Physiology of Exercise

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Dr. Arpita Mishra

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Preface

Exercise physiology is the study of the body's responses to physical activity. These responses include changes in metabolism and in physiology of different areas of the body like the heart, lungs, and muscles, and structural changes in cells.

Compared to our resting state, exercise poses a substantial increase in demand for the body. At rest, our nervous system maintains a parasympathetic tone, which affects the respiratory rate, cardiac output, and various metabolic processes. Exercise stimulates the sympathetic nervous system and will induce an integrated response from the body; This response works to maintain an appropriate level of homeostasis for the increased demand in physical, metabolic, respiratory, and cardiovascular efforts.

Exercise physiology is the physiology of physical exercise. It is the study of the acute responses and chronic adaptations to a wide range of exercise conditions. Exercise physiologists study the effect of exercise on pathology, and the mechanisms by which exercise can reduce or reverse disease progression.

Exercise is a term that has a variety of possible meanings, each dictated by circumstances. In a sports context, exercise is the performance, conditioning or training undertaken in respect to a particular athletic or sporting purpose. Exercise may also be directed to improvement of a person's general health, physical fitness, or as physical therapy, to augment an existing treatment to remedy or to ameliorate the effects of a disease or illness upon the body.

Therapeutic exercise can be defined as a specific program of regular exercise with certain objectives. It refers to physical activity

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undertaken to treat chronic musculoskeletal, cardiopulmonary, or neurologic conditions as part of a rehabilitation program, as distinct from exercise undertaken for general health maintenance, recreation, or as a social activity. Therapeutic exercise may vary from exercises directed towards a specific body part or muscle group to general workouts intended to restore a patient recovering from illness or surgery to better physical condition.

The gain in the endurance of a muscle as a result of exercise, however, is out of all proportion to its gain in size. Therefore, the quality of contractions must be improved through such factors as the following: fuel is made more available and in greater amount; oxygen is more abundant, owing to improved circulation of the blood through the muscle; and better co-ordination of the individual muscle fibers and more complete use of all fibers are realised. Systematic exercise facilitates the transmission of nerve impulses across motor end-plates, which, in turn, leads to a more complete use of all muscle fibers. Also, improved co-ordination of agonists and antagonists and of the timing of impulses which reach the individual muscles are significant contributors to the amount of strength and power that is possible.

The process of developing muscular strength through exercise is physiological; muscle fibres cannot reproduce, although they can increase in size. This growth is due to a number of factors, which include toughening and thickening of the sarcolemma (wall) of the muscle fibre, increasing the amount of connective tissue wiithin the muscle, enlarging individual muscle fibres, and increasing circulatory and respiratory activities during repeated contractions. Individual muscle fibres do hypertrophy as a result of certain types of exercise.

The term exercise physiology is used to identify the corresponding course of academic study offered at universities around the world.

—Dr. Arpita Mishra
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Physical Education,
Shri Agrasen Mahila Mahavidhyalay, Azamgarh

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1

Introduction

Exercise physiology is the physiology of physical exercise. It is the study of the acute responses and chronic adaptations to a wide range of exercise conditions. Exercise physiologists study the effect of exercise on pathology, and the mechanisms by which exercise can reduce or reverse disease progression.

METABOLIC CHANGES

Rapid energy sources

Energy needed to perform short lasting, high intensity bursts of activity is derived from anaerobic metabolism within the cytosol of muscle cells, as opposed to aerobic respiration which utilizes oxygen, is sustainable, and occurs in the mitochondria. The quick energy sources consist of the phosphocreatine (PCr) system, fast glycolysis, and adenylate kinase. All of these systems re-synthesize adenosine triphosphate (ATP), which is the universal energy source in all cells. The most rapid source, but the most readily depleted of the above sources is the PCr system which utilizes the enzyme creatine kinase. This enzyme catalyzes a reaction that combines phosphocreatineand adenosine diphosphate (ADP) into ATP and creatine. This resource is short lasting because oxygen is required for the resynthesis of phosphocreatine via mitochondrial creatine kinase.

Therefore, under anaerobic conditions, this substrate is finite and only lasts between approximately 10 to 30 seconds of high

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intensity work. Fast glycolysis, however, can function for approximately 2 minutes prior to fatigue, and predominately uses intracellular glycogen as a substrate. Glycogen is broken down rapidly via glycogen phosphorylase into individual glucose units during intense exercise.

Glucose is then oxidized to pyruvate and under anaerobic condition is reduced to lactic acid. This reaction oxidizes NADH to NAD, thereby releasing a hydrogen ion, promoting acidosis. For this reason, fast glycolysis can not be sustained for long periods of time. Lastly, adenylate kinase catalyzes a reaction by which 2 ADP are combined to form ATP and adenosine monophosphate (AMP). This reaction takes place during low energy situations such as extreme exercise or conditions of hypoxia, but is not a significant source of energy. The creation of AMP resulting from this reaction stimulates AMP-activated protein kinase (AMP kinase) which is the energy sensor of the cell. After sensing low energy conditions, AMP kinase stimulates various other intracellular enzymes geared towards increasing energy supply and decreasing all anabolic, or energy requiring, cell functions.

Brain

At rest, the human brain receives 15 per cent of total cardiac output, and uses 20 per cent of the body's energy consumption. The brain is normally dependent for its high energy expenditure upon aerobic metabolism. The brain as a result is highly sensitive to failure of its oxygen supply with loss of consciousness occurring within six to seven seconds,with its EEG going flat in 23 seconds. If it affected the oxygen and glucose supply to the brain, the metabolic demands of exercise could therefore quickly disrupt its functioning.

Protecting the brain from even minor disruption is important since exercise depends upon motor control, and particularly, because humans are bipeds, the motor control needed for keeping balance. Indeed, for this reason, brain energy consumption is increased during intense physical exercise due to the demands in the motor cognition needed to control the body.

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Cerebral oxygen

Cerebral autoregulation usually ensures the brain has priority to cardiac output, though this is impaired slightly by exhaustive exercise. During submaximal exercise, cardiac output increases and cerebral blood flow increases beyond the brain's oxygen needs. However, this is not the case for continuous maximal exertion: "Maximal exercise is, despite the increase in capillary oxygenation [in the brain], associated with a reduced mitochondrial O_2 content during whole body exercise" The autoregulation of the brain's blood supply is impaired particularly in warm environments

Glucose

In adults, exercise depletes the plasma glucose available to the brain: short intense exercise (35 min ergometer cycling) can reduce brain glucose uptake by 32 per cent.

At rest, energy for the adult brain is normally provided by glucose but the brain has a compensatory capacity to replace some of this with lactate. Research suggests that this can be raised, when a person rests in a brain scanner, to about 17 per cent, with a higher percentage of 25 per cent occurring during hypoglycemia. During intense exercise, lactate has been estimated to provide a third of the brain's energy needs. There is evidence that the brain might, however, in spite of these alternative sources of energy, still suffer an energy crisis since IL-6 (a sign of metabolic stress) is released during exercise from the brain.

Hyperthermia

Humans use sweat thermoregulation for body heat removal, particularly to remove the heat produced during exercise. Moderate dehydration as a consequence of exercise and heat is reported to impair cognition. These impairments can start after body mass lost that is greater than 1 per cent. Cognitive impairment, particularly due to heat and exercise is likely to be due to loss of integrity to the blood brain barrier. Hyperthermia also can lower cerebral blood flow, and raise brain temperature.

EDUCATION IN EXERCISE PHYSIOLOGY

Accreditation programmes exist with professional bodies in most developed countries, ensuring the quality and consistency of education. In Canada, one may obtain the professional certification title – Certified Exercise Physiologist for those working with clients (both clinical and non-clinical) in the health and fitness industry. An exercise physiologist's area of study may include but is not limited to biochemistry, bioenergetics, cardiopulmonary function, hematology, biomechanics, skeletal muscle physiology,neuroendocrine function, and central and peripheral nervous system function. Furthermore, exercise physiologists range from basic scientists, to clinical researchers, to clinicians, to sports trainers.

Colleges and universities offer exercise physiology as a program of study on various different levels, including undergraduate, graduate, and doctoral programmes. The basis of Exercise Physiology as a major is to prepare students for a career in field of health sciences. A program that focuses on the scientific study of the physiological processes involved in physical or motor activity, including sensorimotor interactions, response mechanisms, and the effects of injury, disease, and disability.

Includes instruction in muscular and skeletal anatomy; molecular and cellular basis of muscle contraction; fuel utilization; neurophysiology of motor mechanics; systemic physiological responses (respiration, blood flow, endocrine secretions, and others); fatigue and exhaustion; muscle and body training; physiology of specific exercises and activities; physiology of injury; and the effects of disabilities and disease. Careers available with a degree in Exercise Physiology can include: non-clinical, client-based work; strength and conditioning specialists; cardiopulmonary treatment; and clinical-based research.

PSYCHOLOGICAL QUALITIES OF A GOOD OFFICIAL

The game ended more than a hour ago. You no longer need to be extremely alert or prove yourself to the players, coaches, and

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fans. You feel drained physically and emotionally. So you sit back with a cool drink, put your feet up, and try to relax. But for some reason you can't unwind.

Your mind is replaying every call you made. You wonder what the members of the officiating crew think about your performance. You worry that you may have blown some calls, and you can still hear the criticisms of spectators ringing in your ears. Then you remind yourself to "Ieave the game on the field" -and you try. You tell yourself "I was prepared for the game"; "I worked well with other officials"; and "Overall, I did a good job." Yet the lingering self-doubt persists despite your efforts to toss it aside.

These conflicting postgame thoughts are not uncommon. AlI types of officials, whether voluntary or professional, must deal with them. They occur when you are a part of a large officiating group for foot-balI, volleyball, or tennis or when you work in smaller officiating teams for basketball, ice hockey, or wrestling. If you have officiated a sport recently, these disturbing thoughts are probably all too familiar to you.

The Official's Role

Why do officials experience this inner turnmoil? Much of it is simply a consequence of their unique role. After athletes and coaches, officials are the third dimension of athletic contests; yet officials perform one of sport's most difficult tasks.

Good officiating facilitates the sport event, ensuring that the outcome is dependent upon the skills and tacties of the players. Poor officiating detracts from the contest and decreases the enjoyment of the game for players, coaches, and fans.

The work of game officials is open to public scrutiny, and they are often discussed and publicized because of their rnistakes. In contrast, when a game goes smoothly, few people even notice the officials.

On what basis, then, should officials judge themselves or be judged? Their primary job is to ensure that a contest progresses according to the rules while interfering as little as possible.

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More specifically, officials must be committed to fulfilling four major responsibilities:

1. See that the event proceeds within the context of the rules of the game.
2. Interfere as little as possible, never seeking to become the focus of attention.
3. Set and maintain an atmosphere for the enjoyment of the contest.
4. Show concern for the athetes.

Mental-physical Demand Of Officiating

A strong relationship exists between the psychologicall skills and the physical performance of officials. Therefore, a referee's succces or failure depends on his or her physical abilities (e.g., conditioning for the demands of a particular sport, techniques and mechanics, visual skills) and mental abilities (e.g., confidence, concentration, emotional control).

TIhis relationship between the physical and psychological aspects of officiating is an interesting one. Officials most often talk about the importance of mental, rather than physical, skills in performing theirr difficult tasks—making the unpopular call, not letting the game get out of hand, staying cool, and not becoming ratlled.

In fact, veteran officials claim that managing psychological skills accounts for 50 percent-70 percent of an official's success. Similarly, supervisors of officials in various professional sports, who assign and evaluate the work of referees and umpires, emphasize consistency, fairness, mental toughness, quick and accurate decision making, and calmness as the most important assets for good officials.

Without question, sports such as tennis, track, and volleyball also place a premium on an official' s mental skills. Other sports, however, like lacrosse and basketball, require officials to be both physically and rnentally capable. Thus it seerns strange that training camps and clinics emphasize physical techniques, interpretation

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of rules, proper attire, and writtten and practical tests. If officials and supervisors agree that the mental aspect of officiating is critical to one's success, why is so littIe time and emphasis placed on developing and practicing psychological skills? A major reason is the misconception that psychological skills are innate: Either you have them, or you don't. In fact, just as physical skills can be honed, so too can psychological skills. Effective officials are not born with a complete set of psychological skills. Rather, their ability to concentrate, relax under pressure, maintain confidence, and relate to other members of the officiating team is systematically and repeatedly practiced. And because these qualities are indeed skills, they wiII dissipate just as physical skills do if not nurtured.It appears, then, that a certain combination of physical *and* mental skills is necessary to become a superior official. Just what that combination is may become clearer as we discuss the most important qualities of a good official.

PSYCHOLOGY AND COACH

The increased stress of competitions can cause athletes to react both physically and mentally in a manner that can negatively affect their performance abilities. They may become tense, their heart rates race, they break into a cold sweat, they worry about the outcome of the competition, they find it hard to concentrate on the task in hand. This has led coaches to take an increasing interest in the field of sport psychology and in particular in the area of competitive anxiety. That interest has focused on techniques that athletes can use in the competitive situation to maintain control and optimise their performance. Once learned, these techniques allow the athlete to relax and to focus his/her attention in a positive manner on the task of preparing for and participating in competition. Psychology is another weapon in the athlete's armoury in gaining the winning edge.

The 4C's

Concentration, confidence, control and commitment (the 4C's) are generally considered the main mental qualities that are important for successful performance in most sports .

- Concentration - ability to maintain focus
- Confidence - believe in one's abilities
- Control - ability to maintain emotional control regardless of distraction
- Commitment - ability to continue working to agreed goals

The techniques of relaxation, centering and mental imagery can assist an athlete to achieve the 4C's.

Concentration

This is the mental quality to focus on the task in hand. If the athlete lacks concentration then their athletic abilities will not be effectively or efficiently applied to the task. Research has identified the following types of attention focus:

- Broad Narrow continuum - the athlete focuses on a large or small number of stimuli
- Internal External continuum - the athlete focuses on internal stimuli (feelings) or external stimuli (ball)

The demand for concentration varies with the sport:

- Sustained concentration - distance running, cycling, tennis, squash
- Short bursts of concentration - cricket, golf, shooting, athletic field events
- Intense concentration - sprinting events, bobsleigh, skiing

Common distractions are: anxiety, mistakes, fatigue, weather, public announcements, coach, manager, opponent, negative thoughts etc. Strategies to improve concentration are very personal. One way to maintain focus is to set process goals for each session or competition. The athlete will have an overall goal for which the athlete will identify a number of process goals that help focus on specific aspects of the task. For each of these goals the athlete can use a trigger word (a word which instantly refocuses the athlete's concentration to the goal) e.g. sprinting technique requires the athlete to focus on being tall, relaxed, smooth and to drive with the elbows - trigger word could be "technique" Athletes will

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