LOCOMOTION IN SEDENTARY SOCIETIES

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Summary

The human species has developed over few million years for a life of hard work through evolutionary processes. At present fewer and fewer have such demanding jobs, as machines take care of heavy loads and even the transportation of people takes place with little physical effort. Walking over long distances was a necessity in earlier times and food could be sparse for weeks or even months. Therefore it was important to be

able to store energy in adipose tissue. At present good tasting energy-rich food is available in many societies in excess, while the consumption of energy has decreased to levels but a little over the resting level in sedentary lifestyle. More or less constant motion by walking has been replaced by sitting. The sitting posture is more demanding to the spine and back tissues in general than standing and walking postures as the proper oxygenation and nutrition of tissues needs the motion and pumping activity of the muscles. Therefore at present the historic background and our present life style are in contradiction. Due to this the inactivity related disorders and diseases like the development of metabolic syndrome and chronic disorders of circulation and musculoskeletal system, as well as their neuronal and hormonal controls, are reaching unique dimensions as epidemics. Life style and leisure time activities need to be more strongly emphasized. Research into basic components of our daily life including postures, walking and sitting, and energy consumption should be placed in the central focus.

1. Introduction

Hippocrates (c. 460-377 BC), father of medicine, stated some 2500 years ago that if we could give every individual the right amount of nourishment and exercise, not too little and not too much, we would have found the safest way to health. High schools still carry in many countries the name ‘gymnasium’ (a place where naked people practiced physical activity) to indicate the importance of physical exercises in education in ancient Greece. The Olympic Games, which started in ancient Greece, indicates the importance of good fitness in adults. Perhaps the greatest philosopher through the ages, Aristotle (384-322 BC), a teacher of Alexander the Great, said that brains operate properly only if the body is warm, after exercise. In reality the muscles are the main generators of heat, as at rest the body produces only some 70 watts (equivalent to a normal lamp) while maximum energy consumption can reach some 2000 watts for a short while in heavy physical activity.

J.C. Dalton repeated some 130 years ago that muscular exercise, in order to produce proper effect, should be regular and moderate. Exercise, which is violent and continues to produce exhaustion or unnatural fatigue, causes injury instead of advantage. The quantity of exercise to be taken is not the same for different people, but should be measured by its effect.

The human species has been developed over perhaps 7 million years. Most of those generations have been working hard to find food by gathering and hunting, which both required a lot of walking and running—motion with or without heavy loads. When food was available in excess, it was good to be able to store the energy it contained in adipose tissue under the skin and elsewhere. This helped to maintain proper thermal balance and provided energy, both for the current and the next generation. Those individuals with a good set of genes for these properties succeeded to propagate their genes to the following generations. Even now, the human organism should keep walking every day as a basic need of the body, like eating and resting. During the last hundred years many factors have changed, but not our genome. In our sedentary society greater and greater discrepancy has taken place between the genetic background and the life style of people.

The physical fitness of the majority is poor in well-off countries. It has been estimated that one hundred years ago about 80% of Americans did hard physical work for their living, but now perhaps 80% or more do light office type of work in USA. Similar figures describe the situation in many other western countries, too. Urbanization, increased use of machines in all sectors of life, and access to energy-rich foods have paved the way to the present situation. The human body has been "made", however, for physical work.

Commuting to work and home now takes place mostly by using public transportation or private cars. The time people are immobile and spend sitting have also increased, as children and adults watch television and play electronic games. Children work with computers for their school tasks and adults for their living. The use of muscles is becoming required only during leisure time physical activity.

Urbanization is providing a very different environment for children compared with where their parents spent their early years. In cities there simply may be no safe places for children to play outdoors. Adults are often too busy with their jobs to be able to play with their children. The outcome is, unfortunately, that only 2% of Americans are physically continuously active for ten minutes or more every day.

Already more than one out of five Americans has been reported to be obese (Body Mass Index, BMI 30 or more) and many of the rest are overweight. The future seems to be even worse, as in USA more than one out of three children are either overweight or obese, in Europe one out of five, and China one out of ten. In England the number of obese people has tripled in 20 years. Chinese and Europeans will rival the U.S. statistics soon if their life styles are not changed. It is appropriate to recall what Hippocrates said about nutrition—excessive amounts of energy-rich food bring about problems. Many other nations have adopted similar lifestyles, and the body weights of their citizens are increasing. Obesity means a risk of getting metabolic syndrome with slowly developing disturbance of glucose metabolism and adult type diabetes, problems of high blood pressure and disturbance of blood lipid profile. Adipose tissue contains a lot of macrophages—cells which are related to inflammation. This may be one reason for increased C reactive protein (CRP) in the blood, which indicates ongoing inflammation. About one out of five suffer from these conditions in rich countries.

Poor sitting postures promote neck-shoulder and back pain. Perhaps only one out of ten escape these problems. Bone mineral density tends be poor. Physical activity does not provide the hits needed for bone formation, they remain too rare to be effective. Ability to maintain balance also deteriorates. Muscle strength reduces towards old age as the muscle mass diminishes as a result of muscle atrophy. Physical inactivity is thus a "mother" of disturbances and diseases, as physical activity is the mother of health.

The long sitting hours during the overseas flights lead to blood clotting, and it has been estimated that one out of 100 has a thrombosis in flights lasting more than 4 hours. As computer users regularly sit still for many hours, one can only emphasize the need for periodic leg exercises—not just during flights but also when working with computers and watching television. Mental stress causes muscles to contract and an accumulation of acidic metabolites like lactic acid. Long sitting hours also hamper oxygen supply to other tissues, as motion helps the heart in its work. In normal conditions the partial pressure of oxygen in the human body ranges from 90 to less than 3 mm Hg, i.e. its concentration ranges from 12 to less than 0.5%. Thus the range is quite broad. Anoxia is a common situation, especially in muscle tissue when it is working at its extremes of energy consumption, but it can also be the case during mental stress. Cells have oxygen sensing systems, and they try to adjust their metabolism accordingly.

Luckily many people have started exercise programs. Computers help in their planning, as also in dietary counseling. However, all these efforts may recover only a small part of the deleterious effects of sedentary life style.

2. Physiological Responses to Exercise

Acute and chronic adaptations to exercise are described in detail in other chapters (see *Muscle Energy Metabolism*) and (see *Physiological Basis of Exercise*). The human body responds through a series of integrated changes to physical activity. They involve most of the physiological systems including the musculoskeletal, cardiovascular, respiratory, neuronal, hormonal and immune. The responses depend on the load and its characteristics like its form, volume, intensity, duration, frequency and rest periods between exposures. However, several recent studies have shown that the total amount of the physical activity is more important than its specific characteristics.

The metabolism of the musculoskeletal system increases to meet the energy needed to handle the exposed workload. As long as the performance is dynamic and oxygen provision is adequate, the metabolism is aerobic. In this phase most of the energy is supplied from fatty acids in fit persons. When the load increases, the anaerobic threshold will be exceeded i.e. the oxygen provision is no longer adequate, and anaerobic consumption of muscle glycogen and blood glucose starts to dominate with increasing release of lactic acid.

Exercise training improves insulin sensitivity and promotes access of glucose into the muscle cells in muscle fibers. Physical inactivity paves the way to impaired glucose metabolism (IGT). Those IGT subjects who respond to exercise with weight reduction also show a decrease in insulin and glycated haemoglobin levels. Exercise promotes glycemic control, if the exercise program is intensive enough.

Fatty acids are important sources of energy in muscle. AMP activated protein kinase regulates fatty acid oxidation. The activity of this kinase is increased by several conditions including muscle contraction, decrease in pH and inhibition of glycolysis. The ability of muscles to use fatty acids is promoted by exercise. Blood lipid levels are regulated to a great extent by muscle activity. Actually exercise is the only successful way to decrease the levels of lipids which have been ingested and stored in adipose tissue. In body weight control physical activity and diet determine the outcome.

Exercise increases the activity of sympathetic nerves, and it also increases the release of epinephrine from the adrenal glands that promotes release of glucose from the liver and free fatty acids from the adipose tissue.

The cardiovascular and respiratory systems respond to increased demand for oxygen consumption. The capillaries of the working muscle open and blood circulation increases manifold. Oxygen uptake increases in proportion to the increasing rate of work. The intensity of exercise can be evaluated by recording the heart rate. Comparing the value obtained with the maximal heart rate and heart rate at rest, the relative heart rate of the work can be calculated. The value is individual, and it depends on the fitness of the person, her or his gender, and age.

Respiration will provide more oxygen by increasing the minute volume, i.e. deepening the inspiration and increasing breathing frequency. The respiratory muscles may, however, be weak and unable to provide the necessary response.

The regulation of the cardiovascular system is neuronal and humoral. During exercise the blood stream diminishes in the gastrointestinal tract and increases in muscles (see *Muscle Energy Metabolism*). As physical activity stimulates the release of epinephrine, this contributes to the redirection of the blood stream and it increases the energy, while stronger heart contractions provide the pressure for the circulation of blood.

Increased glucose and insulin delivery with enhanced blood flow and vascularization, and increased enzyme activity, promote muscle fitness in trained subjects.

2.1. Gliding Filaments

During muscle contraction the myosin and actin filaments glide so that the sarcomeres shorten. Energy for this gliding comes from the hydrolysis of ATP catalyzed by the ATPase activity of the heads of myosin molecules. During the interaction of the myosin heads and actin, a conformational changes takes place in the actin filament and the interaction takes place at 36 nm intervals. As the structure of the sarcomeres is highly organized, so, most probably, are the water molecules surrounding the filaments. One can say in lay language that the myosin filaments are in a way skating towards the Z-bands of sarcomeres like the fluid and icy forms of water form a slippery interaction. The sarcomeres amplify the outcome of the effect of the contraction. Without sarcomeres the contraction would be a significantly poorer and slower phenomenon.

When the muscles work, both the energy metabolism and the mechanical work release heat. This heat also affects the physical state of the water on the protein filaments and the surrounding spaces. Thus the warm-up exercises, which athletes perform, are also recommended for everybody before any demanding exercise. The increase of the body and especially muscle temperature promotes the gliding of filaments. It increases the rate of metabolism in general. The propagation speed of neural signals promotes the coordination abilities of agonist and antagonist muscles.

2.2. Measurement of leisure-time physical load

There are several ways to measure physical load, but intensity, duration and type of exercise are most commonly used. Duration expresses the number of minutes of activity in each session. Frequency expresses the number of exercise sessions per day, week or month. Intensity refers to the effort needed for a type of exercise. There are several ways to describe intensity and the type of physical activity, such as aerobic, resistance, leisure-time and occupational physical activity. In general, intensity of exercise can be expressed in both relative and absolute intensities. Both concepts are based on the amount of energy used in a certain amount of time.

2.2.1 Absolute Intensity

Absolute intensity refers to the rate of energy expenditure or volume of leisure-time physical activity and could be expressed as kcal or kJ per minute, oxygen uptake ($L \bullet min^{-1}$), oxygen uptake relative to body mass ($mL \bullet kg^{-1} \bullet min^{-1}$), multiples of resting metabolic rate (RMR) or metabolic equivalent (MET)s, or RMR per kg body mass. The metabolic rate also reflects the amount of the energy spent and the amount of oxygen consumed. This can then be used to calculate the energy expenditure. Indirect calorimetry estimations showed that one liter of oxygen consumption corresponds to 5 kcal or 20.95 kJ.

Metabolic equivalent (MET): this is the unit of resting metabolic rate which has been measured after eight hours of fast and eight hours of sleep. One MET is defined as the amount of oxygen required or energy consumed under total resting conditions, per kilogram of body weight per minute (MET-min) or per hour (MET-hours). One MET is equal to 3.5 ml of oxygen consumed per kilogram of body weight in a minute.

MET provides an easier method compared to VO_{2max} calculations for exercise prescriptions. There are estimated energy expenditure values in METs calculated for different exercise intensities and different body weight for bicycle ergometer and also for running treadmill exercises. These are presented as tables in many exercise physiology books. It is important to distinguish the gross and net cost of exercise, for the calculation of net energy expenditure of leisure-time physical exercise. This net cost can be calculated by subtracting resting energy expenditure (RMR, 1 MET) from the total energy consumption. At lower intensities of exercise like 3-4 METs, disregarding RMR for the estimation of net energy expenditure will avoid over-estimation of the volume of the physical exercise.

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Biographical Sketches

Dr Osmo Otto Päiviö Hänninen, DMS, Ph..D., Professor of Physiology, Chairman of the Department, University of Kuopio, Finland. Born 1939, Lahti, Finland. He studied at the University of Helsinki and the University of Turku, Finland, where he received his Master of Sciences (Biochemistry) in 1962, Licentiate of Medicine (MD) in 1964, Doctor of Medical Sciences (DMS) in 1966, and passed his dissertation in biochemistry for his Ph.D. in 1968. He has also studied genetics. He has been a specialist in sports medicine since 1986. He served as the Research Assistant of Professor K. Hartiala, 1962–4; Assistant of Physiology, 1964–5; Laborator of Physiology, 1966–7; Docent of Physiology, from 1967, and Associate Professor of Biochemistry, 1969–71, at the University of Turku; Acting Professor in the Planning Office, 1971–2; and from 1972, Professor of Physiology and Chairman of the Department of Physiology, University of Kuopio; Vice-President of the University of Kuopio, 1972–9; and President, University of Kuopio, 1981–4. Furthermore, he served as Visiting Professor of Physiology at Shanghai Medical University, China, 1991–2, and at Sun Yat Sen Medical University, Guangzhou, China, 1998–9; as Foreign Member of the Russian Academy of Natural Sciences, from 1994; and as Secretary General, International Council for Laboratory Animal Science, 1988–95. He was the President of Societas Physiologica Finlandiae, 1990–9, and has been President of the International Society for Pathophysiology and a Member of the Executive Committee since 1994, and the Treasurer of the International Union of Biological Sciences since 1997.
His special interests in research are:

- Biotransformation and adaptation to chemical loading, biomonitoring of toxicants, and comparative biochemical toxicology.
- Muscle metabolism and function.

- Ergonomics.

He has contributed 289 papers in refereed journals and 80 in proceedings, and written fifty-nine reviews, and thirty-two books or book chapters. He serves on the editorial board of four international journals and is at present the European Editor-in-Chief of *Pathophysiology*.

Of his post-graduate students (thirty-two in biotransformation, twenty-seven in muscle metabolism and physiology, and five others), twelve serve as professors in China, Finland, Greece, Sweden, and the USA.

Mustafa Atalay was born in 1963 in Ankara, Turkey, and received his M.D. degree in the University of Ankara School of Medicine in 1986. He specialized in family practice in the State Hospital of Ankara in 1992, and continued his postgraduate studies on exercise physiology and sports medicine in Kuopio, Finland, from 1993. In 1995 he received a Master of Public Health degree from the Department of Public Health, University of Kuopio. In 1998 he defended his Ph.D. thesis on "Tissue Antioxidant Responses to Physical Exercise-Induced Oxidative Stress" in the department of Physiology, University of Kuopio, and he received the degree of "Docent of Sports Medicine" from the National Board of Higher Education of Turkey in 1999. He was selected as a Fellow of the American College of Sports Medicine in the same year. He completed his postdoctoral fellowship at Ohio State University Medical Center and Laboratory of Molecular Medicine between 2000 and 2001. In 2003 he received the degree of "Docent of Exercise Physiology" from the Faculty of Medicine, University of Kuopio. His research interest is in exercise-induced oxidative stress and antioxidant defenses. Currently he is working in the University of Kuopio, Finland, as a senior lecturer and researcher. He serves as the associate editor-in-chief in the journal of "*Sports Science & Medicine*