WHY EXERCISE?

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Abstract:

There is a pronounced plasticity and adaptability in the structural and/or functional properties of cells, tissues, and organ systems in the human body when exposed to various stimuli. While there is unanimous agreement that regular physical activity is essential for optimal function of the human body, it is evident that extrinsic factors, such as diet, smoking, exercise habits, are reflected in the morbidity and mortality statistics, especially in the elderly. Aging is obligatorily associated with reduced maximal aerobic power and reduced muscle strength, i.e., with reduced physical fitness. As a consequence of diminished exercise tolerance, a large and increasing number of elderly persons will be living below, at, or just above "thresholds" of physical ability, needing only a minor intercurrent illness to render them completely dependent. Physical training can readily produce a profound improvement of functions essential for physical fitness in old age. Adaptability to regular physical activity serves to cause less disruption of the cells' "milieu interieur" and minimizes fatigue, thereby enhancing performance and the economy of energy output during physical demands of daily activities. Regular physical activity reduces the risk of premature mortality in general, and of coronary heart disease, hypertension, colon cancer, and diabetes mellitus in particular. Physical activity also improves mental health and is important for the health and optimal function of muscles, bones, and joints. The most recent recommendations advise people of all ages to include a minimum of 30 min of physical activity of moderate intensity, such as brisk walking, on most, if not all, days of the week.

WOZU KÖRPERLICHE AKTIVITÄT?

Zusammenfassung:

Die ausgedrückte Plastizität und die Anpassungsfähigkeit von strukturellen und/oder funktionellen Charakteristiken von Zellen, Geweben und Organsystemen im menschlichen Körper ist bemerkbar unter dem Einfluss von verschiedenen Reizen. Trotz einer vollkommenen Übereinstimmung in bezug auf die Bedeutung von regelmäßigen Körperübungen/körperlichen Aktivitäten, die als wesentlich für das optimale Funktionieren vom menschlichen Körper betrachtet werden, ist es offensichtlich, dass sich die extrinsischen Faktoren, wie z.B. Nahrung (Diät), Rauchen oder körperliche Aktivität, in den Statistiken reflektieren, die die Krankheiten (Morbidität) und die Sterblichkeit (Mortalität), besonders in bezug auf die älteren Personen, beschreiben. Die reduzierte maximale aerobe Kapazität und die reduzierte Muskelkraft, d.h. die reduzierte körperliche Leistungsfähigkeit, sind mit dem Altern verbunden. Dies resultiert in einer erhöhten Anzahl von älteren Leuten, die unter oder knapp über der 'Schwelle' von köperlichen Leistungsfähigkeiten leben oder leben werden, so dass jede Krankheit genügen würde, solche Menschen total abhängig zu machen. Das Training von körperlichen Leistungsfähigkeiten kann sehr schnell zur einen wesentlichen und gründlichen Verbesserung von denjenigen Funktionen führen, die für den guten Status und für die Lebensqualität (Fitness) in hohem Alter notwendig sind. Die Anpassung auf die regelmäßige physische Betätigung dient dazu, die Anzahl von verursachten Unterbrechungen und Störungen in der intrazellulären Umgebung zu vermindern, und die Ermüdung so viel wie möglich zu reduzieren, so dass sich auf diese Weise die Ergebnisse und die Ökonomie vom Stoffwechsel und Energieverbrauch verbessern werden. Die regelmäßige physische Betätigung reduziert sowohl die Risiken des vorzeitigen Todes, als auch die Risiken von Koronarkrankheiten, erhöhtem Blutdruck, Darmkarzinom und Diabetes. Körperübungen verbessern auch die mentale Gesundheit und ergeben sich als wichtig für die Gesundheit und das optimale Funktionieren von Muskeln, Knochen und Gelenken. Die neuesten Forschungen beweisen die Empfehlung, dass man sich täglich wenigstens 30 Minuten physisch betätigen sollte (z. B. schnelles Gehen).

Introduction

In my opinion, "exercise physiology" is very important because an exercise situation in various environments provides a unique opportunity to study how different functions are regulated and integrated. In fact, most functions and structures are in one way or another affected by acute and chronic (i.e. in a training program) exercises. Therefore, exercise physiology is to a high degree an integrated science that has as its goal the identification of the mechanisms of overall bodily function and its regulation. A review of some factors of key importance in exercise situations will follow.

Basic physiology

For an individual's aerobic performance the maximal oxygen uptake is decisive. However, in prolonged exercise the availability of substrates for the oxygen consuming metabolism is another

factor to consider, as well as the economy of the movements. During this century much research has been devoted to analysing whether a particular step in the oxygen cascade from environmental air to the mitochondria in the skeletal muscle is the limiting factor, these efforts include: pulmonary ventilation, pulmonary diffusing capacity, cardiac output, oxygen diffusion from blood to the mitochondria, and the quantity of oxidising enzymes in the mitochondria. At present there is general agreement that the central circulation of the human limits the maximal oxygen uptake during exercise in which large muscle groups are involved (Astrand, 1997; Astrand and Rodahl, 1986, pp. 183-185).

A training program including interval or continuous exercises at 50% (beginners) and up to some 80% of maximal aerobic power or heart rate reserve for 30-40 min three times per week can effectively increase stroke volume and, therefore, maximal cardiac output by about 15% or more, albeit with large individual variations. Actually, the percentage improvement in maximal oxygen uptake when applying similar training principles is the same in young and old adults, in women and men (13). In extreme situations one can find large variations in maximal oxygen uptake: After 3 wk bed rest this maximum averaged 1.74 $1.min^{-1}$ in three subjects; then, after 60 days with intensive training, it had almost doubled to 3.41 1. min-1 (Astrand and Rodahl, 1986, p. 442).

From cross-sectional studies it is concluded that there is a decline in maximal oxygen uptake amounting to 0.5-1.0% per year. However, the degree of habitual physical activity and heredity can markedly affect this maximum.

Numerous studies have demonstrated a significant increase in mitochondrial density as a consequence of aerobic training with a proportionate increase in mitochondrial enzymes (Henriksson, 1992). If one expresses skeletal muscles' oxidative capacity for a sedentary individual in 1 "unit," the endurance trained elite athletes have a 3 "unit" capacity. In a rabit muscle, 3-5 wk of chronic electric stimulation with a frequency of 10 Hz can bring the capacity up to 6 "units." In a leg subjected to encasement in plaster for some weeks, the activity may drop to 0.7 "units" (Henriksson, 1992). From these data we can conclude that with aerobic training there is a shift in the trained skeletal muscle to greater reliance on oxidative metabolism to provide energy for ATP resynthesis.

With age there is a decrease in muscle strength that seems to parallel the reduction in muscle mass. This age-associated loss of muscle fibers is related to a loss of alfa-motoneurons (Ansved and Larsson, 1990). The force-generating capacity of residual contractile material is, however, unaltered. The muscle fibers per motor unit have been reported to increase, which is interpreted as a reduction in motoneurons, partly compensated for by peripheral sprouting from "healthy" nerve terminals and thereby a reinnervation of muscle fibers that lost their original motoneurons.

When starting a strength-training program, a 20-40% increase in strength may occur during the first weeks, without a noticeable increase in the cross-sectional area of the muscles involved. This suggests a more efficient activation of the muscles. With continued strength training there is an adaptive hypertrophy exclusively achieved by an increase in fiber size without increase in the number of muscle fibers (MacDougall, 1986). It is remarkable that as little as a 6-s isometric contraction repeated five times, three times per week can prevent loss of muscle mass and muscle function during periods of recovery from injury with joint immobilisation.

Fiatarone et al. (1990) studied nine frail, institutionalized volunteers 90 year old (range 87-96) who undertook 8 wk of high-intensity resistance training. They employed an adaptation of standard rehabilitation principles of progressive resistance training with concentric (lifting) and eccentric (lowering) activation of knee extensor muscles. Three times per week the subjects performed three sets of eight repetitions with each leg in 6- to 9-s per repetition, with a 1- to 2-min rest period between sets. Except for the first week the load was 80% of the one repetition maximum. Strength gain averaged 174 %. Midthigh muscle area increased 9.0%. The activation of the muscles involved only lasted some 10 min per week. These findings would suggest that age does not appear to affect the trainability of skeletal muscle.

Clinical aspects

Well-documented risk factors for cardiovascular disease (CHD), independent and in some cases interrelated, are sedentary lifestyle, increases in triglyceride and low density lipoprotein levels in the blood, decrease in the high density lipoprotein level, cigarette smoking, hypertension, diabetes, obesity, post-prandial hyper-insulinemia, and carbohydrate intolerance. During the last decade, there have been several reports showing a significant reduction in morbidity and mortality in CHD in physically active persons compared with sedentary control groups (Andersen and Hippe, 1996; Bernadet, 1995; Blair et al., 1989; Cerami et al., 1987; Paffenbarger et al., 1990; Rauramma and Leon, 1996; US Department of Health and Human Services, 1996).

The biggest reduction in risk of CHD was associated with going from a low level of cardio-respiratory fitness to a moderate or average level of fitness for a person's age (Blair et al., 1989). They concluded that higher levels of fitness appear to delay all-cause mortality primarily due to lowered rates of cardiovascular disease and cancer.

These studies indicate a substantial independent risk for CHD for persons with sedentary lifestyles. A high level of habitual physical activity will reduce premature mortality. Physical activity also confers other important health benefits. Habitual physical activity reduces the incidence of, or is otherwise beneficial to, hypertension, hyperlipidemia, obesity, diabetes type II, impaired glucose tolerance, osteoporosis, psychologic impairment, colon cancer, and back injury. It induces benefits on the function of metabolic, endocrine, and immune systems (US Department of Health and Human Services, 1996). The effect on some of these factors may be small and statistically nonsignificant; however, the sum of these effects may have an important positive impact, influencing health and disease, life and death.

Sedentary people often have a reduced response to insulin in their untrained muscles. Elderly individuals may develop a reduced glucose tolerance and blood glucose concentrations is, at times, elevated (Cerami et al., 1987). It may trigger a feedback and cause a hyperinsulinemia, in itself a risk factor for CHD.

A training program, as described above, can normalize the glucose tolerance in elderly people and enhance the muscle's sensitivity to insulin (Cerami et al., 1987). It should be emphasized that muscle contractions per se will promote the muscle's uptake even with no insulin present (Wallberg-Henriksson, 1987).

Bone mass is subject to both local (mechanical) and systemic (hormonal) homeostatic control mechanisms. Strain induction, the deformation that occurs in bone under loading, may cause a greater level of formation and an inhibition of resorption within normal remodelling cycle of bone, or it may cause direct activation of osteoblastic bone formation from the quiescent state (Kohrt et al., 1991). The local forces acting on bone tissue are due to gravity and muscular contraction. Standing upright is a better stimulus for bone hypertrophy than exercise in the bed, and walking is better than swimming in this respect. Both middle-aged and elderly women increase bone mass or reduce the rate of bone tissue loss in response to exercise intervention programs (Chilibeck et al., 1995; Suominen, 1993). There are promising evidences that strength training and other forms of exercise in older adults can preserve the ability to maintain independent living status and reduce risk of falling. In summary, regular physical activity is necessary for maintaining muscle strength, joint structure, and joint function. To counteract osteoporosis, the strategies are for adolescents and young adults to increase peak bone mass, and then adults and the elderly should focus on maintaining and/or slowing down the rate of bone loss.

The more physically active a person is, the higher the energy intake can be without risking obesity. From a nutritional viewpoint the advantage with such activity is that higher energy intake will better secure an adequate intake of essential nutrients (Astrand and Rodahl, 1986, pp. 574-576). At increased age there is a gradual reduction in the basal metabolic rate, but no proportional reduction of the demand for essential nutrients. For this reason it is recommended that old people try to stay physically active. In treatment of obese patients it is essential to combine a recommendation of restrictions of energy intake with an increase in energy output by daily physical activity (Miller, 1991).

A key question is to what extent impairment morbidity, and mortality are inevitable consequences of the individual's innate genetic composition, i.e. intrinsic factors, and to what

extent environment, and the individual's lifestyle, i.e., extrinsic factors, can modify these processes? It has been pointed out that aging is obligatorily associated with reduced maximal aerobic power and reduced muscle strength, i.e., with reduced physical fitness. Being overweight in addition to these handicaps is additionally unfortunate because these factors taken together make walking, climbing stairs, getting up from bed or chair, entering a bus or train more difficult and fatiguing, and eventually impossible. The ability to lift and carry weights becomes reduced. The aging persons will lose their independence and autonomy. As a consequence of diminished exercise tolerance, a large and increasing number of elderly persons will be living below, at, or just above "thresholds" of physical ability needing only a minor intercurrent illness to render them completely dependent. Now we are back to the question of the respective places of intrinsic and extrinsic factors in the deteriorations typical for "usual" aging. Physical training can readily produce a profound improvement of functions essential for physical fitness in old age and thus effectively postpone physical deterioriation for some 10-25 yr (Kohrt et al., 1991). We know very little about the relative contributions from intrinsic and extrinsic factors behind these achievements. Rowe and Kahn (1987) argue that: "a direct-assistance treatment is typical of approaches to older people that do for them what they could do to learn to do for themselves."

"The greatest health benefits from an increase in physical activity appear to occur when very sedentary persons begin a regular program of moderate intensity, endurance type activity. Further increases in intensity or amount of activity appear to produce further benefits in some, but not all, biological or clinical parameters. The magnitude of benefits becomes less for similar increase in intensity and/or amount of activity" (Haskell, 1994). A similar message is presented in the 1996 report of the Surgeon General in the USA "Physical Activity and Health" (U.S. Department of Health and Human Services, 1996). There it is pointed out that during the past few years American College of Sports Medicine, the Centers for Chronic Disease Control and Prevention, the National Center for Chronic Disease Prevention and Health Promotion, the American Heart Association, the President's Council on Physical Fitness and Sports, and the National Institutes of Health have all recommended regular, moderate-intensity physical activity as an option for those who get little or no exercise. And they are many: more than 60% of American adults are not regularly physically active. In fact, 25% of all adults are not active at all. In the report it is pointed out that many Americans may be surprised at the extent and strength of the evidence linking physical activity to numerous health improvements. Most significantly, regular physical activity greatly reduces the risk of dying from coronary heart disease, the leading cause of death in most Western industrialized countries. Habitual physical activity also reduces the risk of developing diabetes, hypertension, and colon cancer. It fosters healthy muscles, bones, and joints. Regular participation in physical activity also appears to reduce depression, improve mood, and enhance ability to perform daily tasks throughout the life span. In other words, it helps to maintain function and preserve independence in older adults. This report grew out of an emerging consensus among epidemiologists, experts in exercise science, and health professionals that physical activity need not to be of vigorous intensity to improve health. Moreover, health benefits appear to be proportional to amount of activity. Thus every increase in activity adds some benefit. Emphasizing the amount rather than the intensity of physical activity offers more options for people to select from incorporating physical activity into their daily lives. Experts advise previously sedentary people embarking on a physical activity program to start with short durations of moderate-intensity activity and gradually increase the duration or intensity until the goal is reached.

The most recent recommendations advise people of all ages to include a minimum of 30 min of physical activity of moderate intensity, such as brisk walking, on most, if not all, days of the week. Not necessarily continuously, it could be, e.g. 3 x 10 minutes! It is also acknowledged that for most people, greater health benefits can be obtained by engaging in physical activity of more vigorous intensity or of longer duration.

With "support" from Table 1, the following recommendations represent an exercise program for good function and health.

Daily. At least 30 min of physical activity, not necessarily vigorous, not necessarily

continuously. During the daily routine of moving, walking, climbing stairs, etc., whether for 1 min 30 times a day, 10 min three times a day, or any other combination totalling 30 min may demand 0.6 MJ (150 kcal).

Weekly. Exercises, say 30-45 min three times per week (e.g., brisk walking, jogging, cycling, swimming, "aerobic dancing/gymnastics", canoeing, rowing, skiing, playing golf, racket games) are efficient efforts to achieve and maintain good cardiovascular fitness.

Table 1: Effects of habitual physical activities

• INCREASE IN MAXIMAL OXYGEN UPTAKE AND CARDIAC OUTPUT
• REDUCED HEART RATE AT GIVEN OXYGEN UPTAKE
• REDUCED BLOOD PRESSURE
• REDUCED HEART RATE x BLOOD PRESSURE PRODUCT
• IMPROVED EFFICIENCY OF HEART MUSCLE
• FAVORABLE TREND IN INCIDENCES OF CARDIAL MORBIDITY AND MORTALITY
• INCREASED CAPILLARY DENSITY IN SKELETAL MUSCLE
• INCREASED MITOCHONDRIAL DENSITY IN SKELETAL MUSCLE
• REDUCED LACTATE PRODUCTION AT GIVEN PERCENTAGE OF MAXIMAL OXYGEN UPTAKE
• REDUCED PERCEIVED EXERTION AT GIVEN OXYGEN UPTAKE
• ENHANCED ABILITY TO UTILIZE FREE FATTY ACIDS AS SUBSTRATE DURING EXERCISE - IS GLYCOGEN SAVING
• IMPROVED ENDURANCE DURING EXERCISE
• INCREASES METABOLISM - ADVANTAGEOUS FROM A NUTRITIONAL VIEWPOINT
• COUNTERACTS OBESITY
• INCREASES HDL CONCENTRATIONS IN BLOOD
• IMPROVED STRUCTURE AND FUNCTION OF LIGAMENTS, TENDONS, AND JOINTS
• INCREASED MUSCULAR STRENGTH
• INCREASED PRODUCTION OF ENDORPHINES
• ENHANCES NERVE FIBER SPROUTING TO REINNERVATE MUSCLE FIBERS?
• ENHANCES TOLERANCE TO HOT ENVIRONMENT-INCREASED SWEAT PRODUCTION
• REDUCED PLATELET AGGREGATION?
• COUNTERACTS OSTEOPOROSIS
• CAN NORMALIZE GLUCOSE TOLERANCE
• CAN REDUCE RISK OF COLON CANCER

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