3

COMPONENTS OF PHYSICAL CONDITIONING

The main components of physical conditioning are cardiovascular endurance, flexibility, muscular strength and endurance, and skill development. The cardiovascular system is conditioned most effectively by active exercise such as running, swimming, or bicycling, and to a lesser degree, by weight resistance exercise and arm-cranking. Controlled passive exercise using machines, temperature changes, medication, or diets cannot replace active exercise. Flexibility, which also can be improved by weight training, is best achieved through stretching exercises that increase the body's range of motion. Muscular strength and endurance are developed through weight resistance exercise and, to a lesser degree, through sports activities.

A great deal is known about muscle physiology. Recent studies and technological developments have changed training techniques to verify certain practices which, in the past, had been based on empiric observations. The sports therapist, physiologist, trainer, and physical educator can adapt their methodology based on this new scientific information.

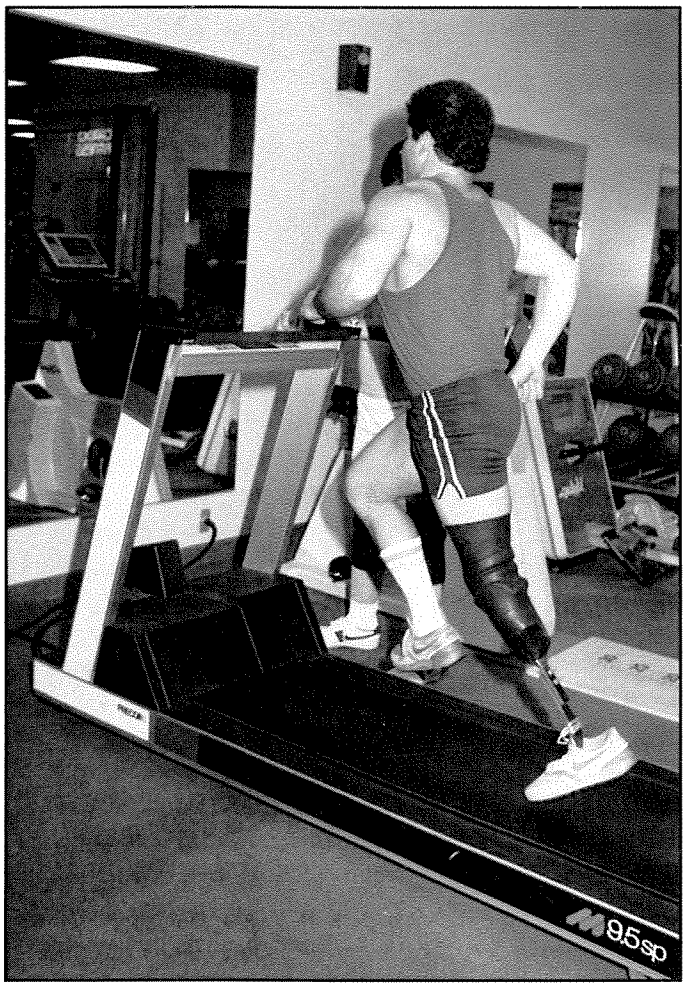
Computerized equipment accurately measures and monitors cardiorespiratory function at rest and while exercising. Many of the advances in the techniques of training and physical conditioning have been stimulated by organized sports competition. Biomechanical video analysis is useful to coaches who are trying to improve team performance. Football players participate in aerobic dance classes; weightlifting for strength and endurance is used by athletes in every competitive sport to improve performance.

A person with a lower limb amputation can exercise for fitness and train for sports in virtually the same ways as a nondisabled person. There may be some modifications to the workout routine depending on the level of amputation and the accessibility of special facilities.

CARDIOVASCULAR ENDURANCE

The word "aerobic" refers to a state of physical well-being in which the heart and lungs combine to provide life-giving oxygen and nutrition to the body's cells. The heart, lungs, and circulatory system transport the gases and nutrients which reach every body cell. In these cells, the complicated process of energy conversion takes place and waste products are discarded. We breathe and our hearts beat continuously many trillions of times during the course of our lives. The more efficient our system, the greater our capacity to perform mechanically.

The efficiency of the cardiovascular system is improved by the things that improve general health. These include diet, weight control, appropriate rest, and exercise. Several changes take place in the cardiovascular system once aerobic conditioning begins. For example, stroke volume will increase after regular intervals of physical conditioning. This means that every time the heart beats, more blood is made available to the circulatory system. The heart



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Treadmill Running Training on the treadmill is a form of steady state exercise. The speed of the treadmill can be varied to achieve individual aerobic fitness levels. The treadmill provides an opportunity for a person with amputation to run in a controlled environment on a regular basis.

will be able to beat fewer times to accomplish work at the same rate. The amount of work accomplished is dependent upon the amount of time expended. Both at rest and against a given load, the heart rate is lower as one's stroke volume increases. Another important effect of conditioning is that more oxygen can be taken from the hemoglobin (the iron-containing pigment in the red-blood cell that carries oxygen from the lungs to the tissues). Tissue oxygenation is also improved by increasing the number and density of capillaries in the muscles being worked. Even in sedentary individuals, these aerobic effects can begin to be realized after as little as 3 weeks of regular aerobic exercise.

Dr. Kenneth Cooper in his book, *The Aerobics Program for Total Well-Being,* defines aerobic exercises as activities "that demand large quantities of oxygen for prolonged periods and ultimately force the body to improve those systems responsible for the transportation of oxygen. In other words, the exercise is being performed with the body in a 'steady state'."[1] The healthy body always maintains homeostasis, a balance of its physiological systems. However, the level of energy expenditure needed to maintain homeostasis is quite different if one is sleeping or performing an active aerobic exercise. For aerobic conditioning, one must perform some kind of active training that brings oxygen into the muscular system (e.g., running, slow jogging, bicycling, swimming, cross-country skiing, rowing, playing basketball) for sustained periods of time. The opposite of this is anaerobic exercise during which the energy is provided without utilization of inspired oxygen (i.e., exercise that is limited to short bursts of vigorous activity, such as weight lifting).

To improve cardiovascular endurance, one should continually try to increase the length of time and level of energy expenditure so that the cardiovascular system can respond to the increased loads. Only by increasing the intensity, frequency, and duration of the exercise can the individual progress to higher levels of fitness. This is known as the "overload" principle because it requires the exercise intensity to be near the maximum when applied to either aerobic or anaerobic training programs.[2]

For example, there are a variety of training programs for running long- and short-distance races. Each varies with the length of the race. Many of the techniques involved can be attributed to refinement of training methods used by coaches and athletes throughout the years. Anaerobic/sprint capacities can be increased and aerobic/endurance performance can be improved. Interval training is a system that involves several bouts of hard work alternating with periods of lighter work or rest, thereby allowing for maximum intensity during the work intervals. "Manipulation of the rate and distance of the work interval, the number of repetitions, and the time and type of relief interval provides training programs that can meet the needs of many athletes and non-athletes."[3]

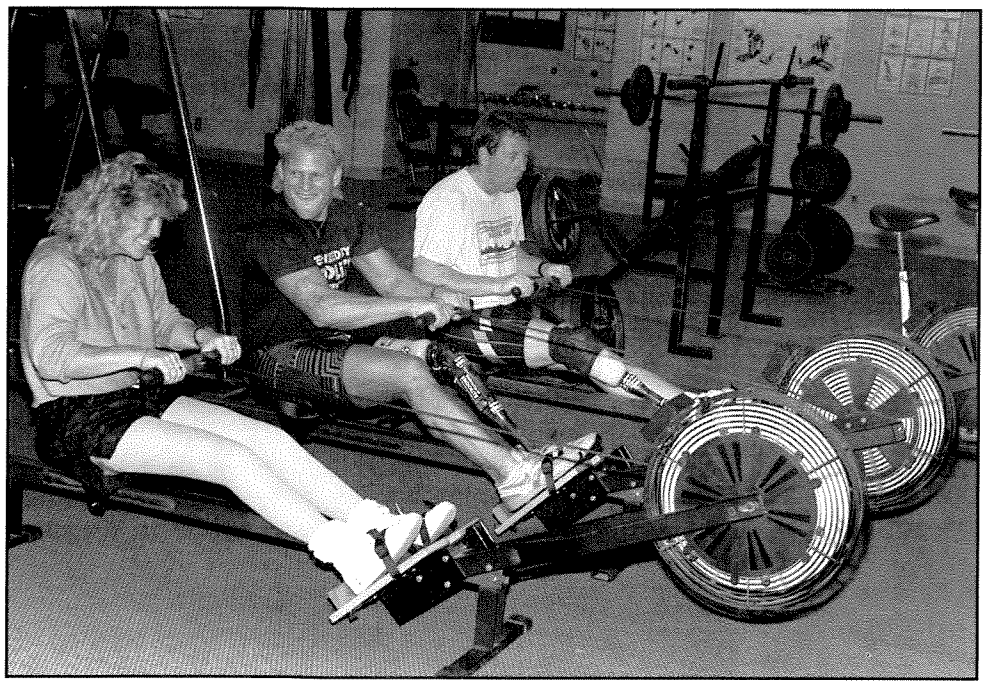
Research results have demonstrated the benefits of aerobic conditioning for people with lower limb loss. In one study, 10 such people participated in a

15-week aerobic conditioning program to determine whether it would improve cardiovascular fitness and reduce the effort required for walking.[4] Two of the subjects had bilateral amputations, three had above-knee (AK) amputation, four had below-knee (BK) amputation, and one had a partial foot amputation. All had been sedentary prior to the program; none had participated in any form of physical exercise or sport for several years. The average age of the subjects was 39. The program consisted of regular weekly exercise on a Schwinn® Air-Dyne Ergometer. Subjects exercised at 60 to 80 percent of their estimated maximum heart rate. Tests of maximum exercise on the ergometer and walking on a treadmill were conducted before and after training. Results showed a 25 percent increase in the maximum capacity for exercise on the ergometer and notably lower values for heart rate and oxygen consumption during treadmill walking at various inclines.

In another study demonstrating the positive effects of aerobic conditioning in the early stages of rehabilitation, subjects were middle-aged to elderly and had unilateral AK or BK amputations.[5] Following 14 weeks of regular exercise on a Schwinn Air-Dyne Ergometer that was modified for combined lateral arm/unilateral leg training while seated in their wheelchairs, all subjects showed improved cardiovascular response. Moreover, preliminary findings suggest that a combined arm-leg ergometer may provide improved function in wheelchair propulsion and prosthetic ambulation as well as aerobic conditioning and endurance training.

FLEXIBILITY

Flexibility is the ability to move without restriction during a normal range of movement: it is the quality of being bent without breaking. It is measured by the range of motion present through the connective tissues of ligaments and tendons that surround the joints between the bones and other parts of the body. Natural flexibility decreases with age. A child's body is flexible because the skeleton contains more cartilage, the bones are soft, and the muscles, ligaments, and tendons are more elastic. The loss of flexibility from childhood through adulthood cannot be avoided. However, it can be delayed by regularly performed exercises that stretch and improve the range of muscle and joint movement. Adults who maintain their flexibility through stretching exercises feel better, have more energy for everyday activities, and are less susceptible to injuries during sports participation. Stretching exer-



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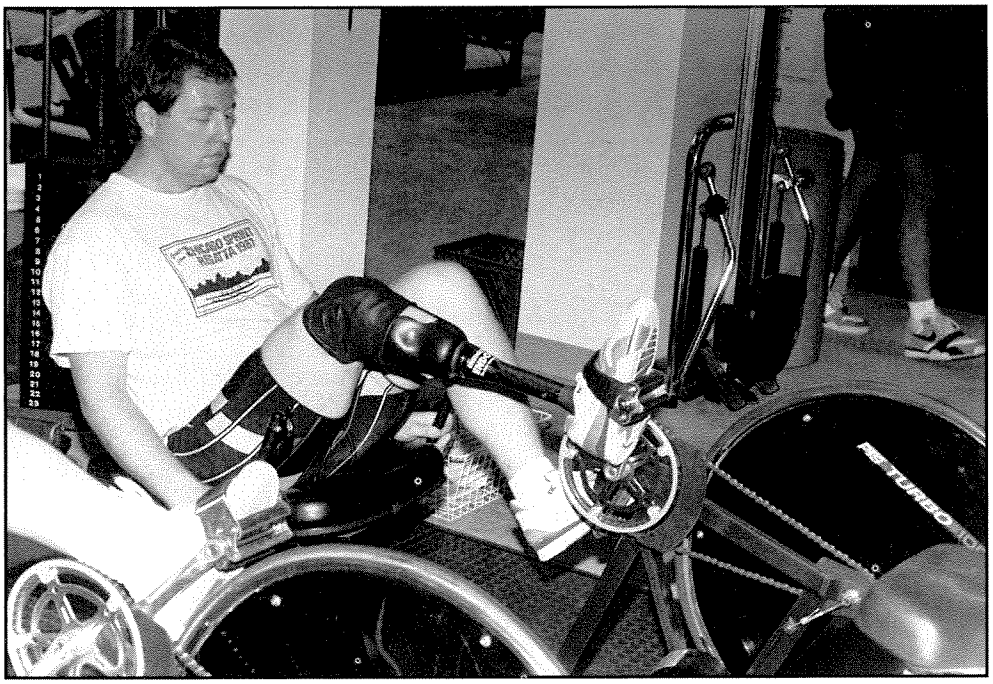
Rowing While we normally think of rowing a boat on a lake or river, the benefits of this exercise are accessible on stationary rowing machines available for in-home use or in the gym. These machines and computerized rowing machines can provide good aerobic conditioning.



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Stationary Bicycle Riding The stationary bicycle can be used at home as well as in the gym. Interval training can be done manually or on computer-driven exercise bicycles.

cises done on a regular basis will help people who suffer from chronic muscle "stiffness" to limber up and maintain a stretched-out feeling.

Stretching is a simple and painless method of preparing for vigorous physical activity without causing undue strain upon the body. Anyone can learn to stretch and regain some of the flexibility lost through the aging process. Athletic ability, past or present, is not necessary. However, before beginning stretching exercises, it is important that the potential exerciser carefully assess his or her physical condition, health, and capacity for muscle tension and flexibility, since stretching exercises should be individually tailored. A physician should be consulted and advised about any existing physical problems, recent surgery (particularly pertaining to the joints and muscles), or prolonged inactivity.

Stretching exercises must be performed correctly with the exerciser focusing on the range of motion of a particular muscle group and stretching only far enough to feel tension—not pain. Those who have been involved in other forms of conditioning have been told, "No pain, no gain." This philosophy does not hold true for stretching because muscles need to be relaxed in order to stretch further. People who stretch incorrectly have a tendency to bounce up and down until the exercise creates pain, which should be the signal to stop.

Muscle strain activates the protective stretch mechanism called the "stretch reflex." Each time muscle fibers are stretched too far by either bouncing or over-stretching, a nerve reflex sends a signal to the muscle to contract. This involuntary contraction keeps the muscle from being injured or over-stretched. When over-stretched, muscles actually tighten and the body's natural defense mechanism protects them from injury. However, repeated incorrect methods of stretching can cause not only pain, but microscopic tearing of the muscle fibers. This tearing eventually causes the formation of scar tissue which gradually results in the loss of elasticity and flexibility.

MUSCULAR STRENGTH AND ENDURANCE

Physical strength is achieved through muscle development. Muscular strength is defined as the force or tension of a muscle group which can be exerted against a resistance in one maximal effort. Muscle strength and increase in muscle size are acquired by muscles working against a resistant force which is gradually increased as the muscles become stronger.

A strength conditioning program usually consists of progressively resistive weight exercises. The

exercises can concentrate on specific goals such as building muscle bulk, power weightlifting, muscle definition, muscle tone, endurance for a specific sport, or skills. The muscle groups of the body can be isolated and trained. Nutrition, amount of rest, and genetics also play a part in achieving these goals.

Endurance is acquired by repetitive exercise against a constant level of resistance. Light resistance exercises repeated many times produces endurance. However, muscle exercise for endurance affects muscle bulk only slightly and does not increase muscle strength. For that reason, it is necessary to combine endurance and strength exercises in a coordinated program.

Increases in strength and endurance are accompanied by physiological changes, that is, increased muscle size (hypertrophy), biochemical alterations, and adaptations in the nervous system. A muscle shortens while lifting, and lengthens while lowering, a constant load. The tension developed over the range of motion depends upon the length of the muscle, the angle of the pull of the muscle on the skeleton, and the speed of the shortening.

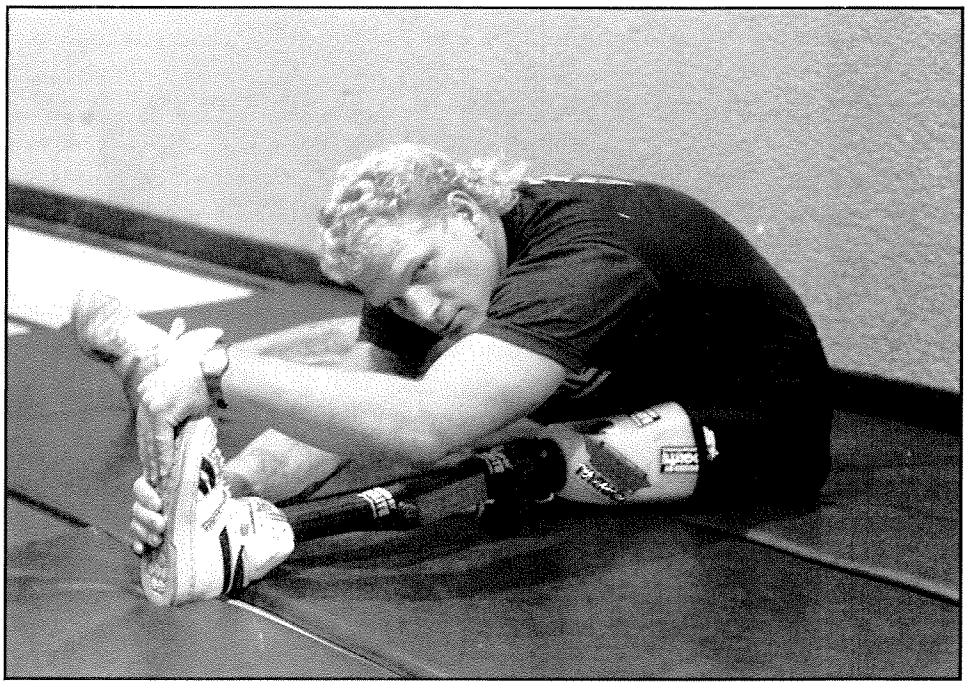
Muscular strength and endurance are developed by practicing the overload principle. Strength, endurance, and hypertrophy of a muscle will increase only when that muscle performs for given periods of time at its maximal capacity to work against resistance and loads that are above those normally encountered.

As one develops strength and endurance, participation in aerobic and sports activities becomes easier. Strength gains can be specifically oriented toward sports performance by focusing on exercises that simulate movement patterns used in the skill of a particular sport. Most exercise physiologists feel that it takes from 6 to 12 weeks of progressive, organized, muscle-resistance exercise to build up an optimum level of strength for the performance of many competitive sports activities. For outdoor seasonal sports, the program can be combined for maintenance-conditioning during the sport season and for strength-conditioning during the off-season.

Muscle Soreness

Muscle soreness is common to beginners in a strengthening program. Two types of soreness can result from muscle strain: acute and delayed.

Acute muscle soreness is often caused by inadequate blood flow. Tension created in a muscular contraction occludes blood flow to the muscles being worked thereby causing ischemia. Metabolic



Stretching Exercise
Greg Mannino works to touch his head to his knee.

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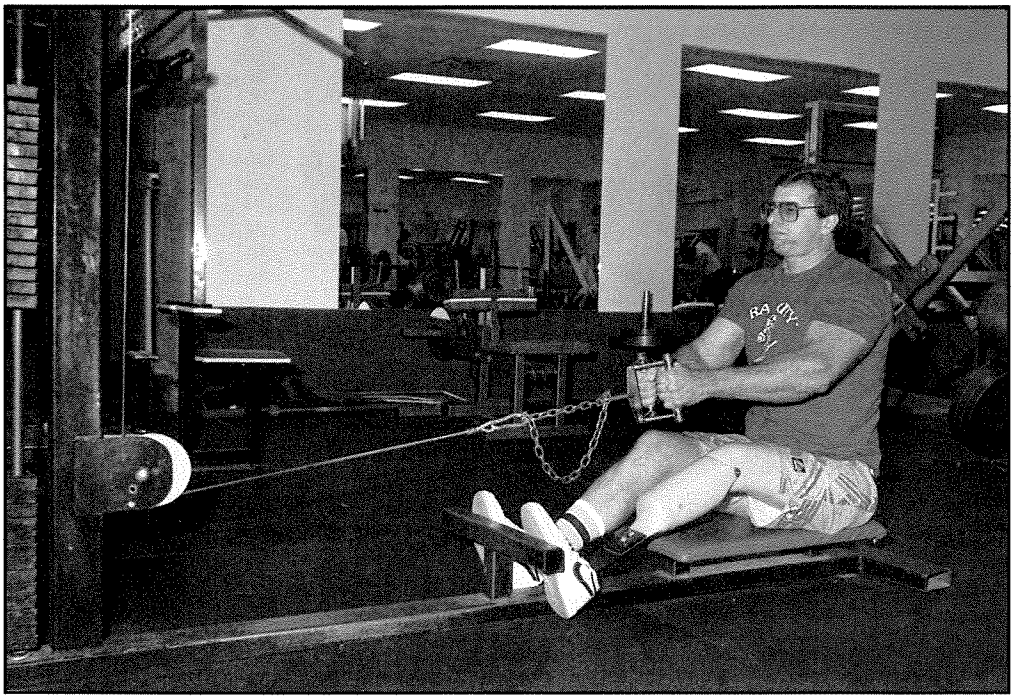

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Strength Conditioning Pulling against resistance and lifting weights strengthens the muscles of the arms and upper back.

waste products like potassium and lactic acid cannot be removed from the blood because of the build-up of ischemia. This build-up can actually stimulate the pain receptors in the muscles, causing soreness. The pain or soreness will subside when the exercise producing the contraction of the muscles is reduced or completely stopped. The blood can then flow in a normal manner, creating an environment for the removal of lactic acid and potassium. The complete removal of these waste products can take many hours, but a majority are removed within the first 15-60 seconds after the contraction of the muscle has ceased. For this reason, a 30- to 60-second rest period between each set of weightlifting exercise is always recommended to allow any soreness to subside.

Delayed muscle soreness is usually caused by a disruption of the connective tissues. This form of soreness is commonly noticed between 24-48 hours after exercising. Several theories exist regarding the cause of delayed muscle soreness and some observations have been made pertaining to prevention. For example, controlled stretching before and after an activity has been found to be helpful. Stretching is also effective in soothing existing muscle soreness. A carefully graduated exercise program can help prevent delayed muscle soreness.

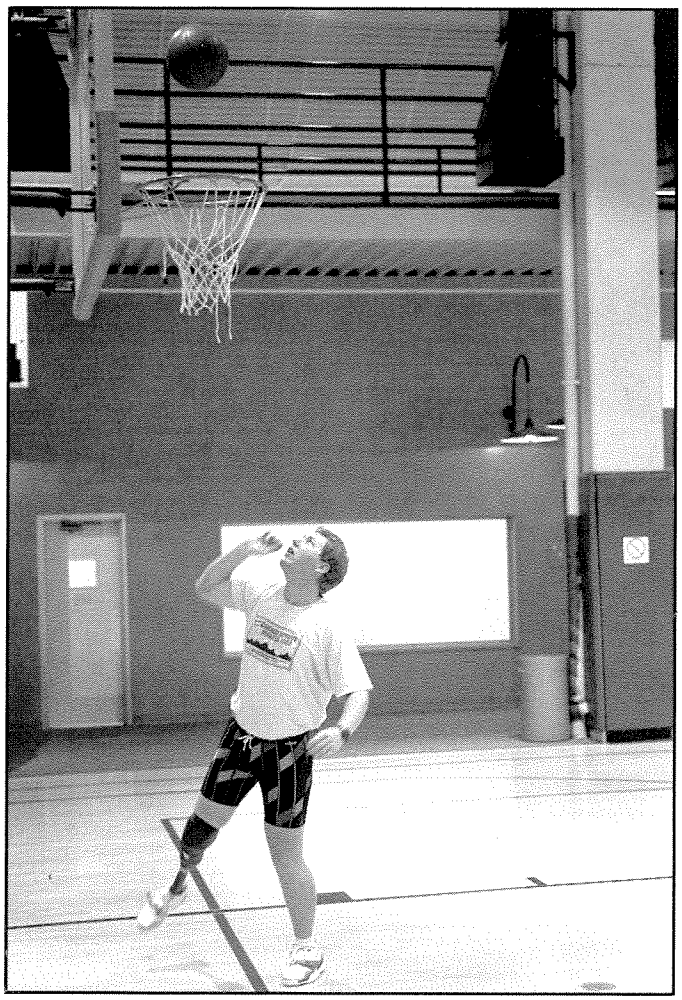
SKILL DEVELOPMENT

Being skilled in sports implies the ability to excel. Time, distance, and accuracy objectively measure skillful performance. Competition is also a measure of skill; as are coordination, balance, and speed.

Skill also can be expressed in terms of grace, beauty, and aesthetics. The ballet dancer, equestrian, basketball player, and gymnast perform with varying degrees of artistry. While these qualities are not easy to measure objectively, they represent true forms of physical and artistic skill. Thus, many athletic skills are both physical and artistic.

Skillful physical performance is also the result of neuromuscular coordination. Finely-tuned coordination can be both inborn and acquired. Certain voluntary and involuntary movements can be described as being clumsy, awkward, and poorly coordinated. On the other hand, trained and coordinated movements are usually graceful and precise. Young children playing active physical games during a school recess exhibit a wide variety of inborn neuromuscular coordination.

Acquired skills are the result of physical conditioning, fitness, and practice. No matter how much natural physical ability a person possesses, proper



DALE TILLY/DVAMC, SEATTLE, WA

Skill at Work Basketball combines skill and concentration with enjoyable exercise.

coaching and training will develop skill. Successful athletes continually improve their skills through the application of more refined techniques, and not necessarily by building greater strength and endurance. Precision sports, such as golf, constantly exemplify the need for perfecting technique.

For the person with lower limb loss, there are always compensations to be made when participating in physical activities. However, the compensations can be reduced by effective prosthetic substitution and/or adaptations. It also becomes natural for such individuals to enhance their performance through creative use of other parts of their body. Participating in activities wherein the physical loss of a limb can be successfully compensated for will result in maximum enjoyment and potential for skill development.

NOTES

1. K.H. Cooper, *The Aerobics Program for Total Well-Being.* New York: Bantam Books, 1982, p. 112.

2. E.L. Fox and D.K. Mathew, *Physiological Basis of Physical Education and Athletes.* Philadelphia: CBS College Publishing, 1981, pp. 273-291.

3. *Ibid.,* p. 162.

4. K.H. Pitetti, P.G. Snell, J. Stray-Gundersen, and FA Gottschalk, "Aerobic Training Exercises for Individuals Who Had Amputation of the Lower Limb." *Journal of Bone and Joint Surgery,* 69-A(6), 1987, pp. 914-921.

5. A.G. Bostom, E. Bates, N. Mazzarella, E. Block, and J. Adler, "Ergometer Modification for Combined Arm-Leg Use by Lower Extremity Amputees in Cardiovascular Testing and Training." *Archives of Physical Medicine and Rehabilitation,* 68(April), 1987, pp. 244-247.

Greg Mannino demonstrates a muscle strengthening exercise.

All photographs in Chapters 5 through 12 (unless otherwise credited) were taken by Dale Tilly or John Woodmansee of the Medical Media Service, Department of Veterans Affairs Medical Center, Seattle, WA.