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Effective Endurance and Strength Training for Patients With Chronic Musculoskeletal Disorders

Master's thesis, Exercise Physiology

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Summary

BACKGROUND: Peak oxygen uptake (VO_{2peak}), maximal strength (measured as one-repetition maximum (1RM)), and walking economy (C_w) have a great impact on physical work capacity, disability and mortality. The study aimed to compare the effects of aerobic high intensity interval training and maximal strength training versus moderate intensity training on VO_{2peak}, 1RM and C_w in the rehabilitation of patients with musculoskeletal disorders aiming to return to work. **METHODS**: Fifty-eight patients with musculoskeletal disorders (mean age 45 years) were either randomized to high intensity training at 85-95% of maximum heart rate (HR_{max}) and 85-95% 1RM or moderate intensity training, 5 days/week, for 4 weeks at Hokksund rehabilitation centre. Primary outcomes were VO_{2peak}, 1RM and C_w at baseline and after rehabilitation. **RESULTS**: $VO_{2peak,}$ 1RM and C_w improved in the high intensity group (33.8±8.1 vs. 37.3±8.4 $mL \cdot kg^{-1} \cdot min^{-1}$, 92.9±25.6 vs. 127.2±28.0 kg, 16.0±2.2 vs. 14.4±1.8 $mL \cdot kg^{-1} \cdot min^{-1}$, $p < .001$) and the moderate intensity group (33.0±7.0 vs. 34.6±7.5 $mL \cdot kg^{-1} \cdot min^{-1}$, 108.0±37.7 vs. 125.8±39.1 kg, 15.3±2.1 vs. 14.0±1.4 $mL \cdot kg^{-1} \cdot min^{-1}$, p <0 .001), with a significance group difference ($p < 0.001$) in VO_{2peak} and 1RM. Systolic and diastolic blood pressure decreased significantly in both groups ($p < 0.01$ and $p <0.001$), with no significant difference between groups. **CONCLUSION**: Four weeks of intensive endurance and strength training improved VO_{2peak}, 1RM and C_w significantly after both high intensity training and moderate intensity training. The results show that high intensity training was twice as effective in increasing VO_{2peak} and 1RM after 4 weeks rehabilitation. Increased physical work capacity could lead to increased quality of life and perhaps return to work.

Appendix

Abbreviations

C	Work economy
C_w	Walking economy
CVD	Cardiovascular disease
HIG	High intensity group
HR_{max}	Maximal heart rate
HR_{peak}	Peak heart rate
$[La^-]_b$	Blood lactate concentration
LT	Lactate threshold
*v*LT	Running velocity at LT
M_b	Bodyweight
1 MET	The energy expended sitting quietly, equivalent to $3.5 mL \cdot kg^{-1} \cdot min^{-1}$
$mL \cdot kg^{-1} \cdot min^{-1}$	$Millilitres \cdot kilograms^{-1} \cdot minutes^{-1}$
$mL \cdot kg^{-0.75} \cdot min^{-1}$	$Millilitres \cdot kilograms^{-0.75} \cdot minutes^{-1}$
$mmol \cdot L^{-1}$	$Millimole \cdot Litres^{-1}$
MSD	Musculoskeletal disorders
Q	Cardiac output
R	Respiratory exchange ratio
RFD	Rate of force development
1RM	One-repetition maximum
RTW	Return to work
SV	Stroke volume of the heart
MIG	Moderate intensity group
VO_2	Oxygen uptake
VO_{2max}	Maximal oxygen uptake
VO_{2peak}	Peak oxygen uptake
W_{max}	Maximal workload

Introduction

Background

Exercise training is a frequently used intervention in rehabilitation. The physical training for patients with musculoskeletal disorders (MSD) works by breaking a vicious cycle of inactivity. Pain, reduced endurance, muscle strength and fatigue limit the patient’s physical functioning (Pedersen and Saltin 2006). Physical inactivity increases the risk for development of MSD, psychological health problems, cardiovascular disease, diabetes, obesity and increased blood pressure (Dunn, Trivedi et al. 2005; Pedersen and Saltin 2006; Williams, Haskell et al. 2007; Martinsen 2008). These disorders place a considerable burden on the healthcare resources and are a significant cause of long term sick leave and disability (Ekberg and Wildhagen 1996; Benavides, Benach et al. 2001; Vingard, Lindberg et al. 2005; Waddell 2006; Lydell, Grahn et al. 2009). In Norway, more than 45% of long time sick leave (>8 weeks), almost 33% of all costs to disability benefits and 45% of costs to rehabilitation are related to MSD (National Insurance Administration 1998). The most common health complaints are fatigue, headache, worries about daily life, back pain, and pain in the upper arm and neck (Eriksen, Svendsrod et al. 1998). Self perceived health complaints have very often few or no objective findings (Eriksen, Ihlebaek et al. 1999). A common result of these complaints is reduced quality of life (Martin, Church et al. 2009).

Physical exercise is strongly recommended in both primary and secondary prevention of chronic MSD, including diseases that do not primarily manifest as disorders of the locomotive apparatus (Hagberg, Harms-Ringdahl et al. 2000; Pedersen and Saltin 2006; Blangsted, Sogaard et al. 2008; Oja, Bull et al. 2010). Multidisciplinary rehabilitation is found effective for return to work (RTW) (Schonstein, Kenny et al. 2003). There is strong evidence that exercise as part of a multidisciplinary treatment increases quality of life, health and reduces sick leave further (Bendix, Bendix et al. 2000; Edmonds, McGuire et al. 2004; Kool, de Bie et al. 2004; Storro, Moen et al. 2004; Busch, Barber et al. 2007; May, Van Weert et al. 2008).

Reduced physical capacity is common for MSD patients, compared with healthy controls (Busch, Schachter et al. 2008; Smeets, van Geel et al. 2009; Wang, Haskell et al. 2010). The exercise training should therefore aim to improve physical work capacity (Ilmarinen 2001). Maximal oxygen uptake (VO_{2max}) and maximal muscle strength, measured as one-repetition

(1RM), are the most important factors for exercise capacity and mortality risk for both healthy people and patients (Myers, Prakash et al. 2002; Ruiz, Sui et al. 2008). High intensity training is shown to be most effective in increasing VO_{2max} and 1RM for both the healthy population and patients (Rognmo, Hetland et al. 2004; Helgerud, Hoydal et al. 2007; Schjerve, Tyldum et al. 2008; Tjonna, Lee et al. 2008). It also seems that strenuous exercise on a regular basis reduces the chance of high sick leave (Andersen, Frydenberg et al. 2009). Proper, van den Heuvel et al. (2006) found that workers meeting the recommendation of vigorous physical activity had significantly less sick leave (>21 days a year), than people doing moderate intensity. Aerobic high intensity exercise is also shown to decrease pain by 30%, recover lost functioning by 34% and to reduce anxiety/depression by 25% (Chatzitheodorou, Mavromoustakos et al. 2008).

Effective training interventions will probably have a positive effect on general health, work capacity and disability (Pedersen and Saltin 2006). Activities of daily living like physical work, could then be performed at a lower percentage of maximal capacity and improve quality of life (Pedersen and Saltin 2006; Andersen, Frydenberg et al. 2009; Martin, Church et al. 2009).

Aerobic endurance training for chronic musculoskeletal disorders

Aerobic endurance has traditionally been considered as one of the most fundamental components of physical fitness (Helgerud, Hoydal et al. 2007). Pate and Kriska (1984) have described a model that incorporates three factors concerning inter-individual variance in aerobic endurance performance. These factors are VO_{2max}, lactate threshold (LT) and work economy (C). This model should serve as a useful framework for examination of the effects of aerobic training on aerobic endurance (Helgerud, Hoydal et al. 2007).

Maximal oxygen uptake (VO_{2max})

VO_{2max} is defined as the highest oxygen uptake (VO_2) an individual can attain during exercise engaging large muscle groups while breathing air at sea level (Åstrand and Rodahl 1986p.304). VO_{2max} is a measure of the body's ability to transport oxygen from the ambient air to the working muscle and to use the available oxygen. VO_{2max} has become the preferred laboratory measure of cardio-respiratory fitness and is the most important measurement during functional exercise testing both for patients and healthy (Albouaini, Egred et al. 2007).

Fick's equation incorporates factors contributing to VO_{2max}. It states that VO_{2max} equals cardiac output (Q) times the arterial- venous oxygen difference (a-vO_2 difference). VO_{2max} varies among individuals due to factors such as body size, muscle mass, genetics, age, gender and condition status (Pate and Kriska 1984). VO_2 increases linearly with increasing power output and reaches a plateau with further increases in work rate at VO_{2max}. However, in many subjects, such as patients with chronic MSD and pain, termination of work is demonstrated before this plateau is reached (Wagner 2000). When VO_{2max} criteria are not fulfilled, the term peak oxygen uptake (VO_{2peak}) is more commonly used. This term refer to the highest level of oxygen that can be consumed and utilized by the body during exercise under a given condition. Only a few studies of patients with MSD use VO_{2peak} and VO_{2max} as a measure of aerobic capacity.

Lactate threshold (LT)

LT was defined by Davis (1985) as the intensity of work where the blood lactate level represents a balance between production and elimination. LT changes in response to training with the alteration of VO_{2max}, and also sometimes as a percentage of VO_{2max} (Pate and Kriska 1984; Helgerud, Engen et al. 2001). Helgerud, Hoydal et al. (2007) found no significant change in LT in any training groups when expressed as % of VO_{2max}. This in line with other studies (Sjodin, Jacobs et al. 1982; Helgerud, Engen et al. 2001; McMillan, Helgerud et al. 2005). All groups in (Helgerud, Hoydal et al. 2007) significantly improved running velocity at LT (*v*LT). However, because *v*LT follows the improvement in VO_{2max} (Helgerud, Engen et al. 2001; McMillan, Helgerud et al. 2005), and because all groups improved the running economy (C_R), higher *v*LT would be expected.

Work economy (C)

C refers to the ratio between work output and oxygen cost. Sometimes C is referred to as walking economy (C_w), and is defined as the steady-rate VO_2 in $mL \cdot kg^{-1} \cdot min^{-1}$ at a standard velocity (Helgerud 1994). Subjects with a good C can execute more absolute work at any intensity than subjects with a poor C (Bassett and Howley 2000). Pain in patients with MSD could alter the gait patterns, and increase oxygen cost. Both maximal strength and endurance training has been shown to improve C in the healthy population and in patients (Slordahl, Wang et al. 2005; Helgerud, Hoydal et al. 2007; Karlsen, Helgerud et al. 2009).

VO_{2max} limitations

In order to improve physical work capacity in rehabilitation it is necessary to use effective training methods and valid and reliable exercise testing equipment to detect changes. The oxygen pathway from the atmosphere to the muscle cell mitochondria contains several steps which all could contribute to limit VO_{2max} (Bassett and Howley 2000). Wagner (2000) addressed the topic of limiting factors to VO_{2max}, and categorized them into oxygen supply limitations or metabolic capacity limitations (demand). Supply limitation refers to limited delivery of oxygen to the muscle cell, while demand limitation refers to the skeletal muscle cells' ability to consume oxygen as the main limiting factor.

Most evidence shows that VO_{2max} is mainly determined by maximal cardiac output (Q), the oxygen carrying capacity of the blood, and the oxidative capacity of working skeletal muscles (Pate and Kriska 1984; Richardson, Grassi et al. 1999; Bassett and Howley 2000). The major limiting factor for supply limitation is Q (Saltin 1985). Q depends on the heart rate (HR) and stroke volume (SV) (McArdle, Katch et al. 2007p.352). Researchers agree that SV increases as work rates increases up to around 50% of VO_{2max}, but reports about what happens after that point differ widely (McArdle, Katch et al. 2007p.484). Some have suggested that both HR and SV increase linearly during increased work rates until about 50% of VO_{2max}, where SV plateaus or only increases modestly in both trained and sedentary individuals (Plotnick, Becker et al. 1986). However, recent studies have shown that SV continues to increase above the intensity of 50% of VO_{2max} (Gledhill, Cox et al. 1994; Zhou, Conlee et al. 2001). Zhou, Conlee et al. (2001) found that SV continued to increase with increasing work load up to VO_{2max} in elite trained subjects. In contrast, the sedentary and moderately trained study participants showed the classical levelling off in SV. Wagner (2000) concluded that during whole body maximal exercise, VO_{2max} is limited by oxygen supply in normally fit individuals, and a demand limitation in patients and sedentary people.

Physical work capacity in patients with musculoskeletal disorders

One challenge in evaluating the physical capacity of, and the exercise training effect for MSD patients, is limited availability of targeted high quality research (Verhagen, Karels et al. 2007). Lack of standardization of testing protocols and procedures, and of methodology in relation to training procedures often makes interpretation difficult (Pollock, Gaesser et al. 1998). Most studies only evaluate pain or self perceived health (Hayden, van Tulder et al. 2005). Few studies measure changes in endurance. A low VO_{2max} is found to be inversely associated with increased risk of disability pension due to cardiovascular disease and MSD (Karpansalo, Lakka et al. 2003). The VO_{2max} of 1300 people was measured, mostly full time workers, using respiratory gas exchange analysis during maximal, but symptom limited exercise on an electrically braked cycle ergometer. The accuracy of this test is high, ±2-4% (McArdle, Katch et al. 2007p.185), but it could be argued that a test on a treadmill has a better specificity to everyday life. They found an increased risk of disability pension with oxygen uptake below 33 $mL \cdot kg^{-1} \cdot min^{-1}$, but the greatest incidence with values below 25 $mL \cdot kg^{-1} \cdot min^{-1}$. Other studies also using direct measurement, but with unfit patients, has found values of VO_{2max} ranging from 20 – 27 $mL \cdot kg^{-1} \cdot min^{-1}$ (Hakkinen, Hannonen et al. 2003; Valkeinen, Alen et al. 2008).

Several studies using submaximal bicycle tests according to the method described of Åstrand and Rodahl (1986) are found. Storheim, Brox et al. (2005) identified cardiovascular fitness as one of the best predictors of RTW for non-specific low back pain when 93 people were tested. Those not returning to work rated self perceived disability higher, and had an estimated VO_{2max} of 28.3 $mL \cdot kg^{-1} \cdot min^{-1}$ versus 33.0 $mL \cdot kg^{-1} \cdot min^{-1}$ for those who went back to work. Wormgoor, Indahl et al. (2008) also found patients with low back pain to have 29 $mL \cdot kg^{-1} \cdot min^{-1}$ with mean age 42 years. Other studies have found values of 20-33 $mL \cdot kg^{-1} \cdot min^{-1}$ for patients with fibromyalgia, low back pain and pain in the neck and upper arm (Da Costa, Abrahamowicz et al. 2005; Andersen, Kjaer et al. 2008; Smeets, Vlaeyen et al. 2008). All these submaximal bicycle tests are difficult to compare with indirect calorimetry because of the error of margin of ±15% (Åstrand and Rodahl 2003p.287). The specificity of this submaximal test should also be as close as possible to the activity performed in training and everyday life (McArdle, Katch et al. 2007p.472). A functional test on a treadmill could be better.

Aerobic training intensity

Frequency, duration and intensity are important parts of exercise training according to Pollock, Gaesser et al. (1998). There seems to be a consistent finding that aerobic high intensity training is superior to aerobic training of low and moderate intensity irrespective of age, pathology and physical capacity (Rognmo, Hetland et al. 2004; Helgerud, Hoydal et al. 2007; Schjerve, Tyldum et al. 2008; Tjonna, Lee et al. 2008; Adamsen, Quist et al. 2009; Moholdt, Amundsen et al. 2009; Wang, Helgerud et al. 2009). The high aerobic training intensity is close to VO_{2max} or 85-95% HR_{max}, or around 80% of maximal power as tested using a ramp protocol. This intensity is sustainable in periods lasting 3 to 8 minutes before exhaustion, and repeated bouts of 4 minutes intervals are commonly used. The training effects are linked to shear stress both in terms of the effect on SV and the small muscle circulatory adaptations (Nishiyama, Walter Wray et al. 2007). It has been clearly demonstrated that the intensity of training cannot be compensated for by the longer duration even though the limitations for the oxygen transport may vary (Helgerud, Hoydal et al. 2007).

Most studies in rehabilitation of MSD use low to moderate intensity (Viljanen, Malmivaara et al. 2003; Harts, Helmhout et al. 2008; Valkeinen, Alen et al. 2008; Wormgoor, Indahl et al. 2008). Two studies that have high intensity training (> 85% HR_{max}), did not include any exercise testing of physical endurance capacity (Chatzitheodorou, Kabitsis et al. 2007; Chatzitheodorou, Mavromoustakos et al. 2008).

Strength training for chronic musculoskeletal disorders

Muscular strength and power are qualities in everyday performance. Resistance training enhances muscular strength and endurance, muscle mass, functional capacity, daily physical activity, risk profile for cardiovascular disease, and quality of life (Williams, Haskell et al. 2007).

Strength is defined as the integrated result of several force-producing muscles performing maximally, either isometrically or dynamically during a single voluntary effort of a defined task (Hoff and Helgerud 2004). Typically, maximal strength is defined in terms of 1RM in a standardized movement (McArdle, Katch et al. 2007p.511). Power is a product of force and the inverse of time, i.e. the ability to produce as much force as possible in the shortest possible time (Hoff and Helgerud 2004).

Research on strength training is often not conclusive in terms of training intensity, measurement techniques and specificity. Some studies use the dynamic testing of 1RM (Hakkinen, Hannonen et al. 2003; Valkeinen, Alen et al. 2008). Other use training intensity in relation to 1RM, but without any tests (Bircan, Karasel et al. 2008). Most studies use isometric testing, while training dynamically (Fulcher and White 1997; Andersen, Kjaer et al. 2008; Harts, Helmhout et al. 2008). Different training and measuring procedures makes it hard to compare the effect of different studies. This is shown by Thorstensson, Hulten et al. (1976). They found functional improvement of 70% in a 1RM squat to be reduced to only 20% in maximal static strength and no improvement at all in isokinetic knee extension. To improve a specific physical performance through resistance training, one must exercise the muscle(s) in movement that mimic the movement requiring force-capacity improvements, with focus on force, velocity, and power requirements (McArdle, Katch et al. 2007p.533). A variety of training methods are applied in an effort to increase strength and power (Baker, Wilson et al. 1994). Adaptations can be divided into two broad categories, muscular hypertrophy and neural adaptations.

Muscular hypertrophy

Muscular hypertrophy is related to a connection between the cross-sectional area of the muscle and its potential for force development (McArdle, Katch et al. 2007p.515). Age and gender affect muscular strength and muscular power. Motor unit remodelling represents a normal, continual process that involves motor endplate repair and reconstruction. Motor unit remodelling gradually deteriorates in old age (McArdle, Katch et al. 2007p.894). Aging, inactivity or chronic disease, will also lead to atrophy of muscle mass, particularly from the fast twitch type II fibres (Doherty, Vandervoort et al. 1993; Kirkendall and Garrett 1998; de Vos, Singh et al. 2005). Resistance training to increase muscle mass can be beneficial, especially for patients with long term atrophy. Several methods for developing hypertrophy are reported (Tesch and Larsson 1982). Most use 8-12 repetitions in series with submaximal resistance (60-90% 1RM).

Neural adaptations

The term “neural adaptations” is a broad description of several factors, but in general it affects the activation of the muscle and/or the velocity and force of the nerve signal (McArdle, Katch et al. 2007p.540). A significant part of the improvement in the ability to do more weights is an increased ability to coordinate other muscle groups involved in the movement (Rutherford and Jones 1986). Behm and Sale (1993) suggested two major principles for maximal neural adaptation. To train the fastest motor units, which develop the greatest force, one has to work against high loads (85-95% 1RM), which guarantee maximal voluntary contraction. Maximal advantage would be gained if the movement was trained with a rapid action in addition to the high resistance. To increase the rate of force development (RFD), based on neural adaptations, Schmidtbleicher and Haralambie (1981) suggested dynamic movements with a few repetitions. The resistance should range from submaximal to maximal (85-100% 1RM, with explosive movement). This may result in neuromuscular adaptations with minimal hypertrophy (Almasbakk and Hoff 1996). If the goal is to increase RFD and 1RM from neural adaptations, a training regime of 4-6 repetitions in 3-4 series using the maximal mobilisation of force, or maximal “intended” velocity in the concentric phase is recommended (Behm and Sale 1993).

Strength training intensity

A muscle strengthens when trained close to its current force generating capacity. As with cardiovascular training, muscular strength improvements vary inversely on a continuum with initial training status. To improve maximal strength it is shown that a higher load than 66% of 1RM, which correspond to about 15 repetitions, must be applied (Schmidtbleicher and Haralambie 1981; McDonagh and Davies 1984). Pollock, Gaesser et al. (1998) have recommended resistance training 2 to 3 days a week, using major muscle groups, with weight loads allowing completion of 8-12 repetitions of 1RM for normal healthy individuals under age 50. Older and previously sedentary persons should perform one set of 10-15 repetitions. Also recognized are the potential benefits of regular, moderate resistance exercise on reduction in HR and blood pressure (Pollock, Franklin et al. 2000; Mota, Pardono et al. 2009). Recently, several studies on patients using high intensity resistance training (85-95% 1RM) have showed larger increases in muscle strength, walking ability and no increased risk of injury compared with lower intensity (De Backer, Van Breda et al. 2007; Hoff, Tjonna et al. 2007; King, Birmingham et al. 2008; Schjerve, Tyldum et al. 2008).

Strength training effect on aerobic performance

Maximal strength training has been reported to improve aerobic endurance performance through an improved C (Hoff, Gran et al. 2002; Osteras, Helgerud et al. 2002; Hoff, Tjonna et al. 2007; Storen, Helgerud et al. 2008; Karlsen, Helgerud et al. 2009). Maximal strength training is shown to improve C by approximately 5-20% in healthy individuals as well as in patients with chronic disease (Paavolainen, Hakkinen et al. 1999; Hoff, Gran et al. 2002; Hoff, Tjonna et al. 2007; Wang, Helgerud et al. 2009). The mechanisms behind the improved aerobic endurance performance are demonstrated to be caused by changes in the power-load and velocity-load relationship by an increased RFD, 1RM and an increased peak force (PF) after the training interventions (Osteras, Helgerud et al. 2002). The increased RFD leads to longer relaxation periods between contractions, whereas an increased 1RM and PF lead to a reduction in the relative load placed on the muscle during submaximal effort (Richardson, Harms et al. 2000; Osteras, Helgerud et al. 2002).

Aging, inactivity, muscle strength and aerobic endurance in musculoskeletal disorders

Both the cardiovascular and musculoskeletal system decline with age (Wilson and Tanaka 2000; McGuire, Levine et al. 2001; Yu, Hedstrom et al. 2007) and inactivity (McGuire, Levine et al. 2001). The classic “Dallas bed rest study” demonstrates 3 weeks of complete inactivity has the same detrimental effect on VO_{2max} as 30 years of ageing (McGuire, Levine et al. 2001). A decline in VO_{2max} of 10 % per decade after 30 years of age has been observed in studies of healthy subjects (Hagberg 1987). It has been found that the decline in VO_{2max} is proportional to a decreased Q, VO_{2peak}, SV_{max} in older subjects (Higginbotham, Morris et al. 1986). These changes are strongly dependent on the aerobic exercise, or lack of it (Ilmarinen 2001). The levels of VO_{2max} can thus become critical in physically demanding work much earlier than expected.

Aging also decreases the muscles ability to generate a rapid contraction speed more than muscle strength (de Vos, Singh et al. 2005). Reduced muscle strength is common in MSD patients (Pedersen and Saltin 2006). Reduced leg strength is shown to be associated with decreased functional performance (Wang, Helgerud et al. 2009). High intensity strength training has showed an increased walking distance for patients (Husby, Helgerud et al. 2009; Karlsen, Helgerud et al. 2009).

It has been questioned how much of the decline in VO_{2max} and 1RM that is due to aging or as a direct result of inactivity (Wilson and Tanaka 2000; Hunter, McCarthy et al. 2004). Regular aerobic exercise seems to prevent and restore the muscle metabolic and vascular losses in aging people (Kirkendall and Garrett 1998; Lawrenson, Hoff et al. 2004), in the same way as regular strength training can prevent or delay the age-related loss in muscle strength and power (Hunter, McCarthy et al. 2004; Martel, Roth et al. 2006).

International recommendations claim that physical work should not require more than 50% of a worker’s VO_{2max} (Ilmarinen 2001). If an unfit woman 40 years of age has a VO_{2max} of only 1.5 $L \cdot min^{-1}$, she is allowed to consume up to 0.75 $L \cdot min^{-1}$ without causing overload. In practice, this level of cardio-respiratory capacity would correspond to work in a sitting position or light work while standing (Ilmarinen 2001). An increase in both endurance and maximal strength would then give the same person the possibility to work at a lower percent of maximal work capacity, and could reduce overload and sick leave (Ilmarinen 2001; Vingard, Lindberg et al. 2005; Proper, van den Heuvel et al. 2006; Lydell, Grahn et al. 2009). Reduced physical capacity in MSD patients can be an extra risk factor for decreased RTW (Karpansalo, Lakka et al. 2003). The main goal in vocational rehabilitation is RTW. Rehabilitation should also try to reduce general health risks by increasing endurance and strength using effective training methods (Ilmarinen 2001; Myers, Prakash et al. 2002; Ruiz, Sui et al. 2008).

This evaluation will try to give answer to the following hypotheses;

H_0: There are no differences in endurance and maximal strength between the current rehabilitation with moderate training intensity, and controlled high intensity training

H_A: There are differences in endurance and maximal strength between the two rehabilitation interventions

Methods

Subjects

A total number of 74 patients were offered to participate in this trial at the rehabilitation center between January and June 2009. The patients were sick listed and out of work due to MSD and light psychiatric disorders. A flowchart illustrating the progress in the study is presented in Fig. 1.

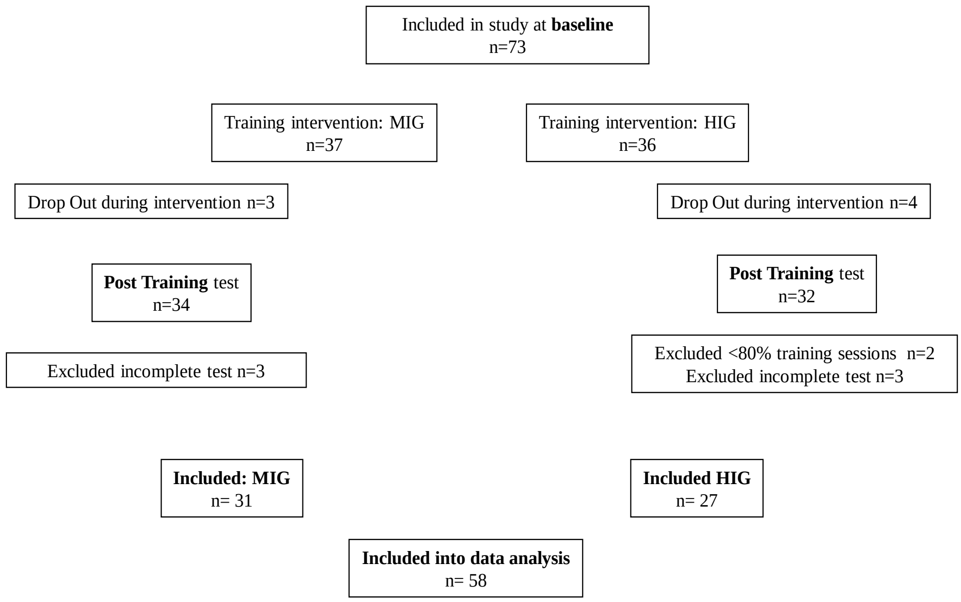

Fig. 1, Flow chart of the participants from baseline to data analysis. MIG: moderate intensity group, HIG: High intensity group

The Regional Committee for Medical Research Ethics approved the study (ref.nr 2009/2144-1), which was conducted in accordance with the Declaration of Helsinki. All subjects received both a written and oral invitation to participate. 73 patients gave their informed, written consent, and were tested. All subjects participated in supervised training interventions. The half of the patients were randomized to follow the current training with moderate intensity (MIG), and the other half took part in controlled aerobic high intensity training and maximal strength training (HIG) (Table 1).

Table 1. Group Characteristics at baseline.

Variable	**MIG (n=31)**	**HIG (n=27)**
Gender (male/female)	11 / 20	8 / 19
Age (years)	44.1 ± 10.9	46.2 ± 8.8
Height (cm)	170.9 ± 8.4	170.3 ± 10.4

Values are mean ± SD. MIG: moderate intensity group, HIG: high intensity group

Apparatus

Maximal strength (1RM) was measured in a horizontal leg press machine (Technogym 451, Italy). An h/p/cosmos T 150 med (Germany) treadmill calibrated for inclination and speed was used for all physical capacity measurements. VO_{2peak}, C_w and all ventilatory parameters, and pulmonary gas exchange measurements were obtained using the Cortex Metamax II portable metabolic test system (Cortex Biophysik GmbH, Leipzig, Germany). HR was measured using Polar type RS400 (Polar Electro, Kempele, Finland), and HR_{max} was defined by adding 5 beats·min^{-1} to peak heart rate (HR_{peak}) value obtained during the VO_{2peak} test as in Schjerve, Tyldum et al. (2008). A Lactate Pro analyzer (Arkray inc., Japan) was used measuring lactate concentration in blood $[La^-]_b$.

All the tests were performed the same day at the research laboratory at Hokksund rehabilitation centre by the exercise physiologist supervised by a medical doctor. Measures were done at 2 time points: at baseline and after 4 weeks of rehabilitation.

Testing procedures

Weight and height

Bodyweight (m_b) was measured with clothes and shoes on, then 0.5 kg was subtracted (Soehnle, 150kgx100g, Deutschland). Height was measured with shoes minus 1 cm, with the back against the wall.

Blood pressure

The blood pressure was measured in standardized sitting position after 3 minutes of rest. The right arm was in a relaxed position with light flexion in the elbow, and the cuff was fixed 1-2 cm above the elbow joint. Equipment used was a half automatic blood pressure device (Bosu-Medicus, Bosch+Sohn GMBH U. CO., Germany, and cuff TYP CA01).

Maximal leg strength (1RM)

Leg press was carried out on a horizontal leg press machine (Technogym 451, Italy), down to a knee joint angle of 90 degrees between tibia and femur. Both legs were tested together, but also individually. Default position was standardized individually, where position of the shoulder, feet and sitting angle was noted. Every test, the patient got a warm up series of 10 repetitions on a submaximal level. 1 RM was measured by repeated lifts with increasing loads of 4.5 kg until the subjects were no longer able to complete the lift. 1RM was achieved within 4-6 lifts. The best lift was tested twice to be sure this was the true 1RM. Thirty seconds to one minute rest was given between each attempt.

Walking economy (C_w)

C_w, was determined before the peak exercise test and after a 10 minutes warm up period (50-60 % of HR_{max}). Subjects walked on a treadmill at 5 % inclination with a 3.0 $km \cdot h^{-1}$ velocity for 3.30 minutes. Continuous respiratory measurements every 10 seconds were carried out, and mean VO_2 values from the last 30 seconds were used to as a measure of C_w (Helgerud, Wang et al. 2009). HR was monitored continuously by short wave telemetry.

Peak exercise test with blood lactate (VO_{2peak})

This procedure was executed immediately after the test of C_w. VO_{2peak} was determined by treadmill walking (running if necessary) with increasing work load until the subjects reached exhaustion. Both velocity and inclination was increased. The criteria of exhaustion were respiratory exchange ratio (R) above 1. VO_2 was measured in 10 seconds intervals, and the VO_{2peak} was obtained as the mean of the three highest intervals in a row. This method has high validity and reliability and is the gold standard for measure of VO_{2max} (Åstrand and Rodahl 2003p.276). VO_2 was analyzed with the portable Metamax II metabolic test system. HR_{peak}, R and pulmonary ventilation were obtained at the same time as VO_{2peak}. HR_{peak} was measured using a HR monitor. Blood samples were drawn from the fingertip for measurement of lactate concentration in blood $[La^-]_b$ within one minute after the test using a Lactate Pro analyzer.

Validity and reliability of measurement of VO_2, lactate tests and 1 RM leg press

Metamax II has been validated against the classic Douglas bag technique (Larsson, Wadell et al. 2004). Mean differences in VO_2 (0.03, 0.02, and 0.04 $L \cdot min^{-1}$ for 100, 200, and 250 W, respectively), and pulmonary ventilation (V_E; 1.6, 2.9, 1.5 $L \cdot min^{-1}$ for 100, 200, and 250 W, respectively) were small but significant for 100 W (VO_2 and V_E) and 200 W (V_E). However, intraclass coefficients of correlation were high throughout. Bland - Altman plots revealed 95% limits of agreement of $\pm$ 0.2 $L \cdot min^{-1}$ for VO_2 (bias 0.04 $L \cdot min^{-1}$) and slightly below $\pm$ 6 $L \cdot min^{-1}$ for V_E (bias 1.9 $L \cdot min^{-1}$).

A recent validation (Baldari, Bonavolonta et al. 2009) of Lactate Pro against the EBIO plus analyzer found this analyzer to be suitable for sports research field. An average accuracy difference was revealed ($p < 0.05$). The limits of agreement between Lactate Pro and EBIO plus were between 2.8 and 5.0%. Lactate Pro had good reliability for intra-, inter-analyzers, and between test strips (ICC r = 0.999). The linearity was determined versus the EBIO plus as reference. The slope coefficient for Lactate Pro was close to 1 (1.1053).

Verdijk, van Loon et al. (2009) conclude that 1RM testing represents a valid means to evaluate leg muscle strength in vivo in both young and elderly men and women.

Inclusion criteria

All subjects, except for one who declined to participate were included. Every subject was screened for cardiovascular disease (CVD). If CVD was found, the subject was tested with ECG.

Exclusion criteria

Subjects were excluded from the data material if they had below 12 aerobic training sessions (maximum of 15) and below 8 (maximum of 10) strength sessions (80% of all sessions) during the 4 week rehabilitation program. Subjects in the interval groups (HIG) with too low intensity during the workouts were also excluded from the material.

Allometric scaling

MSD patients are not a homogenous group in terms of m_b (54.0 – 138.3 kg). Comparison of VO_{2peak} between patients with different m_b is imprecise when made in absolute terms ($L \cdot min^{-1}$) or relative to m_b ($mL \cdot min^{-1} \cdot kg^{-1}$). Allometric scaling raises the m_b to the power of 0.75 ($mL \cdot min^{-1} \cdot kg^{-0.75}$) (Bergh, Sjodin et al. 1991; Helgerud 1994) was therefore applied in the present study. Dimensional scaling must also be considered when evaluating strength measures like 1RM. Since muscular strength is related to muscle cross sectional area, and m_b varies directly with body volume, whole body muscular strength measures will vary in proportion to $kg^{-0.67}$ (Wisloff, Helgerud et al. 1998; Åstrand and Rodahl 2003p.299).

The rehabilitation program

The multidisciplinary rehabilitation program lasted for 4 weeks, with 6 hour long sessions 5 days a week. The aim was to help patients on long term sick leave improve their level of functioning and to improve their work ability. The criteria for inclusion at the rehabilitation centre were work motivation and an intentional goal and a plan to RTW. Relevant medical examinations and treatment had to be performed before admittance to the program. Exclusion criteria are serious psychiatric disorders or undecided applications for disability pension or insurance. The rehabilitation program included physical activity, education, cognitive behavioral modification and workplace based interventions. The rehabilitation team consisted of a physician, a psychiatric nurse, a physical therapist, a vocational social worker and a sports educator. The rehabilitation program was given partly in the form of group activities, group training sessions and follow up. Confidence, coping and learning were important objectives for all the physical activities offered. The sports educator and physical therapist led the various group activities.

Training procedures

Moderate intensity training group, MIG

The different physical activities included in the current rehabilitation have no systematic focus on intensity of training, with the exception of 1 controlled high aerobic intensity interval session a week on a spinning bike. HR monitoring of the subjects is not common. During this project we monitored different patients during the activities to check for exercise intensity (see intensity curves, Fig. 7 and 8). The training sessions 5 days/week included both aerobic and strength training. Rehabilitation periods included a maximum of 15 aerobic sessions and 8 strength sessions. The aerobic activities included various indoor exercises as one session of spinning, one with treadmill walking/running, one with aerobics and ball activities, and one session outside with Nordic walking and one session of uphill walking/running. The strength training consisted of different exercises of the upper- and lower body. Three sets and 8 repetitions of 1RM were used. They have 2 supervised strength sessions a week, but patients are free to do more by themselves. The testing only consisted of horizontal leg press. Both the MIG and HIG had aqua exercise, as well as body awareness training and relaxation training (2 hours a week).

High intensity training group, HIG

The only component that changed for the HIG was the intensity of training, and one extra supervised strength session a week. The HIG did the same amount of 5 aerobic sessions a week, but with controlled high intensity monitored with HR receivers for all subjects (see intensity curves, Fig. 9 and 10).

Aerobic high intensity interval training

A traditional interval session is a 10min warm-up; intensity gradually increases to reach the target HR zone (85-95% HR_{max}) within the first 4-minutes bout. In the second, third and fourth bout the target zone is reached after 1 ½ - 2 minutes.

Maximal strength training

The strength training sessions consisted of four sets of four repetitions with a focus of the concentric contraction from a 90º bend in the knees to straight legs. Instructional emphasis was placed on stopping the eccentric phase with 90º bend in the knees, a pause, and the maximal mobilization of force in the concentric movement. The load corresponded to 85-95% 1RM. After each set, the subjects rested for 2 minutes. When a patient was able to perform more than four repetitions in a set, the load was increased by 4.5kg increment until only four repetitions could again be achieved. All strength training was performed on the same seated horizontal leg press apparatus used for the strength testing.

Statistical analysis

Statistical analysis were performed using the software SPSS (Statistical Package for Social Science, Chicago, USA), version 17.0 for Windows. Table values are expressed as mean ± standard deviation (SD), while the spread in the figures are standard error of the mean (SEM). Due to the large number of subjects and based upon Q-Q plots examining the line of best fit, normality was assumed. Parametric tests were used. A paired sample T-test was used to detect changes within the group, and an independent sample T-test was used to detect differences between the groups. A two-tailed p value < 0.05 or less was accepted as statistically significant for all the tests.

Results

No differences were apparent between the MIG and HIG at baseline, except the R-value at VO_{2peak}, but with no difference in blood lactate $[La^-]_b$ at VO_{2peak}.

Participant and protocol deviations

69 patients completed the rehabilitation program. 58 patients are included in data analysis (Fig. 1). Two patients from each group went home. Three patients did not participate in posttest. One person in MIG got a knee injury at home and could not attend the posttest, and two patients in the HIG did not want a posttest. A total of eight patients who completed rehabilitation and both tests, were excluded from the data material. Six of the patients were excluded because of incomplete testing, three from each group. Two patients in the HIG were excluded because of too few training sessions (below 80%). No injuries were related to training.

Aerobic endurance

VO_{2peak} increased significantly 10.7% ($p < 0.001$) in the HIG (Fig. 2-4, Table 2), whereas the MIG increased significantly 4.8% ($p < 0.001$), with a significant difference between groups ($p < 0.001$). $[La^-]_b$ at VO_{2peak} increased significantly 13.7% ($p < 0.001$) in HIG and 7.4% ($p < 0.01$) in MIG, with no difference between groups (Table 2).

Maximal strength

1RM increased significantly 42.5% ($p <0.001$) in HIG (Fig. 2, 5, 6, Table 2), whereas MIG increased significantly 19.1% ($p < 0.001$), with a significant difference between groups ($p < 0.001$).

Treadmill walking economy

C_w at 5 % inclination and 3.0 $km \cdot h^{-1}$ on the treadmill improved significantly 9.4% ($p < 0.001$) in HIG (Fig. 2, Table 2), whereas MIG improved 7.5% ($p < 0.001$), with no significant difference between groups. A significant decrease in submaximal HR of 10.4% was also detected ($p < 0.001$) in HIG (Table 2) and 8.3% ($p < 0.001$) in MIG, with no difference between groups.

Bodyweight and blood pressure

A small, but significant increase in m_b occurred in HIG ($p < 0.05$), no change in MIG. However, there was no significant difference between groups. Systolic blood pressure (SBP) decreased significantly in both groups 6.5 mmHg in HIG, whereas MIG decreased 6.1 mmHg ($p < 0.01$). Diastolic blood pressure (DBP) decreased also significantly in both groups. 5.7 mmHg in HIG, and MIG decreased 3.8 mmHg ($p < 0.001$). No significant difference between groups (Table 2).

Table 2: Changes in physiological parameters at baseline and after 4weeks

Variable	MIG *n=31*		HIG *n=27*	
	Baseline	**Post Training**	**Baseline**	**Post Training**
Bodyweight (kg)	88.3 ± 21.3	88.2 ± 20.8	79.6 ± 14.5	80.2 ± 14.5*
BMI ($kg \cdot height^{-2}$)	30.0 ± 5.8	30.0 ± 5.6	27.6 ± 5.5	27.8 ± 5.5*
SBP (mmHg)	134.9 ± 16.1	128.8 ± 11.2**	134.2 ± 14.8	127.7 ± 11.6**
DBP (mmHg)	81.7 ± 10.4	77.9 ± 8.2***	82.2 ± 7.5	76.5 ± 7.2***
VO_{2peak} ($L \cdot min^{-1}$)	2.87 ± 0.75	3.01± 0.80***	2.65 ± 0.64	3.94 ± 0.66***+++
VO_{2peak} ($mL \cdot min^{-1} \cdot kg^{-1}$)	33.0 ± 7.0	34.6 ± 7.5***	33.8 ± 8.1	37.3 ±8.4***+++
Vo_{2peak} ($mL \cdot min^{-1} \cdot kg^{-0.75}$)	100.3 ± 20.5	105.1 ± 22.0***	100.4 ± 22.8	110.8 ± 23.6***+++
$[La^-]_b$ at VO_{2peak} ($mmol \cdot L^{-1}$)	8.1 ± 1.7	8.7 ± 1.9**	7.3 ± 2.1	8.3 ± 1.8***
HR_{max} ($beat \cdot min^{-1}$)	184 ± 10	185 ± 9	186 ± 13	186 ± 12
VE ($L \cdot min^{-1}$)	93.0 ± 21.9	98.8 ± 24.5***	85.6 ± 22.6	98.1 ± 24.4***++
R	1.05 ± 0.05	1.10 ± 0.05***	1.01 ± 0.05++	1.08 ± 0.04***
C_w - VO_2 ($L \cdot min^{-1}$)	1.34 ± 0.32	1.23 ± 0.29***	1.27 ± 0.30	1.15 ± 0.24***
- VO_2 ($mL \cdot min^{-1} \cdot kg^{-1}$)	15.3 ± 2.1	14.0 ± 1.4***	16.0 ± 2.2	14.4 ± 1.8***
- VO_2 ($mL \cdot min^{-1} \cdot kg^{-0.75}$)	46.5 ± 5.8	42.6 ± 4.5***	47.6 ± 6.9	42.9 ± 5.5***
- HR ($beat \cdot min^{-1}$)	122.6 ± 15.6	112.4 ± 13.3***	127.4 ± 11.8	114.2 ± 12.0***
1RM Leg press (kg)	108.0 ± 37.7	125.8 ± 39.1***	92.9 ± 25.6	127.2 ± 28.0***+++
1RM Leg Press ($kg \cdot m_b^{-0.67}$)	5.3 ± 1.5	6.3 ± 1.5***	5.0 ± 1.3	6.8 ± 1.5***+++

Data presented as mean ±SD. BMI; body mass index, SBP; systolic blood pressure, DBP; diastolic blood pressure, VO_{2peak}; peak oxygen uptake, $[La^-]_b$ at VO_{2peak}; blood lactate at peak oxygen uptake, VE; lung ventilation, R; respiratory exchange ratio, C_w; walking economy at $3km.h^{-1}$ and 5% elevation on a treadmill, 1RM; one-repetition maximum.

*significant from baseline within group p≤0.05; ** p≤ 0.01; *** p≤ 0.001

+significant from MIG at same time point p≤ 0.05; ++ p≤0.01, +++ p≤ 0.001

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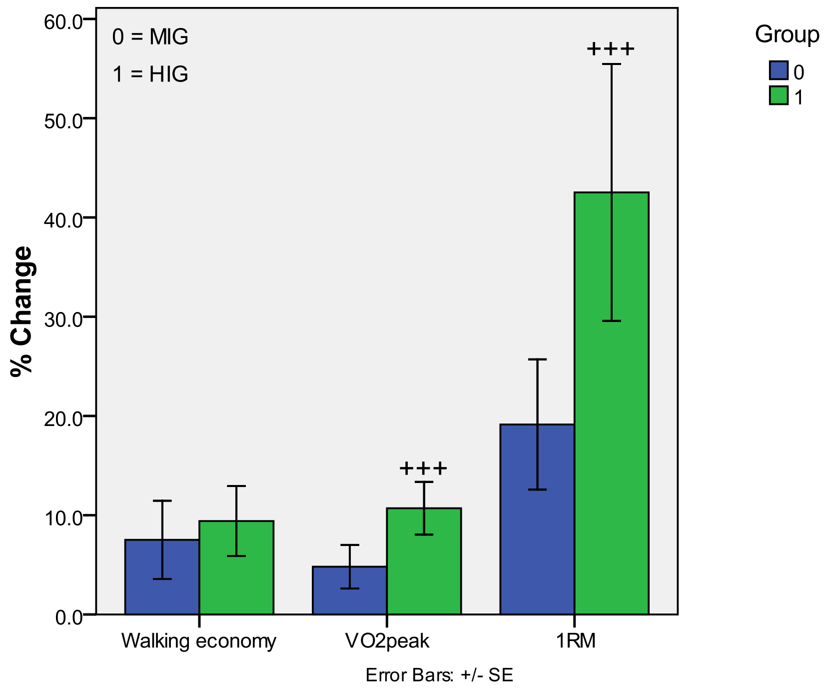

Fig. 2. Error bars are presented as SEM. The y-axis present the mean changes in percent from baseline to 4 wk for; walking economy (C_w) in mL^{-1}·kg·min^{-1}, peak oxygen uptake (VO_{2peak}) in mL·kg^{-1}·min^{-1} and one-repetition maximum (1RM) in kg. +++ significant from MIG at same time point (p <0.001).

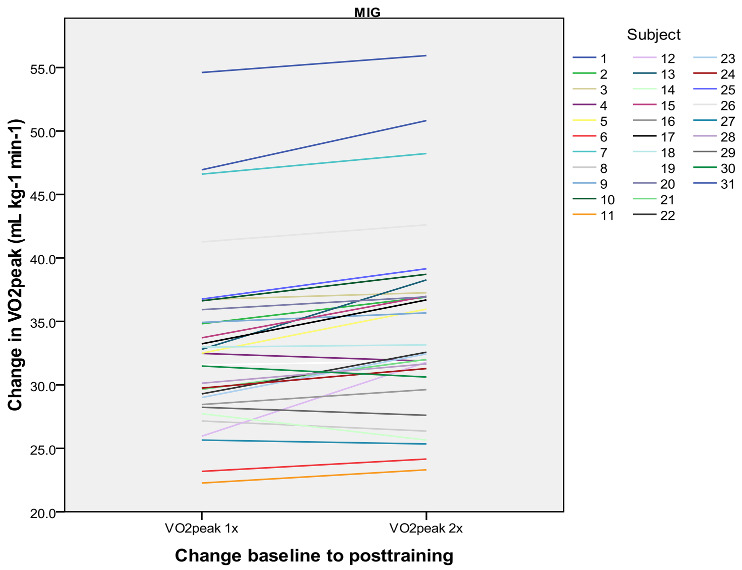

Fig. 3. Individual changes for VO_{2peak} (mL·kg^{-1}·min^{-1}) from baseline to 4 wk MIG

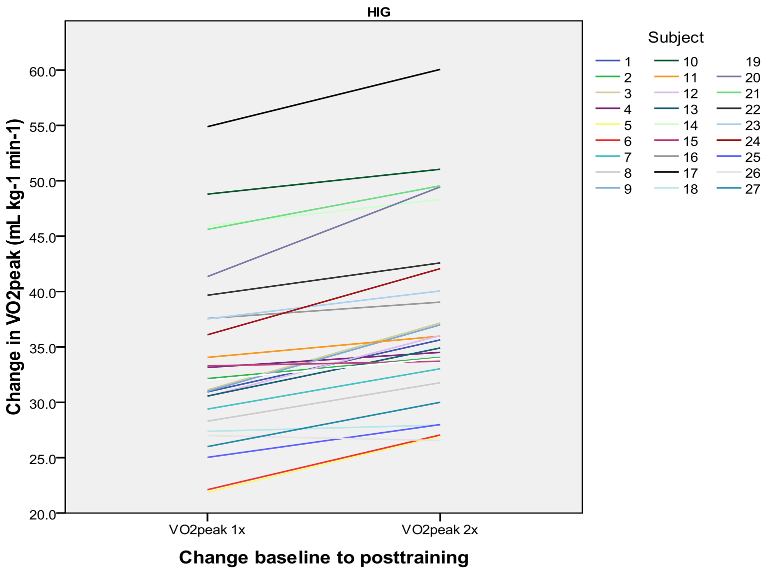

Fig. 4. Individual changes for VO_{2peak} ($mL \cdot kg^{-1} \cdot min^{-1}$) from baseline to 4 wk HIG

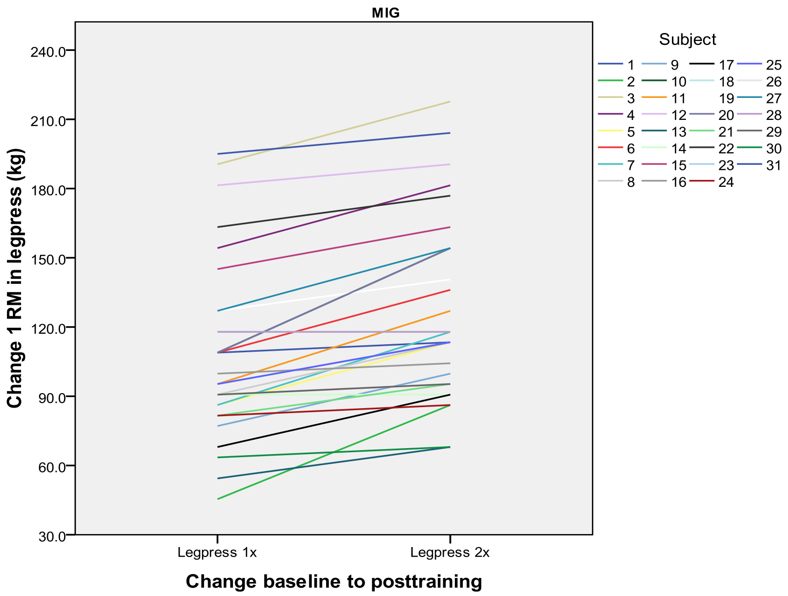

Fig. 5. Individual changes from baseline to 4 wk in 1RM leg press (kg) for MIG

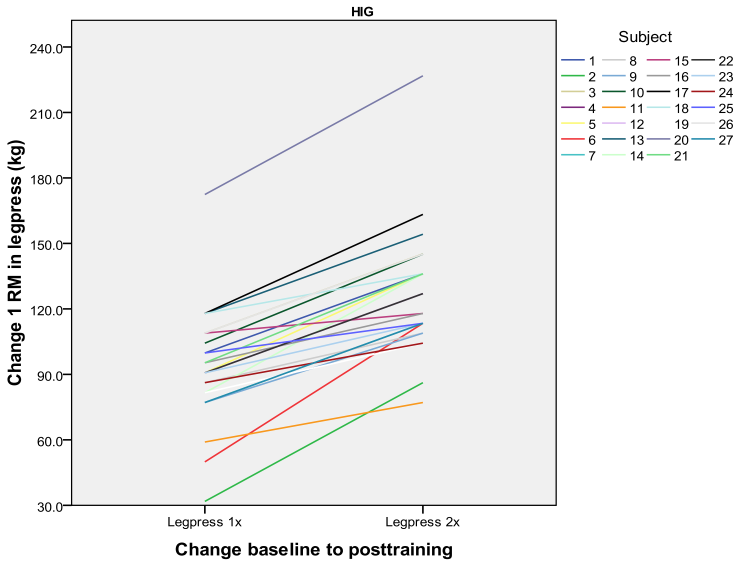

Fig. 6. Individual changes from baseline to 4 wk in 1RM leg press (kg) for HIG

Training intensity

The aim was > 85% HR_{max} during the endurance intervals for HIG, and this was achieved in most of the work outs. Most patients reached around 90% HR_{max} at the end of each interval. The MIG was not in any way only low to moderate training (< 85% HR_{max}). Intensity curves from the five sessions showed that one to two sessions had intensity > 85% HR_{max}. Intensity curves follow below for both groups (Fig. 7-10).

During the intervention, controls showed that the strength training in the MIG, in reality were 8 - 10 repetitions of 1RM, instead of 8 as stated.

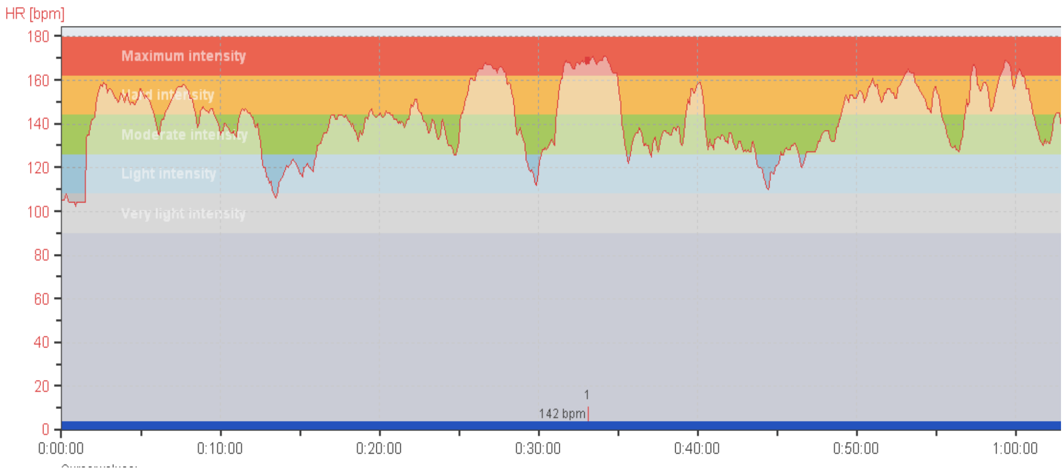

Fig. 7. Game based variable intensity activity inside in a gym, MIG. HR_{max} 195

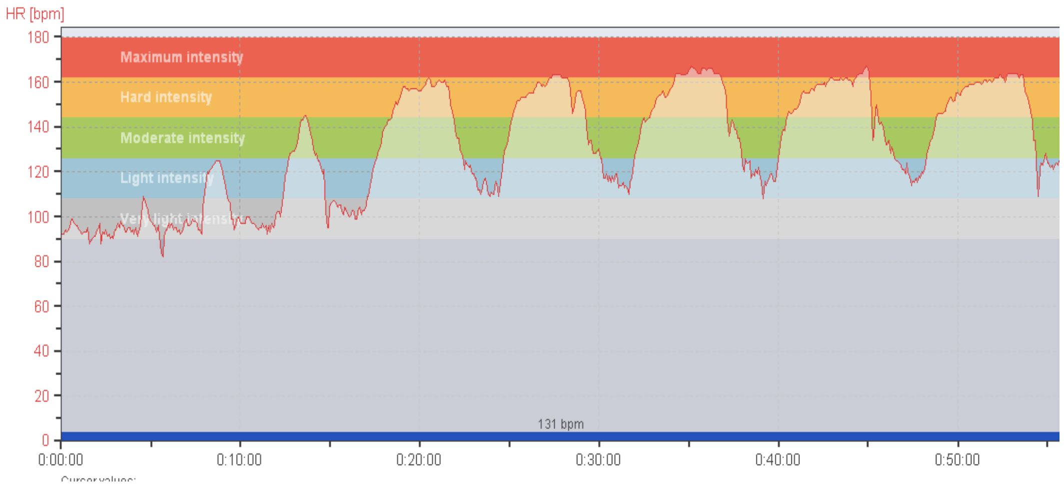

Fig. 8. Spinning (cycling), MIG, high intensity intervals. HR_{max} 190

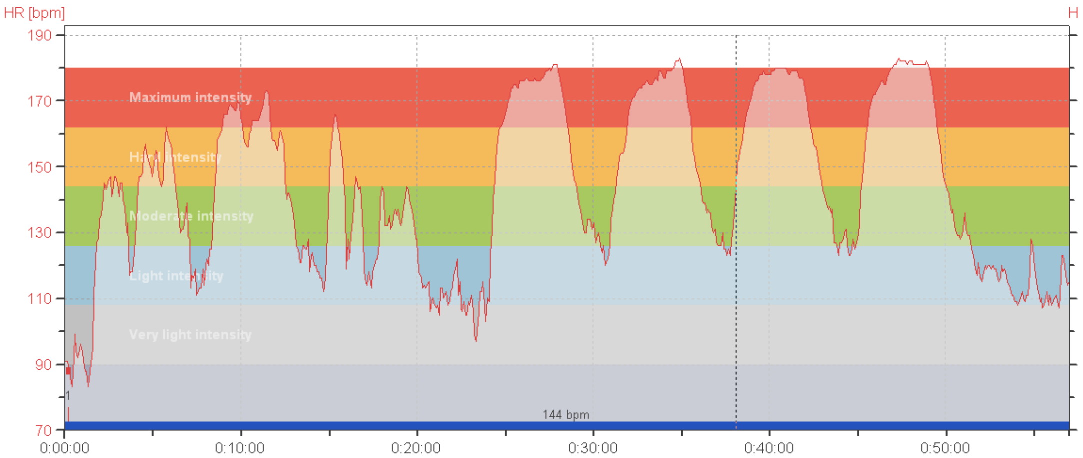

Fig. 9. Game based interval training using a ball dribbling track in HIG. HR_{max} 200

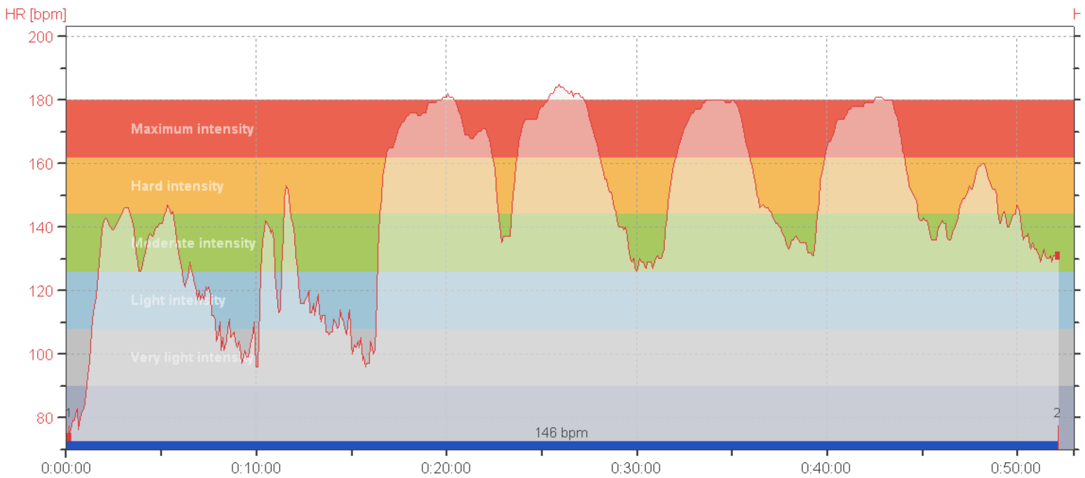

Fig. 10. Nordic walking interval training outside in HIG. HR_{max} 200

Discussion

Patients with MSD often experience reduced physical capacity and pain, leading to impaired ability to work (Ilmarinen 2001). Inactivity often leads to impaired general health and reduced quality of life (Pedersen and Saltin 2006). The main finding in this study was that effective exercise training showed a significant increase in VO_{2peak} and 1RM in both groups after 4 weeks of rehabilitation. However, high intensity training was twice as effective. The increased strength resulted also in improved C_w. The increased strength and endurance are likely to have impact on the MSD patients' daily activities and functional tasks, contributing to an increased quality of life and RTW.

Aerobic training effects on endurance

VO_{2peak} increased twice as much in HIG (10.7%), compared to MIG (4.8%) during intervention (Figure 2, table 2). The 3.5 $mL \cdot kg^{-1} \cdot min^{-1}$ increased VO_{2peak} in HIG could decrease mortality risk by 12%, according to the regression analysis of Myers, Prakash et al. (2002).

No other studies are found that have used systematic high intensity training (> 85% HR_{max}) and at the same time measured VO_{2peak} in a rehabilitation program for patients with MSD aiming for return to work.

Improvement in VO_{2max} in earlier studies ranges from 10-30% depending on quantity and quality of training during a 6-12 month period, also dependent of initial fitness level (Pollock, Gaesser et al. 1998). Since most patients in our study had a low initial fitness level, relatively large improvement could be expected. A very unfit person can get less training effect on VO_{2peak} due to limitations in the oxygen pathway from the atmosphere to the muscle cell mitochondria (Bassett and Howley 2000). Wagner (2000) categorized these limitations to VO_{2max}, into oxygen supply limitations or metabolic capacity limitations. In the initial phase of training this could make it difficult to reach the intensity of training necessary to affect the heart, and thereby reduce the effect on VO_{2peak}. A substantial decrease in HR was observed at a submaximal level (Table 2). A longer rehabilitation period would probably lead to a supply limitation in all patients, as suggested by Helgerud, Wang et al. (2009).

Previous studies of patients having MSD have found increases in VO_{2peak} from nothing up to 21% (Fulcher and White 1997; Hakkinen, Hannonen et al. 2003; Valkeinen, Alen et al. 2008). These interventions had duration of 12 to 21 weeks, with a frequency from 1- 5 days/week and intensity < 85% HR_{max}. All studies used bicycle in testing, but bicycle, walking and swimming during training intervention. A review from Busch, Barber et al. (2007) amongst patients with fibromyalgia, found a 2.8 $mL \cdot kg^{-1} \cdot min^{-1}$ or 12 % increase when walking on treadmill after interventions ranging from 2 ½ to 24 weeks. Compared to these studies the results in the present study seem good, especially for HIG considering it was only a 4 week intervention period. The initial fitness level of 33 $mL \cdot kg^{-1} \cdot min^{-1}$ was below healthy controls (Wang, Haskell et al. 2010). The low initial level may explain some of the increase (Pollock, Gaesser et al. 1998). Results showed that even moderate intensity increased VO_{2peak}, but was only half as effective as our results after high aerobic intensity training.

It is a challenge to compare with VO_{2peak} in MSD patients in other studies, due to the lack of valid measurement procedures and equipment. Most studies use indirect tests for VO_{2max} with a large error of margin ±10-20% (Noonan and Dean 2000). Most commonly used was a submaximal bicycle test (Åstrand/Rhyming) with a margin of error of ±15% (Åstrand and Rodahl 2003p.287). A study with chronic fatigue patients exercising 2 days/week, for 12 weeks in different activities as walking, cycling or swimming improved VO_{2peak} by 9.6% (Wallman, Morton et al. 2004). Wormgoor, Indahl et al. (2008) showed baseline values of VO_{2peak} of 29 $mL \cdot kg^{-1} \cdot min^{-1}$ amongst chronic back pain patients. Exercise training was based on a sports medicine approach with weight bearing activities, i.e. exercise with low intensity and many repetitions, with gradually increased intensity during the training period, aimed to increase aerobic fitness, strength and flexibility. After exercise training 5 days/week, for 3 weeks, an increase in VO_{2peak} of 7.8% to 12.6% was found. A study from Andersen, Kjaer et al. (2008) found a 21 % increase in VO_{2max} after 1 hour/week, for 10 weeks with intensity stated as 50-70 % of predicted VO_{2max}. Even if these studies show large increases, they cannot so easily be compared to our results due to measuring error of margin and specificity.

Published studies on heart patients, comparing moderate intensity (70% HR_{max}) with aerobic high intensity interval training (4x4 min, > 85% HR_{max}) 3 days/ week, for 10 weeks, showed almost the same increases in VO_{2peak} as in the present study (Rognmo, Hetland et al. 2004). They also found that VO_{2peak} increased twice as much in the interval group compared to the moderate intensity group (17.9% vs. 7.9%) after uphill walking on treadmill. They only did uphill walking, which was highly specific to a treadmill exercise test. Our study had different activities. Our training was executed both inside and outside and under different weather conditions. A study from Moholdt, Amundsen et al. (2009), compared aerobic interval training versus continuous moderate exercise after coronary artery bypass surgery, exercising 5 days/week, for 4 weeks at a rehabilitation centre. Their patients increased VO_{2peak} in the same magnitude as in the present study (12.2% and 8.8%).

In the present study, volume and frequency of training were the same in both training groups. The intensity was the only difference in the rehabilitation program. The size of the improvement for HIG in our study may be explained by the use of high aerobic intensity (Helgerud, Hoydal et al. 2007). These findings demonstrated the importance of intensity also in rehabilitation of patients with MSD. It appears to be a universal finding that high aerobic intensity training shows greater responses compared to low and moderate intensity on VO_{2peak}. High aerobic intensity training is well documented to be superior from studies on healthy (Helgerud, Hoydal et al. 2007), cardiac patients (Rognmo, Hetland et al. 2004), metabolic syndrome patients (Tjonna, Lee et al. 2008) and obese adults (Schjerve, Tyldum et al. 2008). However, Moholdt, Amundsen et al. (2009) found no significant differences in VO_{2peak} between interventions with low and high aerobic intensity of coronary bypass surgery patients after 4 weeks of rehabilitation.

The present study found significant change in R and $[La^-]_b$ at VO_{2peak} in both groups from baseline to posttest, with no difference between groups. This may be due to that none of the patients had ever done a maximal exercise test before, and were not used to be exhausted. All subjects have MSD, so pain from the locomotor system and low fitness level can limit the ability to do a maximal test. All patients fulfilled the exercise criteria of R above 1 and $[La^-]_b$ above 7.3 $mmol \cdot L^{-1}$ at baseline.

Strength training effects on maximal strength

1RM in leg press increased twice as much in HIG (42.5%), compared to MIG (19.1%) during intervention (Fig. 2, table 2). The increase in MIG showed that intensity of strength training is high enough to improve 1RM in leg press, but maximal strength training is twice as effective. One explanation of MIG result could be that Hokksund rehabilitation centre was introduced to maximal strength training several years ago. Comparable studies have found small or no changes in strength parameters after traditional training in patients (Hoff, Tjonna et al. 2007; Husby, Helgerud et al. 2009).

A study of patients with rheumatoid arthritis from Hakkinen, Hannonen et al. (2003) found a 25% increase in 1RM in leg press after 21 weeks of training with intensity of 40-80% 1RM. These results are in line with our result from the MIG of 19.1%. The lower initial level of strength may explain the larger increase in patients with rheumatoid arthritis. Alterntively it may be due to the duration of the study (4 versus 21 weeks). This may show that today's rehabilitation in our study is quite effective, especially considering the duration of the intervention. The results from HIG also showed that the rehabilitation can be improved further.

Most studies evaluating muscle strength in patients with MSD are hard to compare with results from the present study. The biggest challenge is the lack of testing of strength. Only pain and self perceived health are evaluated (Hayden, van Tulder et al. 2005). Another challenge when comparing these results is the lack of valid measurement procedures and equipment. Most studies have used isometric testing for muscle strength, but using dynamic training. This will give problems in detecting the change after an intervention (Thorstensson, Hulten et al. 1976), due to the error of margin. Andersen, Kjaer et al. (2008) found an increase of 30% in isometric strength while performing dynamic strength training. A review from Busch, Barber et al. (2007) found no increase in maximal isometric strength after 2 1/2 – 24 weeks of training. Dynamic training was done using 8-12 reps per exercise 2-3 days/week. Fulcher and White (1997) found a 26% increase in maximal isometric strength in the quadriceps muscle after 12 weeks of training in patients with chronic fatigue syndrome. None of these results can easily be compared with our results because of specificity of training and testing.

However the results in the present study can be compared to results from studies in other groups of patients with the same initial fitness level. Studies of obese adults and heart patients ((Schjerve, Tyldum et al. 2008; Karlsen, Helgerud et al. 2009; Wang, Helgerud et al. 2009) found 25-44% increased 1RM using high intensity strength training 85-95% 1RM. The duration of interventions was 8-12 weeks and 3 days /week.

A possible explanation for the great difference in maximal strength seen after rehabilitation in the present study may be because the HIG had one extra supervised strength session, and was closely followed up during the leg press exercise. The aim of MIG was to evaluate the practice of today, so we did not want to change any instructions even if this was observed.

Criticism against maximal strength training is based on increased risk of injury (Pollock, Gaesser et al. 1998; Evans 1999). This risk can be reduced to a minimum, with good progression in load and with qualified instructors and good training equipment. A thorough clinical examination of patients could reduce the risk further. In the present study we had no reported injuries related to training. Compared to the current rehabilitation, we did not have any more drop-outs either. From this we can conclude that this training had no increased risk, and that patients with pain in the locomotor system can do this type of training.

Aerobic endurance training and strength training effects on walking economy

Both groups significantly improved C_w at 3 $km \cdot h^{-1}$ and 5% inclination by 9.4% in HIG and 7.5% in MIG, with no difference observed between the groups. This was followed by a significant decrease in submaximal HR. Improved C_w was to be expected because of the large amount of walking/running carried out during the training program for all patients, low initial level and lack of regular training for most subjects before the study. A better C_w affects performance, either from endurance training (Helgerud, Hoydal et al. 2007) or from maximal strength training (Husby, Helgerud et al. 2009; Wang, Helgerud et al. 2009). Since both groups increased VO_{2peak} and 1RM, the change in C_w was expected.

A study from Valkeinen, Alen et al. (2008) found a 10% increase in maximal workload (W_{max}) using a bicycle and a 13% increase in work time after 21 weeks of endurance and strength training in patients with fibromyalgia. C was not tested, but the improved work time may reflect a better C given that there was a 7% increase in muscle strength in the lower extremities and no change in VO_{2peak}. The present results are in line with results shown earlier for patients doing only endurance training (Slordahl, Wang et al. 2005). These authors found a 14 % increase in C_w for patients with peripheral arterial disease after 3 days/week, for 8 weeks in both groups. Helgerud, Engen et al. (2001) found a 6.7% increase after 2 days/week, in 8 weeks for healthy soccer players.

Practical implications of increased aerobic power and maximal strength

A decreased physical work capacity will affect a person's ability to perform a specific task (Ilmarinen 2001). It has been shown that VO_{2max} is important to stay in work (Karpansalo, Lakka et al. 2003). Low VO_{2max} is inversely associated with increased risk of disability pension due to cardiovascular disease and MSD (Karpansalo, Lakka et al. 2003).

Effective training will probably decrease the consequences of this. Frequency, duration and intensity are important factors in exercise training (Pollock, Gaesser et al. 1998). Traditional exercise therapy in rehabilitation of patients use low to moderate intensity, and often increase the duration and frequency instead of intensity. The present study illustrates the importance of intensity. High intensity is also found to reduce sick leave, while moderate activity does not (Proper, van den Heuvel et al. 2006; Andersen, Frydenberg et al. 2009). Since high intensity training is shown to increase physical work capacity more effectively than traditional training, this should be the way to exercise for both healthy people and patients. Increased VO_{2max} and 1RM will give a person the possibility to perform the same activity as before, but at a lower percentage of her or his VO_{2max} or 1RM. The large increases in physical work capacity as seen in the present study will probably improve general health, quality of life and perhaps prime RTW (Ilmarinen 2001). The present results showed that it is important to use effective exercise training regimes to increase work capacity, and also in the rehabilitation of patients with MSD.

Body weight and blood pressure

Elevated blood pressure is associated with increased risk of stroke and ischemic heart disease (Lewington, Clarke et al. 2002). Both HIG and MIG decreased both SBP and DBP after training. MIG decreased SBP by 6.1 mmHg and DBP by 3.8 mmHg. HIG decreased 6.5 mmHg and 5.7 mmHg. These results are in line with others after aerobic training interventions (Schjerve, Tyldum et al. 2008; Tjonna, Lee et al. 2008), but after longer duration. On the basis of a meta-analysis of 1 million adults, this would translate to a 30% lower risk of premature deaths from stroke and ischemic heart disease (Lewington, Clarke et al. 2002). Getting these effects after only 4 weeks of training seems as a very effective rehabilitation. However, valid measurement of blood pressure demand more than two tests (as we did), but our results does show an interesting tendency for reduced cardiovascular risk.

In the present study, both of the rehabilitation interventions caused small changes in weight. The MIG did not change weight significantly. The HIG group increased weight 0.5 kg and this was significant, but has no clinical importance. Both obesity and aerobic power are strong and independent prognostic markers of cardiovascular mortality, but the link to aerobic power appear to be the strongest (Blair and Brodney 1999). It has therefore been suggested that improving aerobic power is more important than losing weight (Gaesser 1999).

Specificity of exercise testing and training

The specificity of tests should be as close to the activity performed in everyday life as possible, both for athletes, workers and in rehabilitation (McArdle, Katch et al. 2007p.472). This is especially important for patient groups, as e.g. in chronic diseases. A test based upon use of a bicycle will seldom match the needs of everyday life. Studies by Wormgoor, Indahl et al. (2008) and Valkeinen, Alen et al. (2008) are examples of testing on a bicycle, but doing mostly weight bearing training. VO_{2max} is task specific and has been found to be 5-10% lower when biking compared to walking/running (Åstrand and Rodahl 2003p.240; Albouaini, Egred et al. 2007). The use of different activities in testing and training can reduce the exercise training effect, or give trouble visualizing the changes. All exercise testing procedures for aerobic power in the present study are walking/running on the treadmill. Some of the workout sessions used bicycle. Hokksund rehabilitation centre tried to make the aerobic exercise training program as specific as possible, but at the same time many patients with pain in the locomotor system can have trouble doing only weight bearing activities. Uphill walking was also used to reduce the impact on joints and to reduce speed, since most patients do not tolerate high impact landings and running. In the present study, we could have been more cynical and only done activities in weight bearing position. Because the rehabilitation program tries to give positive experiences using different activities to promote more physical activity, this was not done. The strength training of the legs were performed dynamically on the same horizontal leg press apparatus used for the strength testing. This gives a high specificity. Most studies found on patients with MSD use isometric testing, but exercise dynamically. This gives a low specificity, and makes it hard to compare results.

The rehabilitation program

Patients with MSD are a complex and heterogeneous group of people. They often experience a lot of pain from both joints and musculature, and they have often tried lots of treatments and different exercise therapies. Almost all patients presented a diagnosis which one could believe would restrict movement. No patient complained over more pain than usual after high intensity training than regular rehabilitation. Regardless of the group, some people complained over tiredness during and after training.

Of totally 73 patients included in the study, 69 completed rehabilitation (94.5%) and 58 were included in data analysis. There were no more drop-outs in HIG compared to the MIG. Based upon our experience there is no reason to claim that the use of aerobic high intensity interval training (85-95% HR_{max}) or maximal strength training (85-95% 1RM), will give an increased number of drop-outs during training.

This intervention also shows that even if patients have specific diagnoses on an impairment level, almost all could do the training prescribed. Many of these patients came to rehabilitation with a preconception that they could not exercise, or had been told to be careful. After both training and cognitive behavioral therapy, many patients experienced that they were able to do a lot. Hopefully this will lead to increased physical activity after discharge from rehabilitation.

Training intensity control

The use of HR monitors was very educative in training for these patients. Most of the subjects did not have a relationship to intensity in training before rehabilitation. Patients getting their own individualized intensity zone for training experienced a much better control over own practice. Now they could follow their own HR, and feel when it was too easy or too hard. Many patients experienced they had to lower the intensity after using monitors in training. All sessions were stored. This was crucial, so we could follow the intensity for each subject, and make the necessary adjustments as they got fitter. The use of HR monitors was followed by using the Borg RPE (rate of perceived exertion) scale 6-20, whereby interval training should correspond to 15-18 (Wisloff, Stoylen et al. 2007). This gave patients a tool after discharge from rehabilitation, to continue training without having to buy a HR monitor.

Strengths and limitations

One of the strengths in this study was the use of a randomized training intervention controlling for dose- response factors as frequency, duration and intensity of training. To our knowledge we are the first to evaluate this kind of rehabilitation in Norway using high quality test measurements proved to be both valid and reliable in exercise testing. All training sessions were monitored using HR receivers, so every activity could be controlled for real individualized intensity. High specificity in training and tests were used.

This study is limited to physiological aspects as endurance and strength after 4 weeks of rehabilitation. An evaluation of parameters as pain could have been done. Quality of life was tested, but not analyzed. A follow-up could reveal who continue with training after discharge from rehabilitation. RTW would have been interesting to observe, but connecting to the National Insurance Administration and their databases is a complex process.

Further perspectives

The increase in long sick leave is one of the most expensive costs in a modern society affecting a lot of people in Norway and reduces quality of life. To reduce sick leave and to increase RTW is a high priority. It would thus have been interesting to run a study to investigate to what extent a high physical work capacity can predict RTW using valid and reliable test methods.

Conclusion

This study showed significant differences in the training effect on endurance and strength in the two rehabilitation interventions. This study also showed that VO_{2peak} levels found at baseline are below age matched controls. This could affect work capacity negatively.

Our results demonstrate that the current training intervention with moderate training intensity gave significant improvements in VO_{2peak} and 1RM for chronic MSD patients aiming RTW. It also shows that the exercise training can be done much more effectively. The use of controlled high intensity training was twice as effective in improving important health parameters as VO_{2peak} (10.7%) and 1RM (42.5%) in only 4 weeks of rehabilitation. This increase in VO_{2peak} can give a 12% reduction in risk of sudden deaths.

The criticism of more injuries and drop-out using high intensity training cannot be supported from the present study. No injuries related to training or differences regarding drop-outs were reported.

The increases in aerobic power and muscle strength, is likely to impact the ability to perform work at a lower percentage of maximal work capacity. This could reduce sick leave, increase general health, quality of life and perhaps prime RTW.

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