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ABSTRACT

The principles of kinesiology (the study of the mechanics of human motion) are applied to the energy, action, and reaction used in physical activities in this booklet designed for physical education teachers. In the first chapter, force is defined, and the production, application, and absorption of force are described and illustrated. Effects of force application on objects are discussed, and the efficient use of force in basic athletic skills is demonstrated. The essentials of good posture are delineated in the second chapter. The third chapter is devoted to examples of using force efficiently in activities such as lifting, pushing, pulling, and carrying. The final chapter discusses the importance of efficient movement to physical health and to the principles of injury reduction. (JD)

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"BASIC STUFF" SERIES

A collection of booklets presenting the body of knowledge
in physical education and sport for practitioners and students.

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preface

The information explosion has hit physical education. Researchers are discovering new links between exercise and human physiology. Others are investigating neurological aspects of motor control. Using computer simulation and other sophisticated techniques, biomechanics researchers are finding new ways to analyze human movement. As a result of renewed interest in social, cultural, and psychological aspects of movement, a vast, highly specialized body of knowledge has emerged.

Many physical education teachers want to use and apply information particularly relevant to their teaching. It is not an easy task. The quantity of research alone would require a dawn to dusk reading schedule. The specialized nature of the research tends to make it difficult for a layperson to comprehend fully. And finally, little work has been directed toward applying the research to the more practical concerns of teachers in the field. Thus the burgeoning body of information available to researchers and academicians has had little impact on physical education programs in the field.

The Basic Stuff series is the culmination of the National Association for Sport and Physical Education efforts to confront this problem. An attempt was made to identify basic knowledge relevant to physical education programs and to present that knowledge in a useful, readable format. The series is not concerned with physical education curriculum design, but the "basic stuff" concepts are common core information pervading any physical education course of study.

The selection of knowledge for inclusion in the series was based upon its relevance to students in physical education programs. Several common student motives or purposes for participation were identified: health (feeling good), appearance (looking good), achievement (doing better), social (getting along), aesthetic (turning on), and coping with the environment (surviving). Concepts were then selected which provided information useful to students in accomplishing these purposes.

The Basic Stuff project includes two types of booklets. Series I is designed for use by preservice and inservice teachers and consists of six pamphlets concerning disciplinary areas: exercise physiology, kinesiology, motor development and motor learning, social psychological aspects of movement, and movement in the humanities (art, history, philosophy). This first series summarizes information on student purposes. Series II is also designed for use by teachers but with a different focus. Three handbooks are included: early childhood; childhood; adolescence. Each describes examples of instructional activities which could be used to teach appropriate physical education concepts to each age group.

The development of the Basic Stuff series has been a cooperative effort of teams of scholars and public school teachers. Scholars provided the expertise in the content areas and in the development of instructional materials. Public school teachers identified relevance to students, field tested instructional activities, and encouraged the scholars to write for general understanding.

The format of the booklets was designed to be fun and readable. Series I is structured as a question and answer dialogue between students and a teacher. Series II continues this emphasis with the infusion of knowledge into the world of physical education instructional programs. Our hope is that the Basic Stuff series can help to make this scenario a reality.

Linda L. Bain, *Editorial Committee*
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foreword

Over the centuries people have been gathering knowledge about the mechanics of movement. This science is called KINESIOLOGY. The study of human movement requires a working knowledge of the neuromuscular and skeletal systems of the body as well as the external environmental forces which affect motion. Understanding how the body moves and the effect that gravity, friction, and the laws of motion have on it, provides a basis for purposeful choices of movements, rather than relying on trial and error procedures.

The information contained in the following pages is based on the premise that movement of any kind is initiated, controlled, and stopped by force of one kind or another. To understand the "how" and "why" of efficient movement one needs to know the kinds of force, their origins, their effects, and how we can utilize them to our advantage.

CHAPTER ONE

achievement

Photograph by Scott Forbes, Loudoun Times-Mirror

What Do You Have To Help Me?

Force is needed to produce or change motion

Since force is essential for all movement it is important to understand how it is initiated and how it affects movement. Force is required to put a body in motion, to change the direction in which an object moves or the speed at which it moves, and to stop an object which has been moving. Force is invisible, yet it can be felt. The effects of force can be seen and measured. Force can be described in terms of its magnitude, its direction, and the point at which it is applied.

Inertia is a resistance to change

All bodies possess inertia. Inertia is resistance to change. Inertia is that property by virtue of which a body, if at rest, tends to remain so, or if moving, tends to continue in motion in a straight line, unless acted upon by some external force. A body which is at rest tends to stay at rest and possesses *resting inertia*. A body which is moving possesses *inertia of motion*, moving at the same speed in the same direction. A force applied to an object will produce a change in the movement of the object unless it is counteracted. When all forces acting on a body neutralize one another, the body is in *equilibrium*. Sometimes a force may cause elastic deformation of the object or a distortion of the objects' shape. So without force, movement could not occur nor could it be stopped.

How Do I Get It?

As muscles contract they create an internal force

Gravity, friction, and fluid resistance are examples of external force

There are two general sources of force with which human movement is concerned. One is *internal* force (that which is produced by muscle contraction) and the second source is *external* force such as gravity, friction, and fluid resistance. Both internal and external forces may be used to put objects in motion, to alter the path of objects in motion, and to slow or to stop the movement of objects.

Why Does It Happen That Way?

Force = mass × acceleration

Mass = amount of matter in a body which resists a change of motion

To cause a resting object to move, a force must be applied which is greater than the inertial force of the object. The movement will then occur in the direction in which the force is applied. Let's look briefly at factors which affect force. The formula for force states that force = mass × acceleration. *Force* is therefore the product of the mass of an object and the speed with which it is moving. The amount of force can, therefore, be controlled by altering the speed of movement *and/or* the mass of the object. *Mass* is the amount of body matter which resists a change of motion. Acceleration is the rate of change in the body velocity. The one factor which is usually changed is the amount of speed since the mass is often not amenable to change. Mass is often used interchangeably with weight.

Mass = weight ÷ gravity

Mass and weight are related but not synonymous terms. The relationship is given in the formula: mass = weight/g. The weight of an object is the force with which gravity is pulling it to the earth. Weight scales indicate the gravitational force exerted on a body. For example, if your weight is 150 pounds, a gravitational force equivalent to 150 pounds is holding you on the earth. A classic example of mass and weight is the change of weight of a body on the earth and on the moon. If a person weighs 120 pounds on the earth, the weight when on the moon will be 20 pounds as the gravitational force on the moon is only 1/6 of that on the earth. The mass of the individual, however, is the same on the earth as it is on the moon.

Force equals mass times acceleration. If the mass of an object and its rate of movement acceleration are known, the amount of force required to produce this movement can be calculated.

Mass = force ÷ acceleration

Let's rearrange the formula: mass equals force divided by acceleration. When the amount of force applied to an object is known, and is divided by the rate of movement, the mass of the object can be determined.

Acceleration = force ÷ mass

A third arrangement of the formula is acceleration equals force divided by mass. The rate of motion can be calculated by dividing the amount of force applied by the mass of the object. Compare the acceleration of a softball and a shot following the application of the same amount of force to each. Since the mass of the shot is more than that of the softball, the rate of movement will be less.

In terms of practical application, an understanding of the relationships of force, mass and acceleration explains why it takes more force to put a shot 30 feet than it does to throw a softball the same distance and why a ball goes farther when kicked by an adult rather than a child.

What Else?

Internal force is produced by muscle contraction

To understand how human movement occurs you must understand how the muscles are arranged in your body. The muscles are the "motors" or power source for the internal force which moves the body. This internal force is produced through muscle contraction.

Muscles can only pull, not push

Muscles are arranged in functional pairs

Muscles *attach* to the bones of the body by tendons and the tension generated by the contraction of a muscle is applied to the bone at the *point of attachment* of the tendon. Muscles can only "pull" not "push" so muscles are found in functional pairs, which oppose each other. For example, the biceps brachii, and other muscles which are located on the *anterior* (front) aspect of the arm will flex the forearm against resistance and the triceps brachii located on the *posterior* (back) aspect of the arm will extend the forearm against resistance. In most instances, the *belly*, the contractile portion of the muscle is located above the joint at which the movement will occur. The muscle bulk of the anterior thigh produces movement of the leg at the knee joint. The muscle bulk of the posterior leg, or calf, produces movement of the foot at the ankle.

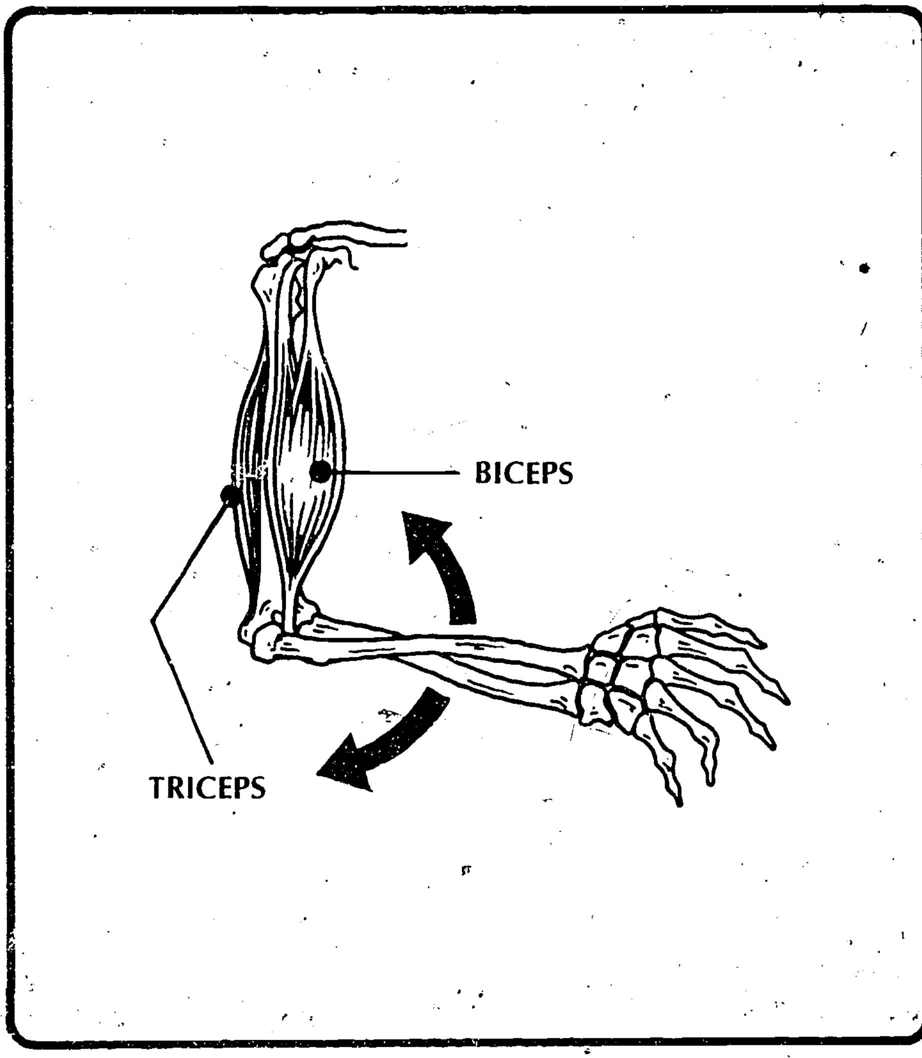

Figure 1: Muscles are arranged in functional pairs.

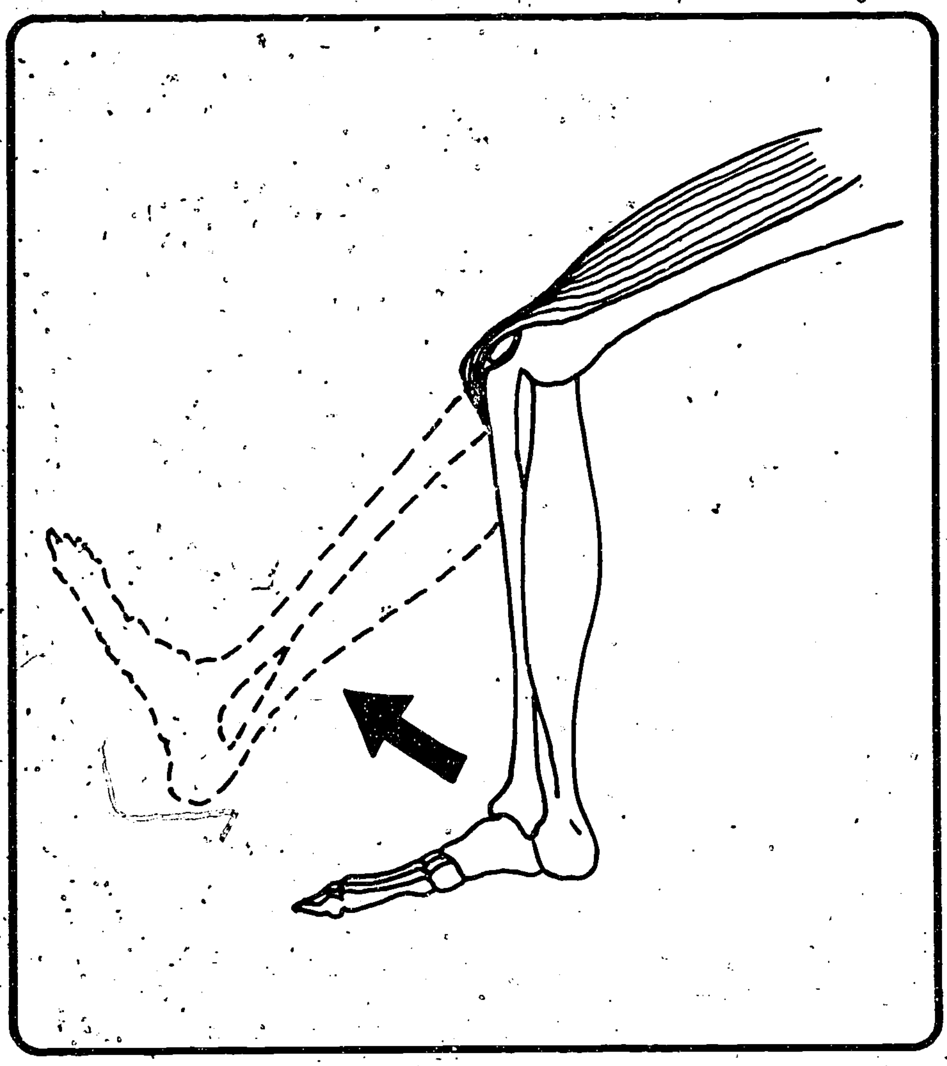

Figure 2: The muscle bulk of the anterior thigh produces movement of the leg at the knee joint.

Muscles can change the angle of the joint

Flexors decrease the angle of a joint

In the upper limb and on the trunk, the muscles located on the anterior aspect of the bones are the *flexors*. That is they will reduce the angle at a joint from that present in the normal standing position. Another way to think of *flexion* of a body segment is to remember that this is the movement which occurs when the segment moves forward when standing with arms at the sides, palms facing forward. For example, flexion at the neck brings the head forward as when you tuck your chin on your chest. Flexion of the spine occurs in the usual sit-up exercise. Flexion of the arm at the shoulder occurs in reaching for the salt shaker in the center of the table. When flexion occurs at the knee the foot moves backward toward the buttocks.

Extensors cause the return from flexion

The muscles on the body posterior produce extension. The muscles of the back straighten the spine as you return to a standing position after tying your shoe lace. *Extension* can be defined as the return from flexion. The large muscle of the hip, the gluteus maximus, extends the thigh as a bicycle is pedaled up a hill. The muscles and tendons on the posterior of the forearm extend or straighten the fingers and wrist. Some of these muscles can hyperextend the wrist, taking it from the straight or extended position to the position used when walking on your hands or standing on your head. *Hyperextension* is movement of a body segment in extension beyond the straight alignment at the joint.

The top of the foot moves toward the front of the leg in dorsal flexion. For plantar flexion the foot moves in the opposite direction

At some point during early embryological development, the upper and the lower limbs lie in the same plane and the thumb and the great toe are the superior or upper parts of the hand and the foot respectively. The upper limb rotates laterally (away from the midline) so that the thumb becomes the lateral part of the hand. The lower limb rotates *medially* (toward the midline) so that the great toe becomes the most medial toe of the foot. This means that the sole of the foot corresponds to the palm of the hand and that the top of the foot corresponds to the back of the hand. In other words the top of the foot is the back, or *dorsal* surface of the foot. As a result of this rotation the extensor muscles of the thigh and leg are located on the anterior surface relative to the bones of the limb. Extension of the leg at the knee causes the leg to come forward as in kicking and extension of the foot at the ankle causes us to point our toes as a gymnast does or to stand on "tip toe." To avoid the confusion between the anatomical location and derivation of the flexor and extensor musculature of the lower limb, movement at the ankle joint is referred

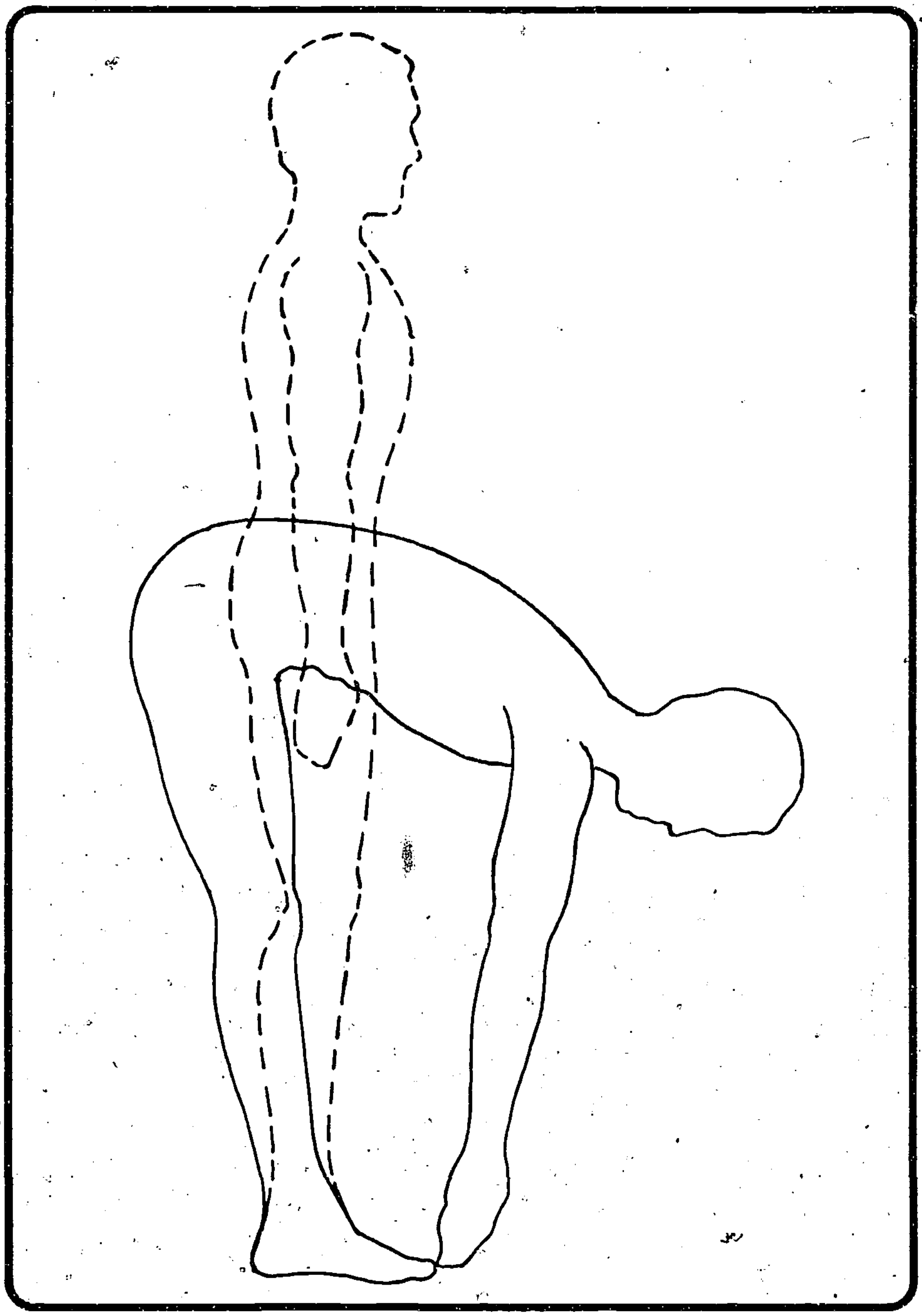

Figure 3: The muscles of the back straighten your spine when returning to a standing position after tying your shoelaces.

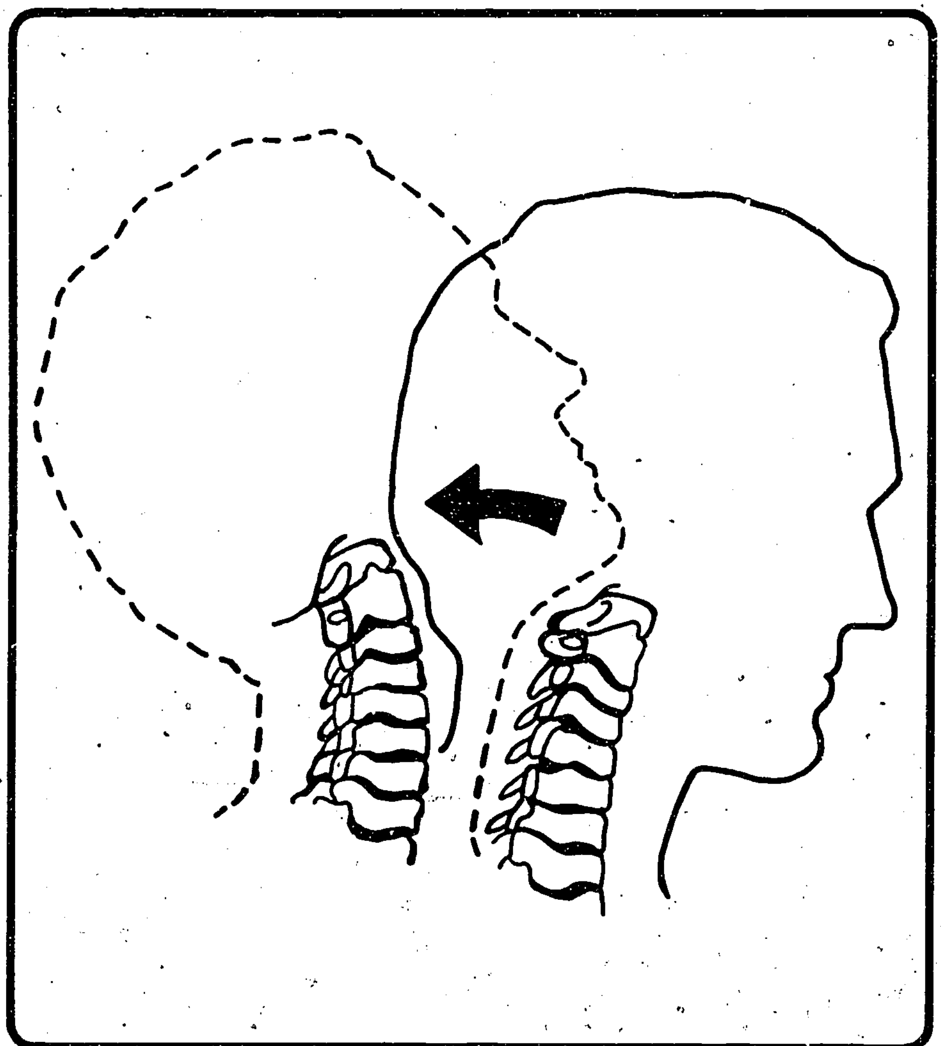

Figure 4: Hyperextension moves the head beyond the straight alignment of the joint.

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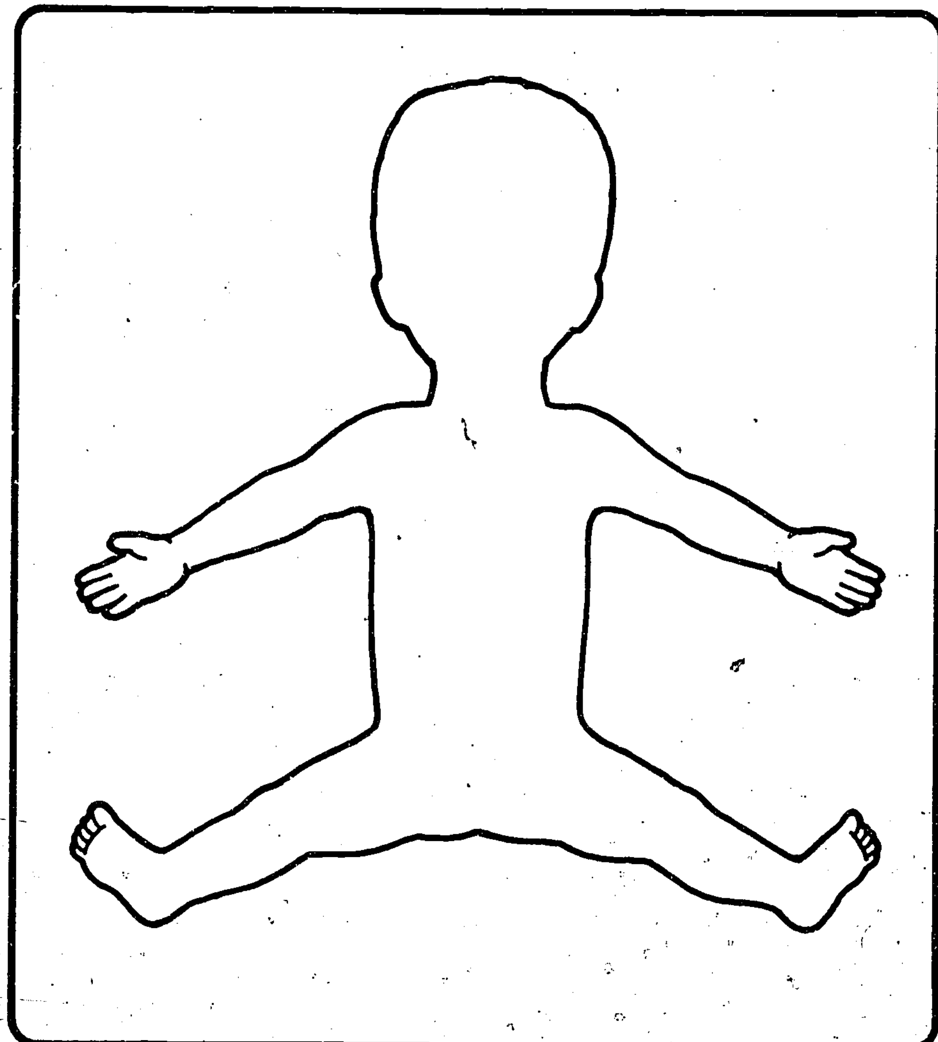


Figure 5: During early embryological development, the upper and lower limbs lie in the same plane.

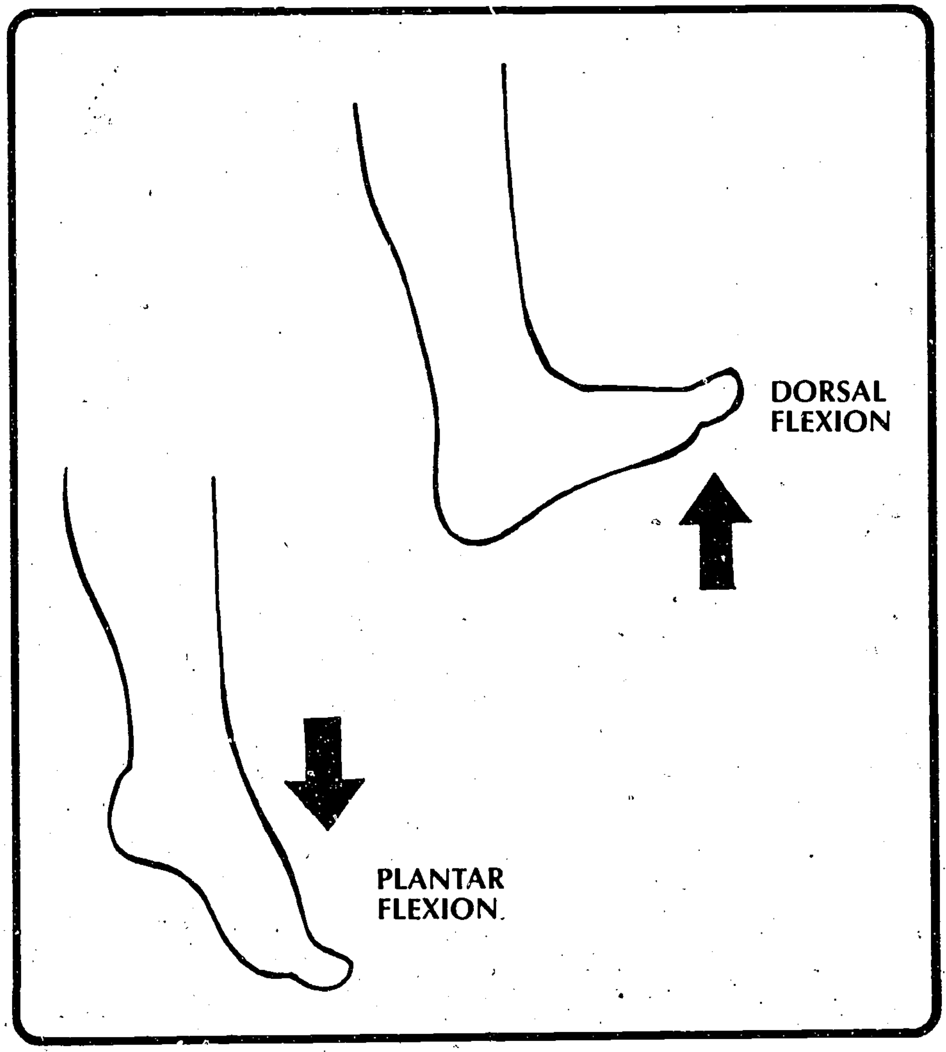


Figure 6: Plantar flexion occurs when you walk "tip toe."

to as either *dorsal flexion*, pulling the toes toward the anterior (front) of the leg, or *plantar flexion* which occurs when you walk "tip toe."

Abduction moves a body part away from the midline of the body. Adduction is the return from abduction

Other movement terms which should be used in describing body movement are abduction and adduction, pronation and supination, rotation, lateral flexion, and forward and backward tilt. *Abduction* occurs at the shoulder and hip joint when the arm or thigh are moved away from the midline of the body. The umpire in baseball signals the runner safe by abducting his arms. *Adduction* is the return from abduction, occurring when the limbs are brought toward the body or returned to their position when standing normally. Abduction and adduction also occur at the wrist joint. Because the hand is used in so many different positions it is often difficult to think in terms of movement toward the body as adduction and movement away from the body as abduction.

Radial flexion is abduction of the hand at the wrist

Ulnar flexion is adduction of the hand at the wrist

To avoid confusion the movement of the hand which reduces the angle at the wrist on the thumb side is called *radial* flexion or *radial deviation*. The radius is the forearm bone on the thumb side of the forearm. The bone on the little finger side of the forearm is the ulna so reduction of the angle at the wrist on the little finger side is known as *ulnar flexion* or *ulnar deviation*.

Pronation and *supination* refer to the hand. The hand is in a pronated position when the palm is down and is in a supinated position when the palm is up.

Medial rotation turns a part toward the midline of the body

Lateral rotation turns a body part away from the midline of the body

Rotation is the turning of a bone around its long axis. Rotation is referred to as medial (inward) rotation in which the bone turns toward the midline or lateral (outward) rotation when the front of the bone turns away from the midline. Rotation occurs in the cervical spine (neck) as you shake your head "no." Medial rotation occurs at the hip joint when you walk in a toed-in fashion. Lateral rotation at the hip produces the toed-out position of the feet. Medial and lateral rotation can also occur at the shoulder joint.

Lateral flexion is sideward movement of the head or trunk

Lateral flexion is the sideward movement of the head and/or trunk. The direction of the movement is identified by right or left. Movement of the trunk cannot be truly labeled abduction or adduction because the midline of the body is not stationary, but is involved in the movement of the trunk and head.

Forward tilt of the pelvis increases the hollow in the lumbar area

Forward and backward tilt are terms which identify pelvis movement. In *forward pelvic tilt*, the crests, commonly referred to as the hip bones, move forward and the sacrum or posterior aspect of the pelvis moves back and up. The forward tilt of the pelvis results in a hollow low back and a protruding

Lateral pelvic tilt raises one hip higher than the other

abdomen. *Backward pelvic tilt* is the act of returning from forward tilt and is accomplished by tucking the hips under. *Lateral tilt* of the pelvis occurs when one iliac crest is higher than the other as is observed when a person stands with the majority of the weight distributed on one foot.

How?

Muscle characteristics influence force production

Contraction of the body muscles provides the major source of internal force. The amount of force produced through muscle contraction is directly influenced by the individual genetic makeup and by the training and practice of various skills. There are certain factors which everyone can utilize to regulate the amount of force produced by muscular contraction:

The number of muscles used will affect the force

1) The *number* of muscles used. To develop maximum force in a given direction use as many of the muscles as possible which will contribute to the movement in the desired direction. Tension should be reduced in muscles which do not contribute in any way to the desired movement. For example, to shoot a basketball from a distance of four feet, the use of the upper limbs is probably sufficient to get the ball to the basket; to develop sufficient force to shoot the same ball from 25 feet, the lower limbs must also be used. If the addition of the force produced by the lower limbs is not sufficient to get the ball to the basket, then rotation of the trunk will be used to increase the number of muscles which are contracting to execute the shot.

The size of the muscle will affect the amount of force possible

2) The *size* of the muscles used. Muscles of the lower limbs are larger in size than their counterparts in the upper limbs. As a result, actions which involve the lower limbs are more powerful than those involving primarily the upper limb. For example, you can kick a soccer ball farther than you can throw it.

Another difference in size is noted when the muscles of the upper arm are compared to the forearm and the muscles of the thigh to the lower leg. The muscles of the arm and of the thigh are larger, hence stronger than the muscles of the forearm and of the leg.

The larger the diameter of the muscle the greater the force potential of the muscle. In other words the force which a muscle is capable of producing is directly dependent upon the physiological cross-section of the muscle. A physiological cross-section includes a cross-section of all the muscle fibers.

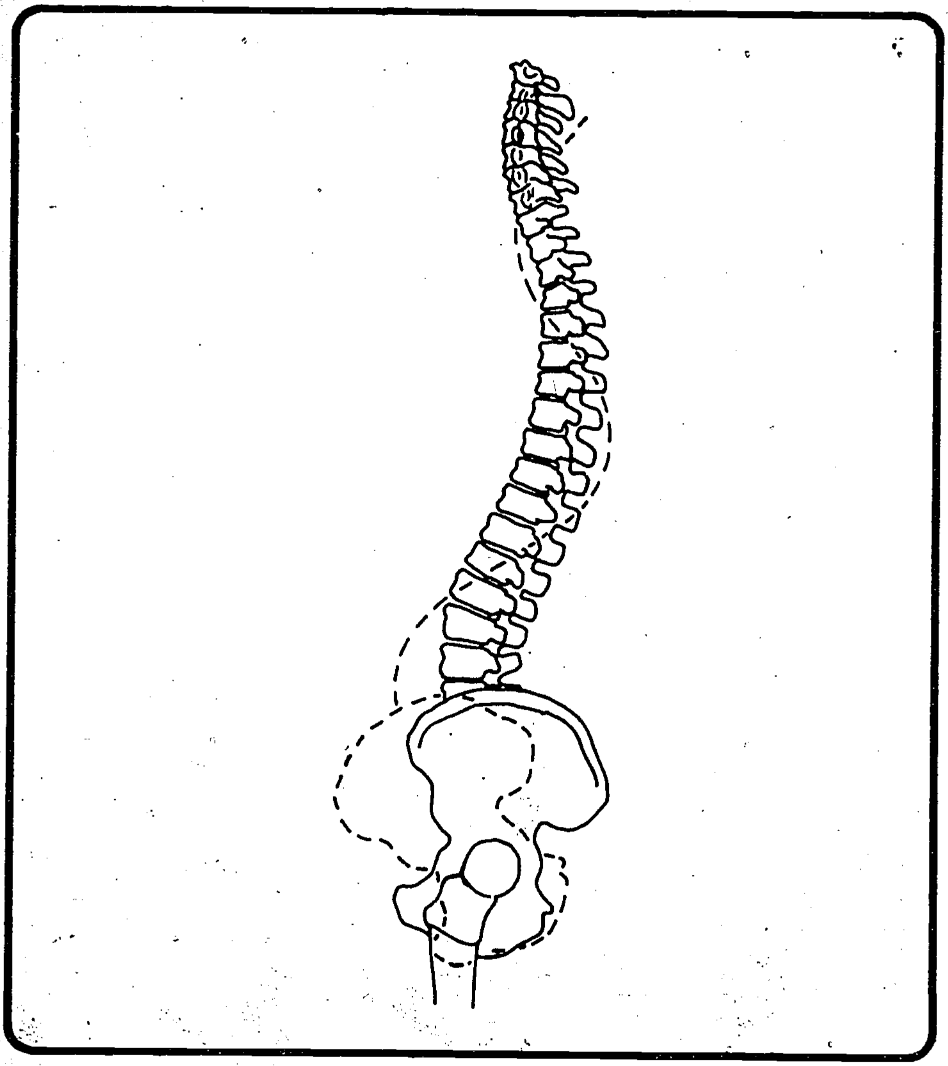


Figure 7: Forward and backward tilt are terms which identify pelvis movement.

When considerable muscle force is needed, such as lifting a heavy box, you should use the strongest muscles possible. The strongest muscle group in the body is the quadriceps femoris, the muscles which extend (straighten) the leg at the knee. To lift a heavy box, for example, you should squat down as close to the box as possible so that the extension of the knees produces the lifting force, while the arms are used primarily for holding on to the box and bringing it closer to the body. Many injuries to the back occur when the person leans over, grasps the box, and tries to straighten up by using the back without first flexing at the knees so that the strong muscle group of the thigh supplies the lifting force as you stand.

Training increases the strength of muscles. Not only do strong muscles usually improve performance, but they also serve to protect the joint against possible injury. Strong muscles must produce force to counter the forces which would otherwise tend to injure the joint structures, particularly the ligaments. The strength of the muscles used in a given activity dictate to a great degree the speed of movement and the distance through which the muscle shortens by controlling the length of the backswing or the depth of the crouch.

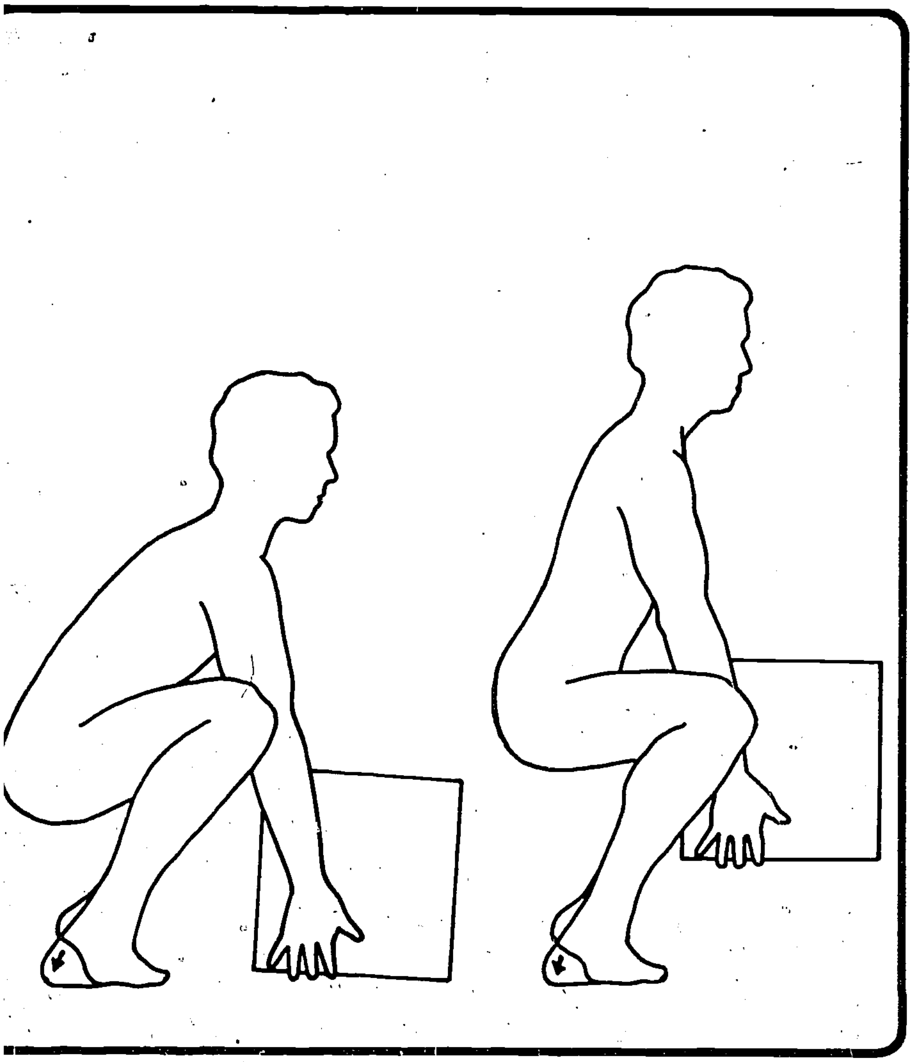
Internal protection mechanisms can be used to increase force

3) The force of a contraction can be increased by first placing the muscle on *stretch*. Placing a muscle on stretch activates a protective reflex contraction. The quicker the muscle is stretched, the stronger the resultant contraction. A crouch before the jump upward or the backswing which precedes a throw are examples of placing muscles on stretch before contraction to utilize this reflex.

Each muscle contains minute structures called *muscle spindles* which seek to protect the muscle from tearing as a result of being stretched beyond a safe range or length. The muscle spindle can be likened to a little radio in that it is constantly sending information to the brain concerning muscle length, the amount of tension in the muscle and whether the muscle is shortening or being lengthened. The muscle is preset by a small nerve from the brain to allow the muscle to operate within set length limits. When the muscle is forced to exceed the set limits, the spinal cord "instructs" the muscle to contract to prevent muscle injury.

The distance through which a muscle contracts affects the force produced

4) The *distance* through which a muscle contracts can increase the resultant force. A muscle which contracts throughout its full range of motion has a greater opportunity to develop more force than it could if it contracted through only a portion of its total range. A full backswing in tennis results in the generation of more force than does a half backswing if the



;ure 8: When lifting a heavy box, use the strongest muscles possible. In this example, e the muscles of the thigh.

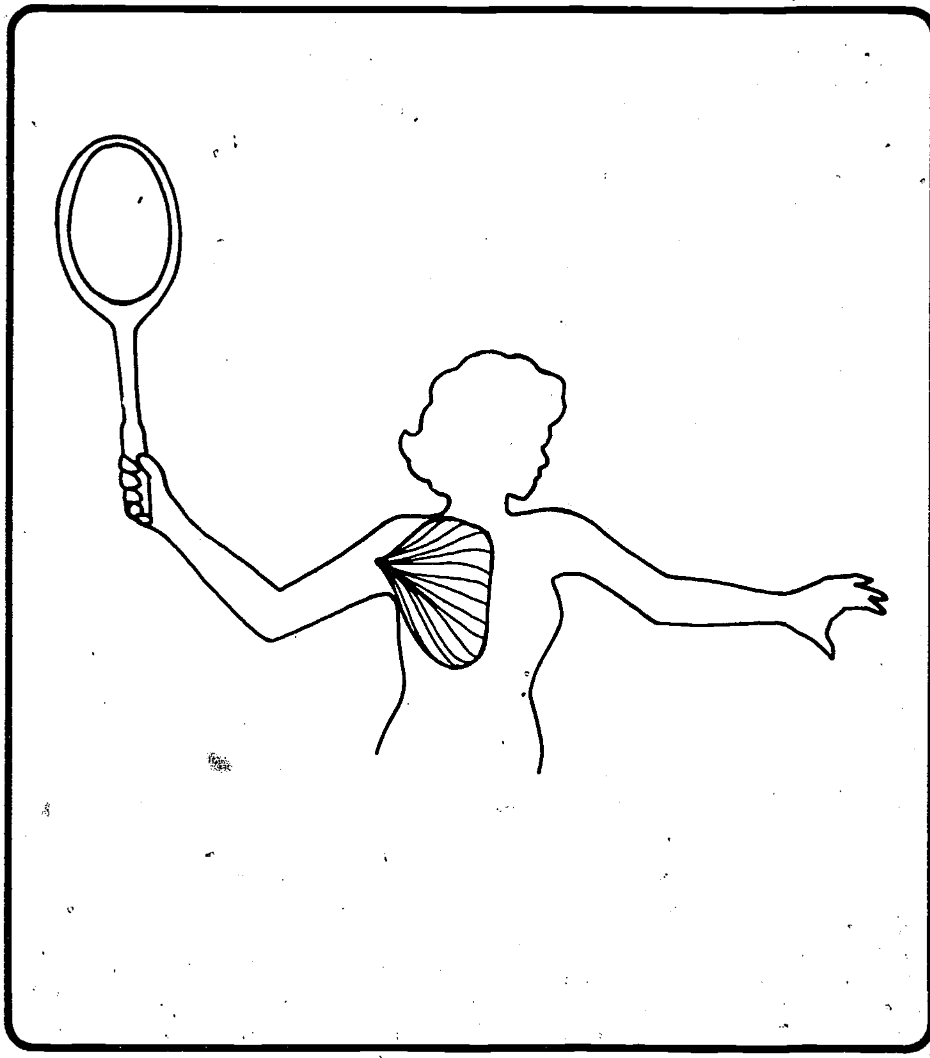


Figure 9: The tennis backswing is an example of placing the pectoralis muscles on stretch before contraction.

speed of the movement is identical. If you want to jump two feet, the depth of the crouch taken prior to the jump is less than that taken when jumping four feet.

Why?

Genetic endowment sets upper limits on capabilities

The specific locations, attachments, and types of muscles in your body are determined by genetic inheritance. The *genetic endowment*, or genotype, will set the upper limits in terms of the amount of strength that can be developed. Your genotype will also play a major role in determining the types of activities for which you are best suited. Some people are good sprinters; others excel in long distance running. Some people show a marked increase in the circumference of muscle groups after lifting weights while others will be just as strong but will not exhibit as great an increase in muscle bulk. In a vertical jump, some person can raise their reach only 12 inches above their standing reach while others may increase the reach to as much as 30 inches or more. Each individual needs to recognize what the genetic limits of his or her own physique are and then goals can be set more realistically. Genetic inheritance, however, is only one aspect of performance. Practice and training are also very important for they help approach your maximal genetic potential. The increase in muscle size will not be the same for all individuals after training due to genetic differences.

Mechanical advantage can be gained by location of muscle attachment

Individual differences in movement strength are also affected by the point at which the muscle attaches to the bone. Muscles may attach closer to the joint in some people than in others. In general the farther from the joint the muscle attaches, the greater the effective force, or joint torque, produced by muscle contraction.

Ratio of muscle fiber types varies in different individuals

Most human muscles contain three types of muscle fibers—fast, intermediate, and slow. The fast fibers are known as white or *fast twitch fibers* and can contract rapidly resulting in explosive movements. The *slow twitch fiber*, sometimes called red, is the endurance fiber. Red fibers contract less rapidly, but can continue activity for a longer period of time. Most people have a ratio of fast and slow muscle fiber types that would fall within the 40%-60% range. Excellent and elite performers, therefore, have a higher ratio of the fiber type best suited for their activity. Elite long distance runners have as high as 80%-85% slow fibers in muscles of the lower limbs.

Those persons with a higher percentage of fast twitch fibers in their lower limbs are the ones with great leaping abilities such as the 5'10" basketball player who can out jump the 6'6" player. A muscle biopsy is necessary to determine the specific ratio of fiber types in a muscle. You may perform a very simple test to learn whether or not you seem to be suited for sprint or for endurance activities. That test is the vertical jump — or jump and reach test. If you can increase your standing reach by over 18"-20", then you probably will do better in sprint activities. These results assume that low muscular strength, obesity, or poor neuromuscular coordination are not the cause of the small increase in the jump and reach. It has been shown that training may improve the efficiency of contraction, but does not seem to markedly change the ratio of the fast contracting fibers to the slow contracting fibers.

A motor unit is a motor nerve and the muscle cells which it innervates

Muscle fibers in a motor unit contract according to the "all or none" law

Another factor which cannot be altered by practice or training is the number of muscle fibers in each motor unit. A muscle consists of bundles of muscle cells. A muscle cell is called a *muscle fiber*. Several of these fibers are innervated or supplied by a motor nerve. This is the *motor unit* — a motor nerve and the muscle fibers (cells) which it innervates. The strength of a muscle contraction is determined by the number of muscle fibers in contraction at the same time. When the motor unit fibers are stimulated to contract, they contract maximally. The force of contraction is reduced by calling into action fewer motor units. When a nerve impulse reaches the muscle, it innervates all the fibers of the motor unit which it supplies. A maximum muscle contraction requires all, or nearly all, of the muscle fibers to contract simultaneously. A maximal contraction can therefore be held for only a short time, because the fibers soon fatigue. Submaximal muscle contractions in which only some of the motor units contract can continue for longer periods of time because the motor units can rotate in and out much as substitutes in a basketball game. A team that has only five players cannot play for as long without resting as a team with substitutes. When substitutes come in, individuals may have rest periods to recover the necessary strength to continue.

Motor units of the lower extremity contain more muscle fibers than those in the upper extremity

All motor units do not contain the same number of fibers. For example, only two or three fibers compose a motor unit in small muscles which control movements of the eyeballs. Several hundred fibers constitute a motor unit in calf muscles of the leg. In general, there are more muscle fibers in the motor units of the muscles of the lower extremity than in the upper extremity. That is why the hands are capable of finer and more

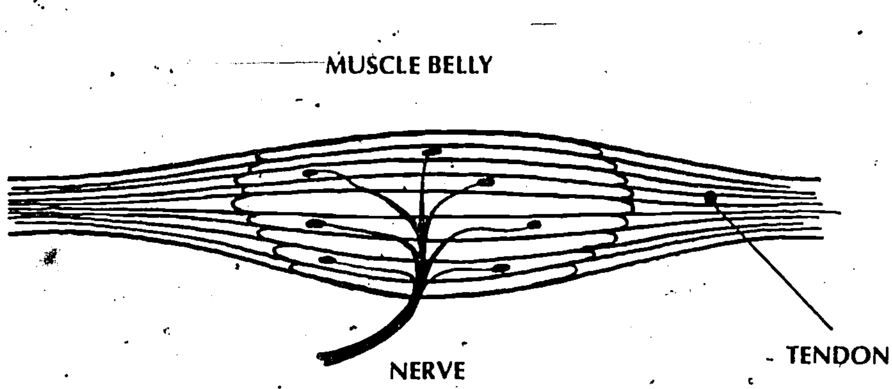


Figure 10: This is the motor unit — a motor nerve and the muscle fibers (cells) which it innervates.

precise movements than the feet. The strength of contraction of a single motor unit, the smallest unit of contraction, will be greater in the lower extremity than in the upper extremity.

Through practice, it is possible for some persons to learn to contract only a single motor unit at one time. Thus the reduction of muscle tension is the goal of neuromuscular relaxation. Many persons can therefore improve their coordination by learning to contract only those muscles necessary to the execution of the task at hand, and only to the degree necessary to provide adequate strength of contraction. A skilled player can eliminate the extraneous movements in an action and is thus more efficient.

In summary the following are inherited factors which determine the magnitude of effective force which a muscle can produce:

1) the distance between the muscle attachment and the joint axis of rotation;
2) the ratio of muscle fiber types in each muscle;
3) the number of motor units in a muscle;
4) the number of muscle fibers per motor unit.

What Else?

External forces will produce or alter movement

If you were to move in a vacuum, you would be only limited by the basic action of the muscle on the joint. But other external forces come to play on movement and influence it in a myriad of ways. Unless you understand these forces, your movements can be inappropriate, non-productive, and awkward.

You must consciously learn to predict which force will alter your movements and become skilled in accommodating these conditions. Also in many sports, dance or in your daily movement tasks, you may wish to alter the environment so that it works with, rather than against you. An efficient performance demonstrates the control that the performer has over both external and internal forces.

In the preceding section the internal forces which are produced by muscle were discussed. Now, let us look at external forces which produce and/or affect all movement. Probably the first external force that one thinks of is gravity.

Gravity attracts objects to the center of the earth

Gravity is the force which keeps us from flying off into space. It is this gravitational force which brings the pole vaulter back to the pit, and the thrown ball down to the ground.

Friction develops when an object moves across another

Friction does not exist until one surface moves over another. Although friction is a resistance, it can be beneficial to our movement. We would have difficulty walking if we did not have friction between our feet and the ground.

Water and air provide fluid resistance

Fluid resistance is the third type of external force. Fluid forces act on all objects which move through the air or through the water. Fluid resistance enables the baseball pitcher to curve the ball on its way to the plate.

How?

When we are performing an action in which the force is directed downward, gravity is an ally and increases the speed of the downward movement. Gravitational force is not so helpful however, when we want an upward projection. Here the constant downward direction of the gravitational force is a resistance to movement which must be overcome. It takes much more effort to jump over a five foot fence than it does to jump down from a five foot fence. Unless you are in a hurry, the only force that would be needed to jump down from the fence is enough to step off the fence. The force of gravity then brings you down to the ground when you are no longer supported by the fence.

Size, shape, surface and speed of movement affect the amount of resistance

While the force of gravity is often used to put objects in motion and to accelerate an object which is moving downward, the external forces of friction and fluid resistance serve to slow the speed of movement and/or to alter the flight path. The amount of resistance produced by these forces depends upon the size, shape, and smoothness of the surface of the object and the speed at which it moves through the fluid. The fluid itself also affects the resistance. The heavier the fluid the greater the resistance.

Drag refers to the resistance an object meets as it moves through a fluid

Fluid forces are drag, lift, and the magnus effect. *Drag* is the resistance to an objects' movement through a fluid. This drag may be a result of friction or of pressure. The surface of an object affects the frictional drag force. The smoother the surface, the less the resistance. Compare the changes in the clothing worn by the Olympic speed skaters in the 1980 Olympics with that worn twelve years earlier.

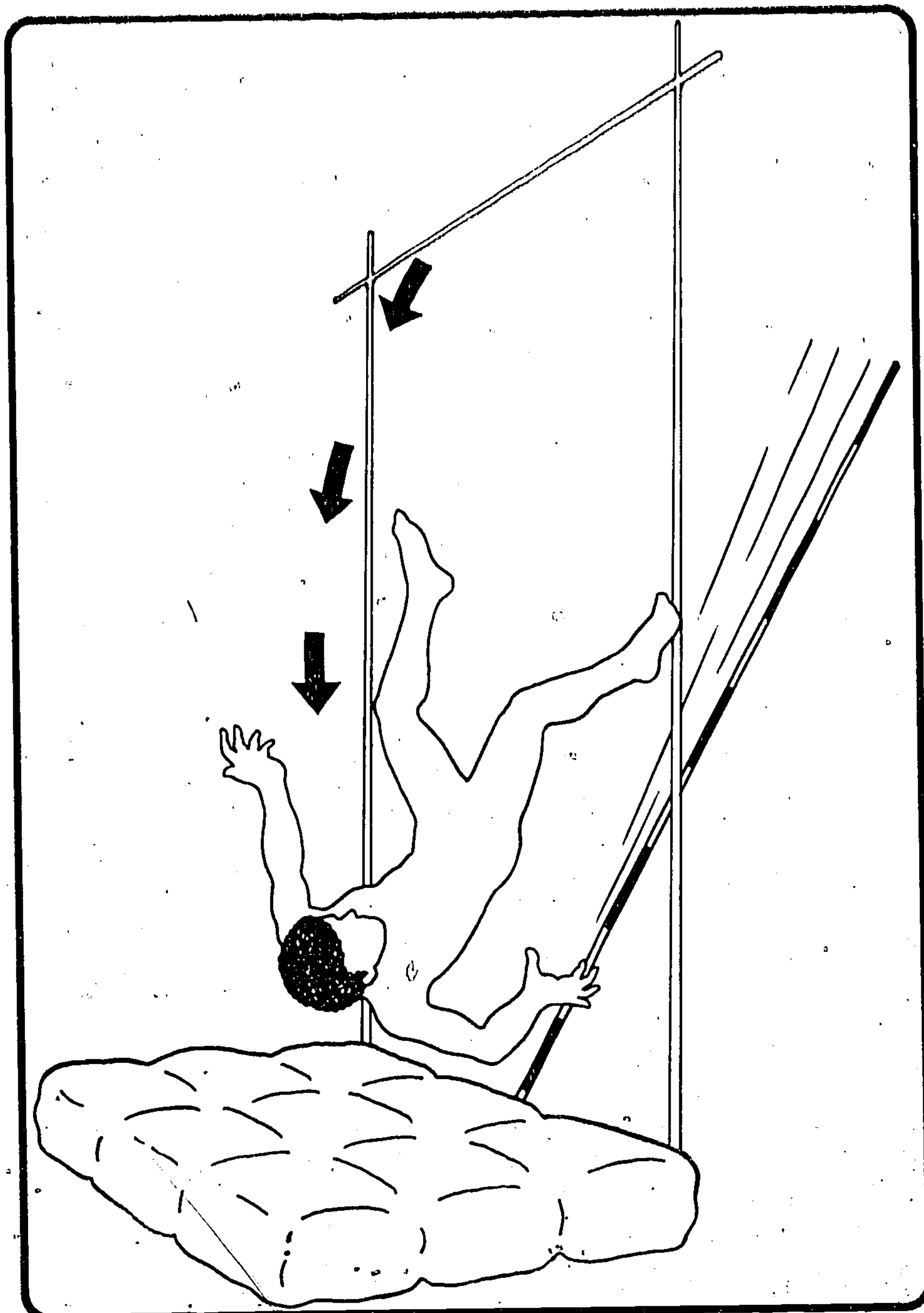


Figure 11: Gravitational force brings the pole vaulter back to the pit.

The drag force resulting from pressure is a function of area of the object presented to the air or water as the moves through it. The speed skater does not stand ur skates the entire race in a flexed position. The trunk bends forward at the hips and the back is kept as flat as possible.

Lift is the force which is perpendicular to the drag

Lift is the force which is perpendicular to the path of motion of an object as it moves through a fluid and is, therefore, perpendicular to the drag. It is the lift which keeps objects airborne. The ski jumper seeks a position that will keep him airborne as long as possible to increase the distance of his jump. Friction and fluid resistance are forces that must be overcome or countered by the forces being used to put an object in motion or keep it moving at a constant speed.

Why?

Gravity is perpetual and always acts in the vertical direction

Gravity is the attraction that the earth has for all bodies. Because of this attraction it causes objects to fall toward the center of the earth at the rate of 32 ft./sec./sec. Gravity is always acting and always acts in a vertical direction. In freely falling bodies the rate of fall due to gravity can be slowed by using the resistance of the air. A sky diver can alter the speed of his fall by using different body positions. Presenting a broad surface slows the rate of fall, as does the parachute, while the rate of fall is increased by falling feet first.

Sliding friction is a gripping force

The two types of friction most often of concern to human performance are sliding friction and rolling friction. *Sliding* friction acts only when a body is in motion or has some tendency to start moving across the surface of another body. The amount of friction between two bodies can be modified by altering the nature of the surfaces and/or changing the forces that hold the two surfaces together. Some examples of situations in which we try to improve our grip by increasing the friction between two surfaces are the use of a golf glove, the use of resin by the baseball pitcher, and wearing rubber soled shoes when walking on ice.

In some situations, it is desirable to reduce the friction between the two adjoining surfaces. The bowler wears a leather soled shoe on the sliding foot and the skiier uses waxed skis. The deck of a swimming pool becomes a hazardous place to walk when it is wet because of the reduced "grip." Removing some of the books from a box which is too heavy to push across the floor is an example of how the amount of sliding friction is affected by changing the forces which hold the two surfaces together.

Rolling friction opposes an object's motion as it rolls across a surface

Rolling friction is the result of the deformation of the two surfaces. Field hockey players must hit the ball harder when playing on a field with tall grass than when the grass has been recently cut or when they are playing on an astro-turf type surface.

Fluid resistance varies with the square of the velocity

Air resistance is most often thought of as wind. This, however, should not be a synonymous usage. In the absence of wind, air resistance is increased by increasing the speed with which you move. You have probably experienced this by holding your hand out the window of a moving car. When a car is traveling at 20 miles an hour, little resistance is noticed, but when the car is traveling 40 miles an hour, considerably more muscular effort is required to keep your hand in position. Fluid resistance varies with the square of the velocity. This is true in the air or in water. In the example just cited the speed was doubled which means the air resistance increased four times.

The larger the object the greater the fluid resistance

In activities which are held out-of-doors, wind can have either an adverse or a positive effect on performance. Running into the wind results in slower progress whereas riding a bicycle uphill with the wind blowing at your back makes the hill climbing much easier. In general the larger the object, the greater the air resistance (drag). In this case there is a larger surface presented for the air to push against. You have probably experienced this when you held your hand out the car window. When a car is moving fast, less resistance is felt when the fingers or the side of your hand is held into the wind than when the palm of the hand is facing forward.

Swimmers use drag to their advantage when they place their hands so that they can "grab" on to the water. The palm is facing the direction opposite that in which they will move. In actuality, the swimmer "holds" on to the water and "pulls" the body over his hand. As you paddle a canoe or row a boat, the same thing is done. You present the broad surface of the paddle or oar to the water so that maximum resistance (drag) will be encountered. As you apply force to the paddle or oar, the water resists and the canoe or boat glides through the water.

To reduce the resistance of the water, the canoeist "feathers" the paddle on the recovery by turning the edge of the paddle to the water. This reduces the amount of surface area presented to the water and reduces the drag. The swimmer in the recovery phase of the side stroke reduces the surface area, and hence, the drag as the hand "sneaks" back through the water by leading with the finger tips.

The Magnus effect explains how balls can curve as they move through the air. This capacity to curve is desirable if you are the softball pitcher, whereas, a long fly ball which curves foul is not appreciated by the batter.

When a body rotates, it tends to carry with it the fluid which is in contact with its surface. This "covering" of fluid affects the fluid that it adjoins. When the fluid "covering" and the fluid through which the object is moving are moving in the same direction, an area of low pressure is created.

When the fluid "covering" is moving in a direction opposite that of the fluid through which the object is spinning an area of high pressure is created. This difference in pressure causes the ball to move in the direction of the low pressure. Whether a ball moving through the air exhibits top spin, back spin, or side spin depends upon where the areas of high and low pressure are located relative to the flight path of the ball.

What Else?

The point at which the force is applied affects the action

When force is used to produce, to stop, or to alter the motion of an object, the point at which the force is applied to an object is important. If the object is to move in a straight line or in a *linear* fashion, the force must be applied through the center of mass of the object and the entire object must be free to move. If an object is resisted at one edge, like the page of a book, the only possible type of motion is *rotatory*, around the bound edge of the page.

Another way in which rotation can occur is when the force is not applied or received through the center of the object's mass. An off-center application of force is used when spin or a rotating action is desired. Baseball pitchers, and batters, are very familiar with the use of spin to make the ball rise, drop, or curve as it travels to the plate. Rotation is also produced when a linear movement is suddenly checked. An example would be sliding on a waxed floor and suddenly hitting a rug. Suddenly you find yourself moving head first, or attempting, in some way, to get your feet back under you.

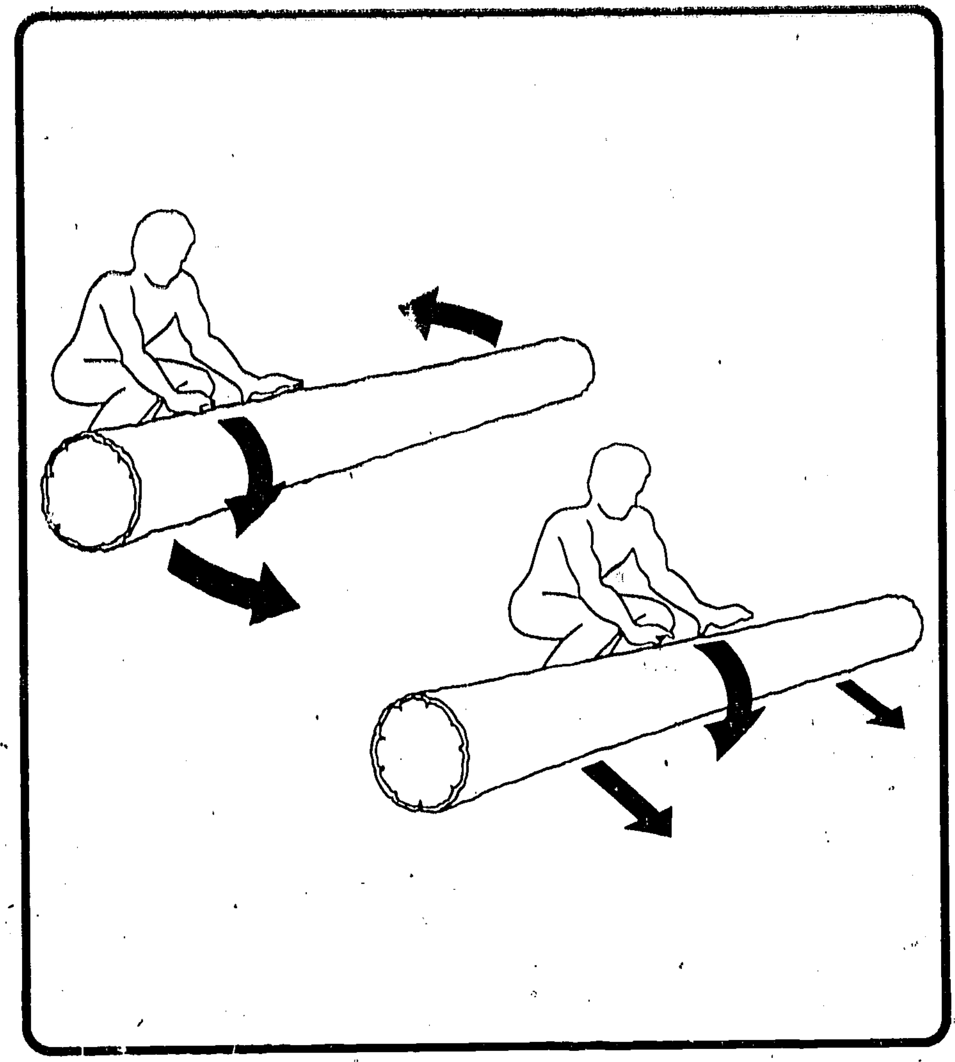


Figure 12: An off-center application of force is used when spin or rotating action is desired. A center application is used to move an object in a straight line.

How?

Motion occurs when the forces acting on an object are greater in one direction than in another

Motion results when the forces acting on a body are greater in one direction than in another. The object will move in the direction of the greater force. When you bump a glass of water with the back of your hand the glass tips over.

If two or more forces are acting in the same direction they may be totaled. Thus a balloon thrown into the air in the same direction the wind is blowing will travel a distance equal to the velocity of projection and the velocity of the wind.

When two opposite forces act on an object, movement will occur in the direction of the force with the greater magnitude. A golf ball hit into a net causes the net to move in the direction in which the ball was traveling.

Why?

The movement path of an object is determined by its speed of rotation and its projection velocity

The resultant motion or movement path of an object is determined by the speed with which the object is rotating and the speed with which it is traveling in a horizontal direction. The slower the velocity the greater will be the deviation from a straight line as a result of the spin force. A ball which travels faster reduces the effect of the spin. The effect of the spin is seen earlier in a slow moving ball, and late or not at all on a rapidly moving ball. Sometimes a ball is caught before the spin has acted on the ball. The effect of spin and the rate of movement is easily seen on a bowling ball. Often the ball does not stay on the lane because the spin applied to the ball at release has caused the ball to go into the channel (gutter) before reaching the pins. A ball which is delivered with too much linear spin reaches the pins before the spin force can act.

What Else?

Not all of our movements are used to put objects in motion. There are many occasions in which we want to stop or to slow a moving object. The moving object may be your own body landing from a jump or a dive or it may be the catching of a ball or landing after a fall from a balance beam.

The quicker the moving object is stopped, the greater is the risk of injury to the body or of rebound from the body. In some instances, we intend for a ball to rebound from our body such as the hump pass in volleyball. In this case, it is important to know how to slow down the rebound to the desired rate of speed.

How?

Increase distance and size of area to safely absorb force

The moving object should be slowed by increasing the distance through which the object moves after contact, and/or increasing the size of the area which is absorbing the force of the object. This will keep the risk of injury and the chances of the object rebounding from the body to a minimum.

Why?

To lessen the rebound, increase the distance over which force is to be absorbed

Catching involves the absorption of force of a moving object. A ball is not often caught if the hands and elbows are stiff. The ball will rebound quickly from a firm surface, especially if the ball is approaching at high speed. A surface can be made less firm by reaching for the ball and "giving" at the elbow and shoulder as the ball makes contact and by bringing the ball and hands in toward the body. This increases the distance over which the force is absorbed. The distance can be increased even more by allowing the ball to come along the side of the body. The distance can be increased further by having the body weight primarily over the forward foot when the ball contacts the hands and shifting the weight to the rear foot as the ball is brought in toward the body. If shifting weight and permitting the ball to come behind the body still does not adequately dissipate the force, one must then attempt to step or to run backward with the object.

Another way to think of increasing the distance through which a force is absorbed, is to think in terms of increasing the time over which the force is absorbed. The first thing to keep in mind is to flex or to give with the joints when landing. You will then end in a crouched position as a result of the flexion at the ankle, knee, hip, and intervertebral joints. If total flexion still does not adequately absorb the force, a series of rebounds into the air will increase the time of absorption. This is frequently seen when cheerleaders land from a jump or leap and absorb the force by one deep landing followed by two or three bounces which use considerably less flexion of the joints.

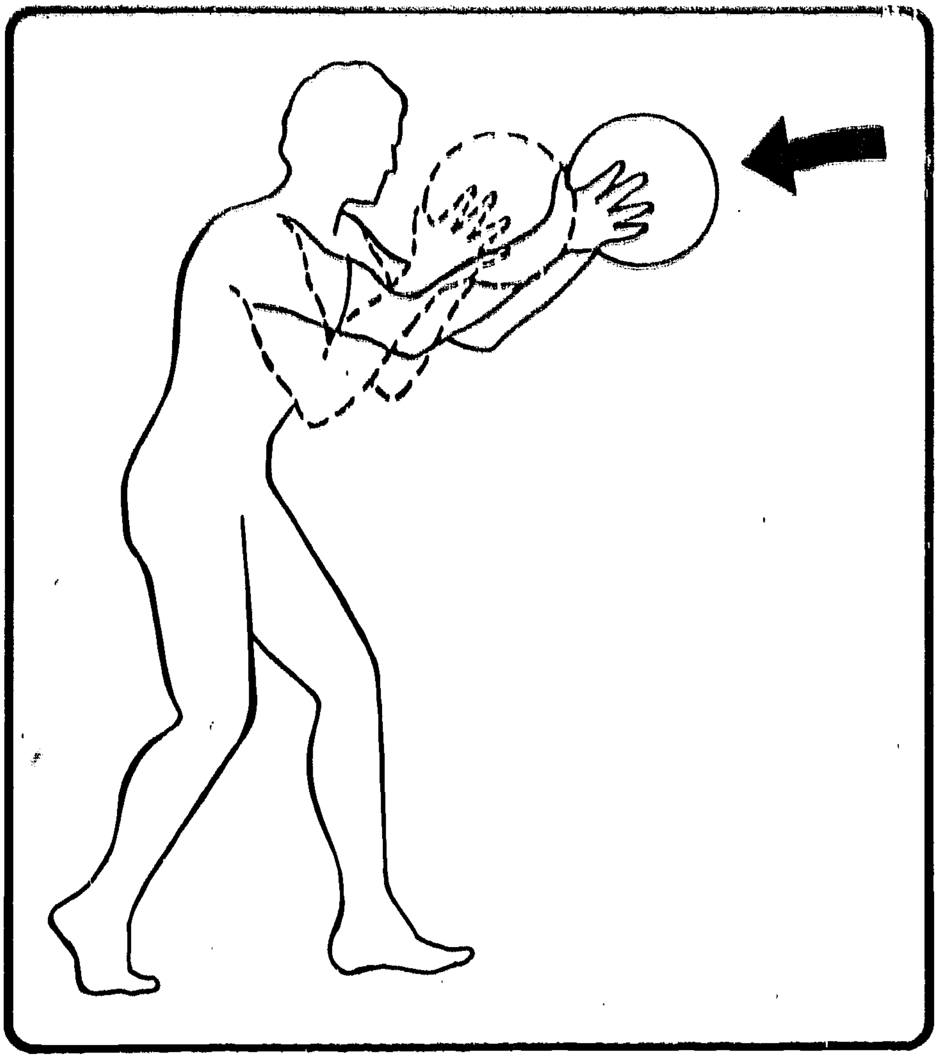


Figure 13: "Giving" with the ball at the elbow and shoulder joint increases the distance over which the force is absorbed.

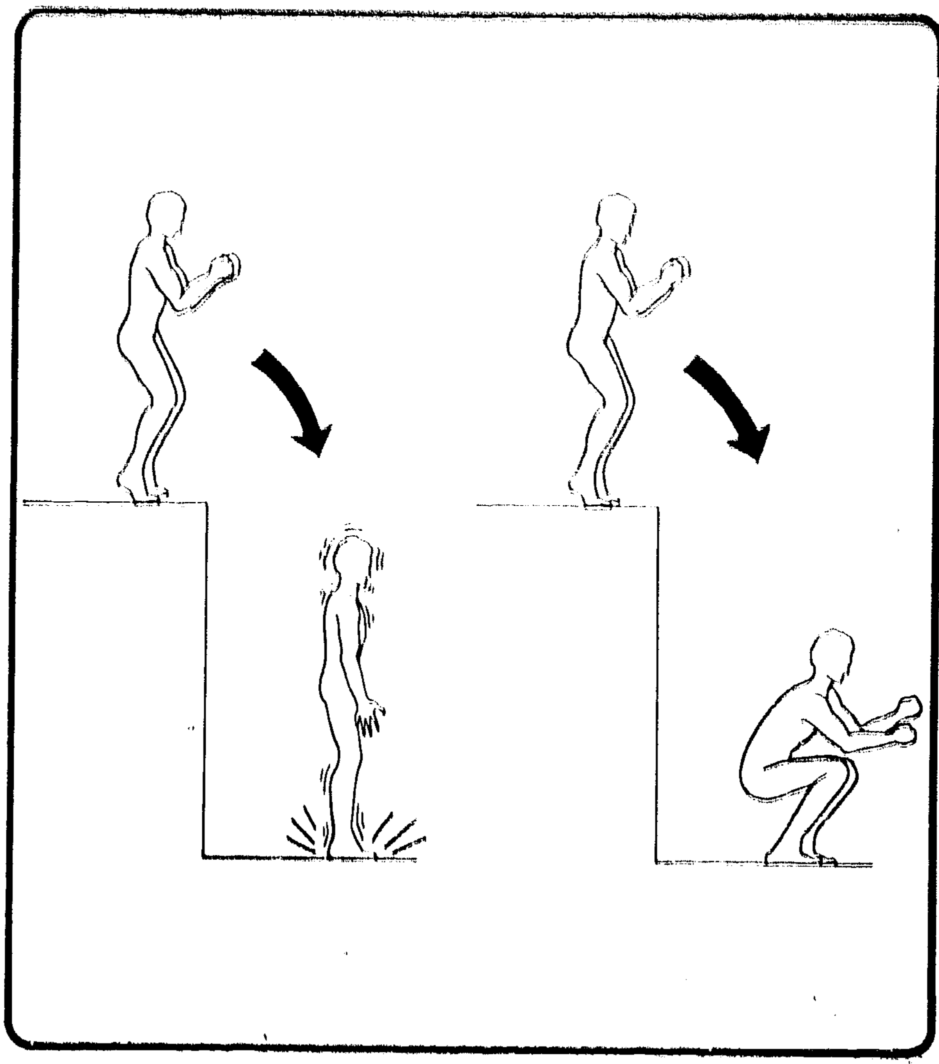


Figure 14: Flexion helps absorb force.

To lessen rebound, increase the size of the receiving area

The size of the area receiving the force of a ball can be increased by catching the ball in the hands and forearms as is sometimes done with large balls, those with odd shapes, or ones which are heavy. A second way is to use a mitt or a glove to catch the ball. The padding also permits the ball to move through a greater distance after contact than does the minimal padding over the bones of the hand.

Landing on the more muscular areas of the body such as a hip or a thigh rather than the bony areas such as an elbow, a knee, or an outstretched hand, increases the area absorbing the shock of a fall. Many injuries occur to wrists because people try to break the fall when falling backward by reaching with the hands rather than landing on the hips. If the force of the landing is quite large, then a roll will help to dissipate the force by increasing the time over which the force is absorbed. Parachutists would suffer many fractures when landing if they did not learn how to roll to gradually absorb the force of the landing. Gymnasts violate these principles and land from their dismounts with little or no flexion in the joints of the lower limb. This is an exhibition of their ability to control their body position to the extent that the body weight remains over the feet when they land. If they have not executed the dismount with precision, you will see them flex the joints or be forced to take a step or two to regain their balance.

What Else?

Force is required to change the direction of moving objects

Force is required to alter the direction in which objects move. A drop shot in tennis and a pitch shot in golf are both examples of the effect of forces altering the directions of an object. In both cases the rebound of the ball is affected. Why does a basketball which is thrown out on the floor return to the thrower?

A spinning object will rebound from a surface in the direction it is spinning

What you are seeing in the above situations is the effect of spin on the rebound of objects when they contact a solid surface. A ball will rebound from a wall or a floor in the direction it was spinning, or rotating, when it makes contact with the surface.

How?

To play catch with yourself, you must push the bottom of the ball away from you so that it spins backward; that is, the top of the ball seems to be coming back toward you. When the ball hits the floor, it will then come back to you. The faster the ball is spinning, the sharper the angle of the return. When the ball goes to the side as you are bouncing it, the ball was spinning to the right or to the left when it contacted the floor. In other words, you did not push with equal force with both hands or if you were using just one hand, you did not push through the center of the ball, but off to one side causing the ball to spin.

Spin results when force is applied off center of the object

In order to cause a ball to spin, force must be applied to the ball off-center. This force can be applied by the hands, a racket, or the foot when kicking. The source of the applied force is not important. The two factors which determine the behavior of the ball are where the force is applied relative to the center of gravity of the ball, and the amount of force applied.

When the top of the ball is moving away from you, the ball is said to have *top spin*. Conversely, when the top of the ball seems to be coming back toward you, this is called *backspin*. These spins are occurring around the horizontal axis of the ball and will alter the height and length of the rebound. When the ball rotates around a vertical axis, as though the ball were on a rod which could be stuck in the ground, the spins created are called *right* (clockwise) and *left* (counterclockwise) *spin*. These spins affect the direction of the rebound but not the height or distance.

Spin is applied to a ball by administering the projecting force off center. The diagram on page 34 may help you to understand the spin which will result when force is applied at a specified point on the ball. In actual situations a ball is usually experiencing a combination of spin forces rather than only one.

If a ball is thrown with the projecting force applied at point 1, no spin will result because the force is applied through the object's center of gravity. This assumes that the ball is perfectly symmetrical. This is not always the case due to the presence of inflation valves and/or laces on the ball. Projection forces concentrated at point 2 will result in topspin, at point 6, backspin. Force applied at point 4 causes the ball to go to the left, at point 8, to the right. Points 3, 5, 7, and 9 represent locations which will produce a combination of top or backspin with right or left spin. For example, kicking the ball at the point 5 location will apply back and left spin to the ball. When the ball lands, it will tend to rebound slightly to the right and retreat. When a batted ball is contacted at point 9, the rebound will be to the left and away from you. The speed

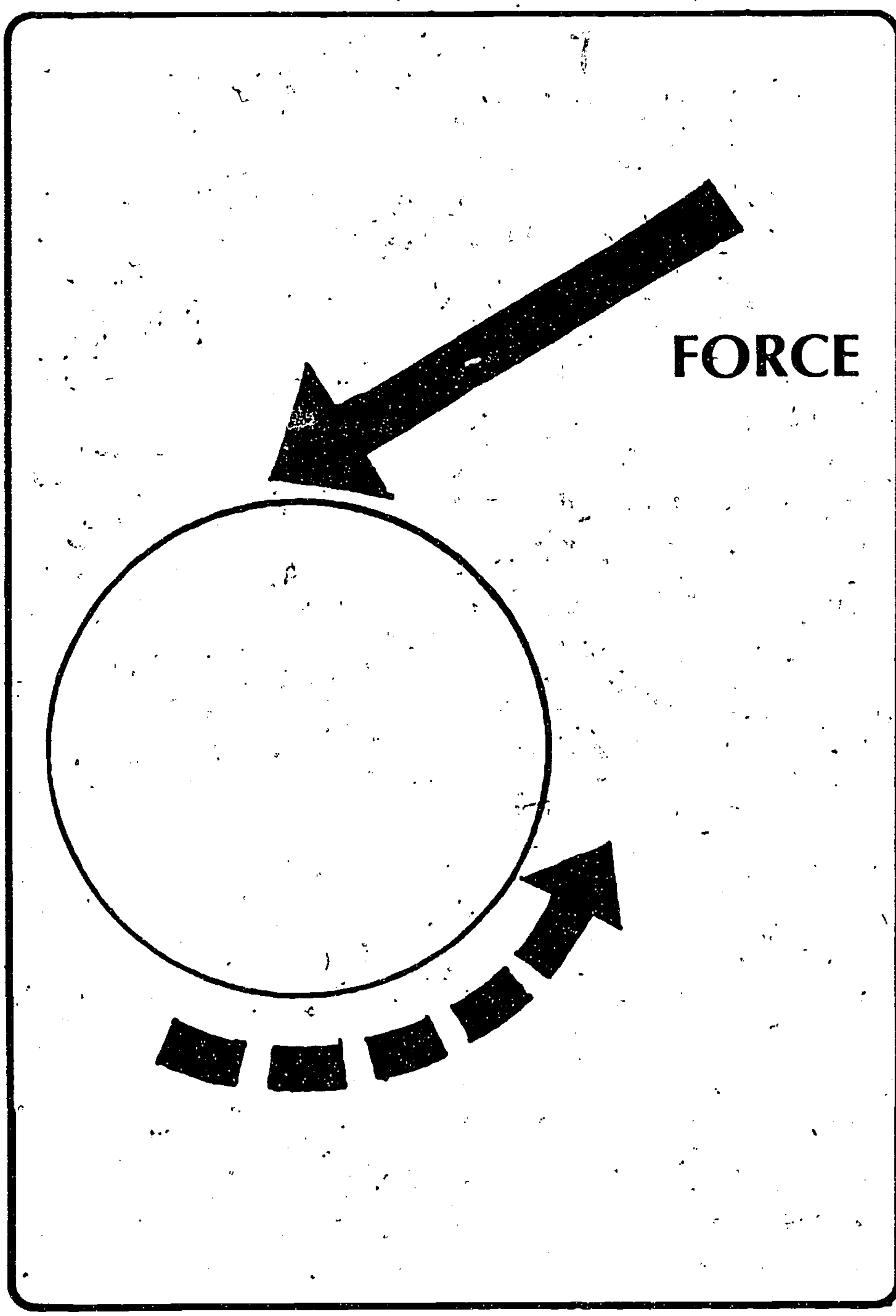
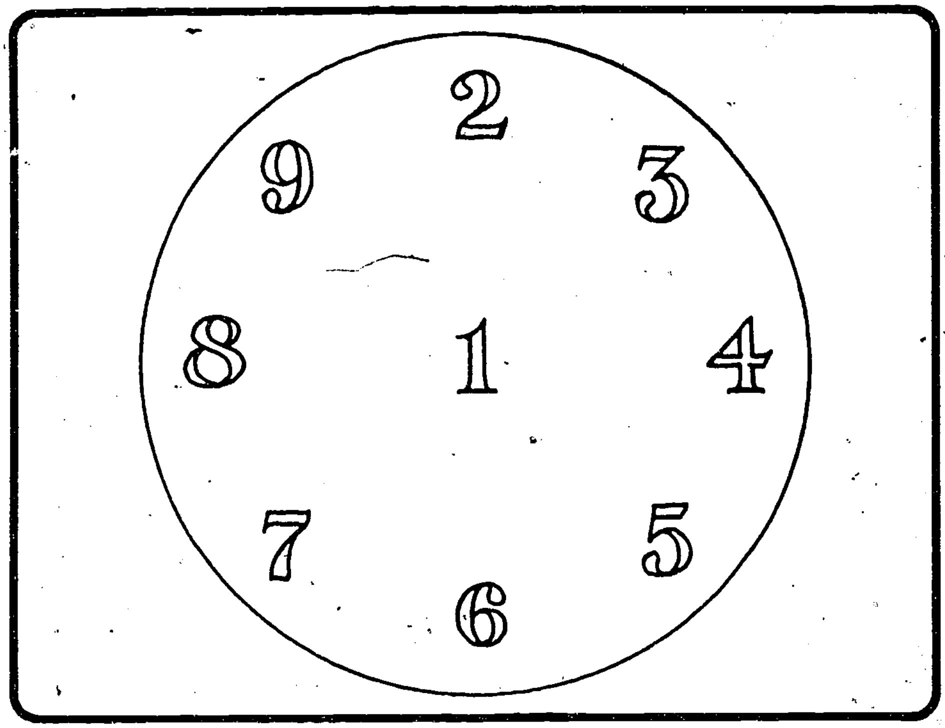


Figure 15: One of the factors that determines the behavior of a ball is the point at which force is applied.



and length of rebound are determined by the amount of force applied at contact.

Why?

Theoretically the angle of incidence equals the angle of rebound. That is a ball with no spin will rebound from a flat surface at the same angle at which it approached the surface. In actual practice this is rarely true but it will serve as a basis to explain how spin alters the rebound behavior of a ball.

Three factors affect the angle of the rebound:

1) *spin* that the ball possesses prior to contact;

2) the amount of *friction* between the ball and the contact surface;

3) the amount of "give" to the ball which is known as its *coefficient of restitution*.

The faster the top spin the faster the rebound

The greater the forward (top spin), the closer the ball will stay to the surface from which it rebounds. A ball which possesses back spin prior to contact will rebound at a more vertical angle. If there is sufficient spin the ball will rebound from the surface in the direction from which it came. Skilled tennis players are able to apply sufficient back spin to a drop shot causing it to bounce back across the net before the opponent can get a racket on it! Top or forward spin also will increase the speed at which the ball rebounds from the surface. The more top spin the faster the rebound.

An object that skids is not affected by its spin while skidding

The friction between the ball and the surface determines when the spin force takes effect. A ball which skids through its first bounce will behave as though it had no spin at all. The first bounce will reduce its forward motion and the spin will then take effect on the next contact. Golfers hitting an approach shot to a wet green have experienced this. The delayed effect of the spin force is also seen in ten pin bowling when the ball contacts the lane and skids several feet before beginning to roll. Spin on the ball is ineffective while the ball is skidding.

A soft ball will rebound lower than a hard ball given the same size and applied force

Some energy is converted into heat at impact

A ball with a low coefficient of restitution will stay closer to the surface from which it rebounds than will a ball with a higher coefficient of restitution. A soft or spongey ball loses more energy as it is deformed upon contact and therefore rebounds more slowly from the surface. A "hard" ball, such as a golf ball rebounds more sharply. Energy lost at impact is converted into heat so that the ball is hotter after impact than it was before. This fact is of little importance for single bounces or impacts, but in a game such as squash or racquetball, where the ball is hit in rapid succession, the ball will get noticeably hotter and play faster.

Spin in the direction of flight will cause the rebound to be closer to the surface than if the spin is opposite to the direction of flight

Right spin causes a ball to rebound to the left. Left spin causes a right rebound

Balls behave in a similar fashion as they rebound from a wall or some vertical surface. A basketball with top spin around a horizontal axis will rebound farther from the backboard and one with back spin will stay closer to the board on the rebound. This is why good shooters usually release the ball so that back spin is applied. This not only brings the ball down at a more vertical angle to the basket, but it will keep the ball closer to the board on a rebound and increase the possibility of the ball dropping in on the rebound. In racquetball a ball approaching the wall from below with top spin will rebound closer to the wall whereas a ball with back spin will rebound farther away from the wall. In games such as handball or racquetball where the rebound of the ball from the wall is altered by the type and amount of spin applied to the ball at contact, the ball frequently is spinning about a vertical axis

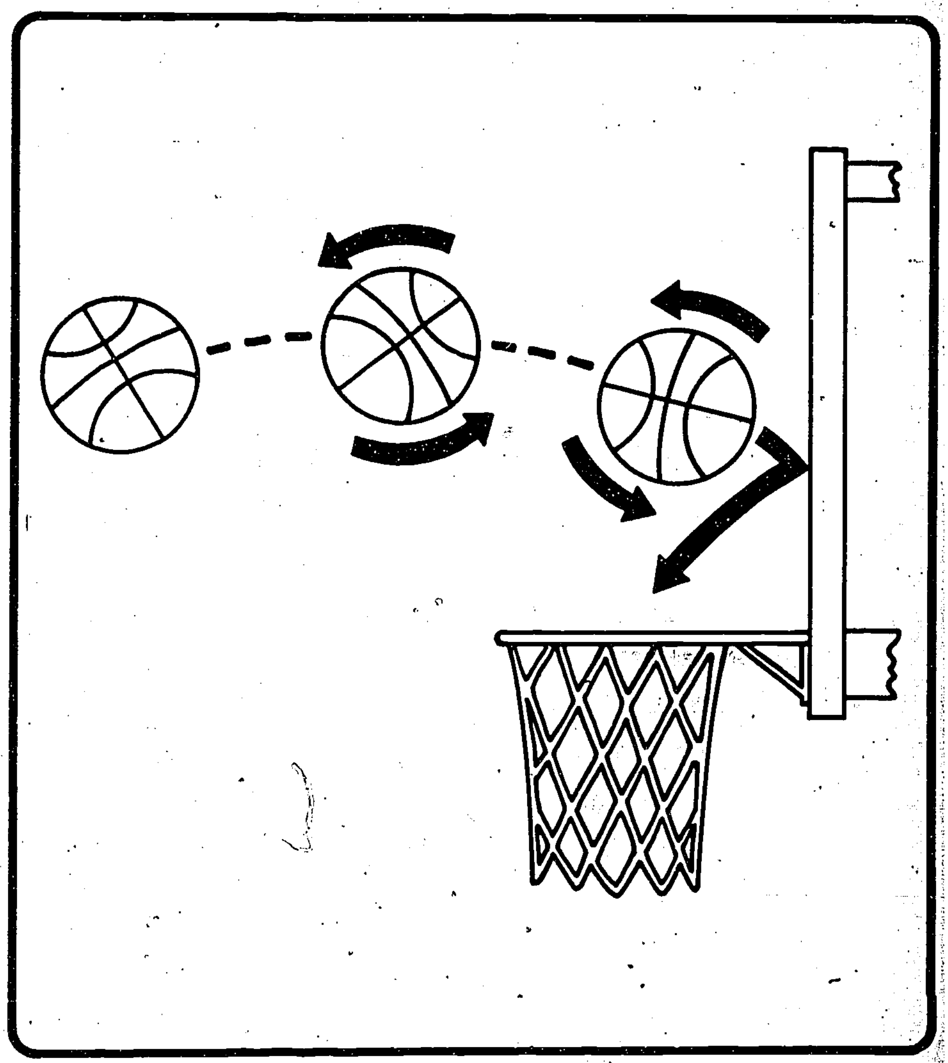


Figure 16: Backspin will cause a ball to remain closer to the backboard on the rebound.

and right or left spin is used to keep the ball closer to the wall on the rebound or to bring it back more sharply from the wall. A ball approaching the wall from the right will stay closer to the wall on the rebound with the right spin and will rebound farther from the wall if left spin has been applied. When the ball approaches from the left, right spin causes it to rebound farther from the wall while left spin keeps it closer to the wall. In general, right spin, around a vertical axis, causes the ball to rebound to the left and left spin, around a vertical axis, causes the ball to rebound to the right.

What Else?

The body also spins when in contact with a supporting surface and when in the air. Spin of the body is often called a *twist* or *rotation*. The diver rotates the body before entering the water and the ice skater spins while in contact with the ice.

The body can rotate in three planes

The body can rotate (spin) in three different planes. The body parts of the ice skater or the ballet dancer doing a pirouette move in a transverse plane as the performer turns around the supporting foot. The gymnast doing a cartwheel moves in the frontal plane and moves in the sagittal plane when performing a forward roll. Spinning movements of the body are easiest when performed in the transverse plane. The most difficult rotational skills are those which require the body to move in the frontal plane.

How?

Rotation in the body is produced in the same way as it is with a ball — an off-center application of force. The force which causes the body to rotate is called *angular momentum*. Angular momentum is acquired by checking linear movement, applying force off-center or by the transfer of momentum.

An example of rotation of the body as a result of checking linear movement is seen when you slide on the ice and suddenly hit a bare spot. The friction is greater between the bare spot and the foot; the foot stops but the body continues to move forward by rotating over the "stuck" foot. An example of rotation as a result of an off-center application of force is when the diver leans slightly forward so that the center of mass of the body is ahead of the contact point with the board. When

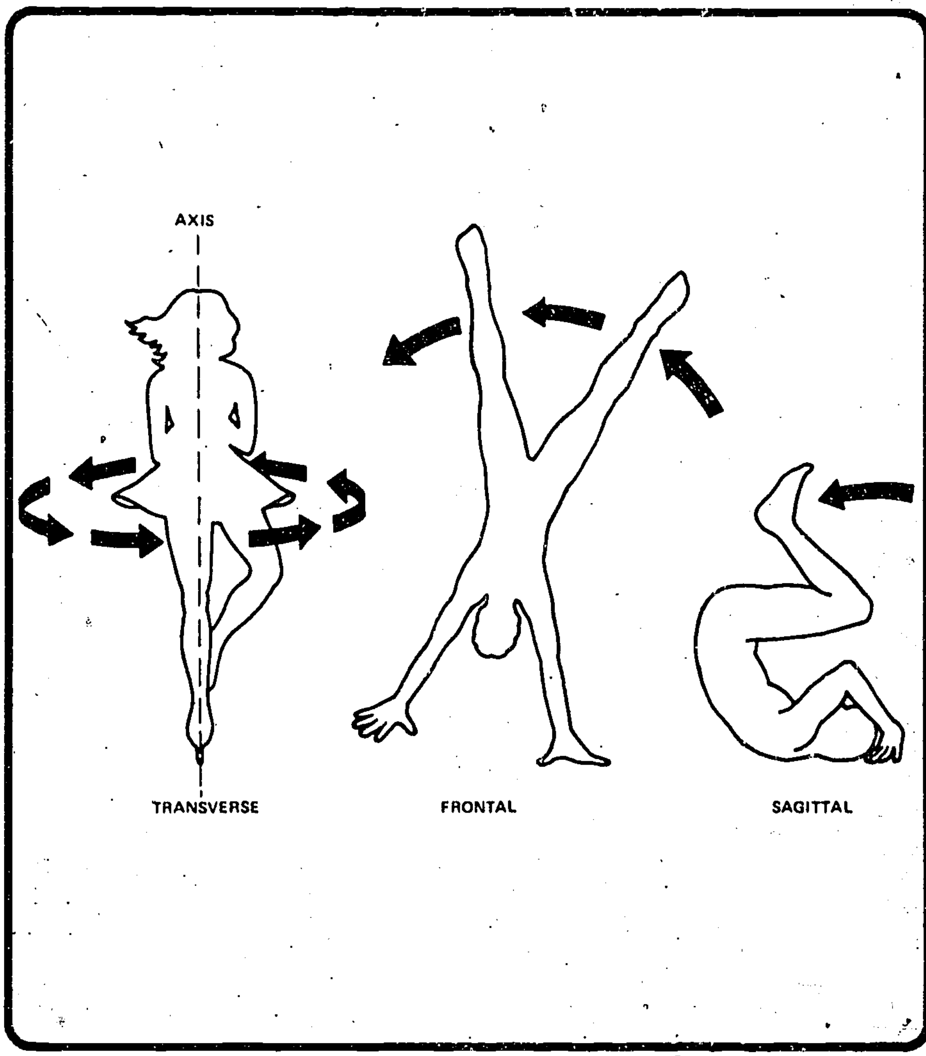


Figure 17: The body can rotate in three planes: transverse; frontal; sagittal.

the lower limbs are extended, the force will produce a lift and forward rotation to the body.

Momentum developed by one part of the body can be transferred to another object or to another part of the body or to the whole body. For example, assume that you are doing sit-ups in a supine position and the arms are over the head. A rapid, vigorous forward and upward swing of the arms which is quickly checked at a 45° angle to the horizontal will transfer their momentum to the trunk and cause you to sit up with little or no help from the abdominal muscles.

Another useful example of transfer of momentum which is used to transfer linear momentum into vertical momentum is the quick knee lift. Many fouls in basketball occur on lay-up shots. If the horizontal momentum of the player is not adequately checked the defensive player is decked. A quick lift of the knee of the lead leg will set up a backward rotation of the body which will counter some of the forward momentum produced during the run and will not only reduce the incidence of fouling but will increase the height of the jump by transferring more of the horizontal momentum into vertical movement.

Why?

Angular momentum = angular velocity × moment of inertia

Spinning movements of the body are the result of angular momentum. Angular momentum is the product of angular velocity (speed of turning) and the moment of inertia (resistance to turning). The *moment of inertia* is the product of mass and the distance to the axis of rotation. Remember that inertia is the resistance to change so the moment of inertia represents the force which must be overcome to produce rotation or to change the speed of rotation.

Moment of inertia = mass × distance to axis of rotation

The speed of rotation can be increased by reducing the resistance to rotation

The speed of rotation (angular velocity) can be increased by reducing the resistance to rotation (moment of inertia). This is accomplished by tucking or by bringing the arms in close to the body. Again, the spinning of an ice skater is an example. The skater develops a given angular velocity. This velocity can be increased when the arms are brought in close to the body. This will increase the velocity of the spin by about three-fold. When the skater wishes to stop or to slow down the spin, the arms are unfolded and abducted at the shoulder. This illustrates how the speed of rotation is governed by the moment of inertia and how that momentum is conserved.

Batting involves rotation of the trunk. The moment of inertia is changed by the placement of the hands on the bat. When you "choke up" on the bat by placing the hands several inches from the end of the bat, the moment of inertia is reduced and you can swing the bat faster than when you hold the bat at the very end of the grip. To handle "adult" size sports implements, children must "choke up" or "grip down" on them to reduce the resistance to rotation.

Let us look at diving and the three basic positions: tuck, pike, and lay-out. In which position do you turn faster? Which position would you choose if you were to rotate three times before entering the water? You can do more rotations in a tuck position than either of the other two positions and the fewest in the lay-out all because of the change in the moment of inertia.

What Else?

When the body, other objects, and the environment are in harmony, the movements feel and look effortless—indeed a picture of grace and poise. Time seems to stand still and you and the movement are one. When this peak experience is present, you are "playing with the ball" rather than the "ball (or environment) playing with you." Much of this feeling comes from your ability to maintain your equilibrium as you resist forces or keep your stability to cause or resist motion.

What do a clown riding a bicycle on a high wire, a girl holding a scale position on the balance beam, and a catcher in a crouch position have in common? All are trying to maintain their equilibrium. Many of the activities which we perform daily are those in which we are trying to maintain a particular position, pose, or attitude. This is called keeping our balance.

When forces are counter-balanced by equal and opposite forces, equilibrium is maintained

Equilibrium is maintained when all the forces acting on the body are counterbalanced by equal and opposite forces. The body may remain at rest, as with the girl on the beam and the catcher, or it may move with uniform motion in a straight line as with the clown. The clown kept his balance by keeping his weight and the weight of the bicycle centered over the wire. The girl on the beam keeps her weight centered over the beam and the catcher must balance his weight over his toes.

Equilibrium is attained when the center of gravity is over the base of support

A body is in equilibrium when its center of gravity is over its base of support so that the line of gravity falls within the confines of the base. The *center of gravity* is the point at which all of the weight of a body may be considered to be concentrated. This point may lie within the confines of the body or it may be located outside the physical confines. Where is the center of gravity of a hula hoop? That's right, in the center. The center of gravity of a racquet ball would be at the geometric center of the ball. This center of gravity of an object is not always located at the geometric center; it may be off center as with a golf club or a tennis racket. The line of gravity is an imaginary line extended from the center of gravity toward the center of the earth. For practical purposes, this line is perpendicular to the surface of the earth.

The center of gravity is the point at which the weight of a body may be considered to be concentrated

The base of support of the human body is the area outlined by the supporting body surfaces

The *base of support* of the human body is the area outlined by the body surfaces which support its weight. Larger body surfaces provide greater stability; that is, sitting down is a more stable position than standing. An increase in the number of parts which support the body tend to increase the area of support. This makes an all fours position more stable than just standing on two feet.

The greater the stability of an object the more difficult it is to disturb its equilibrium

Stability is resistance to change, or the capacity of an object to return to equilibrium or to its original position after having been displaced. The greater the stability of an object the more difficult it is to disturb its equilibrium. A child's toy such as a large clown with a weighted base always returns to the upright position after it has been pushed over. The center of gravity has been moved near the edge of the base of support but has not moved beyond the edge of the base. When the pushing force and its effects are removed the clown returns to its original position. This illustrates *stable equilibrium*. An object is said to be stable when movement of the object causes its center of gravity to be raised from its original position.

Neutral equilibrium occurs when the moving object's center of gravity remains at the same height

A perfectly round ball lying on a table is an example of an object with *neutral equilibrium*. The ball may move in any direction, but its center of gravity does not change its position relative to the supporting surface. The center of gravity of an object possessing neutral stability remains at the same height when the object moves.

Unstable equilibrium causes the center of gravity to move to a lower level

Movement of an object with *unstable equilibrium* will cause its center of gravity to move to a lower level. This is the case of objects with a small base and a high center of gravity. A top is a good example. When the top is not spinning, it is very difficult to balance the top on its base. Standing on one foot with the free foot raised in front of the body is also an unstable position.

How?

Have you ever noticed how a dog lowers its center of gravity by crouching down low when it doesn't want to go in the direction suggested when being walked on a leash? It often widens its base at the same time by assuming a stance which is slightly wider than its normal walking alignment. When someone is trying to push you off your feet one of your first reactions is to flex your knees in order to lower your center of gravity and you will then place your feet farther apart. In which direction do you widen your stance? In the direction of the shove or perpendicular to the oncoming force? Stability is increased as the base is widened in the direction of the oncoming force. If the base is not widened, your equilibrium will be disturbed as the line of gravity is forced outside the base of support. If you cannot move your feet quickly enough to get them under your center of gravity again, you will find that you have established a new base of support by sitting on the floor!

Stability depends upon the height of the center of gravity, direction and size of the base of support, and the location of the line of gravity over the base

In summary the greatest stability is achieved with a large base of support, a low center of gravity, and the center of gravity centered over the base of support. When the direction of disturbing forces is known, stability is further increased by widening the base in the direction of the oncoming force and by moving the center of gravity as close to the edge of the base nearest the approaching disturbing force.

Why?

There are several factors to consider when enlarging the base of support:

1) the *direction* from which the potentially disturbing forces will be coming;

2) the amount of *friction* between your base of support and the supporting surface;

3) the *injury potential* to the joints of your body.

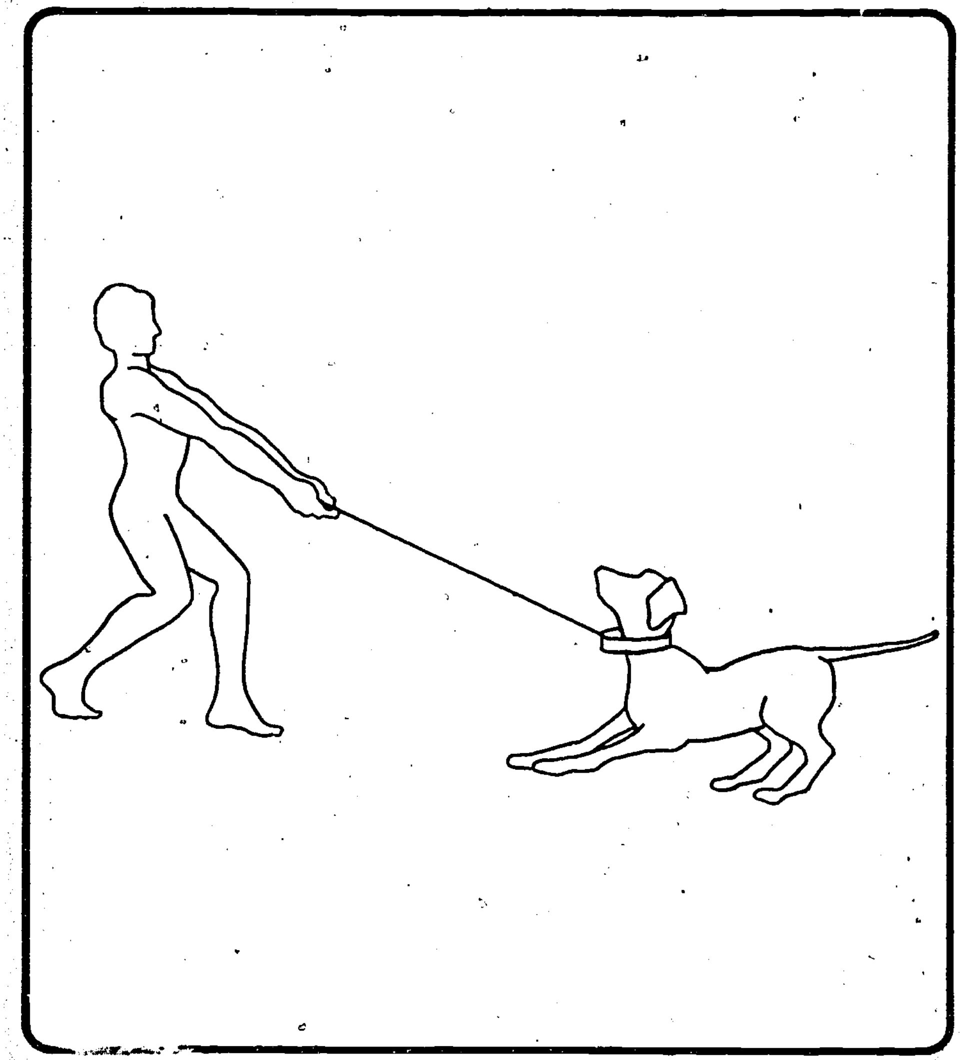


Figure 18: Stability is increased by lowering the center of gravity and widening the base of support in the direction of the imposed force.

The size of the base of support must be proportional to the degree of force to be resisted

Refer again to the example of someone trying to push you off of your feet. The distance which you separate your feet is dependent upon the amount of force which you must supply to counter the force of your adversary's pushing action. If only a slight push is anticipated the feet need not be separated too far, but the distance must be increased as the force of the push is increased.

The degree of friction between the base of support and supporting surface governs the potential size of the base of support

Another factor which will affect the distance that the feet can be separated safely is the friction between the feet and the floor. If in stocking feet on a waxed floor, the feet will start to slide out from under the body when spread more than the width of the hips. If spiked or cleated shoes are worn the feet may be spread further without slipping. Many people wear some type of cleated shoes when walking on packed snow or ice so that they may take longer steps without slipping.

Anatomical structure limits the size and direction of the base of support

The musculature of the lower extremity is usually the source of a large part of the internal force used to counteract external forces. Therefore the body must be kept in proper alignment so that the necessary forces can be adequately developed and applied. At times widening of the base to increase stability is sacrificed for the efficiency of force application. You should make every effort to insure that a sudden slip will not occur as this could cause injury to the joints and/or muscles.

Widen the base in the direction of the oncoming force

Shift the line of gravity toward the oncoming force

A spotter at the horse in gymnastics does not stand with the feet together but has them spread in the direction of the person coming over the apparatus. In other words the spotter has widened the base in the direction of the oncoming force. Stability can be increased even further in this situation by placing the weight over the foot nearest the horse. This permits the spotter's line of gravity to move across the base from one side to the other and reduces the chance of loss of balance. If the vaulter contacts the spotter who has the line of gravity over the center of the base there is only half the distance to sway before balance will be lost. Again, if the feet can move quickly enough, the spotter may not fall, but spotters are often caught napping and not in a position of readiness to receive the oncoming force.

One of the most frequent violations in basketball is traveling. This often occurs as the player attempts to stop after moving rapidly. Most of these violations could be prevented if the player would drop the weight closer to the base by flexing the lower limbs, placing the feet in a forward stride position and centering the weight primarily over the rear foot so that the weight can shift forward across the base of support without pulling the rear foot off the floor.

To move quickly in a known direction raise the center of gravity and move it toward the edge of the base in the direction that movement will occur

The degree of stability desired at any one time is dependent upon the task at hand. Some of our activities require momentary equilibrium and the ability to move quickly. Examples of this situation would be the start in the sprints in track and in swimming. The performers have the base rather narrow in the direction in which movement is to occur, the center of gravity high and very close to the front edge of the base. At the sound of the gun, the athlete easily moves the center of gravity outside the front edge of the base of support. In actuality the front edge of the base is removed as the hands come off the track and the feet off the blocks. Gravity then assists in getting the performer moving by pulling the body down. Gravity is providing some of the force necessary to overcome the resting inertia of the body and therefore most of the force produced by the body can be used to move the performer forward.

To move quickly in an unknown direction keep the center of gravity relatively high and the base narrow

Badminton is an activity in which the player must be ready to move rather instantaneously in an unknown direction. So the ready position is one of narrow stance; weight on the balls of the feet and the center of gravity is relatively high so that the player may move quickly in any direction. Wrestlers by comparison have their weight low, feet spread far apart, ready to receive weight and to apply force without losing their balance. They want a stable position.

Older persons take shorter strides and walk with their feet farther apart than do teenagers. This is a compensatory action for the increased difficulty in maintaining their balance so they are widening their base of support and keeping the center of gravity over the base of support at all times rather than allowing it to fall ahead of the support foot and gambling that the swinging foot will get down in time to keep them from falling. Walking has been defined by many as a series of catastrophies narrowly averted. Older persons have weaker muscles which extend the leg at the knee so they cannot take as great a risk when walking as can the younger person with stronger muscles and quicker reflexes.

In summary, to *move quickly* in a known direction one must keep 1) the base narrow in the known direction, 2) center of gravity high, and 3) close to the movement edge of the base. To achieve *maximum stability* against forces from a known direction 1) widen the base in the direction of the forces, 2) keep the center of gravity low and near to the front edge of the base.

Balance is important to everything that we do whether it is a static activity or a dynamic activity. Violation of the principles of equilibrium and stability affect the accuracy of our movements and may also influence the force available for moving an object in the desired direction. Whether the activity is walking on the hands, doing a head stand, catching a ball, running the hurdles, or sitting on the fence, if the body is not in equilibrium undesirable movement will occur which will affect the execution of the desired action. These undesired actions are usually reflex in nature and are done without conscious thought. The movements lead to a righting of the body, keeping the center of gravity over the feet if possible, trying to prevent a fall. If a bowler is off-balance you will see gyrations of all sorts at the moment the ball is released. The arms and legs flail in righting of the body, keeping the center of gravity over the feet if possible, trying to prevent a fall. If a bowler is off-balance, you will see gyrations of all sorts at the moment the ball is released. The arms and legs flail in the air seeking to balance the body over the foot as the weight is suddenly reduced with the release of the ball. The bowler who is in equilibrium at the release will hold the position over one foot with no change in the body except the follow-through with the arm releasing the ball.

What Else?

A projectile moves under the influence of the projecting force, gravity, and air resistance

Much of our sport activity centers around throwing or hitting some type of ball or propelling ourselves into the air. These actions are known as *projections*. A projectile is any object which is given initial velocity and then allowed to move freely in space under the influence of gravity and other outside forces. Three forces, therefore, act on a projectile:

1) the forces which overcome the inertia of the projectile and put it in motion;
2) gravity;
3) air resistance.

Trajectory is dependent upon the vertical and horizontal velocities imparted at the time of projection and the external forces occuring during flight

The path which the object travels after projection is known as the *trajectory*. The trajectory is therefore dependent upon the resultant of the vertical and horizontal velocities of the object at projection and the external forces acting on the object during the flight.

Gravity exerts a constant downward force on a projectile and moves it toward the earth at a constant rate of speed. Air resistance tends to decrease the horizontal distance which the projectile will travel.

The accuracy of a projection depends upon how well the effects of the forces which act during flight have been estimated and accounted for at the moment of release.

How?

The angle of projection influences the time the object will be airborne

Keep in mind that the effectiveness of a projection is dependent upon the interaction of the angle of projection and the velocity at which the object is traveling at projection. The *angle* of projection influences the length of time the object will stay in the air. The velocity influences the distance that the object will travel. This distance may be in a vertical direction, in a horizontal direction, or somewhere in between.

The projection velocity influences the distance the object will travel

The projections with which we are most concerned are those in which the projection force is produced by muscle contraction and the summation of the resultant momentum of the body parts. An example of the human body as a projectile in which muscle contraction does not produce the projecting force would be when one is shot out of a cannon!

Listed below are factors which are common to all types of projections. These factors influence the velocity at projection when the force is produced through muscular contraction. These factors must be considered whether the projectile is put in flight by throwing, pushing, kicking, striking, or jumping.

The projecting force is affected by the proper sequential contraction of body parts

1. Proper sequential action of body parts. Most projection skills involve a sequential action of the body parts. Following the backswing, or a windup, muscles of the hips and trunk contract to get the body moving. The trunk rotation is then followed by action at the shoulder, then the elbow and wrist if these upper limb joint actions are involved in the skill. This basic sequence of events is seen in both single arm projections such as a tennis drive and in double arm projections such as batting. The action is basically the same when kicking but the lower limb is used rather than the upper. The trunk rotation is followed by action at the lumbo-sacral joint, the hip, knee, and ankle joints. The coordination of the actions is not consciously controlled, but is carried out for us by sub-cortical centers of the brain.

Force will be reduced if firm contact is not maintained at the moment of projection

2. Firm contact or connection. As forces are developed within the body, pressure will be applied to the supporting surface by the feet. If the contact between the feet and the supporting surface is not firm, some of the developed force will be used up in moving the surface. The supporting surface must exert back against the body the same force which has been applied against it if maximum distance is to be achieved. All joints of the body must be held in their proper position by muscular contraction or force will be "absorbed" at the joints and will reduce the force available for projection.

For example it is not possible to jump as far on a dry sand beach as it is on a well-prepared track surface. When the feet apply force against the sand some of the muscular force that was developed is used to move the sand and the reaction force of the ground is reduced.

Distance is also lost when the person loses contact with the ground at projection or impact. The air cannot begin to offer the counterforce that the solid ground does. You cannot throw a ball as far when you jump in the air to release it as you can when you have a solid foot contact with the floor or ground.

A follow-through facilitates projection at maximum velocity

3. Follow-through. Follow-through helps to insure peak velocity through impact or release. If the follow-through is cut short of the projection, velocity has usually been reduced prior to release of the ball or contact with the object to be projected.

Balance is essential for the proper execution of all skills

4. Balance. A balanced position is essential to good force production. Loss of balance during the force production process will usually result in reduced velocity at impact or release. The loss of balance usually affects the direction in which force is applied to the object and this frequently results in an off center application of force. This off center application produces rotation of the object and this rotation affects the direction of the projection and also reduces the distance it will travel.

Reduce the angle when the projection is into the wind

How does air resistance influence the angle of projection? When projecting an object into the wind the horizontal component of the projecting force should be increased by lowering the angle from that used if there were no wind. This increased horizontal force is needed to negate some of the air resistance and to reduce the time that the object is in the air to be acted upon by the wind.

Increase the angle of projection when the wind is at your back

When throwing with the wind at your back, a tail wind, throw at a slightly increased angle of projection so that the ball stays in the air longer. This allows more time for the wind to push the ball forward. The direction from which the wind is blowing often determines whether or not a high fly ball hit to the outfield will drop for a homerun or be caught for an out. If the ball is traveling into the wind the ball drops more vertically and does not go as far as when the wind is with the ball.

Aim into a crosswind

If a crosswind will be acting on the flight of the ball it must be aimed into the wind. The end result then will be the combination of the forward force that the thrower has applied and the force of the wind acting at an angle to the desired path. The effects of a crosswind must be considered in archery. If you aim for the target when a strong crosswind is blowing the arrow will be blown off course and miss the target completely. At times the archer may need to aim at a point that is not directly in line with the intended target.

Why?

Optimum angle of projection is influenced by velocity at release, height of release, size and shape of object

It is impossible to prescribe angles of projection that are optimal for all persons, all objects and all situations. A taller person can use a lower angle of projection than a shorter person to attain the same distance. After determining the purpose of the projection, the variables to be considered in selecting the optimal angle are velocity at release, height of release and size and shape of the projectile.

Maximum distance is achieved with a 45° angle of projection when the level of release and landing are at the same height

Optimum projection angles differ when the projection level and landing level are not at the same height. If the object is to land at the same level from which it was projected then 45° is the optimum angle to achieve maximum distance. It takes the same time for the object to reach its maximum height as it does to land. If the object is to land at a level lower than the height from which it is projected, the optimum angle is less than 45°. The greater the velocity at projection the more nearly the optimum angle approaches 45°. For most objects an increase in the speed at release produces a greater horizontal distance than does a comparable increase in the height at release.

To keep the object in the air as long as possible increase the vertical velocity and angle of projection

When the purpose of the projection is to keep the object in the air as long as possible the vertical velocity should be increased. An example would be a high punt in soccer or football which stays in the air long enough for the defensive players to run down the field to cover the receiver.

The height of release influences the time the object will stay in the air. Gravity causes all objects to fall at the rate of 32 ft/sec.[2] The time that a projectile is in the air will be increased as the height of projection is increased. Horizontal distance covered is at its maximum when the object remains in the air long enough for all of the horizontal velocity to be spent in overcoming air resistance. When this happens the object drops straight down because gravity is the only remaining

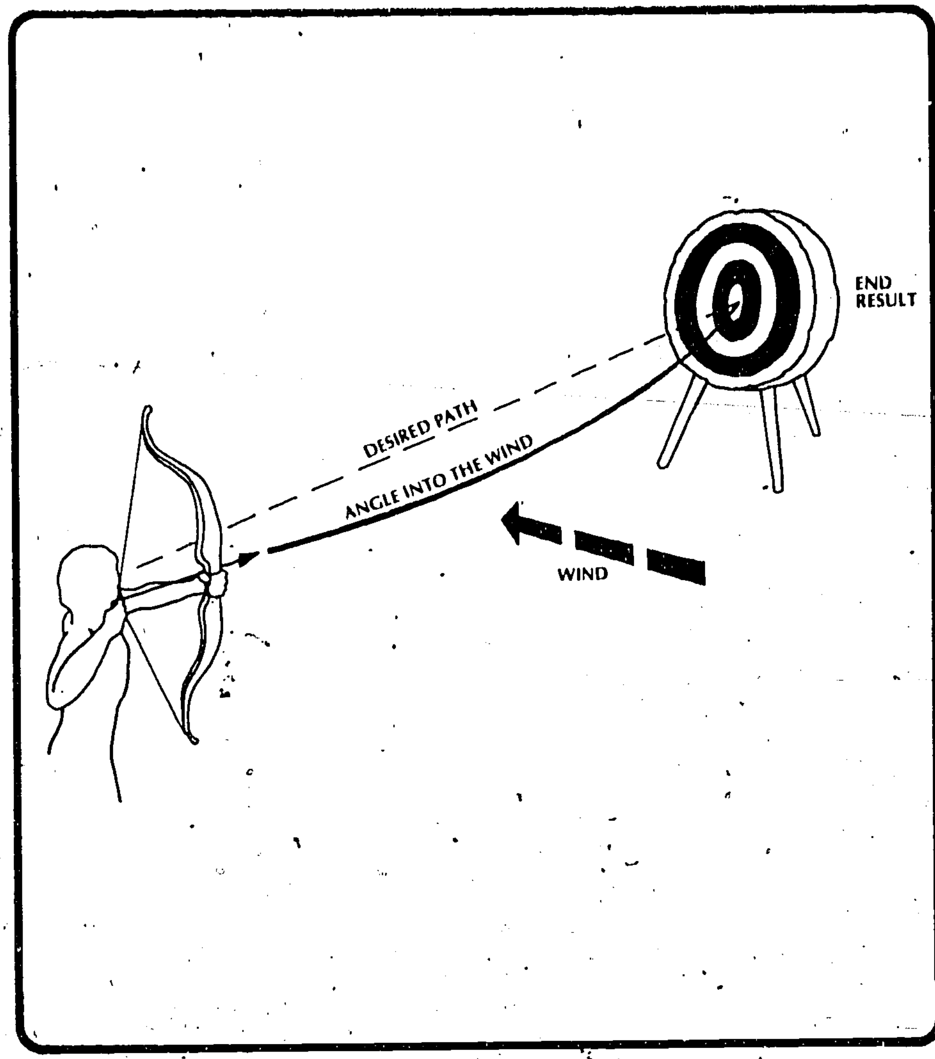


Figure 19: Crosswind effects should be considered in activities such as archery.

force acting on the object. This is best seen in the flight of a golf ball which has been hit with a very high club head velocity. Landing from a long jump will feel as though you are landing on a feather bed if the horizontal projection force has been fully used up during the flight. Usually the feet come down too soon and the legs must absorb some of the horizontal force as well as the accerleration forces due to gravity.

Distance is gained by increasing the horizontal projection velocity

The object being projected often dictates the desired angle of projection. The design of modern javelins is such that the optimal angle of projection is 35° or lower, perhaps nearer to 25° for the experienced thrower. The thrower should concentrate primarily on factors which will increase the horizontal velocity of the javelin at release since this has a greater effect on horizontal distance than does a comparable increase in the angle of projection. Keep in mind that another reason the angle is less than 45° is that the release point is higher than the landing point.

What Else?

What do sailing a frisbie, pitching a softball, hitting a player in dodgeball, passing a football for a touchdown, pitching horseshoes, and tossing an empty can in the wastebasket have in common? They all involve throwing. Throwing can be done overhand, as in passing for a touchdown, underhand when pitching in softball and horseshoes, and sidearm when throwing a discus. As for tossing an empty can in a wastebasket, the styles are myriad—easy underhand toss, just a snap of the wrist, a hook shot, behind the back, perhaps over the head while facing away from the basket.

What determines the success of a throw? Is it determined by how far the object travels? How fast? How high? Hitting a target? Each may be right since it depends on the purpose. However regardless of the purpose of any throw, it involves the projection of an object through space. The success of any projection is largely determined at the moment the object is released. After release, the object will be influenced by outside factors such as air resistance and gravity. Prior to release the movement of the body or parts of the body determines the path the object will travel. That path is determined by the speed at which the object is traveling at the moment of release and the angle at which the object is projected.

If speed is important, use a flat trajectory

It is important to know the purpose of the throw. The desired angle of release and necessary speed at release will depend upon the purpose of the throw. Is the ball to roll along the ground, or is it to stay in the air as long as possible? Is the ball thrown to the floor to bounce on a target, or is it thrown on a line by the second baseman to the first baseman? Is it important to get the ball to its destination as rapidly as possible, or is time unimportant? When the speed of the throw is important, the ball should have as flat a trajectory as possible to reach the desired target. For example a shortstop, after fielding a ground ball, will keep the throw to the first or second baseman as flat as possible so that the ball will get to the base as quickly as possible. Think of the frustration as the first baseman waits for the ball to come down from a high arc as the result of an underhand throw to first. The shortest distance between two points is a straight line!

When the object of the throw is to keep the ball in the air as long as possible then the angle of release is 90° to the horizontal.

How?

Sequential movement of body parts generates force to be imparted to the object at release

The weight, size, and shape of the object to be thrown often determine the style or form with which the projection will be made. Heavier objects such as bricks are usually thrown with an underarm pattern or a pushing action. The two hand underarm pattern is required when an object cannot be controlled by one hand. Overarm and sidearm patterns usually produce more force than an underarm pattern. This is the result of a longer backswing and a greater amount of trunk rotation. Regardless of the pattern the sequence of body actions is similar. At the end of the backswing there is a shift of the body weight to initiate the forward movement. This is followed sequentially by rotation of the pelvis and rotation of the trunk, followed by action in the shoulder area, and, depending upon the object being thrown and the pattern used, action at the elbow joint and wrist. The velocity which is generated during the "windup" is imparted to the object by the fingers or the hand.

The velocity at which the object will travel at release is influenced by the following force producers:

1) length of backswing;
2) number of body parts used;
3) sequential summation of forces;
4) speed at which the body parts move.

Angle of projection is affected by position of hand at release and the point on the arc where the release occurs

Factors which affect the *angle of projection* are the position of the hand relative to the desired line of flight at release and the point on the arc at which the release occurs.

Why?

The basic concerns in throwing are to develop the necessary speed in the hand and to let go of the object at the proper moment so that the object reaches its target.

Speed of the hand prior to release depends upon the time and distance over which momentum can be developed. The following techniques should be used to increase time and distance.

Lengthen backswing to increase force.

1) *Lengthen the backswing.* This is accomplished not only with the arm but can usually include turning the body so that the opposite side is toward the direction of the projection. Shifting the weight over the rear foot also lengthens the backswing. In many activities the distance of the backswing is increased by taking a stride or step forward or in some instances, a hop, a skip, or a short run before the object is released. A spinning of the body is seen in the discus throw to increase the time over which momentum is developed.

Use maximum number of body segments to increase force

2) *Use* the *maximum number* of *body segments* which can contribute positively toward the development of force for the throw. This means that you should use your lower limb and trunk to throw a ball and not just the upper body. The muscles of the lower limbs are the strongest in the body so use them to "drive" forward into the throw. The body should be forward of the rear foot and the body mass should be moving in the direction of the throw at release.

The summation of forces will increase force

3) *Add body parts sequentially*. This may be called the *summation of forces* or the sequential action of body parts. This "summing" action is not done under your conscious direction, but is neurologically controlled by subcortical areas of the brain. If maximum force is to be produced, each successive body part should come into action as the one below it reaches its maximum velocity and minimal acceleration. The timing of these actions is so precise that only the subcortical levels of the nervous system can direct the actions. When we try to control segmental summation, we "foul" it up. Surely

you have experienced this as you try to think about what your elbow or your shoulder is doing when you throw. You should concentrate on the end result. What is it you want the ball to do; where do you want it to go? Precise timing is required so that the momentum of previous movements is conserved and can be passed on to the next segment or to the object at release.

Speed of movement of body parts affects amount of force developed

4) *Speed* up the rate *of movement* of the body parts. The speed at which the parts move is affected by the strength of the muscles, the timing of the contractions and the weight of the object to be moved.

When less than maximum force is desired, some or all of these factors must be modified. You can throw with just the arm, not the use of trunk rotation. You can bring the body parts through slowly and throw in slow motion. The amount of trunk rotation is reduced in some activities by the stance that you use. An open stance decreases the amount of trunk rotation which can occur prior to release whereas a closed stance increases the amount of body rotation prior to release.

The *angle of release* depends upon the point in the arc at which the ball is released. The ball will move in a straight line when released by the hand. The accuracy of the throw depends primarily upon releasing the ball at the proper time. If the arc can be flattened the timing of the release becomes less critical. The ball can then be released at several points on the arc and still travel in the desired direction if the hand is moving in the desired line of flight. In most throwing patterns the arc is flattened by stepping forward and flexing the knee of the forward leg. The arc can be further flattened if the shoulder and upper body move forward along the intended line of flight prior to release of the ball.

What Else?

Kicking, batting, and using a club or a racket are projection skills

Other forms of projection skills are those in which an implement such as a racket, a bat, a golf club, or a body part such as the hand or foot is used to project the object, that is, to impart force to the object. Most of the time, the object is some type of ball. The major concern in striking skills is the momentum of the striking implement when it makes contact with the object to be struck or projected. The point of contact is also important. If the contact is not through the center of mass of

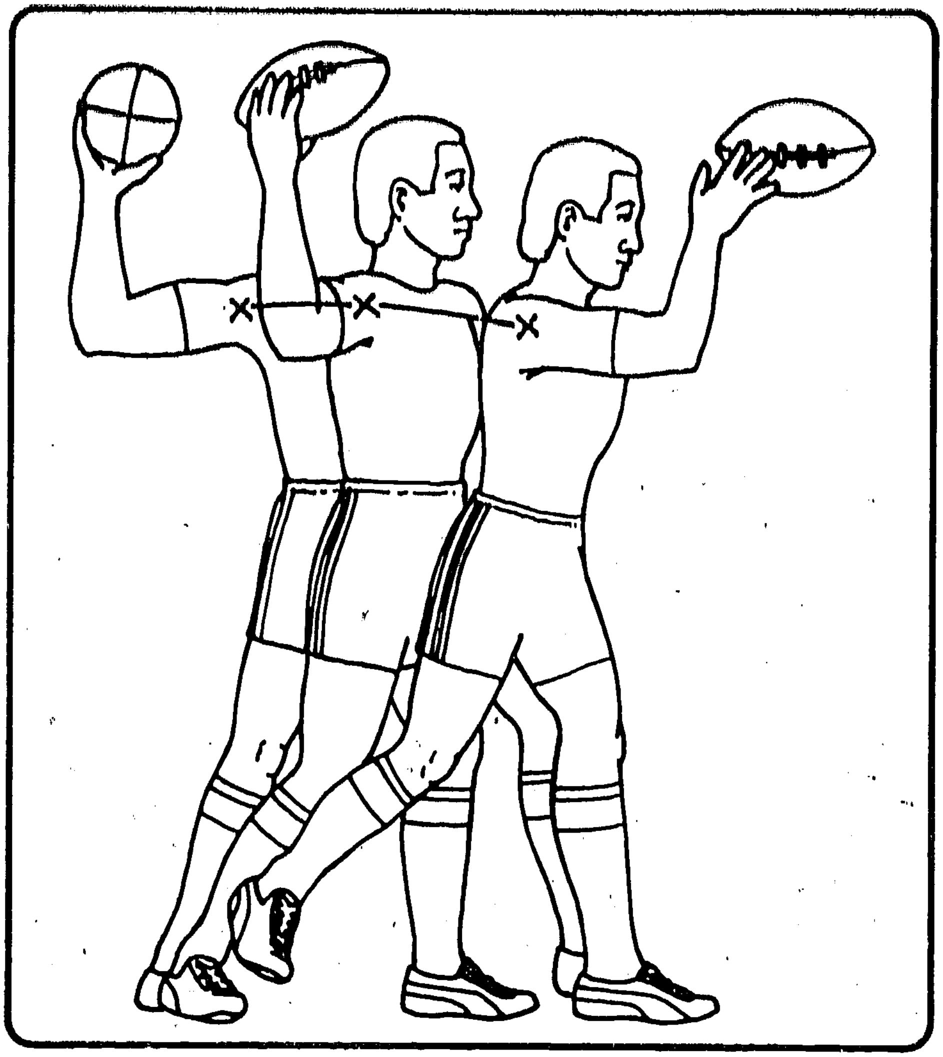


Figure 20: The arc is flattened by stepping forward and by moving the shoulder along the intended line of flight prior to release of the ball.

the object, spin will be imparted and some of the projection force will be lost. The effect of spin on the flight of an object has been previously discussed.

How?

As with all skills, the purpose of the skill must first be clear. Should the trajectory of the struck object be high and short, or low and long? Is the velocity of the projectile important? Is the purpose of the skill to produce maximum distance, or is accuracy of prime concern. After the purpose is clearly identified, remember that to achieve maximum distance the speed of the striking body and the point of contact are of major concern. If the purpose is one of accuracy, you may need to sacrifice some speed to gain control.

The velocity of the projectile following contact with the striking surface is dependent upon the following factors:

The speed imparted to the object depends upon the weight, speed, and amount of give of the striking object and the projectile

1) the mass of the striking object and the speed with which it was moving prior to contact;

2) the mass of the projectile and the velocity with which it was moving prior to contact;

3) the coefficient of restitution of the object and the contacting surface.

The contacting surface may be a body part, a racket, a bat, or a golf club, and is subject to the restraining forces discussed previously.

Let's use tennis to illustrate. What determines how fast the tennis ball will come off the racket after being hit? The first influence would be the weight of the tennis racket and secondly, how fast it was moving at contact. It is the interaction of these two factors which determines the force which is applied to the ball. Force equals mass times acceleration. A heavy racket is helpful only when it does not slow down the speed of the body movements. Some players therefore use a lighter racket which they can swing faster. Force applied depends upon the weight of the ~~server and the~~ racket and the speed at which the racket head was moving at contact.

The second set of factors which apply to the serve is the relationship of the mass and the velocity of the tennis ball. On the serve the forward velocity of the ball is zero and its mass less than that of the racket; thus the server should have no problem in applying sufficient force to hit it over the net. When the tennis player is attempting to return a smash, the combined mass and velocity of the oncoming ball can be of such magnitude that you may not be able to generate enough force to keep the ball from moving your racket backward.

The coefficient of restitution of the racket and the ball is the third set of factors. When the ball is soft and the racket strings give too much, some force applied at impact is used to deform the object and the amount of force available for forward projection of the ball is reduced.

What are some factors which will influence the amount of force that can be developed in a striking implement or a body part prior to impact?

The following factors influence the magnitude of the force which can be applied to an object:

The amount of available force for striking is governed by the degree of muscular force, timing of body movements, length of striking implement, and firmness of grip

1. The amount of effective muscle force developed. The factors which affect the development of muscular forces were discussed earlier and include such things as the number of muscles used, the size and strength of the muscles, the speed of contraction, and the distance through which the muscle contracts.

2. The summation of muscular forces. The sequence of body actions must be such that the momentum of each body part is added to the momentum of those proceeding parts so that momentum is greatest at the time of impact. This transfer of force is from large to small and from strong to weaker muscle groups.

3. The length of the striking implements. The end of a long lever moves faster than a short one when they move through the same number of degrees.

4. Firmness at contact. Force is often lost at impact as a result of a loose grip of the striking implement, joints which are not firmly fixed or do not have firm contact with the supporting surface. This means that you can apply more force to the ball when at least one foot is on the ground than when you jump in the air or loosen contact with a racket or bat at impact. Cleats, spikes, and rubber soles are used to increase the firmness of contact. To firm up the grip, gloves, resins, or moisture may be used. The palm of the hands sweat to improve the grip. However when there is excess perspiration, they become slippery and must be dried.

Spin will reduce the amount of force available for forward projection

How will you apply force to the object? Remember that a force which is applied off-center will produce spin and thus will reduce the amount of force available for forward projection. Sometimes you want to apply spin at contact to bring

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about a particular rebound action when the ball contacts the wall, ground or the opponent's racket. When spin is desired then the direction of contact cannot be through the center of gravity of the object. The angular velocity of the ball as it leaves the bat is the result of the spin which the ball had before being hit and the spin imparted by the striking implement during contact.

Why?

The same factors which apply to throwing also apply to striking skills. That is body actions are usually initiated with a weight shift, followed by hip and trunk rotation and then the use of the arms and sometimes wrists.

Distance is increased by using heavier or longer implements and/or increasing the speed of movement

The principle concern in striking skills is the momentum of the striking implement at the moment of contact. Momentum equals mass times velocity. In most instances it is the velocity that is altered to increase or decrease the force which is applied to the object being hit. This is especially true in handball where only the mass of the body is available. In batting, in tennis, and in golf, different implement weights may be used to increase the momentum at the striking area. The optimal weight of the striking implement depends upon the strength of the individual. This determines the speed with which it can be moved without disrupting the timing or the summation of forces. One person may be able to develop the same momentum using a light bat which can be swung faster as can another person who uses a heavier bat but has a slower swing. It is the combination of mass and velocity which makes the difference.

Accuracy may be improved by reducing the length of the implement, the length of the backswing, and the number of body parts that are used

If accuracy is the primary concern in striking skills the lever may be shortened to gain control at the expense of loss of some velocity. The length of the backswing and the distance through which the implement travels prior to contact may also be shortened to gain control. Longer clubs are used in golf when distance is the chief requisite and as accuracy becomes the prime concern, the clubs are shorter in length. The length of the backswing and the number of body parts used or the distance through which the body parts travel are also reduced to increase control of the shot.

What Else?

To jump for height increase the vertical thrust and minimize the horizontal thrust

To jump for distance the horizontal component is increased while the vertical is decreased

Jumping is another basic skill of projection. Jumping is categorized in two ways: jumping for height and jumping for distance. Some examples of jumping for height would be the jump and reach, the high jump, the spike in volleyball, and various leaps in dance. Examples of distance jumping would be jumping across a creek and the long jump. Jumping for height and jumping for distance can be done from a stationary start or the jumps can be preceded by a run or some shorter preliminary movement to increase the speed at which the body will be moving at take-off. When jumping for height all body actions are aimed toward maximizing the vertical component of force at take-off and minimizing the horizontal component. When jumping for distance the horizontal component is increased and the vertical decreased. Some vertical movement is needed even though the goal is to achieve maximum horizontal distance. It is the vertical force at take-off that counteracts the downward force of gravity and keeps the body in the air long enough to completely use the horizontal force.

How?

Regardless of the type of jump, the major concerns are the same: development of the appropriate amount of force for the jump while leaving the support surface at the proper angle to give the desired height and distance to the performance. The factors enumerated earlier which affect projection all apply to jumping as well. These factors were summation of forces, firm contact, and balance.

To jump vertically the center of body mass should be over the feet at take-off

To jump horizontally the center of body mass should be in front of the feet at take-off

The angle of take-off in jumping is determined by the amount of body lean. When jumping vertically the center of body mass should be over the contact point (feet) at take-off. When the aim is to cover a horizontal distance, the center of body mass must be in front of the contact point. The amount of force applied at take-off is determined for the most part by the speed at which joint actions occur. The rate at which body segments move is the major factor in the determination of the take-off velocity regardless of the direction or angle of take-off.

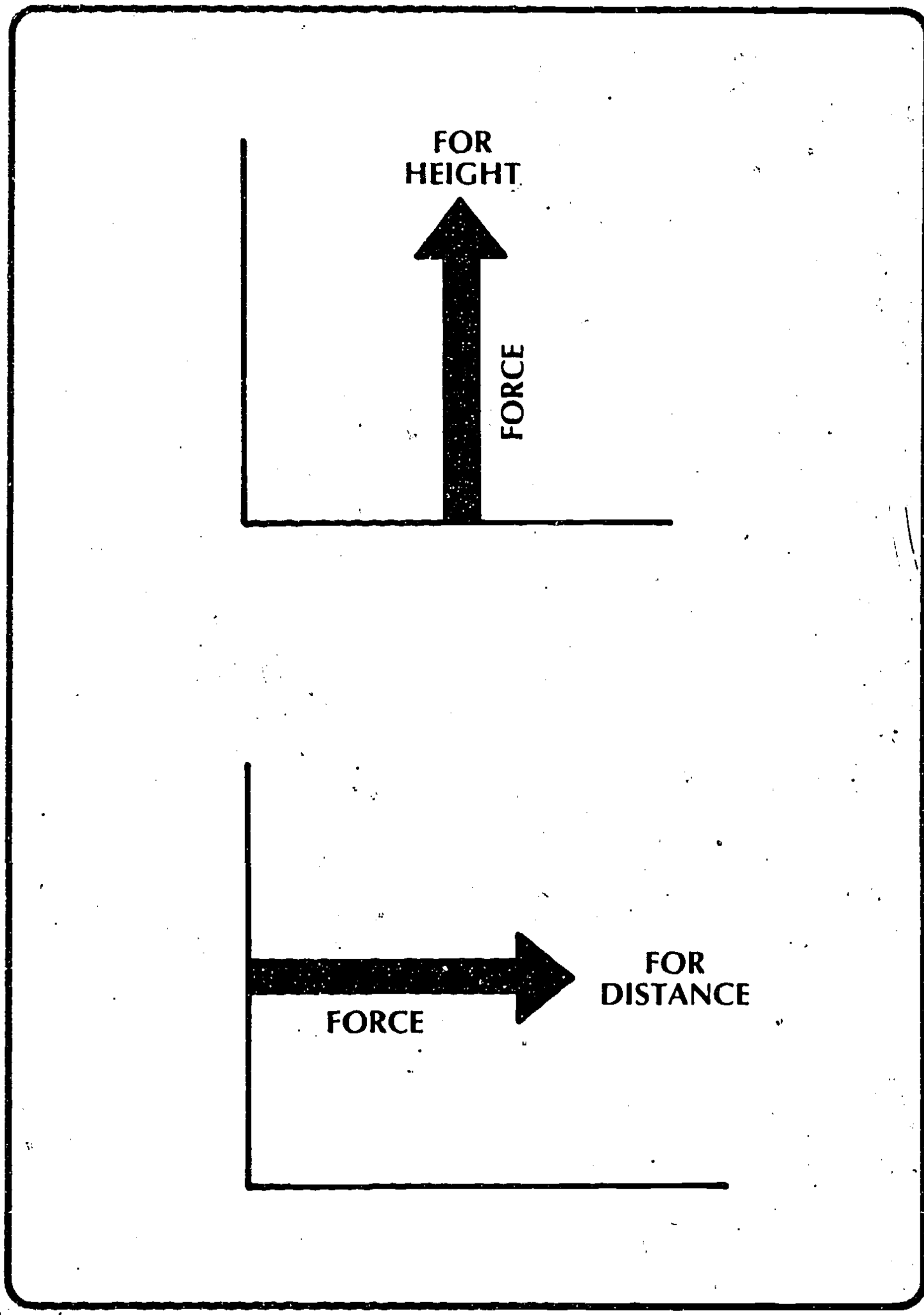


Figure 21: When jumping for height, maximize the vertical component of force at take-off and minimize the horizontal component. When jumping for distance, increase the horizontal component and decrease the vertical.

Why?

The force which can be applied at take-off is from muscle contraction and the transfer of momentum that has been developed is either by the arms or from a preliminary run.

Muscular force for jumping is increased when the extensor muscles of the lower limb are stretched quickly

Regardless of the jump direction the muscles of the lower limbs are put on stretch by flexing the joints of the lower extremity prior to take-off. The depth of the crouch is limited by the strength of the extensor musculature, especially the quadricep muscles which extend the leg at the knee.

Although a deep crouch increases the time and distance through which force can be developed, a considerable amount of force is required to overcome the resistance to movement in an upward direction (moment of inertia).

The crouch prior to jumping should not slow the speed while recovering

The deeper the crouch, the more strength required to jump upward. The depth of the crouch should be governed by the speed at which you can move from it. In other words, do not let the depth of the crouch slow down the speed of extension.

A transfer of momentum and balance is attained by use of the arms

The arms act primarily as balancers during the jump and to create some momentum which will influence the position of the trunk and help to control the body lean. In the lower limb the hip and the ankle seem to serve as positioning joints while the propulsive joints are the knee and the metatarsophalangeal joints. The hip and ankle action prior to lift-off maintain the body segments located above them in the proper alignment. This influences body position, hence angle of take-off. The joint actions at the knee and the ball of the foot move the body in the desired direction. These could be called the propulsive joints. Extension of the leg at the knee provides the majority of the propulsive force at take-off.

Lifting the lead leg forcefully and rapidly contributes to converting horizontal to vertical momentum

When jumping for height following a run or some type of moving approach, the jumper must convert horizontal momentum into vertical momentum. While not easy, this is accomplished by a forceful and rapid knee lift of the lead leg. This is the purpose of the hurdle step in springboard diving, to "rock" the body back over the support or take-off foot. The speed of the lifting action is directly proportional to the speed with which the body is traveling. High jumpers take a slow, bouncing run up to the bar so that they can convert all of their horizontal momentum into the vertical direction. The amount of horizontal movement needed in high jumping is very slight, only enough to cross the bar. The vertical velocity at take-off is further increased by the vertical acceleration of the free leg and both arms. These movements increase the force applied against the ground and result in a greater reaction force. Stand on a scale and swing your arms upward rapidly, then slowly. Notice that when you swing them rapidly the scale reads higher than your actual weight, but when you swing them slowly the reading on the scale does not change. This will illustrate the importance of doing these movements rapidly and not just going through the motions.

Vertical momentum is needed to keep the body in the air during the long jump

In a running long jump the vertical force is about one-half that of the horizontal force

Jumping for distance requires some vertical velocity at take-off too. Long jumping requires the jumper to jump as high as possible while running forward at high speed to create sufficient lift to keep the body in the air long enough for the horizontal force to be expended. In the running long jump, the vertical force is about one-half that of the horizontal, to achieve a take-off angle of about 26° above the horizontal. To achieve a take-off angle of 45°, both the horizontal and vertical velocities would have to be equal. To achieve this angle the horizontal velocity would have to be reduced considerably. In so doing the horizontal velocity at projection would be too small to produce a jump longer than the combination of the high horizontal take-off velocity and the lower angle of projection.

Once the body is in the air the trajectory of the center of gravity of the total body has been determined. The body may change its configuration around its center of gravity but these actions will not alter the flight path. Movements seen during flight are made to gain equilibrium so that a controlled landing can be made. The longer the jumper can keep the feet up the longer the jump. Control at the moment of landing is essential so that the lower limbs will flex upon contact and let the center of gravity continue on down its flight path. If flexion does not occur or the body is not in equilibrium the jumper often falls backward after making foot contact. Some angular momentum was created at take-off as a result of the plant step. Head and arm movement during the initial part of the flight seeks to keep the body from rotating forward. This angular momentum is "stored" until landing and is then available to rotate the body forward over the feet.

What Else?

Walking is or of our most practiced skills. Walking is a reflex action and is regulated by subcortical levels of the brain. This enables us to carry on a conversation or to think about what we want to do after school while we are walking. We become most aware of how we walk when conditions

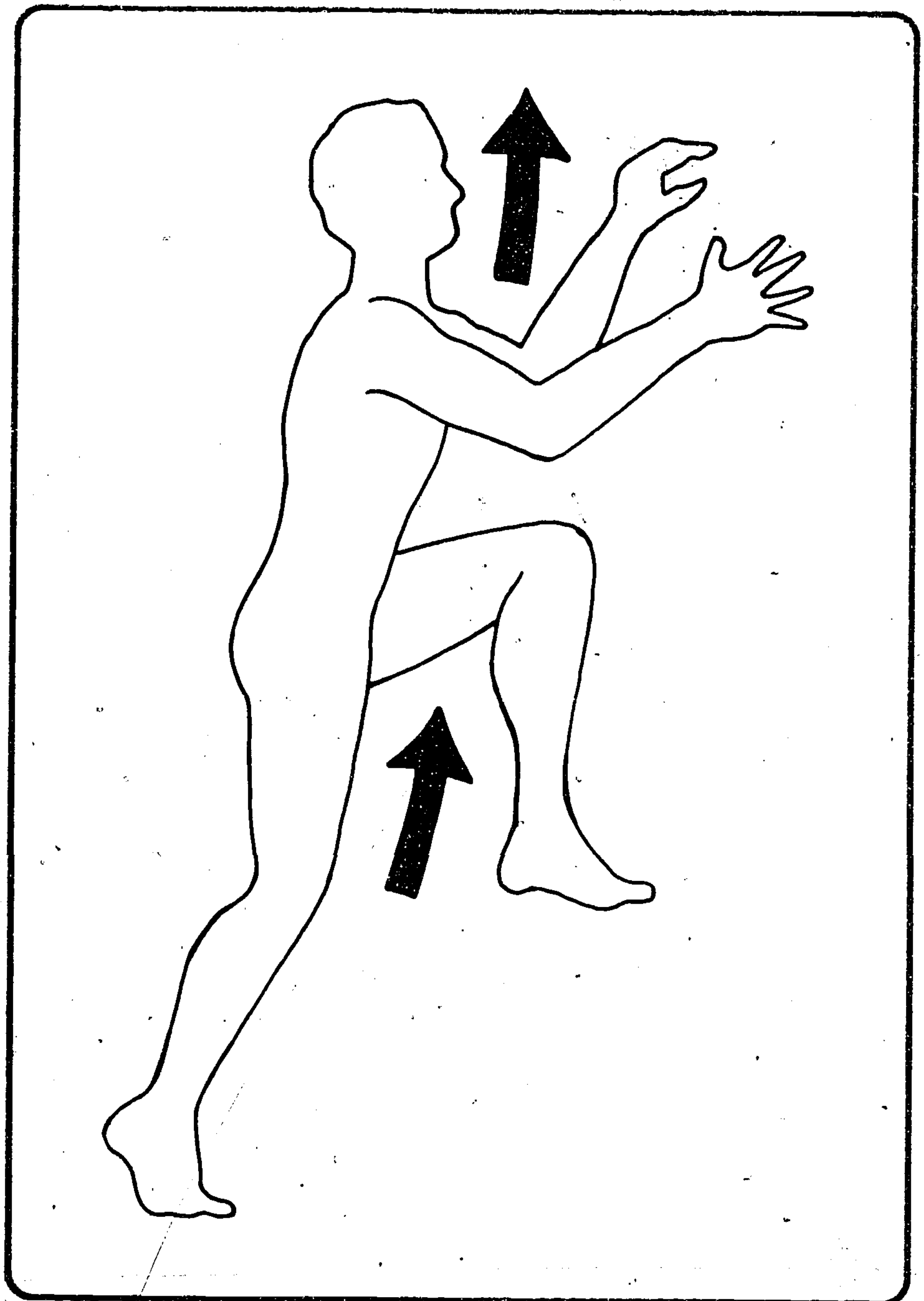


Figure 22: Lifting the lead leg forcefully and rapidly contributes to converting horizontal to vertical momentum.

cause us to change our normal patterns. Some of the special conditions which call for an alteration of the basic pattern are walking on slippery surfaces, such as ice or a wet pool deck; walking on soft surfaces, such as dry sand or in mud; and walking through something, such as tall grass or six inches of water.

When walking, the arms control the rotational forces created by the swinging leg

Walking is accomplished by the thigh swinging forward from the hip while the foot of the opposite limb is pushing against the supporting surface. A lot of gambling is involved for you are gambling that your swinging leg will contact the surface before the pushing foot leaves the ground. The body is actually pushed off balance and caught by the swinging foot before it falls too far. The function of the arms in walking is to counteract the rotational forces created by the swinging leg. If these two rotational forces are equal, the body moves straight ahead; if not, the person will seem to twist from side to side as they walk. The twisting is a wasted, inefficient motion.

For efficient walking, the up and down movement and lateral sway should not exceed 1 3/4" with the foot clearing the surface by approximately 1/8"

It is not possible to remove all unwanted movement from walking, but it should be reduced to a minimum for efficiency. During an efficient walk, there is both up and down movement and side to side movement. A smooth movement is produced when the up and down movement is no more than 1 3/4" in height and the lateral sway is of the same magnitude. The swinging foot clears the ground by an approximate 1/8 of an inch.

How?

Walking is not a simple skill. The body is moved forward in a straight line by the rotation of two stilts (legs) in opposite directions. Force is applied to the pelvis first on one side and then on the other. It is a good thing that walking is controlled by reflexes and does not require our conscious thought! Efficient walking requires the reduction of excessive rotation of body parts and keeping vertical movement to a minimum.

Rotational movement is minimized in walking by the counter force of the swinging arms and by keeping the support foot under the center of gravity

The position of the feet, toes pointing straight ahead, is the first requisite to reduction of excessive rotation. Secondly the arm swing must balance the rotation produced by the limb as it swings forward. It is possible to set up excessive rotation of the trunk by swinging the arms too vigorously. Rotation is further controlled by keeping the feet under the body when in the support phase and by swinging the limbs forward on a straight line.

Timing of the push-off by one supporting foot controls the vertical movement of the walk

Vertical movement is controlled by timing of the pushing action of the support leg. If the support foot pushes off too early, while the center of gravity of the body is still over the foot, a bouncy walk occurs. If the push comes too late the center of gravity of the body has moved too far forward of the support foot and the knee of the swinging limb must flex more than it should to catch the body weight. This is overstriding and causes excessive vertical movement of the body. The center of gravity follows a path that resembles a roller coaster.

The direction in which the feet are placed establishes the line of direction of the walk

Many people waste effort by walking with the feet turned out. This causes force to be applied at an angle to the desired direction of movement rather than straight ahead. This foot placement results in a shortened stride. The speed of the walk is governed by the stride rate and the stride length.

Why?

Children learn to move by imitating others. Walking is no exception. This is why the gait of children is often patterned after the parents. A major fault in walking is outward rotation of the thigh at the hip joint causing the foot to be turned out. When the leg is extended at the knee the position of the foot is controlled by moving the thigh at the hip. When the foot is turned out, forces are applied in two directions, backward and sideward. The force applied in the sideward direction does not aid the forward propulsion of the body.

A reflex plantar flexion which will increase forward propulsion can be induced by placing the toes straight ahead

Toeing straight ahead utilizes a reflex plantar flexion of the foot as the center of gravity falls anterior (in front of) to the point of support. This reflex thrust increases the forward propulsive force. When the foot is turned outward this reflex is not activated. Toeing out also places undue stress on the longitudinal arch of the foot as the body weight rolls over the medial side of the foot. This action also stresses the ligaments and musculature on the medial side of the knee joint. Many lower back pains can be traced to improper foot mechanics. Toeing out shortens the stride because of the lack of reflex action and the toes are not in a position to push off in a forward direction.

Improper directional placement of the feet can cause joint, ligament, and muscular damage

A waddling gait occurs when the inner borders of the feet are too far apart. When the feet are spread, the body must be shifted from side to side with each step. This sideward shift requires energy and reduces the length of the stride.

Some people look as though they are doing the rhumba as they walk down the street. They have a delayed weight shift, that is, they tend to place the foot before shifting the weight forward. This is accomplished by a relaxation of the lateral gluteal muscles as the weight shifts to each foot and you see the pelvis tilting from side to side with each step causing considerable hip sway.

As force of propulsion increases, the stride lengthens

The speed of the walk is regulated by the amount of force applied against the supporting surface. As this force increases, the stride length increases. The trunk leans forward to bring it more in line with the pushing foot. This increases the horizontal component of force. This lean lowers the hips and makes it necessary to increase the flexion in the support leg and in the swinging leg. The increased flexion in the swinging leg reduces the moment of inertia and allows the leg to be brought forward more rapidly. When the swinging leg cannot be brought through fast enough to maintain total body velocity the stride is shortened. Walking at a rapid pace soon becomes tiring because of the amount of muscular force needed to move the legs forward rapidly and to overcome the resistance encountered on each step. At this point it becomes less tiring to break into an easy run.

Smaller strides increase stability on slippery surfaces

Walking on slippery surfaces calls for an increase in friction between the foot and the surface. This is accomplished by increasing the surface area by walking flat-footed. The flat-footed walk shortens the stride length which increases the period of double support and reduces the horizontal component of force at push-off.

What Else?

Fast walking is more tiring than an easy job

How does running differ from walking? The most obvious difference is the rate of speed. Locomotor speed is the interaction of the stride length and stride rate. But running is not just a fast walk. As the limb movements of a walk are speeded up the internal resistances are increased and a considerable amount of force is expended that does not produce forward movement. In fact much of it resists forward movement. You become tired sooner when you walk very fast than you do when you jog easily. A person will break into a run or jog when the speed of movement approaches five miles per hour to reduce the resistance phase of the walk. Women will find it more efficient or easier if they start to run or jog at just over four and a half miles per hour.

When the speed is approximately 5 mph a jog is more efficient

The major ways in which a run differs from a walk are 1) an airborne period exists when both feet are off the ground, 2) the resistive phase is reduced or eliminated, 3) the knee maintains a greater degree of flexion through the early portion of the support phase, and 4) a longer stride is used.

How?

Factors that are common to both sprint and distance running efficiency are minimal vertical and horizontal movement of the body and maximal forward movement of the body. This is accomplished by observing the factors identified for efficient walking, full extension of the leg during the power phase, and keeping a flat lower back.

In sprinting the initial contact is made with the ball of the foot

The techniques of efficient sprint running and of distance running differ somewhat, not only in the rate of movement, but in the foot action. Sprinters tend to make initial contact with the ball of the foot while most distance runners make either a heel-to-toe contact or a rather flat-footed contact.

In sprinting, the foot should be moving backward at the moment of contact

A second difference is in the resistance phase of the run. Sprinters work to have the foot moving backward at the moment of contact so that they are immediately into the power phase of the run. Distance runners may encounter a brief resistance phase as the foot contacts the surface slightly ahead of the body. The speed of a run is determined by the length of the stride and the number of strides per unit of time.

Why?

Force is reduced when the foot is in a position where the toes point straight ahead. A foot position of toes straight ahead maximizes the forward propulsive force if the foot toes out; the forward force is reduced. When the entire foot contacts the ground, the weight is transferred from the heel along the lateral border of the foot across the ball of the foot for the final push-off by the big toe.

Arm length is shortened by bending so they can move faster to counteract the leg rotational forces

Runners carry their arms in a more flexed position than they do when walking. This is necessary to shorten the resistance to rotation so that the arms can be swung forward as rapidly as possible to keep pace with the rapidly moving legs. Arms should be moved forward and back in a relatively straight line unless you are running on a curve. If the hands cross over the mid-line of the body, body rotation of the trunk will occur.

A forward lean of the trunk limits hip flexion and shortens stride

During the propulsive or pushing phase of the run the body should be kept in line with the pushing leg. A forward lean of the trunk limits the amount of hip flexion and shortens the stride. It is impossible to get a good swing forward at the hip. Running with the center of gravity of the trunk too far forward leads to a thumping, noisy type of run. The weight comes down too heavily on the foot.

The uppermost joint of the lower extremity is the lumbosacral joint. The pelvis is where the lower limbs fasten to the trunk. Actions of the limbs can, therefore, be hampered or facilitated by the position of the pelvis. The lower back, lumbar area, should be flat when running to maintain the proper position of the trunk and pelvis for effective movement of the limbs.

Factors affecting propulsion are also operative in running

Stride length, the period from push-off of one foot to contact by the opposite foot, is affected by the length of the limbs. A shorter person must take more strides to cover a given distance than a taller person. Factors over which you have some control are the force applied at toe-off and the body position. You are actually a projectile for the period of time that you are airborne while running. Therefore the factors affecting a projectile apply also to running. These are speed at push-off, angle of projection, and air resistance. The speed at push-off is largely dependent upon the force applied by the muscles and the direction in which this force is applied. The angle of projection is largely determined by the body position relative to the pushing foot. Air resistance can lengthen the stride if it is blowing against the back. If there is a strong head wind, the forward lean is increased to decrease the surface against which the wind can resist your forward progress.

Speed of the stride is dependent upon the ratio of time between contact with the surface and time in the air.

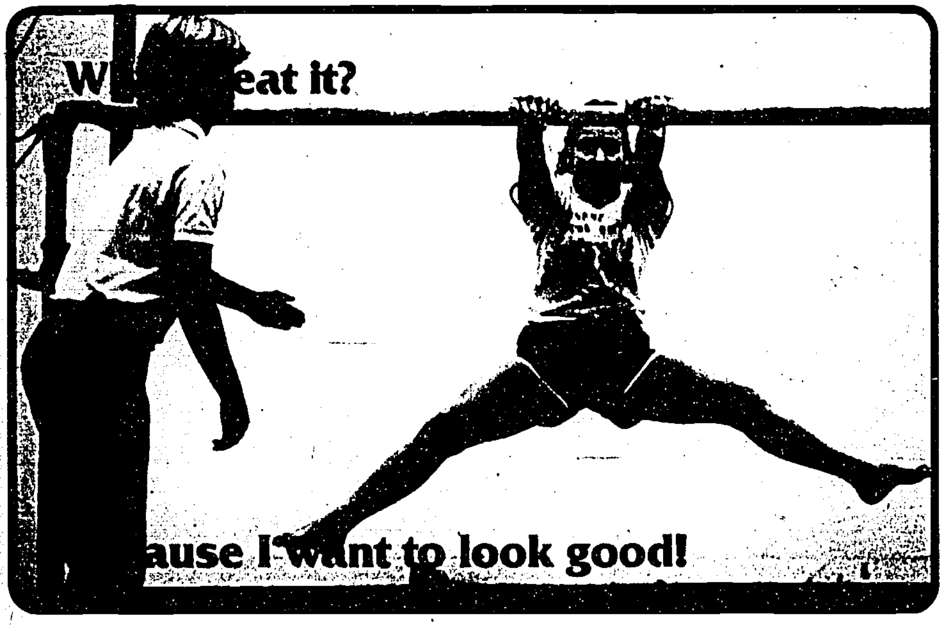
Stride frequency depends upon the time that you spend on the ground and the time that you are in the air. When running at top speed, you spend more time in the air. A jogger spends more time in contact with the ground than in the air. Stride frequency or rate of striding is determined primarily by the strength of the musculature used in running.

For successive quick changes of direction the stride should be shortened to increase time in contact with the surface

Not all running is done for the purpose of speed. When a quick change of direction is required though, steps should be short so that a foot is in contact with the ground nearly all of the time. The body cannot change the direction of a run until a foot is in contact with the ground. Good running backs in football run in a somewhat choppy manner. Short strides enable them to change direction quickly. By frequently changing the foot, which is in contact with the ground, it makes it more difficult for the opposition to tackle them. When the field becomes more open, the running back lengthens his stride to increase the speed of the run.

CHAPTER TWO

appearance



Photograph by Scott Forbes/Loudon Times-Mirror

What Else Do You Have to Help Me?

Personal appearance is important to everyone. The postures of individuals reflect their feelings and sometimes even their health. It is a rather vicious circle. If tired, you slump, demanding more muscular energy to keep the body from collapsing. This results in fatigue.

How Do I Get It?

Balancing the human body is not an easy task, but it is possible. A balanced posture is one that uses minimal muscular effort to keep the body in a particular position and does not place undue strain on the ligaments at the joints. Think back to the requirements for a stable equilibrium. A stable position calls for the center of gravity to be centered above the base of support. It is not always possible or desirable to have a wide base and a low center of gravity but it is possible to keep the center of gravity over the base.

Good posture in the standing position when viewed from the side would find a fairly straight line passing from the ear lobe through the tip of the shoulder, the center of the hip joint, posterior to the knee cap and falling about 1-1½'' anterior to the ankle joint. The body weight should be centered between the heel and the ball of the foot. Laterally the weight should be balanced so that the line of gravity would fall midway between the feet.

Why Does It Happen That Way?

Balancing the human body is easier said than done. When critically examining the body, it is seen as a marvel of instability with its high center of gravity and relatively small base of support. Man does gain an increase in his range of vision from walking on his hind legs however. Keep in mind the principles of stability as we look at the human body — large base, low center of gravity, and line of gravity centered over the base of support.

When standing the position of the feet form the base of support

The base of support is formed by the feet. The feet are not large when compared to the total body size. The size of the base can be increased functionally if the feet are spread apart. Our small base of support enables us to move quickly since it doesn't take long for the line of gravity to move outside the base of support. Sometimes we operate on a very small base when we stand on one foot or smaller yet on tip toe.

The center of gravity in human beings is located in the pelvis on a line with the hip joints

Does the body have a low center of gravity? The center of gravity when in a standing position is located in the pelvis, about one or two inches below the junction of the spine and the pelvis, about on a line with the hip joints. This is not a particularly low center of gravity. When we wish to lower the center of gravity to increase stability, we go into a crouch or squat position. When we are sitting down, we have a very low center of gravity relative to the supporting surface and even lower yet when we are lying down.

The skeleton is composed of specialized bones which facilitate yet limit action

The most difficult task is to keep the line of gravity centered over the base of support. Look at the skeleton to visualize the balance problem that we face. Remember that it is the antigravity muscles which keep the skeleton from collapsing. The lower limbs are set toward the rear of the feet, not over the center. Two long bones balance together on their narrow ends at the knee joint. The pelvis has an eccentric attachment to the femur and can rock forward and back rather easily. The spine attaches in the center of the pelvis from side to side. From anterior to posterior it is to the rear of the pelvis. Remember that the spine is not a solid bone, but is made up of twenty-four vertebra stacked on top of each other and poorly stacked at that. The spine is a series of anterior-posterior curves. In the thoracic region the ribs extend out front. On top of the stilts, topped by a rocker which supports a zig-zag spine, we find the heaviest bone of all, the skull.

The size and length of muscles as well as where they attach to the bones make them efficient for maintaining balance and producing force for specialized action

Some of our skeletal instability is corrected when we consider the location of the muscles of the body. The largest and hence heaviest musclature is in the region of the thigh. This helps to lower the center of gravity of the total body. Another heavy mass is the viscera which is located in the abdominal cavity. Much of this mass is situated anterior to the hip joints and therefore tends to rotate the body forward. This force must be countered by the strength of the muscles of the back which keep the spine erect. Anterior-posterior balance or alignment of the trunk is difficult to maintain. Lateral balance is usually good because there is a rather even distribution of weight around the centrally located spinal column.

Proper alignment of body segments is necessary to optimum balance and efficient movement

The function of the abdominal musculature is to hold the ribs and pelvis together. Well-developed abdominal muscles pull up on the anterior of the pelvis and this reduces the curvature in the lumbar area of the spine and reduces the prominence of the buttocks. The abdominal muscles are not the only muscles attaching to the pelvis and they cannot pull up on the pelvis unless the knees are s ghtly flexed. When the knees are locked, thrown back, this causes the lower back to hollow and the abdomen to become more prominent. The contour of the abdominal wall can be improved by proper positioning of the pelvis.

Weak muscles can not assist in maintaining proper alignment; hence stress is placed in joints and ligaments

A sagging abdomen may be due to lax abdominals. A protruding abdomen in a young child is normal. The liver in the child is relatively large to reduce the space available for the intestines, hence, the prominent abdomen. This disappears by the time the child is eight to ten years of age. In the over forty adult the sagging abdomen may be due in part to a weakening of the abdominal muscles, but it is compounded by the fact that the intervertebral discs, the fibrous pads between the vertebra, have thinned to the point that the person is getting shorter. This means that the abdominals are now too long for the distance between the ribs and the pelvis.

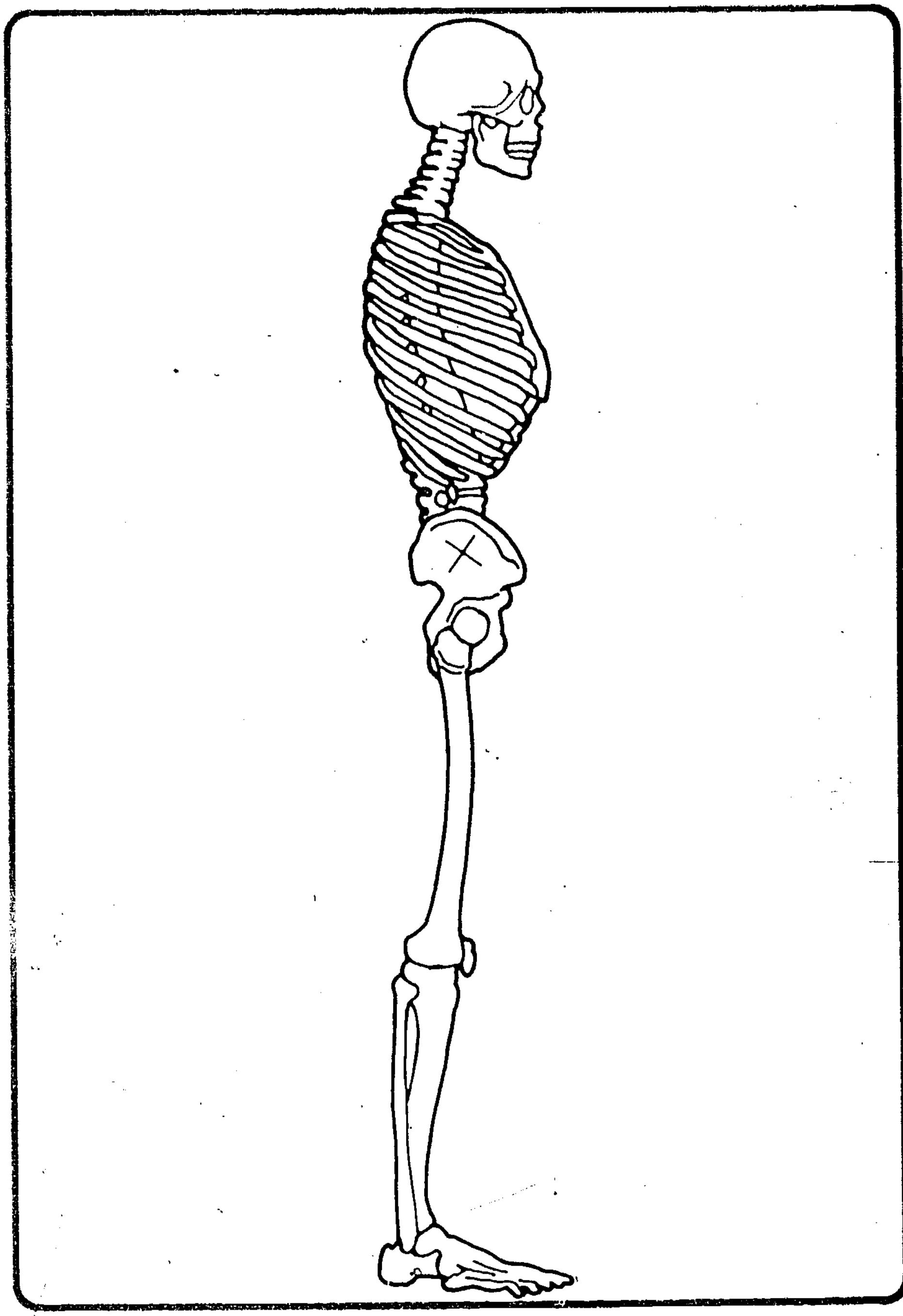


Figure 23: The skeleton is an example of instability with its high center of gravity and small base of support.

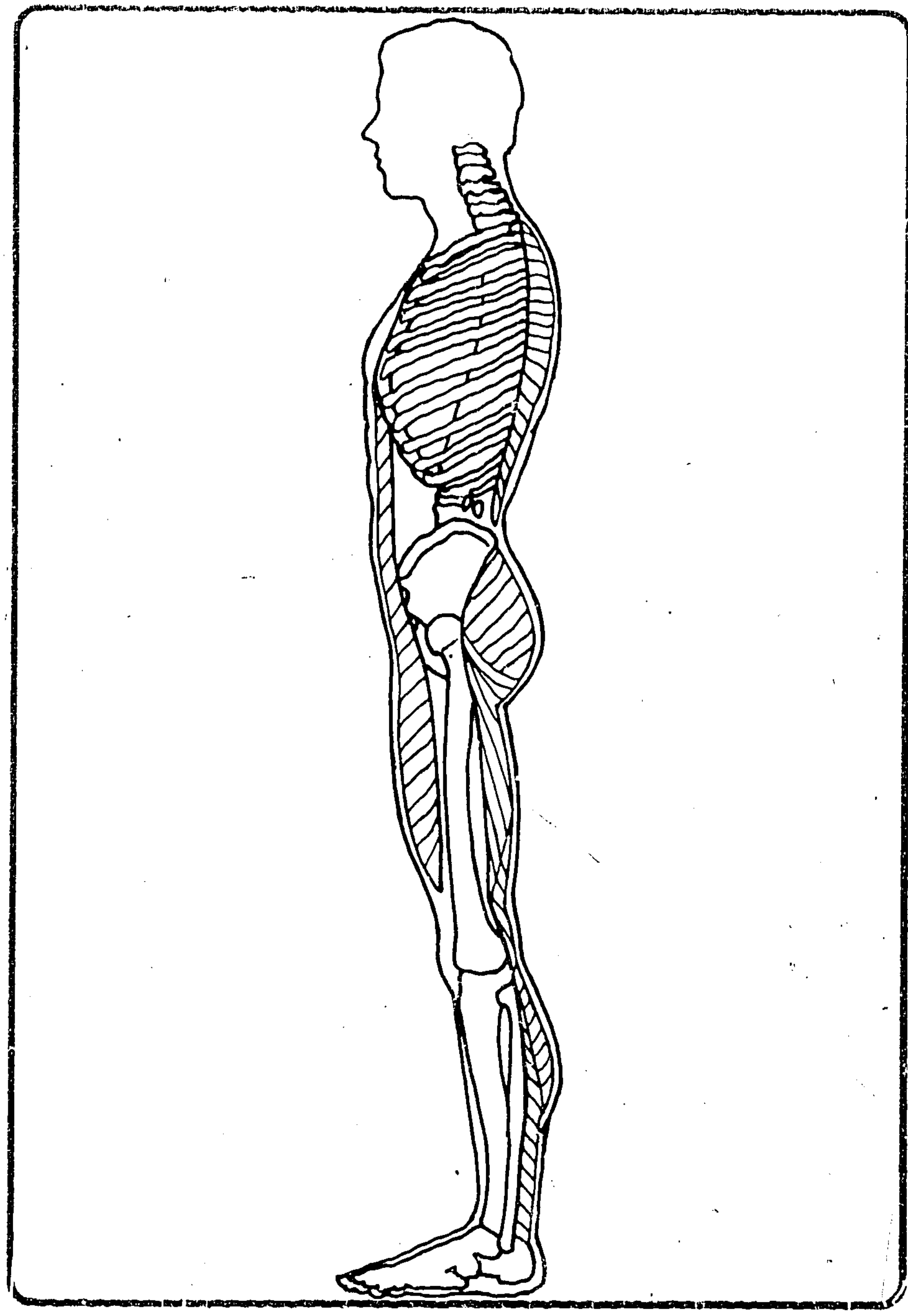


Figure 24: Anti-gravity muscles keep the body upright against the pull of gravity.

The trunk serves as a rigid base for the operation of the appendages, the arms and legs. The abdominal muscles spend a great amount of time stabilizing the unstable vertebral column. It is the anti-gravity muscles which keep the body and anything that the body is supporting, upright against the pull of gravity. These muscles are the extensors of the spine, the abdominals, and the extensors of the hip, knee, and ankle.

The lower extremity is for support and locomotion; upper is for manipulation

The lower extremity has the dual function of support and locomotion while the upper extremity is concerned primarily with manipulation. The sole function of the upper extremity is to position the hand for work

CHAPTER THREE

coping

Photograph by Carlyjane Dunn Rice

Since all movement is governed by our anatomical structure and controlled by the concepts of force, violating these concepts will injure the body

Most movements are involved with the performance of our daily activities. Common activities include walking, sitting, standing, picking up the newspaper, carrying a sack of groceries, putting the box of cereal on the shelf, pulling open a drawer, opening a door, and lifting a sandwich to our mouth.

Movement principles should be observed in the performance of these activities to avoid strain to the muscles and possible sprains of ligaments. You may be able to perform inefficiently and feel no pain for a period of time. As time goes by, the accumulation of these stresses to the body structures will be noticeable. Signals of abuse are osteoarthritis, stiff joints, aches, and perhaps pain from relatively easy work. For a more pain free existance in later years proper mechanics of movement should be practiced throughout your lifetime.

What Else Do You Have To Help Me?

We are lifting objects all the time. We lift a pencil off the desk to write, we lift our arm to see our watch, lift groceries out of the shopping cart, and lift our shoes off the floor when we get dressed. At home we lift a window as we open it, lift the piano bench to vacuum under it, and lift the garbage bag to carry it out.

The muscles used to lift should be matched in strength to the weight of the object

When light objects are to be lifted, only the arm is used. As heavy objects are moved more body parts come into action. The strongest muscles of the body are in the lower limb so the heaviest lifting should be done by extending the legs. Be careful that the lower back is not being over-stressed during heavy lifting. When lifting heavy objects the lifting force is produced by the muscles of the lower limb; the arms hold the object in position and the trunk is the connecting link between them.

How Do I Get It?

Use the legs to lift heavy objects

Very light objects pose few problems in terms of injury. As objects become heavier some general rules of lifting should be observed. Remember to lift with the legs, keep the back relatively flat, and keep the object as close to the body as possible.

To add insurance against the loss of balance spread your feet in the direction of the load to widen the support base. As an object is lifted it becomes part of your weight. Leaning away from the object makes it easier to lift.

Why Does It Happen That Way?

Pull the object as close to you as possible before lifting

Safe and easy lifting is done when all forces are applied vertically through the body. Some force must be resisted on a diagonal, but this should be kept to a minimum. Keeping the object as close to the body as possible reduces the rotational forces that are created by the object when it is held some distance away from the body.

Grabbing a heavy sack of groceries by the top to lift it out of the trunk puts stress on the forearm musculature and the back. A less stressful method would be to flex the knees slightly, place both hands under the sack, and lift with the knees as much as possible. Many automobile designers have not considered good lifting alignment. The trunk and bumper designs force us to use the upper body strength to lift objects up and out of the trunk. How much easier it would be if we could slide the sacks to the edge of the trunk, crouch down to pull the bag against our hip, straighten our legs and walk away. Our backs would be delighted!

Keep the back relatively flat when lifting, especially the lower back. You may even experience soreness of the abdominal muscles after heavy lifting for they must stabilize the position of the pelvis to keep the back flat. A clue to possible excessive stress on the lower back is the hips moving backward before the knees straighten as you start to lift. This causes more lifting to be done by the back and upper body.

What Else?

Pushing requires a constant application of force

Sometimes we have objects which are too large to be lifted yet need to be moved, such as a davenport, a large box, a piano, or a piece of gymnastic apparatus. Other objects are designed to be pushed, such as a lawn mower. Pushing requires a constant application of force to keep the object moving. Efficiency is lost if the application of force is not continuous. When an object is allowed to come to rest then force must be used to overcome the resting inertia. A pushing action is used in sports as well as when putting the shot or shooting a basketball.

How?

Apply force near the center of gravity of object and in the desired direction

A downward push is maximized if one's body weight can be placed on or over the object

Efficient pushing requires that the force be applied as nearly as possible in line with the desired direction of movement and as near the object's center of gravity as possible. If you want to push something in an *upward* direction the body should be under the object. In this way the extension of the hip and knee joints can add to the force produced by the arms. To push an object *forward* place the hands at chest level, flex at the elbows, and lean into the object. When pushing *downward* try to get your body weight over the object. When pushing down the legs cannot be used as an added force. Regardless of the direction in which the object is being pushed continue to apply force once it begins to move. When pushing in the forward direction you may need to take short steps to remain in contact with the object. Sometimes you see people pushing

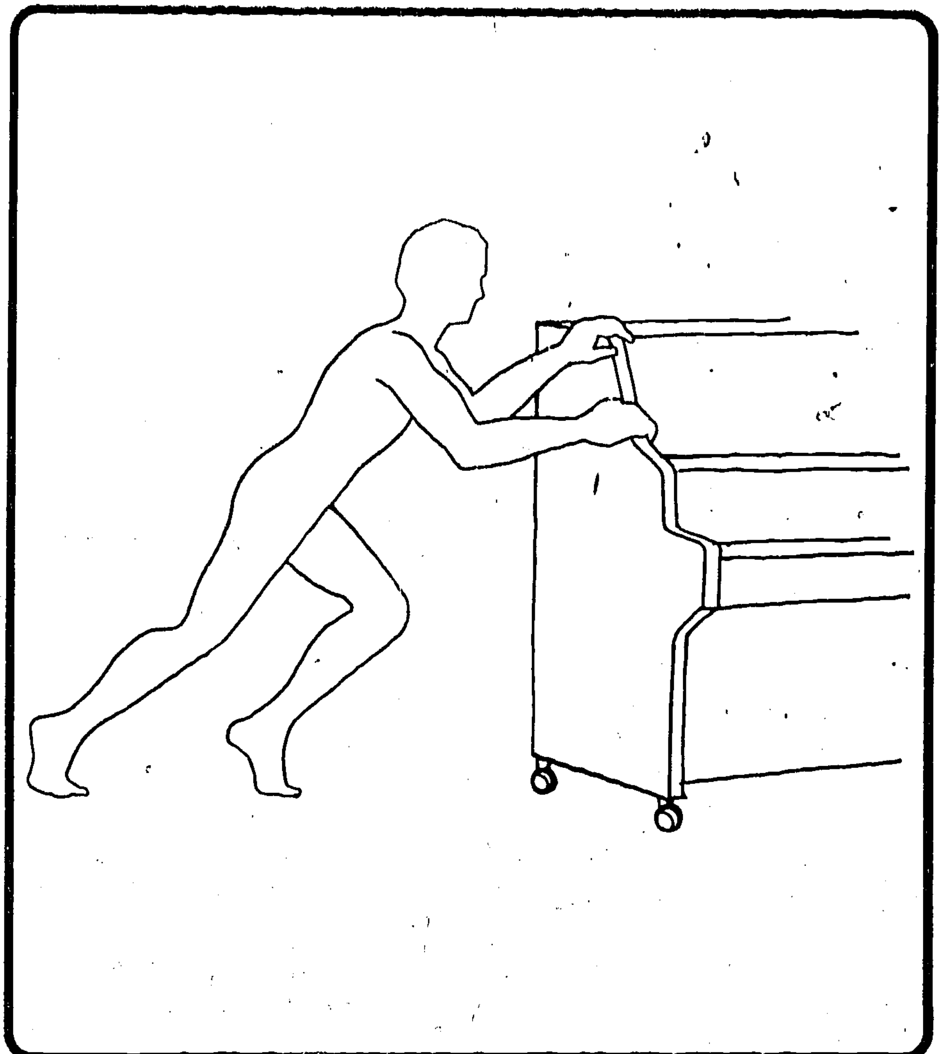


Figure 25: Keep the back relatively straight when pushing.

somethe[illegible] [illegible] p[illegible]ing the hips against the object and using the power [illegible] limbs in extension. This is done when arm strengt[illegible] [illegible] [illegible]fficient for transmitting the force of the legs to the object. A disadvantage of pushing with the hips is that the pusher is unable to see in the forward direction, and it is easy to fall if the feet should suddenly slip, or if the object unexpectedly increases its rate of movement.

Why?

Force which is not applied through the center of gravity of an object produces rotation. This is why the efficiency of the pushing action is increased when the force is applied as close to the center of gravity as possible. Sometimes it is not possible to get in line with the center of gravity of the object and thus one must allow for the resultant rotation. Undesirable rotation of the object can be controlled somewhat by spreading the hands to give better control, especially if the object is long.

Point feet in desired direction of movement

The position of the body also influences the direction in which the force is applied. The feet should be pointed in the desired direction of movement. This allows the force to be projected straight toward the object. The slight forward lean of the body should come from the ankle. This helps to keep the vertebrae of the spine in good alignment. When the hips are flexed the force of the push is reduced since the amount of upward force applied to the object is increased. A reduced effective force results. A forward lean places the center of gravity of the body in front of the pushing foot. Care must be taken to maintain sufficient friction between the feet and the supporting surface. On[illegible] [illegible]hould push with the feet in a forward stride position rather than a parallel position so that if slipping should occur you are [illegible]n a better position to prevent a fall.

Lean to place the center of gravity in front of the feet

A soft surface increases sliding friction

A soft surface produces considerable friction which resists the pushing action. This is especially true if the pushing force must be ap[illegible] [illegible] above the center of gravity of the object because of its size or structure. The downward component of the force which is applied above the center of gravity increases the resistance to movement across the soft surface. In this situation it may be easier to pull the object so that the lifting component of force is increased. Another solution to moving an object across a soft surface is to rotate the object. This is accomplished by applying force at the top edge and allowing the object to fall on its side. This action is rapidly repeated and can be effective for objects which are not too heavy and those that can be moved in this manner.

Less friction is generated if the sizes of two touching surfaces are minimized

Another way of moving objects by pushing actions over highly resistive surfaces is to "walk" it. The object is tipped onto a narrow edge or point to reduce the friction and force is applied to alternate edges to move the object forward. The balance of the object must be maintained over the narrow edge.

Reduce friction as much as possible

Remember that the more the friction between the object and the supporting surface can be reduced the easier it will be to move the object. It will move easier on a waxed floor, provided you can maintain sufficient friction between your feet and the surface to apply the necessary amount of force. The use of wheels also makes it easier to move a heavy object. If you need to move an object such as a mattress from one room to another push the mattress off the bed onto two rolling pins or dowels.

What Else?

Pulling increases the vertical component of force

Pulling is used for objects that are too heavy to lift and for objects which are very difficult or impossible to push. Pulling has the advantage of increasing the vertical component of force and hence applies a lifting effect.

Pulling actions can be of three types. One involves pulling something down from above shoulder level such as, pulling down a window shade, pulling on the rope of a church bell, and climbing a rope. In rope climbing, the rope is fixed so contracting muscles cause the body to be raised nearer the hands. The second type of pulling has the object moving over the ground, such as a coaster wagon or sled. The third type involves a more horizontal action such as pulling open a drawer in a cabinet or chest.

How?

Principles of pulling a[illegible] the same as for pushi[illegible]

The principles for pulling are basically the same as for pushing, i.e., apply force in line with the center of gravity of the object, apply force in the desired direction of movement, and keep the body in proper alignment so that the force generated by the musculature will be applied in an effective manner. Arm action will be sufficient to move an object when

To increase force for pulling, use muscles which yield maximum force and apply the force in the direction you wish the object to move

the resistance is light. For heavier objects the body must be aligned to allow the legs to develop the major force for pulling. To pull an object down on an object from overhead, stand close to the object so that the force can be applied in a downward direction to as great a degree as possible. The body weight can be suspended on the object if necessary by lifting the feet off the floor. To apply a horizontal force place the feet in a forward and back stride position. Extension of the lower limbs can be used to supplement the force of the upper body action when more force is needed.

Why?

Objects can be pulled across the supporting surface by facing away from the object. The abdominal muscles keep the trunk in slight forward flexion as the body leans forward from the ankles. Sometimes it is desirable to pull an object by facing it. This requires more effort by the extensor muscles of the back. The lower limbs are in a good position to apply force. There is a danger of losing balance and falling backward if the object should suddenly begin to move unexpectedly. Should you fall backward try to avoid putting the hands back to catch yourself since the result might be a broken wrist. This injury frequently involves the navicular bone of the wrist. This bone takes a very long time to heal because of its poor blood supply. Try to prevent the loss of balance and falling backward by having the feet in a strong forward and back stride position. This stride position widens the base of support in the direction of movement which makes it more difficult for the center of gravity to move beyond the rear foot.

Increasing the vertical component of force decreases the horizontal component

Pulling has the advantage of reducing the friction between the object and the supporting surface due to the lifting component of force. But remember, as the upward component is increased the horizontal component is decreased. If you eliminate the horizontal component completely you are lifting, not pulling! Some parents dump their children backward out of their wagons quite unintentionally because the tall adult holding on to the short handle of the wagon produces a large vertical component of force. If the weight of the child is concentrated behind the rear wheels of the wagon, little force is needed to cause the front of the wagon to rise. A tall person can pull a wagon or sled more easily if a rope is attached to the handle. This increases the horizontal force and reduces the vertical component.

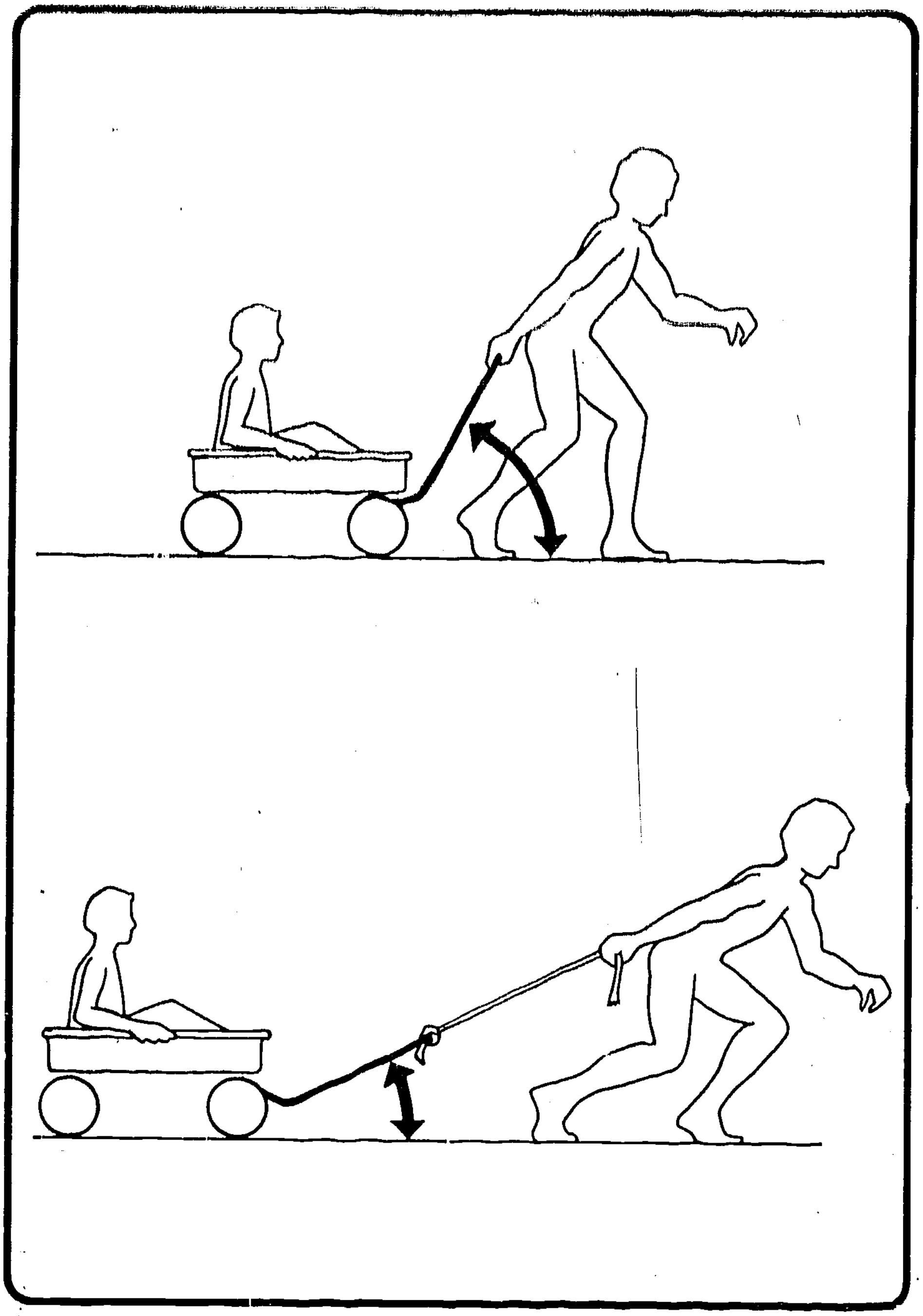


Figure 26: A rope attached to a wagon handle increases the horizontal force and reduces the vertical component.

Whether it is more efficient to push or to pull an object depends upon the nature of the supporting surface, the purpose of the activity, and the amount of available force which can be applied to the object. The more force that is applied in the desired direction of movement, the more efficient the movement.

What Else?

Carrying objects is another daily skill that demands attention to mechanical principles. We carry sacks of groceries, school books, gym bags, and golf clubs. Curvature of the spine can develop if objects are always carried on the same side of the body for a period of years. The heavier the object the more likely this is to occur. Boys and girls who deliver papers should shift the shoulders on which the paper bag is carried. Some newspaper companies have designed bags to fit over both shoulders so that the pouches are in the front and on the back of the child. This is easier for the maintenance of balance than carrying the papers on one side. European children for years have been carrying their books on their backs. The use of knapsacks and book bags is increasing in this country but how many times do you still see the bag slung over one shoulder rather than being worn on the back?

How?

Carry a load as near to your line of gravity as possible

Swinging or swaying loads are more difficult to carry

Leaning the body away from the load counteracts the pull of the load

Carrying is the balancing of an object once it has been lifted. Carry a load as near to the line of gravity of the body as possible. This reduces the rotational movement of the object. Even a light weight is difficult to hold and carry if it is held at some length away from the body. The object that you are carrying is now a part of the total weight that must be balanced over your feet. Carry the load as a part of your body and not as something that has motion independent of your body. Swinging and swaying motions cause a disturbance of equilibrium and make walking very difficult. You must keep the center of gravity of the body and the object over the base of support, usually the feet. Heavy objects require you to lean away from the object to counterbalance its weight and keep the new center of gravity over your base. Sometimes the lean is accompanied by holding the opposite arm out to the side if the object is quite heavy, such as a piece of luggage.

Why?

The best position in which to carry something is one which creates the least strain on the body. This position will be different for various individuals depending upon their size, height, strength, and age. Other factors which influence the way in which an object is carried is the distance that is to be traversed. The principles for carrying an object are the same as those for maintaining equilibrium which were discussed in Chapter 1.

When carrying something you have temporarily become a different weight and have a different shape, but the principles of balance are still the same.

CHAPTER FOUR

health

Photograph by Carl-Jane Dunn Rice

What Else Have You Got To Help Me?

"Oh boy, do I have a backache." "I have to lay off practice today. I have a muscle strain." "I sprained my ankle yesterday." These statements can be heard daily. Obviously movement improperly done can make you physically feel bad or leave you unsatisfied with the results.

You can lessen the chance of injury if you practice the underlying principles governing efficient movement. When you practice these principles you will reduce the possibility for joint injury and muscle strain. Also when movement is done with proper mechanics it becomes easier on the muscles and joint structures. Therefore, you can do more things and use less energy. When you use your body improperly the harmony is violated and you can injure it or move it ineffectively.

Well-conditioned muscles help to prevent joint injuries

Well-developed muscles protect the joints from undue injury. Muscular strength is the first line of defense against joint injury. Injury risks are also minimized when good body alignment is maintained.

How Do I Get It?

Good body alignment reduces the risk of injury

Good alignment helps reduce body abuse. This means that proper mechan[illegible] should be observed at all times and should become a way of [illegible]ving so that conscious thought is not necessary to bring about efficient movement. Let's review some of the effic[illegible] movement principles that have been discussed in earlier pages.

1) Use the strongest muscles of the body to move heavy objects, e.g., the leg muscles.

2) Keep the knees over the feet when flexing the legs.

3) Keep the spine in good alignment.

4) Keep the lower back flat when doing sit-ups and push-ups.

5) Keep the body in line with the hands when pushing and pulling.

6) Keep the head balanced over the spine

7) Keep the toes pointing straight ahea[illegible] [illegible]lking, running, and jumping.

Why Does It Happen that Way?

The type of joint movement is dependent upon the structure of the joint

A joint is formed where two or more [illegible] come together. The bones are held in the appro[illegible] relationship to each other by ligaments, muscle tension, and by atmospheric pressure. The structure of the ends of the bones, the way in which they articulate, and the location of ligaments and cartilage pads determines the type of action possible at the joint.

Synovial fluid "oils" the joints

The joints which permit appreciable movement are called the freely movable or *synovial joints*. These joints are characterized by a joint cavity, that is, a slight space between the bones. This space is enclosed by a thin synovial membrane which secretes synovial fluid. The synovial fluid reduces the friction as the joint moves and may therefore be thought of as the "oil" of the joint. Trauma to a joint may cause an excess secretion of synovial fluid which causes swelling and reduced range of motion at the joint. The thin synovial membrane is reinforced by a fibrous articular capsule. Ligaments often reinforce the articular capsule.

Ligaments are inelastic

Ligaments are tough, inelastic tissue which do not contract. Injuries to ligaments allow an increased range of motion at the joint. This can, over the years, over-stress surrounding structures and lead to arthritis of the joint. Once a ligament has been stretched it does not return to its original length.

Cartilage protects the ends of bones by reducing friction

Fibrous cartilage pads help to absorb shock between the bones

There are two types of cartilage found in some joints. A hard, shiny cartilage (hyaline) covers the ends of the bones in all joints. This type of cartilage reduces friction upon movement. When this cartilage is disrupted, arthritis results. The second type of cartilage, fibrous, forms a pad between the bones of certain joints, notably the knee and between the vertebrae of the spinal column. These fibrous cartilage pads serve as shock absorbers among other things and at the knee serve to reduce the amount of movement between the tibia and the femur.

Abnormal stresses lead to arthritis

Repeated abnormal stresses to a joint can lead to bony changes at the joint. A bone responds to stress by increasing its bone cell production. Therefore excess stress to bones at joints can lead to the production of bone spurs and other nodules of bone around the joint. This extra bone growth is called *exostosis*. These outgrowths of bone can interfere with normal movement at a joint and may lead to pain upon movement.

Keep a flat or rounded lower back when exercising

Abdominal muscles must be strong enough to stabilize the pelvis against the pull of the strong hip flexors

The lower back is an area where many people experience pain and discomfort following activity. A rule to follow is to keep a flat or rounded lower back when exercising. If the lower back hollows when doing sit-ups or any type of activity involving movement of the lower limbs against the pelvis, that particular exercise or maneuver is too difficult for you at that time. There is a strong muscle inside the abdominal cavity which attaches to the vertebrae of the lumbar area of the spine and to the femur. This is the *psoas major* muscle. The psoas crosses the hip joint and produces flexion at the hip joint and hyperextends (hollows) the lumbar area of the spine. The abdominal muscles must stabilize the position of the pelvis and counteract the tendency of the psoas to tilt the pelvis forward. When the abdominals are too weak to negate the action of the psoas in tilting the pelvis forward the lower back arches. To continue to exercise with a hollowed lower back tends to further strengthen the psoas and increases the imbalance between the strength of the anterior abdominal muscles and the psoas.

Keep the lower back flat when working to strengthen the abdominals

When doing sit-ups, curl the lower back, and when doing any type of leg exercises from a back lying position *keep the lower back on the floor*. When doing push-ups there is a tendency to let the abdomen sag by giving in to gravity; this also causes an arching of the lower back. *Keep the back flat*. Keeping the back flat is an excellent way to exercise the abdominal muscles. You do not see very many people with flat abdominal walls and hollow backs. The abdominals are really responsible for maintaining the contour of the lower back.

Where Can I Find More Information?

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