain their hamstrings. This occurs because the hip flexors and knee extensors become disproportionately stronger than the hamstrings. In this relationship, the minimum strength balance is 2:1, or the hamstrings must have at least 50% of the strength of the quadriceps (12; 16). A better balance would be a 25% difference, also stated as a quadriceps/hamstring ratio of 4:3 (15).

Each agonist/antagonist relationship has a specific muscle balance requirement depending on the relative factors of the joint where the movement occurs. In most cases, injury will occur when the weaker antagonist takes on agonist responsibilities. Analysis of a hamstring pull illustrates this phenomenon. The hamstring is the antagonist muscle to the quadriceps during a leg extension but switches roles to become the agonist in the leg curl. In this scenario the majority of force is produced solely by a single muscle group; either the quadriceps is producing the force or the hamstrings are producing the force. In this environment, the imbalance is not as much a concern. The problem occurs when they produce force together. The hamstring pull occurs during activities such as running where hip extensors and knee flexors combine with the hip flexors and leg extensors to produce high-speed locomotion. The stress from the contraction, in addition to the stress of the active imbalance, produces the double stress phenomenon that causes the strain.

In weight training and physical activity, muscle imbalances are very easy to develop. Every sport or activity has the potential to cause imbalances because, more often than not, particular movements and muscles are employed repeatedly and chronically. A notable example occurs in swimmers and wrestlers, who often develop upper cross syndrome, identified by the rounded, internally rotated shoulders and kyphotic spine postures (3; 27). Due to the frequency of the strokes and the muscles used to generate the force in swimming or the constant squeezing which occurs in wrestling, viewable structural shifts can be observed during postural analysis. If imbalances are identified, they should receive priority within the exercise program matrix. With imbalance comes injury, and with injury comes limitation to movement or activity attrition.
~Key Terms~

**Line of action** - The relation of a muscle’s pull to the joint.

**Center of gravity** - The point where the mass of the object is equally balanced. The center of gravity is also called the center of mass.

**Kinetic chain** - A group of body segments that are connected by joints so that the segments operate together to provide a wide range of motion for a limb.

**Rotational inertia** - As a rotating body spins about an external or internal axis (either fixed or unfixed), it opposes any change in the body's speed of rotation that may be caused by a torque.

**Angular momentum** - The product of the momentum of a rotating body and its distance from the axis of rotation. In lay terms, angular momentum can be thought as the "amount of rotation" of the body.

**Antagonist** - Role of a muscle whose torque opposes the action referred to or muscle referred to.

**Agonist** - Role of a muscle whose torque aids the action, referred to as the prime mover.

**Strength balance** - The force production relationship between an agonist and antagonist muscle or group of muscles.

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**Common Errors in Movement and Exercise**

Biomechanical limitations to performance can also occur when the muscle or connective tissue is inflexible or weak along the kinetic chain. In some cases, movement execution is poor due to improper technique. In other cases, the improper movement is caused by limitations in the functioning tissue. Common errors in movement and exercises can provide information about kinetic chain deficiencies. The following identifies some of these common errors.

**Deadlift**

The traditional deadlift exercise uses a flexed knee and hip position with the feet in relative close proximity, or about hip width apart. The bar is grasped using an alternate grip outside the knees, with chest elevated to maintain a flat back position with a slight lumbar curve. The common error in this movement occurs when the legs are extended, but weakness in the trunk causes a forward and downward pull leading to a rounded back position during the ascent. Likewise, if the glutes are inflexible, the start position may cause a posterior shift in the pelvis, leading to a decreased convexity of the lumbar spine. In either case the round back position caused by the lift will place stress on the spinal ligaments and may cause excessive disc compression. To correct the error, more attention should be placed on the back position.
position during the lift. This may require better cueing during the instruction of the exercise, a decrease in weight, or a modification to the position to allow the hips to extend sooner. A common modification is a wider stance with an inside the knee grip on the bar. This leads to greater hip extension ability earlier in the lift and increases adductor contribution. However, the change does reduce the leg extension requirements proportionately to the added hip and adductor contributions.

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**Romanian Deadlift**

The Romanian deadlift (RDL) requires a slightly flexed knee position and maintenance of a neutral spine throughout the movement. The maintenance of proper spinal alignment is where errors frequently occur. Rounding the back either suggests weakness relative to the weight or incorrect instruction. Cueing an exerciser to elevate the chest causes the back extensors to better control a straight spine position. If the exerciser continues flexing the knees as they lower the resistance, it suggests tightness in the hamstrings. Performing the exercise using a staggered stance with less weight can enhance range of motion through dynamic flexibility.
Bent-Over Rows

Similar to the lower body position of the Romanian deadlift, the bent-over row exercise requires the maintenance of a flat back position. Ideally, the lift is performed with mild knee flexion with hips flexed so the line of the spine approximately parallels the floor. Rounding of the back stresses spinal ligaments and places compressive force on the intervertebral discs. Similar to the RDL, inability to maintain the position often suggests too much resistance, stabilizer weakness in the trunk, and/or lack of flexibility in the hip extensors. If the exerciser extends the hip during the row phase of the movement, it again suggests too much resistance.

Incorrect  
Correct Starting Position  
Correct Ending Position

Leg Lifts

Supine leg lifts have classically been used to train the abdominals. The blatant error common in the employment of this movement is the abdominals do not attach to the femur, so the exercise is actually controlled by the hip flexors. The insertion of the hip flexors place excessive stress on the lumbar spine and pull the pelvis into an anterior pelvic tilt, increasing lumbar convexity and disc compression forces. For this reason, the movement is contraindicated. Modifying the movement by beginning the exercise with a flexed hip and contracting the abdominals to pull the pelvis posteriorly reduces spinal stress and increases abdominal activation.

Correct Start  
Correct Ending Position  
Incorrect Ending Position

Knee Raise

The hanging leg or knee raise is subject to the same concerns as the supine leg lift, but disc compression occurs at a lesser degree. The common error is to raise the thigh to a ninety degree flexed hip position with an anterior pelvic tilt. This movement is caused by contraction of the iliopsoas muscle group, whereas the abdominals serve as a stabilizer to the trunk. To correctly perform the exercise so the abdominals serve as the prime mover, a posterior pelvic tilt must be attained. For many exercisers performing the movement from an inclined body position is more desirable for proper movement execution.
Lat Pulldown

Two common errors exist in the lat pulldown exercise. The first is incorrectly pulling the resistance to the back of the neck. This technique causes excessive external rotation in the shoulders, which may damage the shoulder capsule and increases risk of injury to the cervical spine, making the exercise contraindicated. To correct this error, the bar should be pulled to the chest. The second error is common in many back exercises, where hip extension serves to create angular momentum to move more resistance. This action reduces the tension in the desired musculature. To correct this error, the hip and spine relationship should remain virtually unchanged throughout the movement performance.

Overhead Press

Pressing overhead can compromise the shoulder, as excessive force is placed on an open joint. To reduce the stress in the shoulder and prevent humeral head translation, the exercise should not be performed behind the head. Instead, the bar should be lowered in front of the head to the chest, or dumbbells should be used to resist the overhead shoulder abduction movements. During the overhead press, particularly during the standing military press, it is also important to pay attention to the hip and low back position. A common error when too much resistance is used is to lean backward to employ the pectoralis major and gain some mechanical advantage. The backward lean extends the hips and low back, increasing spinal compression forces. The hip and spinal positions should not change from the starting posture during the movement.
Seated Row

As alluded to during the discussion of other pulling exercises, the employment of hip extension is a common error used to generate angular momentum to move the resistance. Correctly performing the seated row, as with the bent-over row, requires a stable trunk and spinal position. Flexing and extending the hip are undesirable during the movement. Additionally, the back musculature acting on the scapula should initiate the movement via scapular retraction. Arm flexion with limited scapular retraction is another common error seen during the performance of row exercises. Due to the fact that the rhomboids do not attach to the humerus, the shoulder complex movements should precede flexion of the arm to increase the effectiveness of the exercises.

Bicep Curl

When too much resistance is used in arm flexion exercises, such as the standing bicep curl, the tendency is to use swing to generate angular momentum. The two most common errors in bicep curling exercises are to flex the shoulder and/or extend the hips during the concentric movement. The humerus should remain fixed against the midaxillary line during the entire movement, and movement at the hip should be minimal.
Leg Press

The leg press is a popular exercise for leg training because very little skill is required to perform the movement. The most common errors exist when placing the feet on the foot plate. Low foot position causes the ankle to dorsiflex and the knees migrate past the toes during the descent. This will cause the resistive forces to be directed into the balls of the feet rather than the heels and often leads to tibial translation and knee ligament stress. To correct the problem, the feet should be placed higher on the foot plate, so the ankle position remains fairly neutral throughout the movement. The second error usually relates to tightness in the hip extensors. During the descent, tight musculature pulls on the pelvis, causing it to migrate posteriorly, reducing the lumbar curvature. This causes low back stress and can lead to injury. To correct this problem requires either improvement in range of motion or performing the exercise within functional range. The third error seen in the movement occurs when too much resistance is used. Frequently, exercisers will allow the resistance to accelerate downward to take advantage of the pre-stretch recoil response. This lack of controlled deceleration often pushes the body into a posterior pelvic tilt, again leading to increased risk for injury.

Lunge

One of the most common errors in lower body exercise is to allow the knee to cross the plane of the toe. This occurs due to an incorrect hip flexion-knee flexion relationship during the descent of the squat, lunge, or step-up. During the step-up and lunge, anterior movement of the hip, combined with a shallow lead step pushes the femur over the heel and consequently, forces the tibia to translate. During the squat, a similar action occurs when knee flexion supercedes appropriate hip flexion. The hips stay forward rather than driving backward, causing the femur to slide over the heel. Pushing the glutes backward to initiate the movement and sitting back into the squat will help prevent anterior knee movement during its performance. Taking a broad step and flexing the back knee early in the movement can correct the lunge technique. To correct the step-up errors, the lead foot should be placed into the center of the step with the weight directed into the heel, and upon the descent, the initial back step should be broad to pull the forward knee back behind the heel.
Prone Leg Curl

The most common error in the prone leg curl exercise is the use of hip flexion to aid in the movement. The tendency for the body to assume a position of mechanical advantage explains the reason the hips flex and the pelvis moves anteriorly during performances when too much resistance is used. If cueing does not correct the error the exerciser can reduce the resistance or switch to performing the movement one leg at a time, which will often correct the problem.

Leg Extension

Similar to the leg curl, the common error with the leg extension most often occurs with too much resistance, as the body compensates by extending the hips. The extended hips provide greater mechanical advantage for the rectus femoris and shorten the resistance arm. To combat this error, the resistance can be reduced or single leg extension can be substituted.
Shoulder flexion and abduction exercises are prone to the same common performance errors. Consistent with the mistakes of many other exercises, incorrect resistance selection is often the cause. The three major errors in the lift are incorrect starting point, the use of hip extension to create angular momentum, and too high an ending position during the ascent phase. Since the supraspinatus is the prime mover in initial humeral abduction and the first twenty degrees of the movement basically transfers resistance across gravity, the ideal starting position would be 20-30 degrees off of the hip to increase the deltoid contractile requirements. Many exercisers start and end the movements by swinging the weights so momentum forces contribute to the ascent phase of the lifts. When this occurs along with the added force from hip extension, the deltoids contribute less to the exercise’s performance. Too high an ascent can also be problematic, as acromion impingement may occur. To reduce the risk, the side and front raise should end at approximately 90 degrees. Additionally, the hand grip for the front raise should be neutral.

**Sit-up**

The full sit-up is a contraindicated exercise because the hip flexors take over as the prime mover at about 40 degrees of the movement, placing excessive stress on the intervertebral discs and spinal ligaments. The employment of the hip flexors is further enhanced when the feet or ankles are secured by an external object or person, or when the movement is performed on an inverted incline bench. To correctly perform the exercise for the abdominals, the abdominal curl-up movement should be executed with a draw-in of the umbilicus to stabilize the spine using the transverse abdominis, accompanied by a posterior pelvic tilt to reduce hip activity and trunk flexion to 30 degrees. Additionally, the exerciser should avoid pulling the cervical spine into flexion and perform the movement at a controlled rate of speed, maintaining contractile stress on the abdominals at all times during the execution.
Triceps Extension/Pushdowns

The most common error in triceps exercises involves movement of the humeral position during the execution of the movement. In many cases, shoulder movements are used to increase angular momentum. The incorrect momentum forces in the triceps extension and pushdown exercises are generated by a starting position in shoulder flexion and use of latissimus contractions to cause shoulder extension prior to arm extension. Momentum may also be caused by hip flexion when the resistance is incorrectly applied. Another error is the use of humeral horizontal abduction and adduction to increase pectoralis major contribution by making it more of a press down. To correct these errors requires a static humeral, spinal, and hip position during the movement and often an appropriate reduction in resistance.

Trunk Rotation

Errors in the performance of trunk rotation usually occur due to a lack of flexibility or inefficiency because the movement is more often combined with hip rotation than isolated. Many people have limited range in true trunk rotation, so they compensate by movement at the hip. To correct these problems, exercisers should be cued to stabilize the hip during rotational movements of the trunk. Stability can also be assisted by having the exerciser perform the movements in the seated position. When the arms are employed to move resistance, it is important to make sure the shoulder position does not change horizontally, so the action occurs at the spine.
CHAPTER TWO REFERENCES


