ORIGINAL ARTICLE

Exercise for Healthy, Active Ageing: A Physiological Perspective and Review of International Recommendations

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ABSTRACT

Healthy, active ageing is an important public health goal, which is supported by appropriate, specific, targeted physical activity. Many physiological changes to the cardiovascular and musculoskeletal system may lead to a decline in strength, fitness and resilience as the human body ages. Exercise is a proven means of overcoming physiological functional limitations and maintaining independence throughout the lifespan. The World Health Organisation, American College of Sports Medicine and American Academy of Family Medicine have proposed guidelines for the minimum amount of physical activity to be performed each week by older adults. Each adult needs an individualized mix of aerobic, strength-training, balance and flexibility exercises, to maintain autonomy, reduce chronic disease risk and enjoy a good quality of life. This review summarizes the important highlights of these recommendations and focusses on the significant physiological gains to be achieved from exercise.

Keywords: Ageing, exercise, physical activity, physiology of older person, senior

Ejercicio para un Envejecimiento Saludable y Activo: Una Perspectiva Fisiológica y un Examen de las Recomendaciones Internacionales

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RESUMEN

El envejecimiento saludable y activo es un objetivo importante de la salud pública, apoyado por una actividad física apropiada, específica y dirigida a tal fin. Muchos cambios fisiológicos en el sistema cardiovascular y musculoesquelético pueden llevar a una disminución de la fuerza, la aptitud física, y la resistencia a medida que el cuerpo humano envejece. El ejercicio es un medio probado para superar las limitaciones funcionales fisiológicas y mantener la independencia durante la vida. La Organización Mundial de la Salud, el Colegio Americano de Medicina del Deporte, y la Academia Americana de Medicina de la Familia, han propuesto pautas para la cantidad mínima de actividad física que los adultos mayores deben realizar cada semana. Cada adulto necesita una mezcla individualizada de ejercicios aeróbicos y entrenamiento de fuerza, así como ejercicios de equilibrio y flexibilidad, para mantener la autonomía, reducir el riesgo de enfermedades crónicas, y disfrutar de una buena calidad de

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vida. Este examen resume los aspectos más sobresalientes de estas recomendaciones y enfoca las importantes ganancias fisiológicas a lograr con el ejercicio.

Palabras clave: Envejecimiento, ejercicio, actividad física, fisiología, persona mayor, adulto mayor

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INTRODUCTION

Physiological determinants of independent living become threatened as a result of normal ageing. As a matter of fact, in normal adults, strength of the muscles in the lower extremities begins to decline as early as the age of 25 years (1). Sarcopenia, which is the loss of muscle mass, strength and endurance with ageing, results from intrinsic diminution in muscle fibre numbers, protein synthesis and mitochondrial function. Additionally, there is selective loss of Type II muscle fibres (fast twitch), asynchrony of motor units and a decline in myosin function. The latter changes have been linked to the decrease in circulating androgens with age (1) and are associated with physiological decreases in total strength and power, increasing the likelihood of fatigue (1).

Functional deficits due to loss of muscle power are heightened by decreases in myocardial performance, stroke volume, ejection fraction and cardiac output (1). Decline in function of the cardiovascular system then results in reduced transport of oxygen to tissues. There is also an increase in afterload, as the blood vessels lose compliance, causing increased peripheral arterial pressure and increased resistance to blood flow. There are structural and functional changes in the myocardium and decreased sensitivity of the heart and blood vessels to catecholamines (2). Functional impairment is more associated with sedentary ageing or chronic disease. The good news is that the functional consequences of age-related cardiac and muscular decline may be buffered by physical activity (3).

Although no intensity, frequency or variety of exercise can stop the process of cellular ageing, there are modifiable factors which may enable healthy, active ageing. Table 1 provides key definitions of terms used in the discussion of physical activity in the older adult. Evidence abounds that exercise can minimize the physiological effects of an otherwise sedentary lifestyle.

In fact, a study of 70-year-old participants who underwent resistance training for 20 years found that those individuals had equal muscle strength and muscle cross-sectional area, compared to a group of 28-year-old University students (4). Additionally, of import to the older adult, exercise improves physiological baselines, halts deconditioning, improves physical function and results in a more active life expectancy by preventing the development or worsening of chronic disease.

Exercise recommendations for older adults

The World Health Organization (WHO) published specific guidelines for the level of activity recommended for adults, and specifically for persons 60 years and older (5, 6). Similar recommendations have been endorsed by the American College of Sports Medicine (1), the American Heart Association (3) and the American Academy of Family Physicians (7). The guidelines, which represent the minimum activity aimed at enabling the older person to continue safe, optimized, independent living are summarized in the Box. The guidelines were created using the results of numerous large-scale studies and meta-analyses, which provided conclusions regarding the changes in functional capabilities and disease status of older persons exposed to a variety of exercise regimens.

Exercise physiology and fitness

Cardiorespiratory fitness is described using the 'maxi-mal oxygen uptake', abbreviated VO_{2max}. VO_{2max} shows the capacity of the cardiorespiratory and vascular system to transport O_2 from the air to the working muscles, as well as the efficiency with which the muscles consume O_2 during dynamic exercise involving large muscles, *eg* running, very brisk-walking, bicycling (8). It is sometimes called 'maximal aerobic capacity' or 'aerobic endurance'(8). It is calculated using the difference in oxygen levels within the arteries compared to veins, during exercise at the highest intensity tolerated by an individual. It is usually expressed as milliliters of O_2 consumed per kilogram of bodyweight per minute (mL kg^{-1} min^{-1}). Average values for VO_{2max} are approximately 45 mL/kg/minute for a sedentary 35-year-old man, 55 mL/kg/minute for an average 35-year-old male runner, 65 mL/kg/minute for a locally competitive male runner and 70 to 85 mL/kg/minute for an elite runner (1).

Table 1: Exercise physiology terminology

Term	Definition
Physical activity	**Body movement that is produced by the contraction of skeletal muscles and that increases energy expenditure**
Exercise	Planned, structured, repetitive movement to improve or maintain one or more components of physical fitness
Metabolic equivalent (MET)	Metabolic equivalent (MET) 1 MET = the amount of energy used in a resting state, like sitting or lying awake
Intensity	Absolute intensity is the amount of energy used by the body per minute of activity, objectively measured in non-laboratory settings as a metabolic equivalent, or MET Relative intensity is the level of effort required to do an activity, as rated by the individual doing the activity; on a 10-point scale, sitting = 0 and working as hard as possible = 10
Light intensity	< 3 METs (*eg*, casual walking, light housework, stretching)
Moderate intensity	3 to 5.9 METs, or the individual will breathe harder with a faster heart beat; the individual should be able to talk but not sing; on a 10-point scale, a moderate-intensity activity would be rated as 5 to 6 (*eg*, brisk walking, water aerobics, ballroom dancing, gardening)
Vigorous intensity	≥ 6 METs, or the individual will not be able to say more than a few words without pausing for a breath (*eg*, jogging or running, aerobic dancing, heavy gardening)
Aerobic/endurance exercise	Exercise in which the body's large muscles move in a rhythmic manner for sustained periods (*eg*, walking, stationary cycling, aquatic exercise)
Balance training	A combination of activities designed to increase the individual's lower body strength and reduce the likelihood of falling (*eg*, backward, sideways, heel, or toe walking; tai chi)
Flexibility exercise	Activities designed to preserve or extend range of motion around a joint (*eg*, stretching hamstring, calves, or triceps)
Resistance/strength exercise	Exercise that causes muscles to work or hold against an applied force or weight (*eg*, exercises using resistance bands, weight machines, handheld weights; digging, lifting and carrying as part of gardening; carrying groceries)
Physical function	The capacity to carry out the physical activities of daily living; physical function reflects motor function and control, physical fitness and habitual physical activity
Sedentary behaviour	Activity that involves little or no movement or activities that are considered posture (*eg*, sitting), having an energy expenditure of ≤ 1.5 METs
Activities of daily living	Routine activities people do every day without assistance. There are six basic ADLs: eating, bathing, getting dressed, toileting, transferring and continence
Deconditioning	A complex process of physiological decline following a period of inactivity, bed-rest or sedentary lifestyle. It includes diminished muscle mass, decreases of muscle strength by two to five percent per day, muscle shortening, changes in periarticular and cartilaginous joint structure and marked loss of leg strength that seriously limit mobility.

References (1, 3, 11, 12)

Box: Physical Activity Recommendations for Older Persons, aged ≥ 65 years

Minimum ***weekly**** activity for best physiological benefit:

- 150 minutes (two hours and thirty minutes) of moderate-intensity aerobic activity (*eg* brisk walking). For most older adults this would be equivalent to level walking at a 2.5–4.5 mph pace

  PLUS

  At least two days of muscle-strengthening activities. Resistance training should include all the major muscle groups (legs, hips, back, abdomen, chest, shoulders and arms). Relevant muscle groups to involve include hip extensors, knee extensors, ankle plantar flexors and dorsiflexors, biceps, triceps, shoulders, back extensor and abdominal muscles. Generally eight repetitions of each exercise are recommended and the amount of resistance will vary for each individual. The individual should use a weight that can be comfortably lifted for the full eight repetitions.

OR

- 75 minutes (one hour and fifteen minutes) of vigorous-intensity aerobic activity (*eg* jogging, running)

  PLUS

Muscle-strengthening activities (as described above) for at least two days

OR

- A combination of moderate- and vigorous-intensity aerobic activities equivalent to the recommendations above, PLUS muscle-strengthening activities for at least two days

AND

- Flexibility exercises (which are static movements) should be performed at least two days per week at moderate intensity, preferably after performing aerobic or resistance exercises, when muscles are more compliant. Perform stretches in a stretch-and-hold fashion. Avoid ballistic or bouncing stretches.

AND

- Balance exercises, such as backward walking, sideways walking, heel walking, toe walking and standing from a sitting position should be done at least three days a week. These should be supervised and progressively more difficult. Train for maintenance of the base of support (*eg* one leg stands), the centre of gravity (*eg* circle turns) and strength of postural muscles (heel stands).

Adapted from references (3–6).

*An exercise programme for an older person must be designed and monitored by a physician, physical therapist or qualified exercise trainer.

A peak aerobic efficiency (VO_{2max}) of 15–20 mL/kg/minutes is necessary to support independent community living. That level of activity tolerance would enable self-sufficiency, activities of daily living, and social activities, and would represent an average of < 3 METs each day. The lack of aerobic, resistance and flexibility challenge associated with the sedentary lifestyle causes a steep fall in potential to withstand physiological stress, such as an illness. This leads to deconditioning (Table 1). Physiological deconditioning also results in functional losses in other important areas, such as mental status, degree of continence and ability to accomplish activities of daily living. It is frequently associated with hospitalization in the elderly, but is predictably overcome with appropriate physical activity (9). For example, healthy men within the age range of 60–72 years were engaged in standard resistance training exercises for 12 weeks and were found to have a 107% increase in knee extension strength and 227% improvement in knee flexion strength. This meant that there was a 5% improvement rate per training session that is consistent with what is seen in strength training in young adults (10). Table 3 highlights physiological gains from all four recommended exercise domains.

Endurance and resistance training

Interestingly, the capacity of the cardiovascular system to adapt to an endurance training load is not affected by age. Older adults experience improvement in fitness according to the intensity of the training stimulus and the state of fitness prior to training. Endurance exercise improves cardiac output, myocardial performance and VO_{2max} leading to improved capacity for normal living. Older men demonstrated a greater ejection fraction and decreased end-systolic volume following 12 months of aerobic training (2, 9) Increased contractile function of the left ventricle was also noted, representing improved inotropic responsiveness. Improvement in post-training systolic function has been associated with an enhanced response to ß-adrenergic stimulation as a result of endurance training (2) Increased ejection fraction noted post endurance training in the older person is also related to a decrease in vascular stiffness, which itself increases the capacity for endurance exercise. Also even small

Table 3: Summary of physiological benefits of exercise in older persons

Physiological Parameter	Exercise type	Benefits
Cardiovascular function	Aerobic	Improves myocardial performance Increases peak diastolic filling Increases heart muscle contractility Improves blood lipid profile Increases aerobic capacity Reduces systolic/diastolic blood pressure
Musculoskeletal	Aerobic, weight-bearing / resistance exercise	Improves endurance Improves muscle capillary blood flow Increases muscle mass Improves protein synthesis rate and uptake into skeletal muscle
Musculoskeletal and Peripheral Nervous System	Balance and Flexibility	Improves reflexes Improves maintenance of upright posture and righting reflex Improves tendon flexibility Improve joint range of motion Prevents falls, improves speed of recovery/righting actions
Bone health / Musculoskeletal	Weight-bearing / resistance exercise	Slows decline in bone mineral density Improves strength Improves nitrogen balance Improves walking speed
Metabolism	Aerobic	Decreases abdominal adipose tissue Reduces cholesterol/ Low Density / Very Low density Lipoproteins Increases high density lipoproteins Increases total energy expenditure
Cognitive/ Higher Functions	Aerobic, balance and flexibility	Improves attention span Improves cognitive processing speed Decreases anxiety and improves mood Improves perceived well-being and happiness Decreases stress-related hormones Increases slow-wave and rapid-eye-movement sleep Provides sense of accomplishment

Reference (7)

improvements in aerobic fitness improved performance on tasks primarily requiring executive functioning, likely resulting from a rise in cerebral blood flow during exercise (2, 11).

Sarcopenia and its associated loss in lean body mass remains somewhat of a mystery. Even master athletes have significant sarcopenia while remaining very active into older age. This suggests that sarcopenia is simply a result of ageing, as opposed to nutrition or other lifestyle factors. This is supported by the observation that simple disuse of muscles leads to reversible muscle atrophy, but not to a loss of fibre number, whereas sarcopenia involves both. We need to remain active to maintain the reproducible force in our muscles.

As much as 75% of the benefits of strength training are lost within three months of ending training! In contrast, regular resistive exercise has been shown to be highly effective in increasing muscle mass and strength, even in very old age. Older persons show significant improvements of muscle strength when loads greater than 65% of the maximum load that can be lifted once (1-RM) are employed. A significant correlation has also been found between the increase in muscle strength and functional mobility, such as gait speed, as well as the reduced risk of falls (2, 12).

Balance, coordination and fall prevention

The recommendations for healthy ageing importantly include emphasis on balance and coordination. The ability to maintain a state of stillness or control involves a dynamic and complex multi-system response whose efficiency wanes as we age. Physiological challenges include diminished visual acuity, proprioceptive, mechanoreceptive and gross sensory impairments, which occur at the level of the receptors, as well as in the brain and spinal cord (11).

Dedicated involvement in exercises to heighten the responses to displacement of the centre of gravity has made the difference between the debilitation and independence (4). According to the medical evidence (3, 4), for optimal results, balance exercises for two hours per week have yielded best results against fall prevention, especially when done in conjunction with aerobic work and resistance training (10). Table 3 provides specific areas of physiological improvement for the older person with regular balance and flexibility training.

DISCUSSION

Physiologic optimization of the older person is tied to a personalized, guided, weekly exercise regimen aimed at improvements in aerobic fitness, strength, balance and flexibility. A physical activity regimen should be supervised by a specialist healthcare professional.

This individual should monitor the progress periodically, provide encouragement and continued guidance and help the patient overcome barriers such as lack of time or fatigue. There are also many electronic devices which track exercise progress, which may serve as motivators for the most sedentary. For example, pedometer use has been shown to significantly increase physical activity if a step goal is set (12) The goal can be incremental increases of daily steps from baseline (*eg*, by 10% every two weeks), or increases of daily walking time (*eg*, by 10 minutes per day) until a step goal is reached (7).

A crucial factor to be borne in mind when creating an exercise prescription for an older adult is the reason why the individual is not currently as active as possible. One recent meta-synthesis of 132 studies identified barriers and facilitators to older adults engaging in physical activity within six themes: social influences, physical limitations, competing priorities, access difficulties, personal benefits, motivation and beliefs (9). As healthworkers move to overcome these barriers, caution should be encouraged when starting exercise regimens. Frailty, a state of physiological compromise predisposing to poor health outcomes, requires a carefully and closely monitored exercise regimen. It involves such components as weakness, slow walking speed, low level of physical activity and exhaustion. It is most often diagnosed in sedentary older adults (11). Those persons benefit significantly from increases in resistance and flexibility activity, regardless of phenotype (8).

Absolute contraindications to exercise in an older person (reasons not to exercise at all) include a recent ECG change or myocardial infarction, unstable angina, third degree heart block, acute congestive heart failure, uncontrolled hypertension and uncontrolled metabolic disease. Relative contraindications (reasons to consider a slow start, low METs, or to wait for specialist clearance) include cardiomyopathy and valvular heart disease (7).

CONCLUSION

The take-home messages are:

i. Prevent inactivity! Some physical activity is better than none
ii. Start with low intensity, low duration exercise for persons who are very sedentary, as they are likely to be highly deconditioned, functionally limited or

have chronic conditions that affect how well they may perform physical tasks

iii. Be sure to tailor all activities to suit the tolerance and preference of the individual

iv. Very frail individuals may need to begin with strength training and balance activities, before embarking on aerobic training

v. In order to improve their overall level of fitness, older persons should try to meet and exceed minimum exercise recommendations.

vi. Balance and flexibility exercises contribute to important reflexes for fall and injury prevention, and should be a part of any exercise regimen

vii. Aerobic exercises have numerous cardiovas¬cular and musculoskeletal benefits for older adults and are key to maintaining autonomy with ageing

viii. Resistance exercise training can improve muscle mass, strength, power, and quality, as well as overall physical function in older adults (12).

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Author contributions

K Thaxter Nesbeth conceived of the paper, reviewed relevant recommendations, wrote manuscript and approved final version.

A Facey co-wrote the manuscript, critically revised the manuscript and approved final version.

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