ENERGY EXPENDITURE AND MUSCLE ACTIVITY IN ACTIVE AND PASSIVE COMMUTE AMONG ELDERLY

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ABSTRACT

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Since the amount of elderly people and people being overweight are increasing, there should be means to prevent people from getting weight and to ensure longer independency and ability in everyday living among elderly people to decrease the costs that are caused by these trends.

Purpose of the study was to compare muscle activity and oxygen consumption in an active and passive commute to demonstrate the effectiveness of active way of living. Thigh muscle EMG activity and oxygen consumption (VO_2) during different daily activities such as walking and stair negotiation in unloaded and loaded conditions were measured from 16 elderly individuals, but due to incomplete data nine subjects were included to the analyses. Measurements consisted of two laboratory measurement days during which body composition, muscle strength and maximal VO_2 test were measured in addition to the daily activities. VO_2 and EMG activities were compared in two conditions 1) commute by bus vs. walking 1 km and 2) ascending and descending floors using stairs vs. lift.

Results showed that in an active way of commute (i.e. walking) an elderly person can use over 3 times the amount of oxygen and muscle activity that is present in passive commute (using bus). Using stairs requires over 11 times the amount of oxygen and muscle activity than when using lift. During stair ascend the mean peak EMG activity exceeded 120 %MVC while mean peak VO_2 was about 70% $VO_{2max.}$ Further, those who were able to ascend all the five flights did not reach 100% MVC muscle activity level but the others did. It seems that active way of commute provides one effective way of preventing individuals from weight gain.

KEYWORDS: muscle activity, elderly, daily activities, weight control

TIIVISTELMÄ

Kuula, Anna-Stina 2011. Energiankulutus ja lihasaktiivisuus aktiivisen ja passiivisen kulkemisen aikana iäkkäillä henkilöillä. Liikuntabiologian laitos, Jyväskylän yliopisto. Biomekaniikan Pro Gradu. 55 s.

Ikääntyminen ja ylipaino ovat globaaleja trendejä ja aiheuttavat rasitetta yhteiskunnalle kasvaneiden terveydenhoitokustannusten muodossa. Tutkimuksen tarkoituksena oli selvittää, kuinka lihasaktiivisuus ja hapenkulutus eroavat passiivisen ja aktiivisen työ- tai asiointimatkaliikunnan aikana ja millainen merkitys erolla voi olla painonhallintaan. Tutkimuksessa selvitettiin myös erityyppisten toimien aikaiset lihasaktiivisuudet suhteessa maksimivoimaan iäkkäillä henkilöillä ja lihasvoimatason vaikutus portaidennousukykyyn. Reisilihasten lihasaktiivisuutta ja hapenkulutusta mitattiin mm. kävelyn sekä portaiden nousun ja laskun aikana sekä verrattiin seuraavia tilanteita 1) 1 km:n kulkeminen bussilla tai kävellen ja 2) kulkeminen portaita pitkin tai hissiä käyttäen. Portaita noustessa mittauksia tehtiin sekä ilman kuormaa että kuorman kanssa. Lihasaktiivisuuksia mitattiin urheilushortseilla, joihin oli kiinnitetty tekstiilielektrodit molempien lahkeiden etu- ja takahelmaan. Hengityskaasumittaukset tehtiin kannettavalla laitteella, joka mahdollisti esimerkiksi ulkona tehtävän kävelymittauksen normaaleissa olosuhteissa juoksumaton sijaan.

Tutkimukseen rekrytoitiin 16 iäkästä henkilöä, joista 9 sisällytettiin analyyseihin. Muut jouduttiin jättämään pois puutteellisen datan vuoksi. Mittaukset koostuivat kahdesta laboratoriomittauspäivästä, joista ensimmäisenä mitattiin mm. kehon koostumus, lihasvoimatasot ja maksimaalinen hapenkulutus, ja toisena tehtiin varsinaiset päivittäistä aktiivisuutta koskevat mittaukset.

Tutkimuksessa havaittiin, että lihasaktiivisuus ja hapenkulutus olivat käveltäessä kolminkertaisia bussilla kulkemiseen verrattuna ja yli kymmenkertaisia, kun verrattiin portaiden käyttöä hissillä kulkemiseen. Tutkimuksessa todettiin myös, että iäkkäiden henkilöiden kohdalla lihasvoimareservien puute on todennäköisin syy kyvyttömyyteen tai laskeneeseen suorituskykyyn portaita noustessa. Aktiivinen ja monipuolinen elämäntapa vaikuttaa hyödylliseltä pyrittäessä pitämään yllä tai parantamaan iäkkäiden henkilöiden fyysistä toimintakykyä ja sitä kautta itsenäisyyttä elämässään. Se tarjoaa myös keinon panonhallintaan.

AVAINSANAT: lihasaktiivisuus, ikääntyneet, arkiaktiivisuus, painonhallinta

CONTENTS

LIST OF ABREVIATIONS

aEMG: Average EMG

BMI: Body mass index

EMG: Electromyography / Electromyogram

HP: Hypothalamus-pituitary

iEMG: integral EMG, cumulated EMG

LPL: Lipoprotein lipase

LTPA: Leisure time physical activity

MET: Metabolic equivalent, multiple of resting metabolic rate, 1MET= 3.5 ml/kg/min

NEAT: Non-exercise activity thermogenesis

OPA: Occupational physical activity

PA: Physical activity

VO_2: Oxygen consumption, expressed in ml/kg or ml/kg/min

1 INTRODUCTION

Nowadays people operate widely with various electronic devices that facilitate sedentary behaviour, such as television, computers and household appliances. The same trend applies to transportation. (Hill & Peters, 1998.) Independent from the time spent in sedentary activities, breaks in this sedentary behaviour reduce the metabolic risk factors. Most of these breaking activities are light in intensity which offers variable possibilities to reduce for instance the sedentary behaviour during work days. (Healy et al. 2008.) Adults have been reported to use up to 12 hours on sedentary behaviour per day. It seems also that sedentary behaviour is more common in people with higher BMIs and that obese people may use as little as half of the time the normal-weighted people use on activities such as fast walking. (Buchowski et al. 2010). On the other hand, it seems quite probable that the more people sit the more they gain weight.

Sedentary behaviour is also present in children and adolescents and it has been shown that adolescents aged 11-15 years sit about 7 hours per day (Norman et al. 2010). Since the recommendation for screen time is less than two hours per day (Lasten liikunnan suositus, n.d.) interventions should be developed that reduce the time spent on these kinds of activities. Additional encouragement towards increasing physical activity is also needed. (Liu et al. 2010.) For adults, a reduction in sedentary behaviour by 2.5 hours per day could help to prevent or even reverse the development of obesity (Levine et al. 2000, 2005).

Because of the great amount of sedentary people it is necessary to find a minimum amount of physical activity needed to reduce the rate of all-cause-mortality. Although the minimum threshold on reducing mortality is not known, it seems that consuming 1000 kcal per week in exercising is enough to produce a 30 % reduction in all-cause-mortality. It is possible that even 500 kcal per week consumption is enough to produce slight reductions. Although there are clear benefits from physical activity it is not easy to determine the right amount of exercise because the same activity dose does not result in similar responses in different individuals. (Kesäniemi et al. 2001.)

Physical activity provides a strong basis for development of musculoskeletal system of children (Canadian Paediatric Society, 2002) and during adulthood helps to prevent several chronic diseases (Warburton et al. 2010). At the older age physical activity provides means to maintain and increase muscle strength and physical performance which are essential when considering ability to live independently among elderly (Kesäniemi et al. 2001, Warburton et al. 2010).

2 PHYSICAL ACTIVITY

Physical activity can be described as any bodily movement which increases energy expenditure. This includes both daily activities and exercise. (Physical Activity Guidelines for Americans. 2008) Conventional methods for assessing daily activity have been diaries, questionnaires (Lakka et al. 2003, Liu et al. 2010, Buchowski et al. 2010, Cleland et al. 2010) and interviews (Buchowski et al. 2010). All these methods are subjective and can result in an erroneous estimate of physical activity level. The bias can be due to the subject or the researcher. (Kozey et al. 2010, Cleland et al. 2010.)

The daily activity of individuals can be measured objectively using accelerometers (Norman et al. 2010, Kozey et al. 2010), pedometers and devices measuring oxygen consumption (Kozey et al. 2010). Also special devices, such as IDEEA (Intelligent Device for Energy Expenditure & Activity, MiniSun LLC, USA), measuring physical activity and different factors contributing to it have been developed (Huddleston et al. 2006, IDEEA (Intelligent Device for Energy Expenditure & Activity), 2007). Use of GPS (Global Positioning System) has also been proposed to assist the assessment of physical activity by providing information about environments and locations in which the activities take place (Maddison & Ni Mhurchu, 2009). Since bodily movement and thus physical activity is initiated by muscle contractions, the use of electromyography as an indicator of physical activity is also applicable (Klein et al. 2010).

Accelerometers measure the accelerations of the body in a triaxial or uniaxial setup and the data is then further analysed to yield so called activity counts (Norman et al. 2010). According to Norman et al. 2010, less than 100 counts per minute can be seen as sedentary behaviour. In the study by Kozey et al. (2010) the acceleration counts for stair ascending and descending were quite similar (2770 and 3157, respectively) but the metabolic equivalent (MET) value for stair ascending was more than two times that of stair descending. Thus the acceleration counts should be linked to e.g. MET values (see chapter 2.2) if energy expenditure is to be estimated. Although the counts may be equal, the energy expenditure values can vary much depending on the task and vice versa. In the aforementioned study the relationship between these variables was developed using a linear regression model. The prediction for METs using accelerometer counts does not serve as a reliable method in case of intermittent high-intensity activities. Thus accelerometers are not yet reliable to predict energy expenditure in free living, although some of them have been validated with energy expenditure measured using doubly labelled water (Bonomi et al. 2010).

2.1 Different types of physical activity

The long version of International Physical Activity Questionnaire (IPAQ-l) contains four different domains of physical activity (PA); job-related/occupational (OPA), transportation, household/care and recreational/leisure-time (LTPA). Exercise-type of activity is included in leisure-time physical activity. The questionnaire also considers the time spent sitting or lying down. (International Physical Activity Questionnaire, 2002.) Non-exercise activity covers all physical activities except volitional exercise for fitness (Levine et al. 2006).

Nowadays occupational activity is considered to be included to the physical activity recommendations since it has been noted that individuals in active or physically demanding works can accumulate a significant proportion of total daily physical activity during their working day. Clearly, when assessing the total physical activity of a person, it is important to include the occupational activity into the analysis in order to get a representative picture of it. (Yore at al. 2005.) In their study Proper et al. (2006) studied the contribution of different activity domains to the total physical activity. In Australian population the household activities played the most important role (34 %) together with occupational activity (27 %). Leisure-time physical activity was the third with a proportion of 23 % of the total physical activity.

Repetitive actions involving numerous contractions during the (working) day are suggested to contribute in helping to keep the musculoskeletal system sound by increasing blood flow (Kruger et al. 2006). Men and women engaging in heavy manual work have significantly better grip power and cardiorespiratory fitness than those with lighter jobs (Figure 1) (Tammelin et al. 2002).

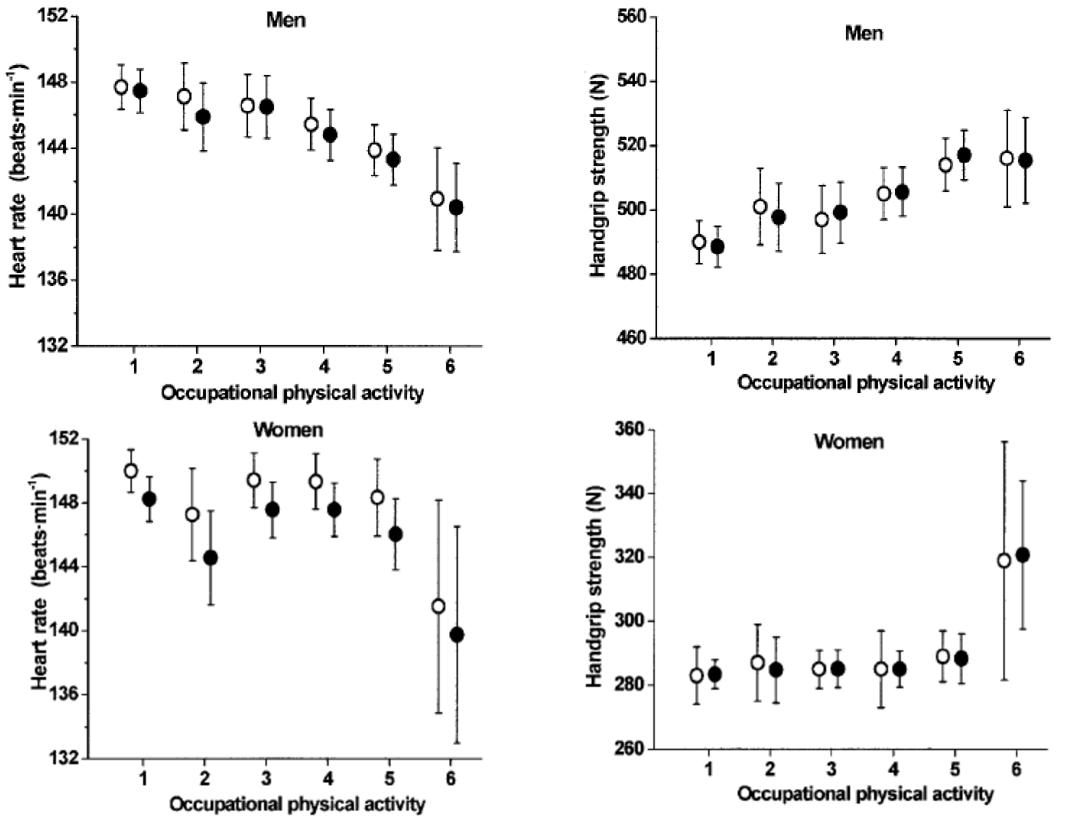

FIGURE 2—Step Test: Heart rate after step test (beats·min^{-1}) according to the following occupational physical activity levels: 1) light sedentary work, 2) other sedentary work, 3) light standing or moving work, 4) medium heavy moving work, 5) heavy manual work, and 6) very heavy manual work. Mean values and their 95% confidence intervals, ● = crude values from univariate analyses, ○ = values adjusted for leisure-time physical activity, height, weight, and smoking.

FIGURE 3—Handgrip Test: Grip strength (N) of the dominant hand according to the following occupational physical activity levels: 1) light sedentary work, 2) other sedentary work, 3) light standing or moving work, 4) medium heavy moving work, 5) heavy manual work, and 6) very heavy manual work. Mean values and their 95% confidence intervals, ● = crude values from univariate analyses, ○ = values adjusted for leisure-time physical activity, height, weight, and smoking.

FIGURE 1. Relation of cardiorespiratory fitness and grip strength to level of occupational activity (Tammelin et al. 2002).

Although opposing results have been presented (Tammelin et al. 2002) several studies reported that people who are active during workdays are also more active outside labour (Table 1) and vice versa (Kruger et al. 2006, George et al. 2010, Probert et al. 2008).

This might be due to the fact that people performing heavy work are in better musculoskeletal and cardiorespiratory condition (Tammelin et al. 2002).

TABLE 1. Ratios showing that occupational activity level has a positive effect on lifestyle physical activity (Kruger et al. 2006).

Adjusted* Odds Ratios (ORs) and 95% Confidence Intervals (CIs) for Lifestyle Activity by Level of Occupational Activity, Stratified by Sex—NPAWLS 2002

	Lifestyle Physical Activity		
Occupational Activity Level	Regular Moderate-Intensity Activity† OR (95% CI)	Regular Vigorous-Intensity Activity‡ OR (95% CI)	Regularly Active§ OR (95% CI)
Men			
Mostly sitting or standing	1.0 (reference)	1.0 (reference)	1.0 (reference)
Mostly walking	1.5 (1.2–2.0)	1.1 (0.9–1.4)	1.3 (1.0–1.6)
Mostly heavy labor	2.4 (1.8–3.1)	1.7 (1.3–2.2)	1.9 (1.5–2.4)
Women			
Mostly sitting or standing	1.0 (reference)	1.0 (reference)	1.0 (reference)
Mostly walking	1.4 (1.1–1.8)	1.1 (0.9–1.4)	1.3 (1.0–1.6)
Mostly heavy labor	2.5 (1.7–3.8)	1.5 (1.0–2.2)	1.8 (1.2–2.6)

*Adjusted for age, race/ethnicity, education, income, and body mass index.
†Thirty or more min 5 d/wk of moderate-intensity physical activity.
‡Twenty or more min 3 d/wk of vigorous-intensity physical activity.
§Regular moderate- or vigorous-intensity activity.

It is common that people in heavy work are less educated or belong to racial minorities (Kruger et al. 2006). When comparing the energy expenditure within work for different educational classes, those having the least education had almost 2.5 times the energy expenditure (4215 MET-min /week) of those with the highest education (1722 MET-min /week). However, it is possible that high-risk behaviour within these lower education groups may outweigh the benefits of increased occupational activity (Kunst et al. 1998).

2.2 Physical Activity and Energy Expenditure

The total daily energy expenditure is divided into three components (Figure 2), those being basal metabolic rate, thermic effect of food and activity thermogenesis. Activity thermogenesis includes both exercise and non-exercise activity thermogenesis (NEAT), and can be derived by subtracting basal metabolic rate and thermic effect of food from the total daily energy expenditure. Physical activity level can be calculated by dividing the total energy expenditure by basal metabolic rate (Levine et al. 2006).

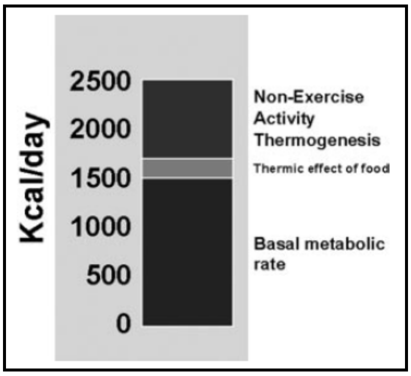

FIGURE 2. Subdivision of total daily energy expenditure to its components (Levine et al. 2006).

Sometimes the resting metabolic rate is used instead of basal metabolic rate which should be measured after overnight fasting and sleep. The resting metabolic rate can be measured after 4 hours without any exercise, eating or drinking caffeinated drinks. The subject stays in a supine position for 15 minutes after which the energy expenditure at rest is measured. (Kozey et al. 2010.)

Physical activity in different intensities can be described as METs. A MET value is defined as the measured task dependent VO_2 consumption divided by resting metabolic rate. 1 MET is the amount of energy used in resting state or while quiet sitting (Liu et al. 2010) and it has been standardized to 3.5 ml/kg/min. (Kozey et al. 2010.) However, Kozey et al. (2010) as well as other researchers have proved the amount being erroneous within general population, which is why the resting metabolic rate should be reported as standard METs or measured METs. Light intensity activity has a MET value of less than 3, moderate 3-5.99, vigorous over 6 and very vigorous over 9.

METs can be used to assess daily physical activity based on measured values within normal daily routines. There is remarkable variation between measured METs in different studies. That is why a great caution is needed when e.g. the compendium based values (Ainsworth et al. 2000) are used to make estimations of daily physical activity (Kozey et al. 2010). Kozey et al. (2010), nevertheless, showed that compendium can be used to estimate the METs for adults aged 20-60 years and that the METs did not vary based on sex or BMI.

2.3 Health benefits of exercise and non-exercise activity

Physical activity has two kinds of influences on health. The influences can be either acute or chronic. Acute effects are present while performing or right after the exercise. The chronic effects can be seen as cumulative responses of acute effects.

Regarding acute effects, studies have shown that a single session of exercise (performed within 50-80 % VO_{2max}) is able to cause a decrease in serum triglyceride level and increase in serum HDL. The same type of exercise can also lower the blood pressure for 18-20 / 7-9 mmHg acutely in persons with small hypertension. Acute exercise can lower blood glucose levels for several days. There is also a linear inverse relationship between the amount of physical activity and the incidence and mortality concerning all the cardiovascular and coronary heart diseases. The amount of physical activity has a role in preventing overweight but is not linearly associated with weight loss. There may also be benefits from physical activity to blood glucose levels in type 2 diabetes, cancer, low back pain, osteoarthritis and osteoporosis. (Kesäniemi et al. 2001.)

The study by Lira et al. (2010) brought out chronic effects among trained athletes, those having significantly lower total cholesterol, low-density lipoprotein cholesterol (LDL), triglyceride and PAI-1 (plasminogen activator inhibitor type-1) levels in plasma than had sedentary subjects. The athletes had a mean training experience of 9 years and a training frequency of 4 times per week. Mean duration of daily exercise was 2 hours and intensity varied from 50 to 100 % of VO_{2max}. 6 months of resistance training was found to be more effective on increasing HDL and reducing waist to hip ratio than 6 months of walking (Kukkonen-Harjula et al. 2005). In a study among elderly women it was found that during the resistance training period of 16 weeks the plasma concentrations of inflammatory markers such as interleukin-6, leptin and resistin were decreased (Prestes et al. 2009). Leptin is inversely linked with the sense of hunger. In weight-stable individuals the concentration is linearly correlated with fat mass. (Rosenbaum & Leibel, 2010.)

Pasman et al. (1999) studied chronic effects of exercise on physical performance of obese and overweight subjects who were exercising for 4 months on a daily basis. The VO_{2max} of the subjects increased one third of the initial level and could be maintained during 12 months of additional exercising. The cessation of exercising in the control group at the moment of 4 months reduced the levels almost to the initial value. Despite the increased performance there were no remarkable differences in the blood pressure or cholesterol between the groups after 12 months of exercising. Nonetheless the waist circumference and waist-to-hip ratio were significantly lower in the trained group thus lowering their risk factor profile.

Lakka et al. (2003) found that occupational physical activity estimated by questionnaire correlated with serum triglycerides. Morris and Crawford (1958) found that individuals having physically demanding jobs had less coronary heart diseases when compared to their age-matched controls having physically light work. The existing symptoms of heart condition were also less severe and developed in later age than in their inactive counterparts. Further, the rate of hypertension was lower in the group of high occupational activity. (Morris & Crawford, 1958.) Independently of leisure time physical activity the increased occupational activity is associated with less risk of any chronic disease, heart disease and diabetes. When combining both activities, a protective effect for heart disease was found with high physical activity. (Probert et al. 2008.) Occupational and commuting physical activity has also been found to possibly reduce the risk of stroke (Hu et al. 2005). In addition, George et al. (2010) found that increased physical activity in household, occupational and transportation domains may be able to lower the risk of invasive breast cancer in postmenopausal women.

2.4 Recommendations regarding exercise and daily activity

It is recommended that people should do vigorous-intensity exercise for 20 minutes three times a week or moderate-intensity exercise on preferably all days of week (Haskell et al. 2007). Also resistance training increasing or maintaining muscle strength is recommended to be performed at least twice a week. One reason for guidelines recommending daily activity with lower intensities may be the increasing amount of people with sedentary behaviour and lower occupational activity. (Kesäniemi et al. 2001.) When promoting physical activity by interventions it should be targeted to those being inactive during their working days and giving possibilities to increase occupational physical activity (Kruger et al. 2006) without forgetting transportation, since people may not be able to meet the recommendations of physical activity in recreational time only (George et al. 2010).

A British study found that if occupational activity was included, 36% of men and 25% of women met the recommendations (more than 30 min of at least moderate intensity, more than 5 days per week) concerning physical activity. When contribution of occupational activity was removed, only 23% of all men and 19% of all women met the recommendations. As can be seen, the actual proportion of those meeting the recommendations is higher among the youngest and lowest among the oldest (Figure 3). When occupational physical activity was included, those meeting the recommendations were mainly manual workers (42-50%) instead of professional and managerial workers (24-28%). (Allender et al. 2008.) In general, women are more likely to be physically inactive (43.3 %) than men (36.5%) (Willey et al. 2010).

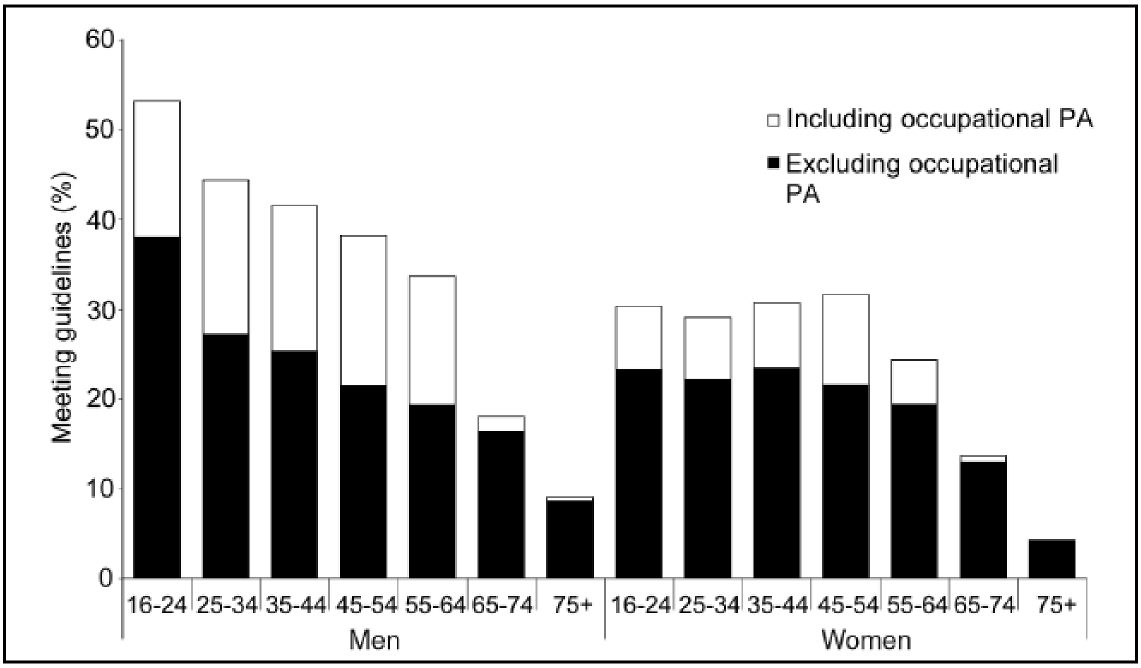

FIGURE 3. Proportion of men and women meeting physical activity guidelines with and without occupational physical activity (Allender et al. 2008).

In Finland the recommendations concerning physical activity include aerobic physical activity 150 minutes per week on a moderate level or 75 minutes per week on a vigorous level (Figure 4). Beyond these it is recommended to train muscle strength and balance two times per week. As it can be seen, the non-exercise type activities like berry picking and house work have been included to the recommendations.

The dose of physical activity is suggested to be accumulated in portions of at least 10 minutes effort. The two intensity levels of activity can also be merged so that the total amount of weekly physical activity is an intermediate of the two recommendations. It is also advised to perform the activities during at least three different days. The Finnish recommendations are based on the guidelines of U.S. Department of Health and Human Services. (Physical Activity Pie, 2010.)

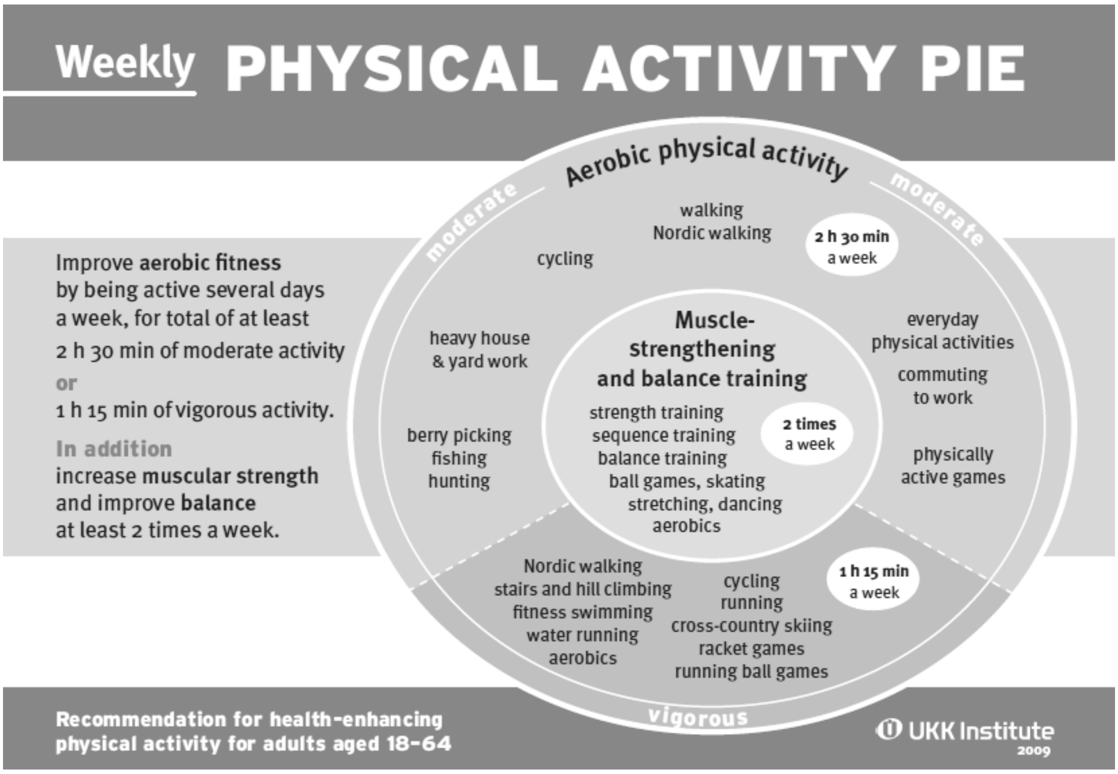

FIGURE 4. Finnish recommendations for physical activity (Physical Activity Pie, 2010).

The FINRISKI 2007 study reported that 59% of men and 66% of women were engaged in regular physical activity at least 2-3 times per week. The study was executed in six different regions of Finland including North Karelia, North Savo, metropolitan area, Turku and Loimaa, Oulu and Lapland. The amount of people exercising regularly has increased during the past decades while occupational physical activity has decreased. (Peltonen et al. 2008.)

3 PHYSICAL INACTIVITY AND OVERWEIGHT

Over the decades industrialization has lowered the rates of occupational and domestic physical activity and it has been estimated that inactivity-caused mortality to cardiovascular disease is 35% (Kesäniemi et al. 2001). Inactivity (meaning sitting and laying down) is considered to be a significant contributor in metabolic diseases. It is possible that there are different modulators reducing risks of metabolic diseases when comparing low-intensity and high-intensity physical activity. Thus, there is a possibility that even though people do exercise, it is not enough to prevent health risks associated with too much sitting. Low-intensity activity related to daily routines increases the energy expenditure in the working muscle. It is believed that these muscle contractions are possible causes to processes that mediate the preventive effect to inactivity related metabolic diseases. When contractile activity does not occur it stimulates several proteins, mRNAs and signalling pathways. (Hamilton et al. 2004.) For example, plasma cholesterol metabolism contributing lipoprotein lipase (LPL, a protein linked also to a risk for coronary heart disease) activity is decreased when normal ambulatory behaviour is not possible (Bey & Hamilton, 2003).

In a study by Bey and Hamilton (2003) a hindlimb unloading for rats was performed in an acute and a chronic setup. Thus the possibility for weight bearing activity was reduced so that no contractile activity was compulsory. When compared with normal low-intensity ambulatory activity the unloaded situation (12 h per day) caused reduced HR-LPL activity in the skeletal muscles. After allowing the rat to ambulate and stand the LPL-levels were restored in 4 hours meaning that inactivity-caused reductions in LPL activity can be reversed performing low-intensity, non-fatiguing muscle contractions. The effects of unloading were not accumulative. The study showed that it is a local process that mediates the LPL activity decrease in the case on inactivity. It was also mentioned that it is possible that postural activity (continuous non-fatiguing contractions) causes higher rates of LPL activity in red oxidative muscles (Bey & Hamilton, 2003) because of local contractile activity. According to Hamilton et al. (1998), this leads to an interpretation of postural control and an upright position being important to health.

Müller-Riemenschneider et al. (2010) found that within German adolescents aged 11-17 the percentage of inactive individuals increased from 10 to 36 in girls and from 5 to 18 in boys when comparing the youngest and the oldest. As can be seen, the inactivity level among girls is much higher than among boys. The decreasing trend of activity continues as people get older and among adults the amount of inactive people in population is 36-43 % with men being more active than women. Within the elderly the inactivity levels are also approaching 43%. (Müller-Riemenschneider et al. 2010, Willey et al 2010.)

3.1 Health risks associated with overweight and inactivity

Recent studies have shown that sedentary behaviour is linked with higher BMI (Buchowski et al. 2010). Obesity, as well as metabolic syndrome, is associated with increased incidence of cardiovascular disease risk factors (Lakka, 2002). Willey et al. (2010) showed that physical inactivity had association with diabetes, hypertension, peripheral vascular disease and heart disease. Reduction of weight decreases the components of metabolic syndrome as does the maintenance of reduced weight (Kukkonen-Harjula et al. 2005).

Lakka et al. (2003) found that men with metabolic syndrome had less leisure time physical activity than their healthy counterparts. These men also had larger waist-to-hip ratio and a higher BMI. Their fasting blood glucose, serum insulin, serum triglycerides and apolipoprotein B were higher while serum HDL and HDL_2 (sub fraction of HDL) were lower. The more the subjects had physical activity the less were their BMIs, waist-to-hip ratios and fasting serum insulin. Together with vigorous intensity the moderate intensity physical activity was enough to correlate with these health markers. Maximal oxygen uptake (VO_{2max}) was inversely correlated with BMI and waist-to-hip ratio and positively correlated with the time spent on leisure time physical activity. Men who were in the lowest tertile based on the physical activity were most likely to have metabolic syndrome.

3.2 Prevalence and causes of overweight and obesity

The Finnish FINRISKI 2007 study shows that the mean value of BMI was 27.0 in men and 26.5 in women meaning that in average the whole Finnish population is overweight. Among men and women the actual prevalence of overweight is 46.6% and 31.3% respectively. The obesity rates are 19.3% and 21.1% for men and women. (Peltonen et al. 2008.) It is evident that human body has strictly controlled energy metabolism that prefers certain weight, of which the evidence will be discussed in the following paragraphs.

Different individuals experience different weight gain in an adipogenic (boosting adipose tissue to increase) environment. In their study Levine et al. (1999) found that when people are overfed by same amount of energy they gain different amount of weight. In this study the excess amount of energy was 1000 kcal per day. The daily energy expenditure was measured beforehand by doubly labelled water. After eight weeks of excess eating, the individuals had gained 1.4 to 7.2 kilograms of weight. The rate of resting energy expenditure was found to increase by 5 % compared to the beginning of the study. Because of the excess amount of food, the postprandial energy expenditure increased by 14 %.

Leibel et al. (1995) found that 10 % increase and decrease in the subjects' weight was accompanied by a 16 % increase and 15 % decrease in daily total energy expenditure after corrections for body composition. The amount of fat-free mass was significantly related with total energy expenditure, resting energy expenditure and non-resting energy expenditure as well as with the thermal effect of feeding. The amount of fat mass was significantly related to the total daily energy expenditure and resting energy expenditure, those being significantly higher in the obese when related to fat-free mass and compared to non-obese subjects. The thermal effect of feeding was lower in the obese compared to the non-obese subjects. After 10% of weight gain, the total energy expenditure, non-resting energy expenditure and thermal effect of feeding had significantly greater increases than predicted. Meanwhile the subjects used same amount of time to move around during the measurements when comparing different weight states. After returning to the initial weight no differences were noted in body composition or energy expenditures when comparing with the initial state. (Leibel et al. 1995.)

In a study by Weyer et al. (2000) two years of restriction in energy intake was accompanied by a weight loss of about 15%. The subjects spent 24 months in enclosed surroundings with restricted amount of food. The weight loss took place within the first 6 months of confinement. The weight stayed constant during the last 18 months of confinement. After leaving the research surroundings back to normal community and adopting their normal diets the subjects gained their initial weight within 6 months. When the subjects left the research surroundings they had significantly lower fat mass than controls but their fat-free mass was not different from controls'. After 6 months in normal diet their body composition was again similar to controls because of the weight gain consisting primarily of fat. When exiting the research environment the 24-hour energy expenditure of the subjects was lower than that of the controls. This difference remained significant after adjusting for age, fat-free mass, fat mass and sex. After additional adjustment for spontaneous physical activity the group differences in energy expenditure were no longer significant. Despite the fact that body composition was normalized after normal diet, the 24-h energy expenditure remained almost at the same low level than right after exiting the research surroundings. Again the spontaneous physical activity was significantly lower when compared to the controls. (Weyer et al. 2000.)

There are different signalling pathways that regulate the thermogenesis of the body thus adapting it to different amounts of consumed energy. The maintenance of reduced body weight is, among others, related to increased activity in the hypothalamic-pituitary (HP)-adrenal axis and decreased activity in the HP-thyroid and HP-gonadal axes. Also autonomic nervous system plays a role in regulating energy expenditure based on afferent signals expressing state of energy stores. Increase in parasympathetic drive causes heart rate to drop together with a decrease in the resting energy expenditure. The sympathetic drive runs counter to the parasympathetic by elevating heart rate, increasing the secretion of thyroid hormone and modulating feeding behaviour. Weight loss and its maintenance are related to decline in the sympathetic drive together with an increase in the parasympathetic drive. This may contribute to hypometabolic state by effecting the skeletal muscle and concentration of circulating thyroid hormone. Brown adipose tissue can release energy from fatty acid oxidation as heat instead of using it to ATP production. The activation of brown adipose tissue requires input from the sympathetic drive and at least one of the two thyroid hormone receptors. The decline in sympathetic drive and concentration of circulating thyroid hormone may be a mechanism that reduces the thermogenesis in brown adipose tissue during weight loss and its maintenance thus reducing the resting energy expenditure beyond that of predicted considering body mass and composition. (Rosenbaum & Leibel, 2010.)

While trying to resist weight gain, the total energy expenditure, non-resting energy expenditure, sympathetic drive, circulating thyroid hormone and leptin concentrations increase and the parasympathetic drive declines. These mechanisms that try to compensate the gained weight are not as long-lasting (few months) as mechanisms present with reduced weight (several years). Thus it is easier for humans to gain weight than to lose it. (Rosenbaum & Leibel, 2010.)

3.3 Physical inactivity and NEAT

It has been shown that about 10 % of all the individuals who lost weight were able to maintain a loss of 10 % of initial bodyweight and one fifth were able to maintain the weight loss of 5 % after several years. This follow-up took place 2 to 11 years after these Canadian women had participated in a weight loss program. (Gosselin & Cote, 2001.) On the other hand, a study by Sarlio-Lähteenkorva et al. (2000) showed that among Finnish adults the amount of individuals who had maintained at least 5 % loss of initial weight after 9 years was 5.1 % in women and 6.6 % in men.

Several studies (Jakicic et al. 2008. Shick et al. 1998, Klem et al. 2000) showed that individuals, who have lost weight and have been able to maintain it, had a remarkably low rate of energy intake despite the fact that they were exercising. Individuals, who have maintained their reduced weight 6 years, spend more time in activities consisting of medium and light intensities when compared to those who have maintained their weight less than 6 years. Those who had maintained their weight 6 years or over had an average of 2427 kcal used weekly on physical activities, of which little less than half consisted of light or non-exercise activity, primarily walking. (Klem at al. 2000.) Similar results were found in a study by Jakicic et al. (2008) with obese / overweight women. Those who were exercising at least 300 min per week or had leisure time physical activity of 2000 kcal per week were able to maintain a reduction of 10 % or more when combined with food restriction after 24 months of follow-up.

Pasman et al. (1999) found that exercising regularly after a very-low calorie diet did not help to maintain the achieved weight loss when compared to controls. Nevertheless, the regain of fat mass was significantly lower than in controls. The amount of training hours per week was inversely associated with the regain of fat mass. On the other hand, after a similar kind of diet Kukkonen-Harjula et al. (2005) studied effects of resistance training and walking to maintenance of weight loss. During the 6 months weight maintenance phase the reduced weight remained almost unchanged in both groups. Wadden et al. (1998) found that volitional exercising during the maintenance period did help to maintain reduced weight.

Levine et al. (1999) found that getting excess amounts of energy by 1000 kcal per day the increased non-exercise activity covered two thirds of the increased energy expenditure. Differences in non-exercise activity clearly predicted the ability of individuals to resist weight gain. As can be seen from the study by Weyer et al. (2000) the excess decrease in total energy expenditure is primarily caused by decreased spontaneous physical activity levels after weight loss. Thus it seems to be important to maintain non-exercise physical activity intentionally to compensate the reduced total energy expenditure during and after weight loss. On the basis of a study by Levine et al. (2005) it seems possible that differences between the time individuals spent sitting and standing/ambulating are based on biological factors. Lean subjects, after being over-eating for 8 weeks, and obese subjects, after weight loss period of 8 weeks, had maintained their initial levels of sitting and standing/ambulating.

Several studies have concerned job related physical activity between different occupational categories. Steele and Mummery (2003) found that within university personnel the difference between the daily step counts of most active and most inactive workers was 6000 while the energy expenditure of most active workers in MET-minutes per week was almost two times that of those most inactive (Table 2). Giving a value of 1 kcal per MET-min for an individual weighing 60 kg this would make a difference of 3000 kcal or 600 kcal per working week and working day respectively. This shows that it requires massive amounts of volitional exercise on a daily basis to compensate the reduced energy expenditure related to sedentary behaviour during work day.

TABLE 2. Mean and standard deviations for energy expenditure including light, moderate and heavy activity (MET-min •wk $^{-1}$) and step counts (Steele & Mummery, 2003.)

Occupational Category	Step-Counts	†TOQ Scores	†MET-min•wk^{-1}	Light (< 3 METS)	Moderate (3-6 METS)	Heavy (> 6 METS)
Professionals	2,835.2±945.7	83.9±23.8	3,987.2±1,029.2	3,257.5±766.9	707.7±806.6	22.1±89.6
White-Collar	3,616.5±1,519.2	75.7±24.1	3,590.1±907.2	2,694.2±490.0	826.3±786.8	69.5±310.5
Blue-Collar	8,757.4*±2,540.4	139.8*±43.4	6,704.9*±1,730.2	1,295.5±895.2	3,696.8±1,706.5	1,712.6±2,218.4

† Past Year Work Activity Units (WAU) Only † METS•wk-1 * = p < .05

By changing commuting and leisure time physical activity behaviour simply by not sitting in car or watching TV, individuals have a possibility to increase their total daily energy expenditure by even more than 1000 kcal, without the substituting activities interlocking with actual exercise (Levine et al. 2006). Effect of such kind of activities to energy expenditure can be seen in Table 3. It has also been found that sedentary, lean individuals stand and ambulate 2.5 hours more per day than their obese counterparts (Levine et al. 2005). Among children, the likelihood of participating in different physical activities is increased if they consider that particular activity being fun and, what is important, if their parents are participating too (Hill & Peters, 1998).

TABLE 3. Energy expenditure in relation to rest (Levine et al. 2000).

Energy expenditure and respiratory quotient associated with fidgeting-like activities and low levels of activity[1]

	Energy expenditure	Respiratory quotient
	kJ/min (% above resting)	
Resting	5.4 ± 1.5 (—)	0.76 ± 0.05
Sitting motionless	5.6 ± 1.6 (3.7 ± 6.3)	0.76 ± 0.04
Sitting while fidgeting	8.2 ± 2.3[2] (54 ± 29)	0.76 ± 0.04
Standing motionless	6.1 ± 1.7[2] (13 ± 8)	0.76 ± 0.04
Standing while fidgeting	10.3 ± 2.9[2] (94 ± 38)	0.75 ± 0.04
Walking at 1.6 km/h	13.7 ± 4.3[2] (154 ± 38)	0.76 ± 0.04
Walking at 3.2 km/h	16.4 ± 5.4[2] (202 ± 45)	0.77 ± 0.04
Walking at 4.8 km/h	21.3 ± 7.9[2] (292 ± 81)	0.77 ± 0.03

[1] $\bar{x}$ ± SD.

[2] Significantly different from resting value, $P < 0.001$.

Klein et al. (2010) found that people in sedentary occupations have their muscles inactive as much as 86.7 % of the waking hours. Furthermore the activity was mainly less than 80 % of MVC. The threshold level for muscle activity corresponded to 1.7 % of MVC. In order to increase standing and ambulatory time in sedentary work such as office workers', multiple re-engineering interventions to environmental solutions need to be made. Different redesigns can help employees to pick a choice that can promote their activity enough to exceed the deficit in NEAT that occurs in obesity. (Levine et al. 2006.)

4 ACTIVITY, INACTIVITY AND AGING

4.1 Physical activity in different stages of life

Children need adequate physical activity to attain optimal growth and development. Activity improves children's balance and posture together with helping them to build strong bones and muscles. (Canadian Paediatric Society: Healthy active living for children and youth, 2002.) The amount of bone mass during adulthood is greatly determined by the peak bone mass the children have gained during childhood. Thus, having strong bones during childhood may prevent from fractures in older age. (Barr & McKay, 1998.)

Adequate physical activity strengthens the heart and children's physical condition and helps them to build a better picture of their body. Children need role models and active participation of parents and other family members to promote their physical activity and other healthy behaviour such as eating habits. Participating to organized activities like sports clubs is not enough to maintain children's health, which is why they also need non-exercise activity on a daily basis. (Canadian Paediatric Society: Healthy active living for children and youth, 2002.)

During adulthood the target of physical activity is primarily the prevention of multiple conditions. Together with this, the increased activity causes health benefits. It is believed that the dose-response relationship between physical activity and health benefits is curvilinear and the biggest benefits are present when the most inactive individuals become less sedentary (Figure 5). Together with these benefits the condition of musculoskeletal system is improved thus preventing from e.g. premature mortality. (Warburton et al. 2010.)

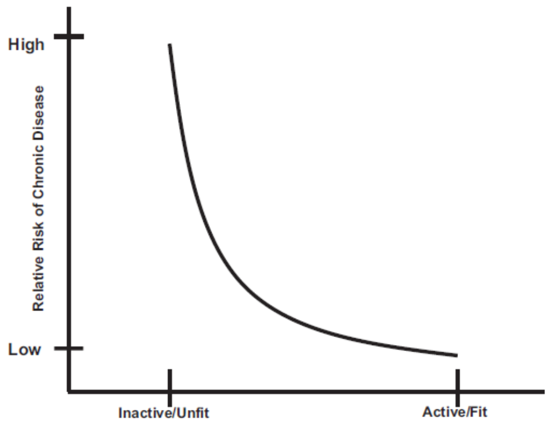

FIGURE 5. Theoretically the risk of chronic diseases diminishes due to an increment in physical activity (Warburton et al. 2010).

Within elderly the muscles are getting smaller because of sarcopenia but inactivity causes additional muscle atrophy (Evans, 2010). Increased physical activity can promote independent living in the elderly as well as overall wellbeing. (Kesäniemi et al. 2001). Enhanced physical activity promotes bone health, functional independence and psychological well-being and it is also evident that a good musculoskeletal fitness is inversely related to fall risk (Warburton et al. 2010) thus preventing from fractures.

4.2 Physical activity among elderly

The main object in enhancing physical activity among elderly is to maintain their functional capability and independency. Additional benefits from physical activity are decreased risk of chronic diseases and extending life. It seems that both the high total volume of energy expenditure (moderate or vigorous intensity) and participation in vigorous activities (>6 METS) play an important role in decreasing the relative risk of morbidity. Among elderly this can be interpreted as brisk or fast walking. In preventing diseases the intensity of 60-70 % of VO_{2max} is seen beneficial by increasing the cardiorespiratory fitness. It is also brought out that it is preferable to measure fitness instead of activity in order to avoid misclassifications. (Paterson et al. 2007.)

Some studies have found that performance of over 15 ml/kg/min is associated with ability to live independently in old age. A decadal decline of about 16 % in cardiorespiratory performance has been reported and is not associated merely to the loss of fat-free mass. Similar effect has been seen in all fitness levels suggesting that exercising does not prevent from decline of performance. However, the values stay higher compared to those with lower levels of fitness. Thus it is likely that exercising regularly to maintain higher level of cardiorespiratory fitness and strengthen the muscles is of benefit to elderly in order to stay independent in their daily activities. (Paterson et al. 2007.)

Because of sarcopenia (the loss of muscle mass), especially type II fibers (Verdijk et al. 2009) the elderly often have muscle weakness. After about 30 years of age, the muscle strength begins to decline gradually. After reaching an age of 50-60 years the decline accelerates. After this acceleration it seems likely that when approaching some essential level of muscle mass the reduction becomes slower. The contractile speed of muscles also decreases with advancing age. This makes the power (strength x velocity) loss remarkable as a whole. However, the older individuals may be able to activate their muscles as effectively as the younger. The loss of muscle mass is partly arisen from the loss of spinal motor neurons innervating the muscle cells. During the remodelling of the muscle the remaining motor neurons adopt the abandoned muscle cells thus increasing the size of existing motor units. (Paterson et al. 2007.)

Despite the aging induced changes the muscles maintain their ability to adapt to exercise thus opposing the effects of sarcopenia (Verdijk et al. 2009). Benefits and gains of resistance training have been seen in many interventions and training programs. In their study Whiteford et al. (2010) showed that both resistance training three times per week and walking for 30 minutes three times per week for one year increase the bone mineral density of hip bone among male subjects aged 55-80 years. Resistance training also increased lean body mass, fitness and lower limb muscle mass when the training program was designed to provide loading at the hip area. Prestes et al. (2009) found that with progressively training strength twice a week for 16 weeks increased maximal strength in several muscles/muscle groups among elderly postmenopausal women. Verdijk et al. (2009) showed that after 12 weeks of resistance training the type II satellite cell content in leg muscles increased significantly meaning that the hypertrophy of type II muscle fibers is possible in older age, too. Also the type II fiber area itself did increase during the training period.

Persch et al. (2009) showed that among elderly women the resistance training improves falls-related gait kinematics. The gains in strength (Figure 6) were beneficial to parameters reducing risk of falls, those being gait speed, stride length, cadence and toe clearance. Little less than half of the improved gait performance could be explained by the increased strength of knee extensors. The finding that double limb stance phase time was decreased and swing phase was increased suggest that the movements have become more stabile during the training period.

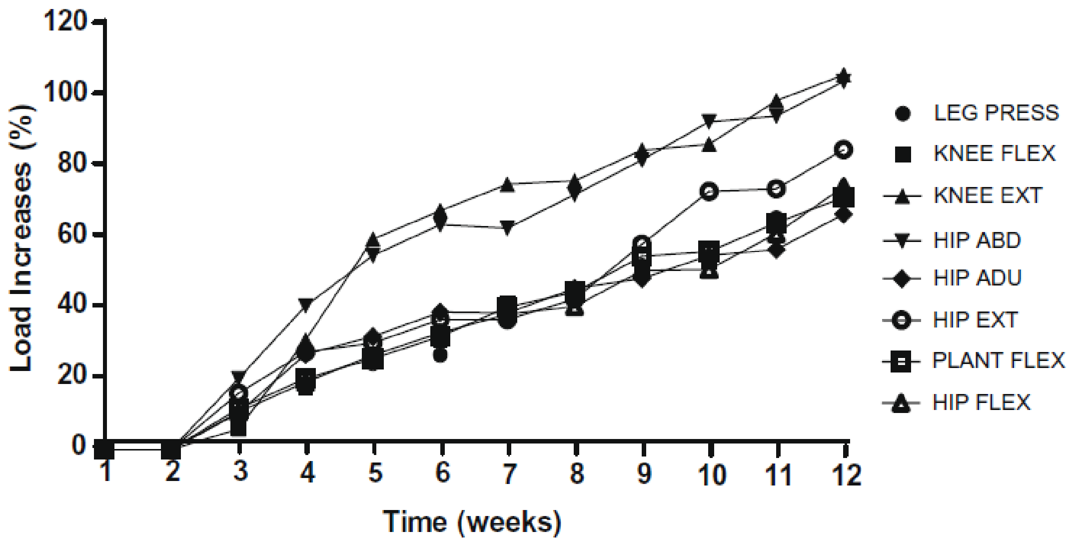

FIGURE 6. Increases in training load during a 12-week training period. (HIP EXT: hip extension, HIP FLEX: hip flexion, HIP ABD: hip abduction, HIP ADU: hip adduction, KNEE FLEX: knee flexion, KNEE EXT: knee extension, PLANT FLEX: plantar flexion). (Persch et al. 2009)

Among middle-aged and old men and women heavy resistance training produces similar relative gains that are partly explained by increased neural activation. Although the level of testosterone did not change much during the training period, the levels of serum testosterone and free testosterone correlated significantly with the strength gains of older women. Excluding older women, one of acute responses to resistance training was a large increase of growth hormone concentration. (Häkkinen et al. 2000.)

These studies referred clearly show that benefits following strength training are versatile and that older individuals are also able to attain remarkable gains in strength. Since older individuals are forced to use almost their maximum effort in certain daily activities e.g. stair ascending, descending and raising from a chair (Hortobágyi et al. 2003) the increase in power reserves seems essential when considering unexpected stumbling or loss of balance. In such situation the remaining strength and power reserves are not enough to prevent from falling. Loss of power may predispose older individuals to immoderate amounts of muscle fatigue thus producing potential basis for overuse injuries and related falls. (Paterson et al. 2007.)

Usual consequences of falls are hip fractures, fractures of other bones and injuries in soft tissues. Graafmans et al. (1996) found 5 risk factors increasing the probability of recurrently falling, those being immobility, poor mental state, orthostatic hypertension, dizziness and stroke. A hip fracture is often a fatal event to elderly people. During a study by Koot et al. (2000) 38 patients of 215 died within the 4 first months after surgery. At this time the initial mobility and functionality of those survived was regained in only 36 % and 29 % of the cases, respectively. After one year the values were 39 % and 24 %. The majority of recovery takes place during these 4 initial months after surgery regardless of rehabilitation.

As a whole, the increased strength and aerobic capacity of elderly plays an important role in promoting independent living and the quality of life.

5 PURPOSE OF THE STUDY

Purpose of the study was to measure muscle activities of thigh muscles using sports clothing with embedded textile electrodes (Finni et al. 2007) simultaneously with oxygen consumption during different passive and active commuting tasks. The aim was to show that active way of life is beneficial when considering energy expenditure and muscle function.

Research question 1: How much more muscle activity is needed and oxygen consumed when replacing motorized commuting with an active one?
Hypothesis 1: Muscle activity and oxygen consumption needed are significantly higher in the active way of commute.
Research question 2: What is the limiting factor when considering ability to climb stairs?
Hypothesis 2: Muscular strength rather than cardiorespiratory fitness limits the stair negotiation.

The following manuscript of scientific paper will be submitted to The Journals of Gerontology, Series A: Biological Sciences, and covers the methods, results and discussion.

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