EXERCISE IS MEDICINE™

OPENBARE LES JUNI 2008

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ISBN/EAN 978-90-8928-011-4

"PHYSICAL ACTIVITY MEASUREMENT SHOULD BECOME ROUTINE IN CLINICAL PRACTICE"

SUMMARY

Talloze studies tonen aan dat een fysiek actieve leefstijl bloeddruk, cholesterol en gewicht verlaagt, botten en spieren versterkt en het risico van hart- en vaatziekten, darmkanker en diabetes type II vermindert. Bewegen kan dus worden gezien als een medicijn wat voor iedereen toegankelijk is.

Ondanks verschillende beweegcampagnes beweegt toch bijna de helft van de volwassen populatie niet genoeg. Ook is de therapietrouw aan beweegprogramma's laag. Er moet gezocht worden naar manieren om mensen aan het bewegen te houden. Zorgverleners moeten zich bewust zijn van de richtlijnen voor gezond bewegen en deze implementeren in de praktijk.

De combinatie van een inactieve levensstijl met het toenemende risico op chronische degeneratieve aandoeningen naarmate men ouder wordt, blijkt zorgwekkend voor de algehele gezondheid. Een tekort aan lichamelijke activiteit is in Nederland jaarlijks verantwoordelijk voor naar schatting ruim 8.000 sterfgevallen (circa 6% van totaal aantal sterfgevallen) en voor een aanzienlijk deel van de gevallen van coronaire hartziekten. De bewegingsarmoede kost jaarlijks 805 miljoen euro door de consumptie van medische diensten. Inactiviteit kan leiden tot chronische ziekten zoals coroniare hartziekten, type II diabetes mellitus, darmkanker, depressie en angst, osteoporotische fracturen en overgewicht.

Eén aspect van gezondheid is het bezitten van voldoende fysieke fitheid om in staat te zijn fysieke activiteiten van het dagelijkse leven zelfstandig en zonder beperkingen uit te voeren. De fysieke fitheid wordt sterk verminderd door tijdelijke inactiviteit, bijvoorbeeld door acute ziekte en ziekenhuisopnames en door chronische inactiviteit als gevolg van leefstijl of chronische ziekte, wat uiteindelijk kan resulteren in beperkingen in fysieke activiteiten van het dagelijkse leven. Daarnaast neemt het risico op inactiviteit gerelateerde ziekten sterk toe. Belangrijke risicogroepen voor

bewegingsarmoede zijn mensen met aandoeningen die het bewegen beperken. Zorgverleners moeten zich bewust zijn van de invloed van bewegen op gezondheid. Het meten van de hoeveelheid fysieke activiteiten bij patiënten moet bij zorgverleners bij het meten van de vitale functies gaan horen.
De huidige instrumenten zijn ontwikkeld voor gezonde mensen. Het is van belang dat er betrouwbare, valide en responsieve manieren worden gebruikt, en waar nodig ontwikkeld, om bij patiënten fysieke activiteiten en fysieke fitheid te meten.
Oefentherapie is bewezen effectief voor veel aandoeningen, maar optimale trainingsinterventies zijn nog niet bekend en kunnen afhangen van het doel van de behandeling. Bewegen op recept moet worden voorgeschreven, begeleid en uitgevoerd door gekwalificeerd personeel.

Het lectoraat Leefstijl en Gezondheid bestudeert fysieke activiteiten, fysieke fitheid in relatie tot gezondheid door middel van toegepast onderzoek. Het doel is om kennis en expertise te verwerven in het onderzoeksdomein Leefstijl en Gezondheid, met als hoofdaccent Bewegen en Gezondheid. Daarnaast wordt de verworven kennis en expertise uitgedragen naar het onderwijs en het beroepenveld met als belangrijkste doel dat patiënten er beter van worden.

Samenvatting

“THE SAME ACTIVITY MIGHT BE EXERCISE FOR ONE AND NOT FOR ANOTHER””

Galen 131 - 201 AD

1 / INTRODUCTION

Physical activity, though not a medicine, can act as one. It has many beneficial effects on the body, helps prevent the development of many chronic diseases and is a useful complement to drug treatment in many diseases, including cardiovascular disease, cancer and diabetes (Eyre et al., 2004). A moderate amount of physical activity at moderate intensities (3-6 METs) for most healthy adults can lead to significant health benefits. Health care practitioners must therefore be aware of existing public health statements relating to physical activity, stay abreast of the evolving scientific literature related to these recommendations and implement these in daily practice.

To date, there have been no prospective studies examining whether the long-term benefits of physical activity seen in healthy persons also apply to those who are not. Health care practitioners must use reliable, valid and responsive tools to measure physical activity and physical fitness in people with impaired health. It is imperative that the consequences of physical activity on physical fitness and health be researched, exercise therapy prescribed as ‘medicine’, and the effects of this intervention measured. Despite the positive physical and mental-health benefits of exercise, long-term adherence to exercise programs remains problematic. Overall physical activity levels decrease with aging and are lower in minority populations, in females, in disabled persons, and in those with chronic disease. People with impaired health are often limited in their ability to perform physical activities as a consequence of real or perceived limitations imposed by their condition. The extent to which the long-term effects of inactivity interact with the normal ageing process to affect the general health, functional ability and independence of people with impaired health has not been the subject of major research. Lack of physical activity may cause deconditioning with loss of functional capacity, thus further limiting the person’s ability to perform physical activities and eventually resulting in disability and dependence. Inactivity is associated with an increased risk of a number of chronic conditions which place the person's health further at risk. Exercise therapy may break this vicious cycle of inactivity, deconditioning, further inactivity and potential co-morbidity (see Figure 1).

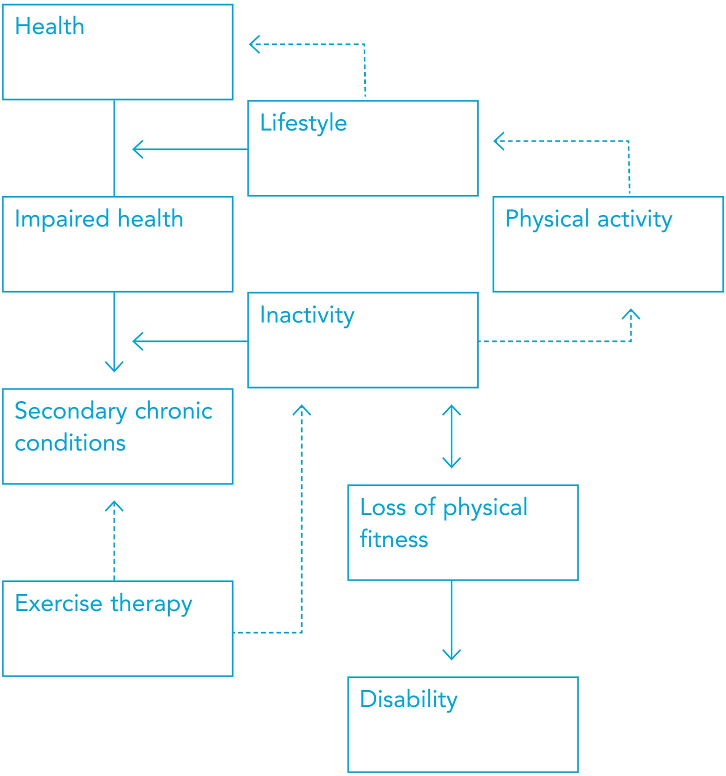


Figure 1
(Hypothesized) relationship between physical activity, physical fitness, health and exercise therapy

Our knowledge of the impact of exercise in the treatment of a number of diseases has grown considerably over the past decades. Today, exercise therapy is indicated in the treatment of a large number of medical disorders. There remains a clear need for medically – and scientifically – sound preventive and rehabilitative exercise programs. These exercise programs should be designed, supervised and conducted by qualified personnel. The optimal evaluation and treatment of many conditions continues to require particular attention and many questions remain unanswered regarding physical activity patterns in people with impaired health and their adherence to exercise therapy. Professionals are not sufficiently aware of the health effects of physical activity and do not routinely measure physical activity habits in their patients. The measurement of physical activity should become just as routine as the measurement of other vital signs, but good measurement tools are needed if this is to happen. The purpose of the Lifestyle and Health research group is to perform applied research into the relationship between physical activity, physical fitness and health in people with impaired health in areas where knowledge is lacking. The Lifestyle and Health group also contributes to innovation of professional practice by sharing our knowledge (and our laboratory) with students, faculty and clinicians as part of the Research Centre for Innovation in Health Care of the Faculty of Health Care of the Utrecht University of Applied Sciences.

The goal, of course, is to build and disseminate a body of knowledge that will contribute to outstanding, evidence-based care, which will benefit our patients.

"THE PREVALENCE OF MANY IMPAIRED-HEALTH CONDITIONS INCREASES MARKEDLY BY AGE"

2 / Lifestyle and Health: the role of inactivity

Our environment has changed drastically during the last few decades, and this can be seen in alterations of behavior, unhealthy dietary habits, and low physical activity. In developed countries, physical inactivity causes a considerable socio-economic burden, with 1.5–3.0% of total direct healthcare costs accounted for by physical inactivity (Oldridge, 2008). The estimated cost of inactivity in the Netherlands was about € 200 million in 1999 (Takken et al., 2002) and € 805 million in 2003. The 2003 costs represent 1.4% of direct health care cost (van Baal et al., 2006), which is comparable to the cost of all musculoskeletal disorders treated in private practice. This cost will continue to rise as the population ages.

Western societies are ageing rapidly, with those 65+ years of age forming the fastest growing segment of our populations. They will constitute 25% of the population of the Netherlands by 2030 (CBS 2007) and it is estimated 1.2 million older adults will live alone by that time (Ruimtelijk Plan Bureau 2006). We need to maintain those people's independence. The decline in physical activity with age may be the most consistent finding in physical activity epidemiology. Age is inversely associated with physical activity in studies of children and adolescents, U.S. adults, and adults in international studies, with the greatest decline being seen during the teenage years (Sallis, 2000). The decline is generally greater for male than female subjects, and the decline varies according to the type and intensity of the activity. A review of animal studies has documented the age-related decline in many species, which suggests that it has a biological basis which is not yet fully understood. Physical inactivity is not only linked to functional limitations, a decline in quality of life, and disability, but also with an increased risk of chronic conditions.

Epidemiological data have established that physical inactivity increases the incidence of at least 17 unhealthy conditions, almost all of which are chronic conditions or considered risk factors for chronic conditions (Booth et al., 2000). Physical inactivity increases the relative risk of coronary artery disease by 45%, strokes by 60%, hypertension by 30%, and osteoporosis by 59% (Booth and Lees, 2007). Chronic conditions related to inactivity include coronary heart disease (CHD), hypertension, Type II diabetes, colon cancer, depression and anxiety, osteoporotic hip fractures, and obesity. Increasing adiposity, or obesity, is itself a direct cause of Type II diabetes, hypertension, CHD, gallbladder disease, osteoarthritis and cancer of the breast, colon, and endometrium (Colditz, 1999).

The prevalence of many impaired-health conditions increases markedly by age. Lifestyle factors such as obesity and lack of physical activity play a significant role in this (Woolf & Pfleger 2003). The prevalence of impaired-health conditions in the Netherlands is currently highest for musculoskeletal disorders; neck and back pain, and arthritis.

Table 1
Standardized year prevalence (chronic) conditions in 2003 in the Netherlands (Poos, 2006)

100,000 – 300,000	**300,000 – 1,000,000**	**>1,000,000**
Stroke Heart failure Osteoporosis Rheumatoid arthritis Anxiety disorders Dementia	Arthritis Coronary heart disease Diabetes mellitus Asthma Depression COPD	Neck and back pain

Musculoskeletal conditions are a diverse group with regard to pathophysiology but their association with pain and impaired function means they are anatomically linked. Moreover, the pain and physical disability brought about by musculoskeletal conditions affects social functioning and mental health, further diminishing the patient's quality of life.

As the population ages, the incidence and prevalence of chronic musculoskeletal pain is expected to rise exponentially along with the associated treatment costs. The burden of musculoskeletal pain was recognized by the United Nations and the World Health Organization (WHO) when they endorsed the Bone and Joint Decade 2000 - 2010. A WHO scientific group meeting found that pain, mobility, and independence were the most important aspects of musculoskeletal conditions. In older adults the activity limitations caused by such conditions may progressively lead to loss of independence, while in those of working age musculo-skeletal impairments are the most common causes for reduced work performance, sick days and work disability. In the Ontario Health Survey, for example, musculoskeletal conditions caused 40% of all chronic conditions, 54% of all long-term disability, and 24% of all restricted-activity days (Badley et al., 1995).

The National Institute for Public Health and the Environment used a prognostic model to estimate the number of people with chronic conditions in the coming 20 years (2005 – 2025). If the rate of obesity continues to increase as it is at present, the prevalence of diabetes will increase by 71%. As for cardiovascular diseases, we can also expect an 18% increase in myocardial infarction, a 57% increase in strokes and a 54% increase in heart failure. A COPD increase of 31% in women and 12% in men is expected. Lifestyle factors contribute to all these chronic conditions (Blokstra et al., 2007).

Those who have impaired health which affects their ability to be physically active are most at risk for a sedentary lifestyle. This includes post-operative patients or patients who have been on prolonged bed rest. Other important groups at risk for inactivity are patients with asthma/COPD, the entire group of patients with cardiovascular disease, women with osteoarthritis and other musculoskeletal conditions, middle-aged men with neurological conditions and older women with cancer and diabetes. In general, women with chronic conditions are the largest group at risk for inactivity (TNO, 2004). Those with chronic conditions are less likely to report that they are in very good or excellent health compared to those without these conditions. They are also more susceptable than the general population to conditions such as heart disease, diabetes and obesity (Ginis and Hicks, 2007).

Low levels of physical activity among those with impaired health may decrease aerobic capacity, muscular strength and endurance and flexibility, all of which have the potential to restrict their functional independence and increase the risk for chronic disease and disability.

Inactivity physiology (deconditioning) research contributes to understanding the physiological impact of inactivity on the body. In the following chapter, the results of a number of studies on the effects of deconditioning on the cardiorespiratory system, muscle, bone and connective tissue will be described and the metabolic changes that ensue as a result of deconditioning.

hoofdstuk 2

Lifestyle and Health: the role of inactivity

“THE LACK OF PHYSICAL ACTIVITY CAUSES DECONDITIONING AND A CONSEQUENT LOSS OF PHYSICAL FITNESS”

3 / THE PHYSIOLOGY OF INACTIVITY

Deconditioning is defined as the integrated physiological response of the body to a reduction in metabolic rate; that is, how the body reacts to a reduction in energy use or exercise levels (Greenleaf, 2004). Research into deconditioning can thus be used to understand the effects of inactivity on the human body. Studies of the effects of deconditioning have included bed rest, simulated microgravity (e.g. head-down tilt), weightlessness (NASA studies), "detraining" in athletes who reduce the intensity or frequency of their training, and ageing. Although these paradigms have not sought to model sedentary living habits entirely, many physiological changes that have been found to occur in these studies are qualitatively similar to those observed during disuse (Convertino et al., 1997). Insight into the physiological impact of disuse on health-related fitness may eventually help us to design therapies to minimize the loss of health-related fitness in people who are in situations associated with inactivity, such as prolonged hospitalization, ageing, and chronic disorders.

3.1 Aerobic capacity

One aspect of health-related fitness is cardio-respiratory endurance or aerobic capacity. Aerobic capacity is a measure of the ability and efficiency of the body to take up oxygen and use it to convert fat and carbohydrates into energy (adenosine triphosphate or ATP). Oxygen uptake, or VO_{2max}, may be physiologically and mathematically defined (Fick formula (Fick, 1870)) as:

$$VO_{2max} = \dot{Q}\ (HR \cdot SV) \cdot \Delta\ a\text{-}v\ O_2$$

Where HR = heart rate, SV = stroke volume and Δ a-v O_2 = arterio-venous difference. It is an important index of cardiovascular fitness and increases with sustained rhythmic contractions of a large percentage of muscle mass. The oxygen uptake system has a central and a peripheral component.

The central component is cardiac output ($\dot{Q}$), which is equivaled to heart rate (HR) multiplied by stroke volume (SV). The peripheral component (Δ a-v O_2) is the difference between arterial and mixed venous blood. Therefore, the level of VO_{2max} depends on the heart's ability to pump blood and the capacity of the muscle tissues to extract oxygen from the blood.

The higher the oxygen uptake, the higher the aerobic energy output. Aerobic capacity is expressed in liters/minute (l/min) and often adjusted for bodyweight milliliters/kilogram/minute ($ml \cdot kg^{-1} \cdot min^{-1}$).

The magnitude of reduction in VO_{2max} varies according to the duration of bed rest and the initial level of aerobic capacity, but appears to be independent of age or gender. In general, fitter people appear to experience relatively greater losses in VO_{2max}, but retain a more efficient oxygen uptake system than people who are sedentary or who have not exercised for prolonged periods (Saltin et al., 1968; Coyle et al., 1984).
The decline in VO_{2max} is the result of a combination of central (cardiac output) and peripheral factors (arterio-venous difference). The rate at which VO_{2max} changes is determined by two factors: one fast-related to cardiac output, one slow-related to decrease in muscle oxidative potential (see also 3.2. muscle). The decline in VO_{2max} during the first two to four weeks of deconditioning is related to a loss of cardiac output, mostly due to plasma volume loss, while further declines are associated with decreases in arterio-venous difference (Coyle et al., 1984). The rate at which VO_{2max} decreases during bed rest becomes progressively slower, the longer that the bed rest is prolonged (Capelli et al., 2006).
Stroke volume decreases as a result of blood and plasma volume loss due to postural change. The heart rate during exercise increases at submaximal and maximal levels of exercise, but insufficiently to counterbalance the decreased stroke volume. This leads to reduced maximal cardiac output. The size of the cardiac muscles decreases, blood pressure increases and and ventilatory efficiency becomes impaired.

An increased Respiratory Exchange Ratio (RER = VCO_2 / VO_2) at submaximal and maximal exercise intensities reflects a shift towards increased reliance on carbohydrate as an energy substrate in exercising muscle and a corresponding decrease in the contribution from lipid metabolism. In addition, a decline in sensitivity to insulin-mediated glucose uptake occurs, which partly results in a reduction of whole-body glucose uptake. Due to the increased reliance on carbohydrate as an energy substrate with deconditioning, the blood lactate concentration during exercise increases at submaximal intensities and the lactate threshold is apparent at a lower percentage of VO_{2max} (Mujika and Padilla, 2001a).

Consequently, exercise performed at the same absolute intensity after detraining results in higher heart rates, higher lactate accumulation, an increase in muscle glycogen utilization and carbohydrate oxidation and a reduction in exercise time to fatigue and dyspnea.

VO_{2max} in absolute (l/min) and relative ($ml \cdot kg^{-1} \cdot min^{-1}$) terms shows a decline with age in both men and women partly because of the decline in the maximal heart rate combined with a reduction in cardiac stroke volume and the consequent reduction in oxygen transport. In their longitudinal study, Fleg and coworkers (Fleg et al., 2005) showed that the previously defined linear decline in aerobic capacity of 5% to 10% per decade is incorrect, particularly in the later decades of life. They found that the rate of decline in VO_{2max} accelerated from 3% to 6% per decade during the 20s and 30s to >20% per 10 years in the 70s and beyond, regardless of physical activity habits. The decline for each decade was faster in men than in women from the age of 40 onward. Although at any age greater levels of physical activity are associated with higher VO_{2max} , such activities do not appear to prevent this decline with advancing age.

3.2 Muscle

In response to decreased usage, skeletal muscle undergoes an adaptive reductive remodeling. This adaptive response has been found in the muscle disuse which occurs in space flight, bed rest, and ageing. Muscle weakening during inactivity is largely attributable to loss of muscle mass. The muscle adapts to the lack of weight bearing and the decrease in the number and/or magnitude of muscle contractions as a result of bed rest within a matter of days (Bloomfield, 1997). Muscle mass decreases due to a general reduction in muscle cross sectional fiber area and a reduction in the overall number of muscle fibers. These changes are associated with a decline in force production and decreased EMG activity (Mujika and Padilla, 2001b). A dose-dependent relationship between the duration of bed rest and the resulting reduction in muscle strength has been observed in a number of studies (MacDougall et al., 1977; 1980). Decreases of 6-40% in muscle strength have been observed within 4-6 weeks of bed rest (Bloomfield, 1997). Extensor groups experience greater decreases in strength than do the corresponding flexor muscles; the loss of strength in lower limb musculature is greater than in the upper musculature (Bloomfield, 1997). An eight-week bed rest study in ten healthy males found that bed rest resulted in selective atrophy of the multifidus muscle. An increased cross-sectional area of the trunk flexor musculature (increases in psoas, anterolateral abdominal, and rectus abdominus muscles) was thought to reflect muscle shortening or possible overactivity during bed rest. According to the researchers, some of the changes resembled those seen in lower back pain and may partly explain the negative effects of bed rest seen in lower back pain sufferers (Hides et al., 2007).

Muscle weakness during old age is largely the result of a decrease in muscle mass. This natural process is known as sarcopenia. From the age of 25 years there is a decline in the number of muscle fibers of 1% per year and a 40 – 50% reduction of muscle mass between the ages of 25 and 80 years (Paterson et al., 2007). Beginning at approximately 30 years of age, human strength declines by 10-15% per decade; it is gradual until 50-60 years of age and then accelerates at older ages to level off in the oldest old. The fact that maximal muscle strength decreases more, relatively, than muscle size cannot be explained by muscle atrophy alone. Changes in motor unit recruitment may occur that include an impairment of the ability to activate motor units (Sale et al., 1982).

Altered motor control, changes in the properties of contractile tissues and the lower efficiency of coupling may all contribute to this loss of strength. Apart from disuse, the other factors that contribute to the age-related sarcopenia are the denervation-reinnervation process leading to muscle wasting, the presence of reactive oxygen species which causes mitochondrial dysfunction and altered gene expression, and an altered hormonal status, such as reduced thyroid hormone, testosterone, and estrogen levels which all affect gene expression and muscle function (Degens and Alway, 2006).

In muscle, detraining is characterized by decreased muscle capillary density, which takes place within 2-3 weeks of detraining (Greenleaf and Kozlowski, 1982), and mitochondrial enzymatic activity with a concomitant reduction in mitochondrial ATP production (Wibom et al., 1992), resulting in decreased oxidative capacity. Mitochondria are often described as the "powerhouses" of the cell because of their important role in the production of ATP. In muscle cells, this function of mitochondria is critical and the regulation of the energy-generating process is important for the healthy functioning of the cell. Muscle disuse is often accompanied by increased fatigability because of the reduced oxidative capacity of disused muscles. Furthermore, capillary loss and reductions in blood flow at rest and arteriolar responsiveness may contribute to this increased fatigability through the resulting impairment of the supply of energy substrates and oxygen to the muscle (Degens and Alway, 2006).

There seems to be a decrease in the relative percentage of Type I (slow) skeletal muscle fibers which leads to an increase in the relative percentage of Type II (fast) fibers (Stein and Wade, 2005; Mujika and Padilla, 2001b), although not all studies are consistent on this (Fitts et al., 1975). This discrepancy between studies may be related to the mechanism through which muscle disuse is achieved, the muscle biopsied, fiber size and other factors. Whereas disuse seems associated with a slow-to-fast fiber type transition, ageing is accompanied by a fast-to-slow fiber type transition.

Type I skeletal muscle fibers are more efficient than Type II muscle fibers, because the former use approximately one-half the quantity of ATP per unit of work. Type II fibers are primarily dependent on intrinsic carbohydrate stores, while Type I fibers favor lipids as their fuel. Glycolysis is very effective for high-intensity short-duration acute activities, but if sustained output is needed, an energy profile favoring fat use is desirable. The combination of increased fatigability of muscle and the loss of strength and possible impairment of motor units could account for falls in deconditioned individuals.

3.3 Bone

The response of the human skeleton to unloading appears to be a rapid and sustained increase in bone resorption and a more subtle decrease in bone formation (Zerwekh et al., 1998). The greatest bone loss occurs at weight-bearing skeletal sites. Recovery of bone mass after immobilization is typically much slower than the rate at which it is lost. The loss of bone mineral after long-duration space flights by NASA astronauts ranged between 2% and 9% across the lumbar spine, trochanter, pelvis, femoral neck and calcaneus. A recovery model predicts only 50% restoration of bone loss for all sites to be within 9 months (Sibonga et al., 2007). American astronauts were shown to have lower bone density in their calcaneus 5 years after their space flight (Bloomfield, 1997).

3.4 Connective tissue

The properties of tendons contribute to the complex interaction of the central nervous system, muscle–tendon unit and bony structures to produce joint movement. Just like bone, connective tissue adapts to mechanical loading (Davis' law). Disuse decreases the collagen turn-over in tendons and muscles (Kjaer, 2004), weakens the attachment of ligaments to bone and causes a disorganization of collagenous fibers. A decrease in tendon stiffness due to disuse is at least partly due to tendon material deterioration, caused by factors such as decreased collagen turnover and packing density, increased collagen molecules crimp angle and decreased water content (Magnusson 2007).

Such changes adversely affect movement rapidity and tendon stress and increase risk of injury. Proprioceptive mechanisms within the muscle and muscle-tendon junction degenerate and become less responsive (Simonson, 2004).

3.5 Metabolic changes

In a recent preliminary study 18 non-exercising healthy volunteers in their twenties decreased their daily stepping for 2 – 3 weeks to 1500 pedometer-recorded steps from a mean value of 6203-1394 steps. During this period they developed metabolic changes which suggested a decrease in insulin sensitivity and an attenuation of post-prandial lipid metabolism, and physical changes which suggested that calories used to maintain muscle mass with greater stepping may have been partitioned to visceral fat (Olsen 2008).

Insulin is the major hormonal regulator of energy storage and release. It stimulates glycogen synthesis, aerobic and anaerobic glycolysis and the synthesis of proteins and fatty acids in the liver. In numerous bed rest studies, it has been shown that bed rest reduces sensitivity to insulin (Pavy-Le Traon et al., 2007). Five days of bed rest was associated with the development of insulin resistance, dyslipidemia, increased blood pressure, and impaired microvascular function in 20 healthy volunteers (Hamburg et al., 2007). Insulin resistance causes impaired glucose tolerance. Forty percent of persons with impaired glucose tolerance develop type II diabetes within 5-10 years, while some will remain insulin resistant and others will regain normal glucose tolerance (Pedersen and Saltin, 2006). Many patients with impaired insulin tolerance, which is largely dependent on skeletal muscle, develop chronic complications in the locomotive apparatus (e.g. painful osteoarthritis). Others develop symptomatic ischemic cardiovascular disease through mechanisms that are not fully understood.

Earlier, we postulated that people with impaired health would be the most likely to suffer from the consequences of a sedentary lifestyle. It can thus be hypothesized that those with impaired health are more vulnerable to functional decline and cardiovascular disease (CVD) risk factors than those who are healthy. There is a paucity of data regarding the prevalence of insulin resistance in chronic conditions, but several studies indicate a higher prevalence of CVD risk. Recent studies have found a peak aerobic capacity in chronic stroke patients (> 6 months) of less than half of that in normal age-matched individuals (Dobrovolny et al., 2003) and double the age-specific prevalence of abnormal glucose metabolism reported in the general US adult population (Ivey et al., 2006). It has been reported that 50% to 80% of patients with Parkinson's disease have abnormal glucose tolerance (Sandyk, 1993) and that patients with chronic rheumatic diseases have an increased rate of CVD (Turesson and Matteson, 2007). Among Canadians under the age of 65, 7.6% of men and 5.5% of women with disabilities report having heart disease compared with just 1.6% and 1.1% of men and women without disabilities. Similarly, 6.4% and 5.2% of disabled Canadian men and women under the age of 65 reported that they had diabetes, compared with 2.1% and 1.8% of men and women without disabilities (Ginis and Hicks, 2007).

An body of evidence is required to establish an association between physical activity in persons with impaired health and the risk of secondary chronic conditions.

3.6 Summary

Deconditioning leads to lower aerobic capacity, reduced muscle strength and endurance, decreased tensile strength of ligaments and tendons, and metabolic changes. This combination of changes results in a lower capacity to engage in physical activities and an increased risk of CVD due to an increase in insulin resistance.
The lack of physical activity causes deconditioning and a consequent loss of physical fitness. Low physical fitness increases the relative energy expenditure of physical activities, which may limit a person's ability to perform physical activities, causing further deconditioning, eventually resulting in disability and dependence (see Figure 2).

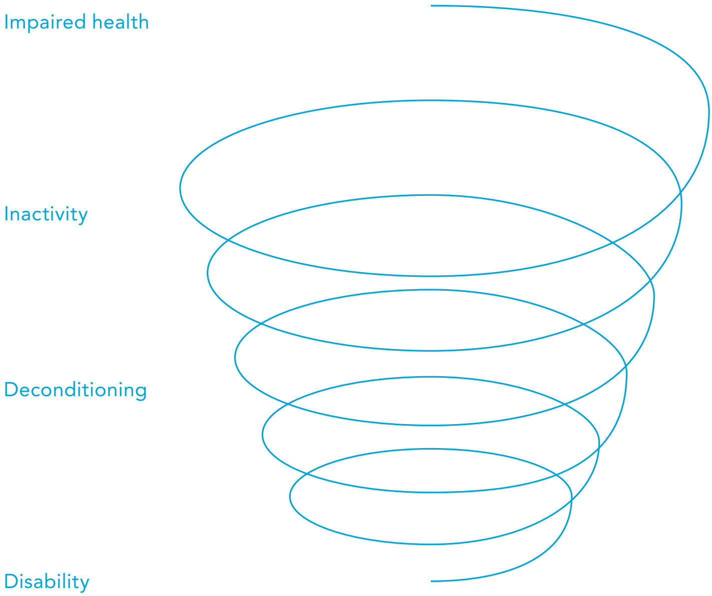


Figure 2
Consequences of inactivity and deconditioning

The next chapter will discuss the importance of physical fitness in the relationship to physical activity.

“WE NEED TO FIND WAYS TO INCREASE LONG-TERM ADHERENCE TO EXERCISE PROGRAMS”

4 / Physical activity and physical fitness

Physical activity and physical fitness are interrelated in that physical fitness provides the capacity to perform physical activities which contribute to physical fitness. One aspect of physical fitness is aerobic capacity. Aerobic capacity refers to the range of possible oxidative metabolism from rest to maximal exercise intensity, and is also called the aerobic scope. Performance refers to the physical activities people undertake in the course of their daily lives, their family role, occupation and recreation. These activities are the outcome of individual choice, but are also subject to the limits imposed by their capacity.

Part of the aerobic capacity is used for physical activities. Physical activities are coded in metabolic equivalent (MET) intensity levels. One MET equals the resting metabolic rate obtained during quiet sitting and equals an approximate oxygen uptake of $3.5\ ml \cdot kg^{-1} \cdot min^{-1}$. The oxygen expenditure for physical activities ranges, for example, from 0.9 MET for sleeping to 16 METs running a 6 minute mile (Ainsworth et al., 2000) (see Table 2).

Table 2
Examples of MET cost

Activities	**METs**
Watching TV	1
Desk work	1,5
Standing	2
Walking the dog	3
Gardening -general	3-4
Cleaning windows	3-4
Cleaning floors	3-4
Mowing lawn	5-6
Carry 10-20 kg	4-5
Bicycling (slow)	6
Running (6 min/mile)	16

A person's aerobic capacity thus directly affects the amount and intensity of physical activity this individual is able to perform. Practical experience has shown that one cannot tax more than about 30%-40% of one's aerobic capacity during an eight hour day without developing subjective or objective symptoms of fatigue (Astrand and Rodahl, 1986), although 50% of VO_{2max} (Ilmarinen, 1992) has also been recommended. If the performance (of physical activities) exceeds a person's capacity for sustained physical work, fatigue will inevitably develop. Here again, it follows that people with higher levels of VO_{2peak} will have a greater capacity for sustained physical activity, or that these people will experience their workload as less fatiguing than those who have lower levels of VO_{2peak} doing the same amount of work. People who perform physical activities above their capacity may become unduly fatigued or have insufficient time between their (working) days to recover sufficiently. Obesity compounds this problem due to the increased energy expenditure associated with moving the additional weight. Fleg et al. (2005) noted that age-related declines in VO_{2max} would be exacerbated in those with chronic conditions. Weiss et al. (2006) examined the determinants of the age-associated decline in VO_{2max} in community-dwelling men and women aged 60-92 years. They noted that in the oldest old, VO_{2max} was as low as 13 $ml \cdot kg^{-1} \cdot min^{-1}$ and at this level, static standing required ~50% of VO_{2max}. Thus, with age-related and inactivity-related declines in fitness, many ADL activities reach a relatively high intensity and are therefore experienced as fatiguing. As a result, some of these activities are avoided and a vicious cycle develops where activity is reduced, walking speed is lowered, fitness levels decline further and the other activities of daily living become too difficult to carry out.

4.1 Aerobic reserve

Aerobic reserve is the difference between capacity and performance, and refers to the latent abilities that can be called upon in demanding circumstances (Figure 3).

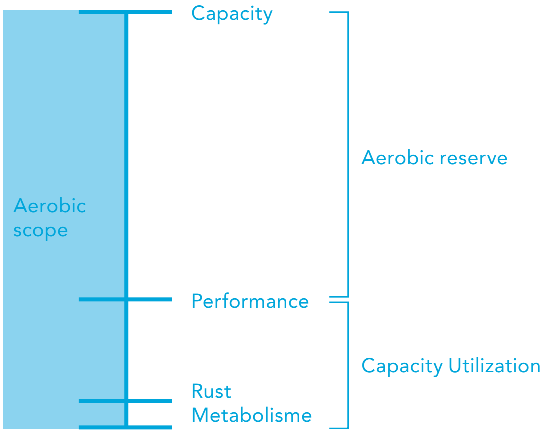


Figure 3
Performance and capacity in a healthy adult (redrawn from Leidy, 1994)

Inactivity and ageing lead to a decrease in this aerobic scope, and the margin between the aerobic demands of various daily activities and the maximal aerobic capacity becomes narrower. In relative terms, the intensity of the activity is expressed in relation to the capacity of the subject performing the activity. For energy expenditure, the intensity is usually expressed as a percentage of the subject's aerobic capacity (percentage of maximal oxygen uptake, or VO_{2max}). For example, walking the dog has an energy cost of 3 METs. For a 55-year-old female with a VO_{2max} of 22.5 $ml \cdot kg^{-1} \cdot min^{-1}$ (Paterson et al., 1999), this represents 47% of her aerobic capacity, but for her 85-year-old neighbor with a VO_{2max} of 16.7 $ml \cdot kg^{-1} \cdot min^{-1}$ this represents 63% of her capacity. The neighbor could compensate by walking slower, thus reducing the energy expenditure of walking. But what if the neighbor breaks her ankle and needs crutches? Walking with crutches has an energy expenditure of 5 METs. This represents 105% of the 85-year-old's capacity.

Walking on crutches thus exceeds the 85-year-old's aerobic capacity and she will not be able to perform this activity for any length of time (see Figure 4).

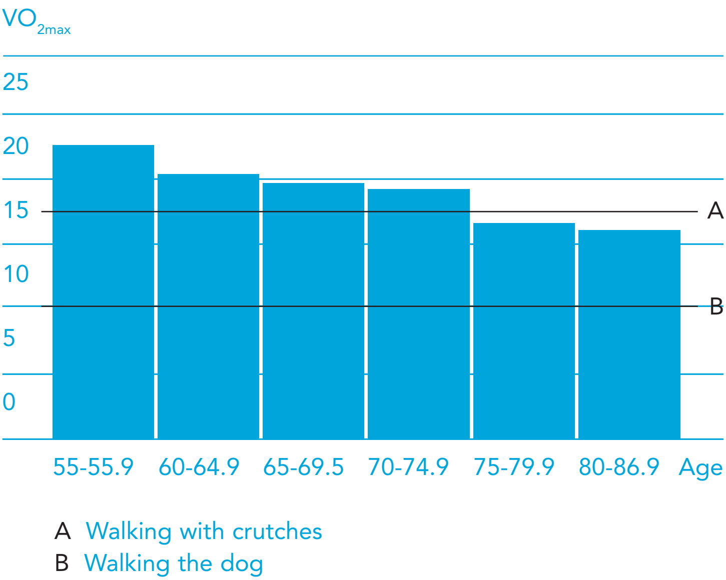


Figure 4
Average aerobic capacity of females living independently (data derived from Paterson, 1999)

It is assumed that 100% of maximal aerobic capacity can be maintained for 5 min, 95% for 15 min, 85% for 30 and 80% for 60 minutes in non-athlete adults (Astrand et al., 2003) before fatigue ensues. Adults with little or no aerobic reserve may be perilously close to, or fall below, the minimum physiological thresholds required to perform daily tasks. An aerobic capacity of between 18 and 20 $ml \cdot kg^{-1} \cdot min^{-1}$ (Cress and Meyer, 2003; Morey et al., 1998) (5 METs) has been found to be the aerobic threshold below which there is a reduced probability of living independently. For each milliliter of oxygen uptake below the threshold, there is an associated eight-fold decrease in physical function (Cress and Meyer, 2003).

A similar effect applies to workers. The age-related reduction in VO_{2max} may reduce the ability of an individual to perform sustained work and recommendations have been made to reduce the physical

load of work, on the basis of the normal decline in physical capacity for workers > 45 years of age (Ilmarinen, 2001). Karpansalo et al. (2002) report that a heavy physical workload increases the risk of retirement due to disability, especially musculoskeletal disorders. This risk is notably higher in men with musculoskeletal or cardiovascular disease and poor cardiorespiratory fitness. Unfortunately, the literature reports fairly consistently that physically demanding work does not maintain or improve VO_{2max} in ageing workers (Nygard et al., 1991). Heavy manual work does not appear to stress the cardiovascular system sufficiently to produce a training effect in older workers (Ilmarinen et al., 1991; Savinainen et al., 2004), although a positive association between heavy physical work and good cardiorespiratory fitness has been found in young males (Tammelin et al., 2004). We have limited knowledge concerning the maximum bodily capacities that specific jobs require, and whether they exceed the aerobic capacity of ageing workers or affect the ability of the older workers in physically demanding jobs to carry out these jobs (Sluiter, 2006).
The energy expenditure for many leisure, occupational and sport activities is known and coded in MET intensities (see Table 2). Decreased aerobic capacity can, of course, limit a person's ability to perform activities; however, a higher energy expenditure for the activities a person performs, may also limit their performance. Impairments may drive up the energy-expenditure required for activities and reduce the aerobic reserve. Although here, too, there is a paucity of data, the available literature suggests that locomotor impairment, which results from many pathological conditions, increases the energy expenditure associated with walking. For example, patients with incomplete spinal cord injury have a 26% higher oxygen expenditure when walking compared with healthy subjects. Similarly, younger amputee patients who have undergone adequate prosthetic rehabilitation have an increase in energy expenditure of 24% compared with healthy individuals even with comparable walking speeds. In those who have experienced a stroke, the energy expenditure of walking is 1.5-2 times greater than healthy individuals (Platts et al., 2006). The energy cost of locomotion in patients with hip joint impairment was up to 50% and 70% higher than controls during level-surface

and uphill walking, respectively (Gussoni et al., 1990). Thus, even when capacity is adequate, when the energy expenditure of performance is high, a person can still become unduly fatigued when performing physical activities.

The gap between capacity and performance may thus be determined by aerobic capacity and the total energy expenditure for an activity. It seems that the larger the gap, the more likely a person is to have the ability to "carry out the full range of actions, activities and tasks required to fully engage in all areas of human life" (Ustun et al. 2003). One study on older adults seems to indicate that a greater aerobic reserve is associated with higher performance (Arnett, 2008).

4.2 Summary

Aerobic capacity as part of physical fitness is an important determinant of the ability to perform and sustain physical activities in the course of everyday life. All physical activities have an associated energy expenditure. For energy expenditure (performance), the intensity is usually expressed as a percentage of the person's aerobic capacity (percentage of maximal oxygen uptake, or VO_{2max}). In general, the higher the energy expenditure (higher percent of VO_{2max}), the more quickly fatigue will ensue when the activity is carried out. Aerobic capacity can fall as a result of ageing, inactivity or sickness, and energy expenditure can be increased by higher energy demands associated with abnormal movement. To be able to understand the limiting factor in a person's ability to perform we must measure both their physical fitness and physical activity levels. The next section will discuss the methods available for doing this.

hoofdstuk 4
Physical activity and physical fitness

"CLINICAL CARE NEEDS TO SHIFT FROM DISABILITY TO ABILITY"

5 / MEASURING PHYSICAL ACTIVITY AND PHYSICAL FITNESS

The seminal epidemiological studies of physical activity and disease have not focused on those with impaired health. The association between physical activity, physical fitness and morbidity and mortality in those with impaired health remains therefore largely unexplored (Washburn et al., 2002). With appropriate tools to measure physical activity and physical fitness in persons with impaired health we can start building an evidence base to establish the association between physical activity in persons with impaired health and the risk of secondary chronic conditions and develop tailored interventions.

Levels of physical activity are not routinely measured in current clinical care. Rather, the focus of measurement has traditionally been on what patients have difficulty doing (disability), rather than on what they can do (ability). Clinical care needs to shift from disability to ability and measure what and how much people can do, rather than what they cannot.

The use of physical activity questionnaires can provide insight into the patterns of physical activity in those with impaired health and has the added advantage that patients can be counseled on their activity levels for health benefits, provided these instruments are reliable, valid and are sensitive to change. Measuring physical activity can help us understand the performance levels of our patients, while measuring physical fitness reveals their capacity for physical activity.

Only a few studies have used physical activity measures in the assessment of patients with health impairments (Verbunt et al., 2001; Nielens, 2001; Smeets et al., 2006). No correlation was found between subjective disability, as measured by the Roland Disability Questionnaire, and physical activity, measured by both accelerometry and doubly labeled water in patients with chronic lower back pain (Verbunt et al., 2001).

5.1 Physical activity

One of the major questions in health research is whether it is physical activity or physical fitness that is more important in determining health outcomes. So far, there seems to be a stronger dose-response gradient for physical fitness, but the explanation may be that physical fitness is measured objectively while physical activity is usually assessed by self-report, which inevitably leads to misclassification (Blair et al., 2001). Unfortunately there are no perfect measures of physical activity, neither for healthy people nor for those with impaired health. In large-scale studies simple, low-cost and time-efficient methods are applied to measure physical activity. Large population-based studies have thus typically relied on questionnaires and self-reports in the evaluation of physical activity. These questionnaires are mostly used in epidemiological studies aimed at assessing typical or long-term physical activity due to its potential association with diseases. Self-report measures include self-administered questionnaires, questionnaires administered by an interviewer, or physical activity dairies, records and logs. Coding schemes are then used to classify each activity by, for example, MET value. Most of the self-administered instruments typically focus on performance – that is, the subject's perception of what they do (activities and participation).

Questions tend to include the frequency, intensity, time and type of activities. The intensity of these activities are usually rated as vigorous, moderate or light (sitting), while the types include occupational, household and leisure activities. Results from validation studies show that questionnaires in general may be a valid method of classifying a population into distinct categories of physical activity behavior (e.g., low, moderate, highly active) but they are not appropriate to quantify the energy expenditure at the individual level (Vanhees et al., 2005). With the wide range of physical capacities and physical activity levels in the population, it is assumed that subjects will "calibrate" the instrument individually (Salen et al. 1994). For instance, a young construction worker will have a different concept of "vigorous activity" than an eighty year old. Various researchers have emphasized the development of self-report surveys for older persons since questionnaires provide reliable and valid methods for classifying elderly persons into physical activity groups (low to high), but have not been shown to measure changes in physical activity accurately or reliably, especially low to moderate-intensity activity (Haskell and Kiernan, 2000). One paper sought to identify physical activity questionnaires for older adults which may be suitable outcome measures in clinical trials of fall-injury-prevention intervention. The authors report limited evidence for the measures' properties, with none of the measures being entirely satisfactory for use in a large-scale trial (Jorstad-Stein et al., 2005).

Objective measures include doubly labeled water, calorimetry, heart rate monitoring, markers of movement (pedometers and accelerometers), job classification and observed or recorded activity (direct observation).

Measuring physical activity directly by physiological monitoring or motion sensors offers a potential advantage over self-reported data by reducing bias from poor memory and over-reporting or under-reporting. Monitoring heart rate can provide a continuous record of a physiological process with the potential to reflect both the duration and the intensity of physical activity. Heart rate (HR) can be used as a surrogate index for oxygen uptake since it has a linear relationship with VO_2 during moderate and heavy exercise (Astrand and Rodahl, 1986). However, one major disadvantage of heart rate monitoring is the need to calibrate each individual; another limitation is that during low-intensity exercise the relationship between exercise intensity and heart rate is frequently not linear (Haskell and Kiernan, 2000). HR can be used as a surrogate index for oxygen uptake since it has a linear relationship with VO_2 during moderate and heavy exercise between heart rates of 115 beats per minute (bpm) and 150 bpm (Astrand and Rodahl, 1986b). With heart rates below 115 bpm, many external factors can affect heart rate.

Due to the large inter-subject variability of HR and VO_2, workload is often described in terms of a percentage of maximum HR (%HRmax) or as a percentage of VO_{2max} (Swain and Leutholtz, 1997; Astrand

and Rodahl, 1986). To assess workload demand using %HRmax or $\%VO_{2max}$ alone is not sufficient, however, since workload is a function of both the intensity and duration of physical work.

As a method of integrating both the duration and intensity of physical work, Banister et al. (1975) developed the concept of training impulse (TRIMP) using %HRmax as a variable. The integration of both %HRmax and duration to compute TRIMP units provides a reliable marker for calculating workload demand (Esteve-Lanao et al., 2005; Foster et al., 2005; Lucia et al., 2003). Foster et al. (2001; 2005) developed this theory further and suggested developing different TRIMP units according to heart rate zones. To compute the total workload demand for a given day, all TRIMPs from the different heart rate zones are summed up. Based on data from professional road cyclists, Foster et al. (2005) proposed that 2000 TRIMP units per week is the upper limit for high-intensity muscular and cardiovascular effort which can be sustained for a maximum of three weeks. Recently, we used the TRIMP method to calculate the workload of police officers from the police department of the city of Utrecht in the Netherlands who patrol on mountain bike (Takken et al., 2008). This approach appears promising in small to medium-scale studies, but we will have to conduct more research using larger samples.

The recommended number of steps per day for long-term health benefits and a reduced risk of chronic disease is 10,000. These steps can be measured using pedometers, small devices with a spring mechanism that register movements in the vertical direction which are usually worn on the waistband in the midline of the thigh. They are used to count the steps over a period of time, often the waking hours of the subject. These steps can be converted to distance by entering an average stride length. Consequently, only walking or running-related physical activities can be registered. Cycling, swimming, upper-body movements, carrying loads or moving on soft or graded terrain are not correctly monitored by a pedometer (Vanhees et al., 2005). Some pedometers allow a step length to be entered (based on a calibration walk) and will calculate walking distance automatically. Pedometers are useful for measuring the total number of steps per day, but only provide a total activity or energy expenditure score over the entire period of recording and do not provide information about the intensity, frequency and time (duration) of activities. Furthermore, they have a limited storage capacity and are unable to distinguish between normal and abnormal movement patterns. Nike and Apple Ipods use wireless technology to connect a pedometer in the heel of a running shoe to the runner, giving feedback on estimated distance, speed and calories burned. No published studies exist on the reliability or validity of this method.

Another device with potential is the accelerometer. Accelerometers are devices that measure body movements in terms of acceleration, which can then be used to estimate the intensity of PA over time. Most accelerometers in current use are piezoelectric sensors that detect acceleration(s) in one to three orthogonal planes (antero-posterior, mediolateral, and vertical). The processed data can be recorded by an internal memory and then downloaded through computer ports (Chen and Bassett 2005).
Systems that use a single uni-axial or tri-axial accelerometer usually do not provide information regarding the type of activities performed and provide a very global measure of activity or mobility. The triaxial accelerometer was shown to be a valid instrument for measuring daily activity in patients with chronic LBP, however (Verbunt et al., 2001). To obtain more detailed data regarding the type of activities, a more comprehensive combination of sensors is required to enable the monitoring of trunk, arm and leg positions and movements. To obtain information regarding basic postures and motion such as lying-down, sitting, standing and walking, a minimum of two accelerometers is required, one on the trunk and one on the leg (Wittink and van Wegen, 2008).
Accelerometers can measure the type and amount of activity, but are not able to measure the intensity of the activity. Portable devices to measure physical activity are being developed which combine heart-rate recording with accelerometry.
Typically, accelerometry has been restricted to small sample sizes, but with the rapid advancement of technology, this method may be applied in larger studies.

Low-cost, commercially available Global Positioning Systems (GPS) may be accurate in studying outdoor walking, provided that simple data processing is applied. Future validation in diseased subjects could allow for the study of free-living walking capacity, such as the maximum walking distance in vascular patients (Le Faucheur et al., 2007). Non-differential GPS has been shown to provide a highly accurate estimate of speed across a wide range of human locomotion velocities (Townshend et al., 2008). Combining GPS devices with other physiological parameters may provide insight into the intensity of locomotion. The specific applicability of such information to patient care is, at this time, unclear.

5.2 Physical fitness

The "gold standard", or criterion measure, of cardiorespiratory fitness is maximal oxygen uptake or power (VO_{2max}). Measured in healthy individuals during large-muscle, dynamic activity such as walking, running, or cycling, VO_{2max} is primarily limited by the oxygen transport capacity of the cardiovascular system. The most accurate assessment of VO_{2max} is made by measuring the composition of the expired air and respiratory volume during maximal exertion. However, this procedure requires relatively expensive equipment, highly trained testers, and a considerable time and cooperation on the part of the subject. A variety of (submaximum) tests have therefore been developed to estimate the aerobic capacity when direct measurement is not possible. These tests usually involve running/walking for a given time or distance, such as the twelve-minute walk/run test (Cooper, 1968), the shuttle test (Leger and Lambert, 1982), various step tests (Francis, 1987; Siconolfi et al., 1985) and the two-kilometer walk test (Oja et al., 1991). Longer distances and shorter test times are associated with higher levels of aerobic fitness. Other tests involve treadmill walking or cycling against a predetermined load, recording the heart rate at submaximal levels of exertion, and then estimating VO_{2max} by extrapolating to maximal heart rate (Astrand, 1960; Astrand and Ryhming, 1954). These tests were primarily developed to test aerobic capacity in healthy people and were validated by comparing the actual measured VO_{2max} to predicted VO_{2max} or to the test performance.

Nomograms and prediction equations, derived from exercise-testing large samples of subjects, were developed to estimate VO_{2max} in healthy populations. Even though these include age and gender corrections, they reflect a mean aerobic fitness level for a particular gender at a particular age and can therefore never be as precise as direct measurement of oxygen uptake. Fear, excitement and other such emotional stress may cause a marked elevation of heart rate at submaximal work rates. This results in an underestimate of the person's real aerobic fitness level when, for instance, nomograms are used to extrapolate heart rate and workload at maximal heart rates. It is usually recommended that the test load should be sufficiently high to bring the heart rate up to, or above, 150 beats per minute in the case of younger subjects (Astrand and Rodahl, 1986). Motivation also plays a role, especially in the timed or distance tests in which the subject can set his or her own pace. A more accurate prediction of aerobic fitness can be obtained from a submaximal-exercise test in which the subject is well-motivated (Cooper, 1968). Underestimates often occur for untrained persons when predicting the maximal oxygen uptake (Astrand and Rodahl, 1986). These tests have a measurement error of about 10-20% of VO_{2max}, a level of error which is often unacceptable in the occupational setting where subjects are being tested to determine their fitness to meet the demands of their occupations (Wittink and Takken, 2008).

The research on VO_{2max} testing in healthy individuals older than 65 years is limited. It does not describe the protocols in detail, and lacks information on the psychometric properties of the exercise tests. The few existing protocols for testing aerobic capacity in older adults need refining, and new protocols specifically applicable to older adults are also required. A consensus on the criteria defining VO_{2max} attainment during exercise in older adults is required, as well as agreement on the most appropriate exercise protocols and equipment, specific to older adults, to fulfill these criteria successfully (Huggett et al. 2005). The various components of physical fitness can be assessed accurately in the laboratory and, in many cases, in the field by using a combination of the performance tests described above.

5.3 Summary

A variety of methods are available to measure physical activity and physical fitness. The assessment of physical activity levels should include its frequency, intensity, type and duration and total time for leisure, occupational and household activities. Application in patient populations is rare and we will undertake research on this topic. A gold standard exists for measuring aerobic fitness, but this method is expensive. More studies are needed in order to establish appropriate field tests in diverse patient and worker populations. We see the development of appropriate field tests as one of our aims.

hoofdstuk 5

Measuring physical activity and physical fitness

"EVEN A LITTLE EXERCISE IS "MORE""

6 / EXERCISE IS MEDICINE

There is a large body of evidence to support the contention that physical activity has major health benefits. A single session of physical activity (50-80% VO_{2max}) results in the lowering of serum triglycerides and an increase in serum high density lipoprotein (HDL="good") cholesterol, decreases blood pressure (50-100% VO_{2max}) and lowers blood glucose (Kesaniemi et al., 2001). Regular physical activity has an inverse and generally linear relationship with the rates of all-cause mortality, total CVD, and the incidence of and mortalities due to coronary heart disease, and the incidence of type 2 diabetes mellitus. It is also associated with a reduction in the incidence of obesity and an improvement in the metabolic control of individuals with established type 2 diabetes. Physical activity is also associated with a reduction in the incidence of colon cancer and osteoporosis. Further benefits of regular physical activity include improved physical function and independent living in the elderly. Individuals with higher levels of physical activity are less likely to develop depressive illness than those with lower levels. Moreover, in those with mild-to-moderate depression and anxiety, prescribed physical activity is associated with an improvement in such symptoms. Physical activity also has a favorable impact on several cardiovascular risk factors, including a reduction in blood pressure, an improvement in the plasma lipid profile, and alterations in coagulation and hemostatic factors (Kesaniemi et al., 2001).

Although the beneficial effect of exercise is "dose related," increasing in proportion to the duration and amount of energy expended, even a modest increase in the levels of moderate physical activity (3-6 metabolic equivalents METs), such as 30 minutes at least 5 days per week, has been found to reduce risk for cardiovascular events and all-cause mortality (Washburn et al., 2002). For sedentary and overweight people, evidence is emerging that "even a little is more" and half the recommended amount of activity can still produce health benefits (Church et al., 2007).

Avoiding a sedentary lifestyle during adulthood not only prevents cardiovascular disease independently of other risk factors but also substantially expands the total life expectancy and the cardiovascular disease–free life expectancy for men and women. This effect is already seen at moderate levels of physical activity, and the gains in cardiovascular disease–free life expectancy are twice as large at higher activity levels (Franco et al. 2005).

Physical activity, though not a medicine, can act as one. It has many beneficial effects on the body, helps prevent the development of many chronic diseases and is a useful complement to drug treatment in many diseases (Eyre et al., 2004).

6.1 Exercise is medicine "over the counter"

The overarching goal of physical activity guidelines is to promote a reduction in sedentary behavior patterns and augment the level of habitual physical activity in the target population (Tremblay et al., 2007). The primary focus is to promote health and fitness and the primary prevention of chronic disease (CVD, metabolic problems, cancer and mental health) and their associated risk factors. The internationally accepted guideline for the amount of physical activity required to promote health is that all adults should undergo at least 30 minutes of moderate-intensity (3-6 MET) physical activity on most days of the week, and preferably every day. Additionally, they should undergo vigorous-intensity aerobic physical activity for a minimum of 20 minutes on three days per week. This target is a long-term goal and can be built up to gradually (Haskell et al., 2007). In the Netherlands, this goal is achieved by about 50% of adults up to 55 years of age, almost 70% of those aged between 55 and 65 years, 71% of males and 63% of females aged between 65 and 75 years. However, more than 94% of males and 60% of females older than 75 years do not achieve this goal (CBS statline, 2005). People are termed "inactive" if they do not achieve this goal on any day in the week. We refer to the lack of physical activity as a sedentary lifestyle which involves "much sitting and little physical exercise" (less than 25 minutes of physical activity per day).

Health promotion activities have mainly been directed at the healthy population. Many initiatives have been and continue to be developed. Efforts are directed towards awareness and behavior change. The message of 30-minutes-per-day moderate-intensity physical activity is clear and applies to all adults. The 30 minutes can be done anywhere, take any form and be "administered" by anyone, hence the similarity to over-the-counter prescriptions. This exercise can do no harm and will benefit most people. Health-care practitioners must therefore be aware of existing public health statements pertaining to physical activity, stay abreast of the evolving scientific literature related to these physical activity recommendations and implement these in daily practice. In the United States, the American College of Sport Medicine has recently initiated the Exercise is Medicine™ movement. Its goal is to make physical activity and exercise a standard part of the disease prevention and treatment medical paradigm in the United States, for physical activity to be treated as a vital sign by all healthcare providers at every patient visit, and that patients are effectively counseled on their physical activity and health needs, thus leading to overall improvement in the public's health and long-term reduction in healthcare cost. This is clearly an example we should follow in the Netherlands!

Not everyone can exercise safely or independently, however, and those who are unable to should receive exercise therapy.

6.2 Exercise by prescription: exercise training

Today, exercise therapy is indicated in the treatment of a large number of medical disorders. There remains a clear need for medically – and scientifically – sound preventive and rehabilitative exercise programs. These exercise programs should be designed, supervised and conducted by qualified personnel: exercise by prescription. Exercise training is a subcategory of physical activity or "physical activity that is planned, structured, repetitive, and purposive in the sense that improvement or maintenance of one or more components of physical fitness is the objective" (Caspersen et al., 1985). Exercise training is one key management strategy used to address impairments (problems with body function or structure such as pain or weakness), activity limitations (the difficulties an individual may have in activities such as walking, sitting, and standing) and participation restrictions (problems an individual may experience in everyday life situations such as working, playing sports or socializing) (World Health Organization, 2001). Physical disabilities are the most prevalent form of disability, with a large number of people reporting disabilities related to mobility, pain and agility. Multiple meta-analyses on the effects of exercise on various painful conditions report that exercise reduces pain and increases aerobic capacity and physical function. The mechanisms behind these effects are not completely clear and are most likely due to multiple factors (Wittink and Verbunt, 2008).

Systematic reviews and meta-analyses have provided strong evidence for the efficacy of muscle conditioning and aerobic exercise to reduce symptoms in those with osteoarthritis of the knee (Brosseau et al., 2003; Fransen et al., 2003; Roddy et al., 2005). Others have reported that exercise therapy is an important tool for reducing pain, stiffness, and joint tenderness in rheumatoid arthritis patients (Hakkinen et al., 2001; Hakkinen et al., 2004) and patients with fibromyalgia (Busch et al., 2002). Exercise has been shown to be effective for short-term pain relief in patients with rotator cuff disease and provides a longer-term benefit with respect to functional measures (Green et al., 2003). Exercise may be helpful for patients with chronic lower back pain, hastening their return to normal daily activities and work (van Tulder et al., 2000; Hayden et al., 2005a). Supervised exercise therapy that consists of individually designed programs, including stretching or strengthening, may improve pain and function in chronic non-specific lower back pain (Hayden et al., 2005b). A systematic review of systematic reviews found that exercise therapy is effective for patients with cystic fibrosis, COPD, claudicatio intermittens, arthritis of the knee, sub-acute and chronic back pain and probably effective in patients with Parkinson's disease, Bechterew's disease, arthritis of the hip and stroke. Exercise therapy was shown not be effective in patients with acute lower back pain (Gezondheidsraad, 2003). In a number of patient categories, there is little or no evidence for using exercise therapy. For instance, a systematic review we are conducting on the effect of exercise therapy during cancer treatment on cancer-related fatigue shows the dearth of studies on this topic, small study samples and heterogeneity of patient populations.

Exercise therapy encompasses a heterogeneous group of interventions and although the previously cited studies found that exercise can have beneficial effects on pain and function, there continues to be uncertainty about the most effective exercise approach. In most studies, there were insufficient data to provide useful guidelines on optimal exercise frequency, intensity, type and time (duration) (F.I.T.T. parameters). Because of the heterogeneity of the interventions, study populations, follow-up time, and outcome measures, the data are still inadequate to formulate clear recommendations for most patient populations.

While there is evidence that the available "evidence" needs to be interpreted with caution, meta-analyses and systematic reviews have often yielded effect sizes that are too small to warrant much enthusiasm (Deyo, 2004; Vlaeyen and Morley, 2005). A possible explanation for these results is the tendency to treat patients as a homogeneous group with generic treatments, though using inappropriate research designs and using outcome measures that are insufficiently sensitive to change could also have played a role (Wittink et al., 2008). Also, exercise training may have focused on impairments, whereas specificity of training dictates that to get better at an activity, that specific activity needs to be trained (functional training).

While RCTs may inform us about treatment interventions, clinical prediction rules resulting from prognostic studies provide evidence that a better utilization of resources may be achieved by performing an easy screening of patients before treatment and allocating the patients to adequate treatment (Haldorsen, 2003). Prognostic studies single out certain risk factors and assess their influence on the outcome of a disease. They allow clinicians to understand the natural history of a disease better, guiding clinical decision-making by facilitating the selection of appropriate treatment options, and allowing a more accurate prediction of disease outcomes.

Most exercise therapy programs have focused on performance and there is little evidence in the literature that the guidelines on physical activity are being followed or that reaching the goal of 30 minutes of physical activity a day is an important outcome parameter for exercise therapy. People with disabilities are more susceptible than the general population to conditions such as heart disease, diabetes and obesity (Ginis and Hicks, 2007), although research is lacking in this area. This means we also need to exercise for health, although Blair (2001) suggests that a distinction between exercising for performance and exercising for health is not always possible as exercise training will contribute to both, see Figure 5 (Blair 2001).

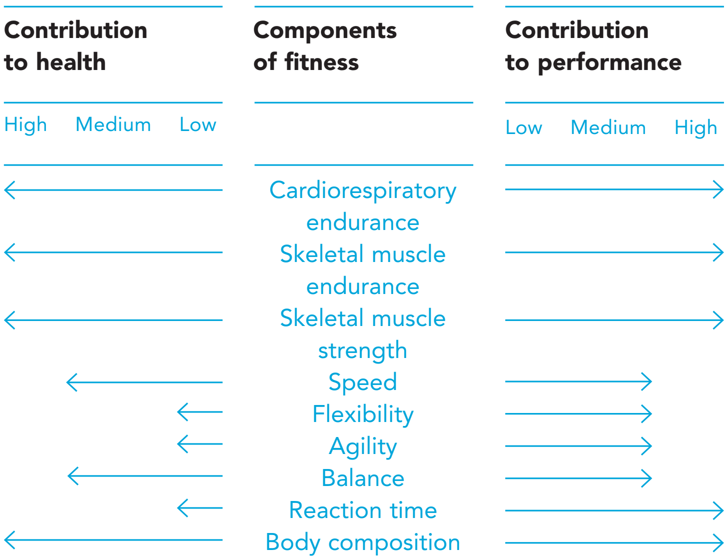


Figure 5
Components of physical fitness and their relation to physical performance and health (redrawn after Blair, 2001)

A regimen of regular physical activity can play a role in the management of many conditions. It is important, however, to recognize the specific characteristics of a particular health impairment before making predictions about the potentially positive role of regular physical activity and determining an exercise prescription for people with that condition.

Since the effects of exercise therapy on health markers in a number of chronic conditions are mostly unknown, studies should include health markers as outcome measures.

Despite the positive physical and mental health benefits of exercise therapy, long-term adherence to exercise programs remains problematic. Overall physical activity levels decrease with ageing, in minority populations, in females, in disabled persons, and in those with chronic disease. Only an estimated 50% of all those who initiate an exercise program continue the habit for more than 6 months. The issue of non-adherence is particularly important because exercise is only beneficial if it is maintained for extended periods. Thus, developing strategies to improve exercise initiation and adherence, especially for those who are among the least active (e.g. the less educated, minorities, obese, older adults), is vital. One of our students is performing a systematic review on the personality traits that influence exercise behavior. Another of our MSc students conducted a systematic review of the effect of exercise therapy versus advice on physical activity in patients with diabetes type II. It was found that exercise therapy yields larger effects than advice in glycemic control (HbA1c), aerobic capacity and strength, although the benefits are smaller for people who are already engaged in sufficient physical activity in their daily lives (van Nieuwaal et al., 2008). Other studies have also shown that patients with chronic conditions are not physically active enough to derive health benefits but perform significantly better with supervised exercise therapy (Bendermacher et al., 2006; Carmeli et al., 2006); however, similar outcomes between supervised and home-based exercise programs have also been shown (Ashworth et al., 2005; Reeder et al., 2008).

6.3 Summary

Exercise training has been shown to be beneficial for a range of conditions to reduce pain and increase function, but the optimal F.I.T.T. parameters to address these conditions continue to elude us. Physical activity may have a different dose response on different health markers. While it is clear that physical activity has a beneficial effect on most health parameters, there is insufficient evidence to state with certainty which F.I.T.T. parameters will have an optimal effect on various health markers. The facilitators for and barriers to regular exercise need to be identified and addressed to maximize patient adherence to exercise programs.

“OUR MISSION IS TO PRODUCE, CIRCULATE AND IMPLEMENT NEWLY ACQUIRED KNOWLEDGE”

7 / Applied research, professional practice and education

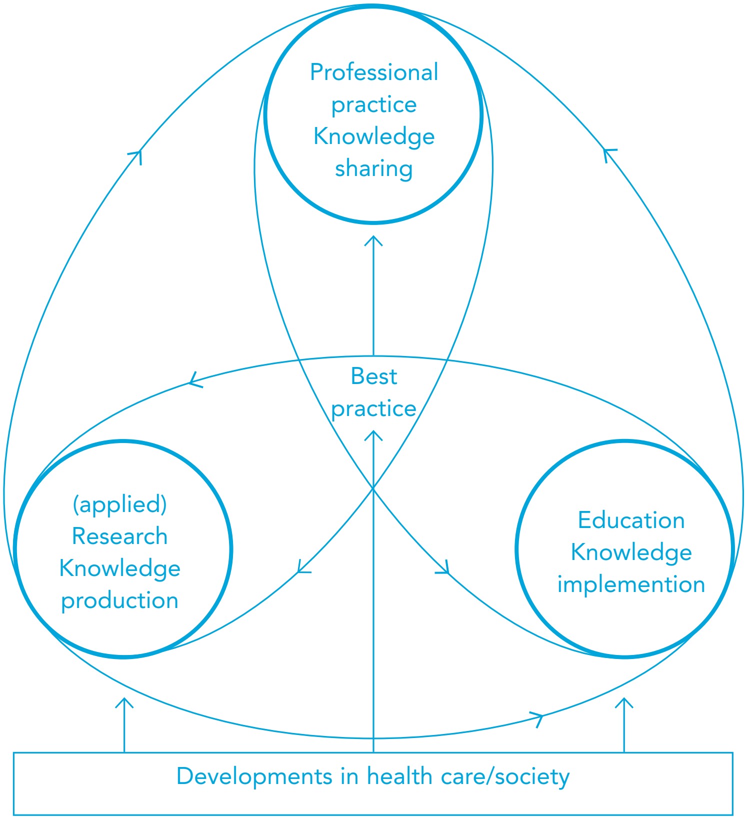
Professor Dr. Luc Vanhees set up the Lifestyle and Health research group in 2003 and much has been achieved since. The major focus of the research group is on the interrelationship between physical activity, health-related fitness and health in adult populations, which can be examined and understood using the Bouchard and Shepard model (Bouchard and Shephard, 1994). This model is now the uniting element of all the doctoral students' work and the basis for the Utrecht Police Lifestyle and Training (UPLIFT) study that has been running for the past five years in our exercise laboratory. Research is continuing to investigate the relationship between physical activity and physical fitness in patients with lower back pain (Catholic University of Leuven), children with spina bifida (Utrecht University and the Department of Pediatric Physical Therapy and Exercise Physiology of the Wilhelmina Pediatric Hospital Utrecht), cognitive functioning (Catholic University of Leuven and Utrecht University), metabolic syndrome and behavior change (Maastricht University) and the role of propriocepsis in back pain (Catholic University of Leuven). Significant knowledge gaps have been identified. To date, little research has been conducted into the physical activity habits of people with health impairments which limit their ability to perform physical activity. Adherence to physical activity programs is limited and ways must be found to encourage people to remain – or become – physically active. Professionals are not sufficiently aware of the health effects of physical activity and do not routinely measure physical activity habits in their patients. The application of instruments to measure physical activity in patient populations is rare. Measuring physical activity should become as standard as measuring other vital signs, but good measurement tools are needed in order for this to happen. The validation and – if necessary – development of instruments to measure physical activity and physical fitness in patient populations is one of our goals. With better tools to investigate physical activity levels in people with impaired health, we can start building an evidence base to establish an association between physical activity in persons with impaired health and the risk of secondary chronic conditions and develop tailored interventions.

Applied research which is linked to professional practice is a tool for knowledge production, circulation and implementation. The goal of such research is the innovation of professional practice to arrive at best practices. Our name symbolizes this notion: The Research Centre for Innovation in Health Care at the Faculty of Health Care. In the Research Centre, we collaborate with Doctors Duijnstee, Schuurmans and Kort and their research groups: Caring for the Chronically Ill and Demand-driven Care. The mission of the Research Centre is to produce, circulate and implement newly acquired knowledge. Our activities bridge the gap between science and practice, and are directed towards innovation in professional practice and ensuring that this innovation has a scientifically sound basis. We contribute to excellence in professional practice and education.

In concrete terms, we focus on: (1) training professionals to apply the principles of evidence-based and reflective practices; (2) integrating existing and new knowledge into professional practice; and (3) generating new knowledge through applied research in response to concrete questions from professional practice. The following knowledge circulation model sums up our activities (Figure 6).

We are most grateful to the Utrecht University of Applied Sciences Board and to the director of the Faculty of Health Care, Harm Drost, for their support in these efforts.

Figure 6
Knowledge circulation



7.1 Applied research

In the UPLIFT study, we assess police officers in the Utrecht area with a battery of tests, consisting of a blood test for triglycerides, glucose, HDL- and LDL cholesterol, skinfold measurements, the circumference of the waist and hips, blood pressure, (resting) heart rate, functional tests for flexibility, muscle endurance of the stomach and back, hand-grip strength, leg strength and a maximal bicycle exercise test. We then give these police officers feedback on their health with advice on modifications to their lifestyle, where applicable. To date, around 2,500 police officers have been tested and around 500 have been re-tested after a two-year interval.

The data are collected by the entire team; the doctoral students and Dr. Hugo Moolenaar, Dr. Wim Burgerhout, Geert Aufdemkampe MSc, Roelof Peters MSc, Kees Arens MSc and Huib van Moorsel. These data are being used in the research work of our PhD students. The exercise physiology laboratory is becoming a teaching tool for both Bachelor and Master students.
Our network is growing and there is increasing collaboration with other knowledge institutions. We have a strong relationship with The National Institute for Public Health and the Environment (RIVM) and two of our doctoral students are participating in research there. There is intensive collaboration with the Physical Therapy Sciences Master of Science of the Utrecht University and a number of these students are carrying out their graduate work with us. With our Dr. Roland van Peppen, the Royal Dutch Society for Physical Therapy, Dr. Sandra Beurskens and Dr. Raymond Swinkels from the University of Applied Sciences, Zuyd we have developed a course on clinimetrics in clinical practice for physical therapists which we are currently piloting.

Professor Erik Puik from the Micro-engineering research group is developing an accelerometer which also measures ECG activity, together with Dr. Takken from the Department of Pediatric Physical Therapy and Exercise Physiology of the Wilhelmina Pediatric Hospital Utrecht and ourselves. We hope to begin a pilot shortly on the reliability and validity of this instrument for children and police officers.

We are collaborating with Professor Rob Gründemann of the research group Organizational Configurations and Labor Relations and Dr. Goof Buijs from the Netherlands Institute for Health Promotion and Disease Prevention (NIGZ) on a project to create a healthy working environment for faculty staff and students alike. We aim to become part of the Schools for Health in Europe (SHE) network and our Topclass students will participate in this project.

7.2 Professional Practice

Professor Dr. Jaap Van Dieën of the VU University Amsterdam, Faculty Human Movement Sciences and a group of practitioners, faculty and researchers from our research group are investigating ways to translate basic scientific knowledge related to back pain to clinical practice.

We inherited the academic workplace – a group of physical therapists and their managers located at five hospitals which are interested in improving and innovating hospital-based physical therapy – from Dr. Nico van Meeteren. Current projects involve pre-operative screening in total hip and knee patients for extended-stay risk, exercise for palliative oncology patients and pre-operative screening and treatment of CABG patients. We will continue to expand on this concept in building Best Practice Units. A Best Practice Unit (BPU) is a form of a community of practice (CoP), with practioners and researchers who have a common interest in some subject or problem and who collaborate over an extended period – sharing ideas, finding solutions and innovating together. Through these BPUs, we will work on the clinical questions generated from professional practices.

7.3 Education

We contribute to education through implementing existing and new knowledge on the relationship between physical activity, physical fitness and health into the curriculum and by helping students to develop academic competencies. We believe that education and research should be integrated as a critical and defining element in the education that we offer our students, so that they can become evidence-based practitioners who are aware of the need for innovation in health care. Participating in scientific research is the best way to achieve an academic approach to thinking and working (Croiset, 2007). We have therefore developed a number of Lifestyle and Health research questions for students and many are participating in these continuing research activities. We have developed a minor Lifestyle and Health and are developing a second minor Science and Physical Activity. In these courses, students can participate in the collection of data from the exercise laboratory and generate their own research questions. A small group of students is now collaborating with one of the doctoral students (Drs. Henri Kiers) in collecting data for his PhD work, demonstrating that student excellence can be achieved by intense collaboration.

Finally, but no less importantly, we build on innovation in education in close collaboration with the director of the Institute of Movement studies, Mieke Klootwijk, MSM and Drs. Rob van Dolder.
The curriculum we are developing is strictly evidence-based and students and faculty alike must learn to critically appraise and make use of evidence in their clinical reasoning. A journal club is being set up to help faculty members further develop their critical appraisal skills and keep the curriculum as evidence-based as possible.

In the medical world, it is conventional wisdom to prescribe the evidence-based treatment known to be most effective and which entails the fewest side-effects or risks. Evidence suggests that in selected cases, exercise therapy is just as effective as medical treatment – and in certain situations more effective – or enhances its benefits. If we want to prescribe exercise as medicine, then our students must be competent to do this. This will involve implementation of the accumulated knowledge about the efficacy of exercise therapy into the curriculum. In cases where there is no evidence, students should be still be able to prescribe exercise on the basis of their knowledge of disease and physiology, specifically exercise physiology, tailor made to the individual patient on the basis of exercise tests. The research group Lifestyle and Health will try to fill the knowledge gaps, where needed, by carrying out applied research, involving students as we work. Training parameters (F.I.T.T.) deserve specific attention, as there is some evidence that different parameters have different health effects. Guidelines on physical activity should be taught and students be made aware of the importance of their implementation. Physical activity levels should be assessed in each person as a matter of routine, but appropriate instruments will need to be developed for those with chronic conditions, that can be used in clinical practice.

We will work together on expanding our body of knowledge on the relationship between physical activity, physical fitness and health thus bridging the gap between science and practice.

BIJLAGEN

/ CURRICULUM VITAE

Dr. Harriët Wittink ontving haar diploma fysiotherapie aan de Stichting Utrechtse Paramedische Academie (SUPA) in 1981. In 1984 vertrok zij naar de Verenigde Staten waar zij in verschillende ziekenhuizen werkte en in 1989 haar master of science in Orthopedic and Sports Medicine haalde aan het MHG Institute for Health Professions. Zij werd daarna clinical specialist en out-patient supervisor in Massachusetts General Hospital (MHG) te Boston.

Tussen 1996 en 2001 bouwde zij samen met haar anesthesiologie en psychologie collega's van het Tufts University New England Medical Center (NEMC) een interdisciplinaire pijnkliniek op voor patiënten met acute en chronische pijn en publiceerde zij het eerste boek over fysiotherapie en chronische pijn. In 1998 promoveerde zij aan Boston University op het proefschrift physical activity, physical fitness and chronic low back pain.

In 2001 keerde zij terug naar Nederland en werkte als substituut hoofd fysiotherapie en onderzoekscoördinator op het VUMC. Tussen 2004 en 2007 was zij betrokken bij het fysiotherapie onderwijs op Hogeschool Utrecht, bij Fysiotherapiewetenschap op de Universiteit Utrecht als docent en als opleidingsmanager van de Professional Master Fysiotherapie. Sinds 1 maart 2007 werkt zij naast Prof dr. Luc Vanhees als lector Leefstijl en Gezondheid binnen het Kenniscentrum Innovatie van Zorgverlening bij de Faculteit Gezondheidszorg.

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