Leg Strengthening in COPD, Two Modalities: - Effects on Muscle Strength, Work Economy and Pulmonary Function

Anita Grongstad
Master of Exercise Physiology/Sport Sciences
Faculty of Medicine
Department of Circulation and Medical Imaging
2009

CONTENTS

ACKNOWLEDGEMENTS

This work would never been carried out if it wasn’t for the encouragement and backing from my superior and boss Agnete Hagelsten Dalelid. All through, you supported me both professionally and privately during the last two years. I am sincerely grateful.

I gratefully acknowledge my supervisor prof. Jan Hoff for support through the study process. You never gave me the answers in the easy way, but guided me through topics which gave me a broader insight in physiology and science, and in that way answering my questions. I also want to thank both prof. Jan Hoff and prof. Jan Helgerud for encouraging us physiotherapists to include “proper” training intensities into clinic – I will take you at your word!

This work was performed at Glittreklinikken, Nittedal. I wish to acknowledge all my colleagues for willingness to cooperate and organize the workday to my account. I want to thank the unit for Respiratory Physiology and Laboratory for goodwill and always finding time to test my subjects, and to Jan Inge, Christine and Liv Karin for being helpful every time I tore my hair because of the Schillers software. A special thank go to dr. philos. Morten Ryg for being my local supervisor - always available and helpful and to Senior BLS and PhD stud. Anne Edvardsen and dr. PhD stud. Aina Kjensli for always having time for my questions and for giving me useful discussions. A special thank to physiotherapist, colleague and friend, Ulla Pedersen, for your critical questions which made me think twice, and your comical comments always cheered me up.

I could never accomplish this master program without the financial grant from Glittreklinikken. This gave me the possibility to be a full time student. I also thank The Norwegian Society of Physiotherapists (NFF) for financial grant.

My sincere thanks go to my family and friends for keeping up with me even if I have been absent-minded during long periods. In particular my cohabitant Jan and our children Tina, Magnus and Ingrid for letting me carry out this master program. I will be delighted to be more present in your lives soon.

Finally, I want to thank all patients who helped me with the study, you all became special to me during 20 sessions with “sweat and tears”! Working with patients has always been meaningful to me, and I`m looking forward being a full time physiotherapist once more.

ABSTRACT

Purpose: Reduced peripheral muscle strength and exercise intolerance accompany chronic obstructive disease (COPD), and inactivity as an important contributor. Exercise training has become mandatory in pulmonary rehabilitation and strength training an important component. Since previous studies of strength training in COPD patients have been performed with different intensities, leg press being almost the only exercise studied, this study was designed to compare two different strength exercises; leg press (LP) and step device (SD) with the same intensities. The outcome measures were effects on muscular strength, work economy and pulmonary function after 4 weeks with maximal strength training. ***Methods:*** Twenty patients with COPD (FEV_1 pred. % = 48±17) were participating in an in-patient, multidisciplinary pulmonary rehabilitation program randomly assigned to LP (n =10) or SD (n =10). Both groups performed four sets with five repetitions five days a week with focus on maximal mobilization in the concentric phase of the movement five days a week. The intensity was adjusted to allow only the performance of five repetitions, corresponding to 85-90% of 1RM. ***Results:*** Both groups showed significant improvement in muscle strength and work economy, LP (19% and 17%) and SD (10% and 18%) respectively after 4 weeks. There was no significant difference between the groups. Neither groups showed significant changes in pulmonary function. ***Conclusion:*** This study reveals the importance of intensity when choosing strength exercises. Both leg press and step device gave improvement in muscle strength and work economy. This gives physiotherapists and COPD patients the possibility to improve and maintain muscle strength independently of available equipment, as long as intensity corresponds to 85-90 % of 1RM.

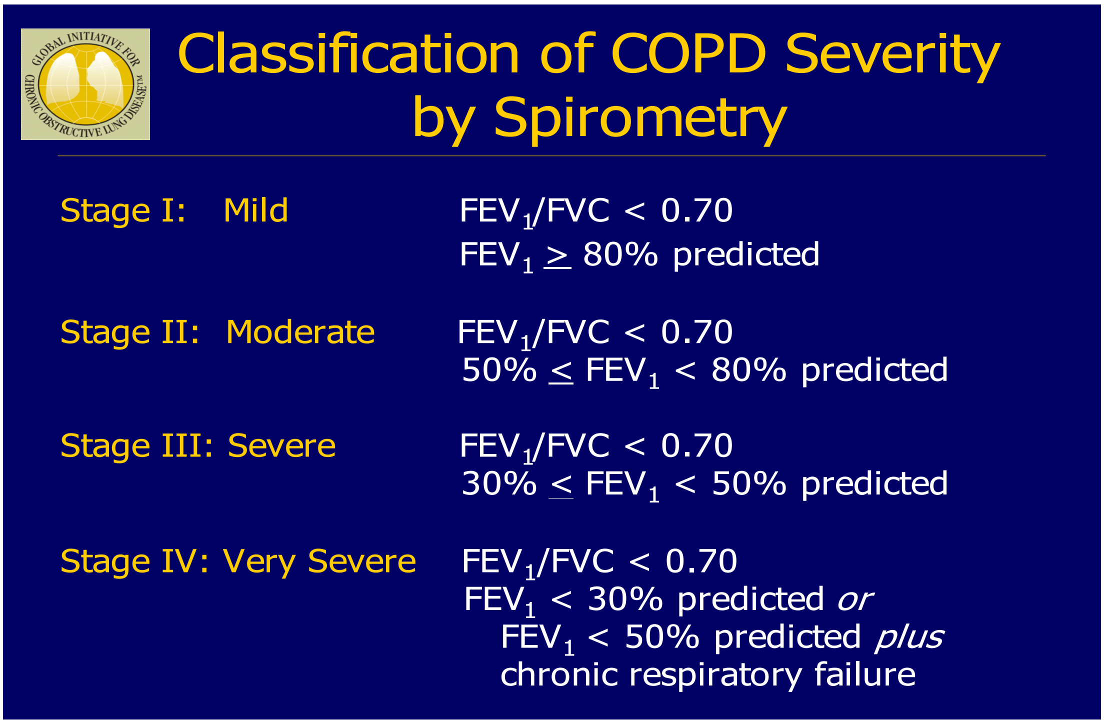
1. INTRODUCTION

1.1 Background

Pulmonary diseases are increasingly important causes of morbidity and mortality in the modern world. Chronic obstructive pulmonary disease (COPD) is the most common chronic lung disease, and is a major cause of lung-related death and disability. According to WHO 210 million people have COPD worldwide and more than 3 million people died of COPD in 2005 (WHO 2007). The latest definition on COPD is: "Chronic obstructive pulmonary disease (COPD) is a preventable and treatable disease with some significant extrapulmonary effects that may contribute to the severity in individual patients. Its pulmonary component is characterized by airflow limitation that is not fully reversible. The airflow limitation is usually progressive and associated with an abnormal inflammatory response of the lung to noxious particles or gases" (Rabe, Hurd et al. 2007). COPD develops insidiously over decades and because of the large reserve in lung function there is a long preclinical period. Symptoms as chronic cough and sputum production may precede the development of airflow limitation by many years, thus affected persons in an early stage may have few symptoms and many are undiagnosed until a relatively advanced stage of the disease (Rabe, Hurd et al. 2007).

COPD is defined on the basis of airflow limitation and spirometry is essential for diagnosis. The measurements are evaluated by comparison with reference values based on the subject's age, sex, race and height (Pellegrino, Viegi et al. 2005). ATS/ERS recommend using The Global Initiative for Chronic Obstructive Lung Disease (GOLD) guidelines to set universal standards in the prevention, diagnosis, and management of patients with COPD (GOLD 2008 Updated). The classification of COPD severity is categorized in four stages based on post-bronchodilator $FEV_{1.}$ The presence of airflow limitation is defined by a post-bronchodilator $FEV_1/FVC < 0.70$ *(Figure 1)*. Even if the diagnosis is confirmed by spirometry, it is important to note that the clinical diagnosis of COPD should be considered when a patient has a history of exposure to risk factors and/or dyspnea, chronic cough or sputum production (Rabe, Hurd et al. 2007).

***Figure 1.* -** GOLD-stage classification of COPD severity based on post-bronchodilator values of FEV_1 and FVC.



Classification of COPD Severity by Spirometry

Stage I: Mild	$FEV_1/FVC < 0.70$ $FEV_1 \geq 80\%$ predicted
Stage II: Moderate	$FEV_1/FVC < 0.70$ $50\% \leq FEV_1 < 80\%$ predicted
Stage III: Severe	$FEV_1/FVC < 0.70$ $30\% \leq FEV_1 < 50\%$ predicted
Stage IV: Very Severe	$FEV_1/FVC < 0.70$ $FEV_1 < 30\%$ predicted *or* $FEV_1 < 50\%$ predicted *plus* chronic respiratory failure

FEV_1, forced expiratory volume in one second; FVC, forced vital capacity

1.2 Symptoms

Dyspnea and chronic cough are well-known symptoms in COPD and the reason most patients seek medical attention. Patients with COPD show poor exercise performance, and exercise intolerance is one of the main factors limiting participation in activities of daily life (Nici, Donner et al. 2006). Peripheral muscle dysfunction is a well recognized disabling feature of COPD, and the target muscle of investigation has been quadriceps femoris. The quadriceps muscle is of interest because of the significant correlation between quadriceps strength and both FEV_1 and exercise capacity (Bernard, LeBlanc et al. 1998). There are evidence pointing at reduced physical activity as an important contributor to the muscle weakness because lower limb muscle strength and exercise intolerance are common features, not only in COPD patients, but among several other patients groups as well as in elderly subjects, all with reduced level of activity as a common component (Rantanen, Guralnik et al. 1999; Hoydal, Helgerud et al. 2007).

2. COPD AND TREATMENT

2.1 Exercise training

The overall management of COPD is, in addition to reduce risk factors and relief symptoms, to improve exercise capacity, health status and patients' quality of life. Smoking cessation is the most important action (Ries, Bauldoff et al. 2007). Studies reveal that the ability to improve lung function pharmacologically in patients with COPD is quite limited (Rabe, Hurd et al. 2007) while several studies have shown that physical exercise reverses COPD induced skeletal muscle dysfunctions and improve exercise tolerance, reduce dyspnea and substantially improve quality of life (Nici, Donner et al. 2006). A study comparing patients with COPD, diabetes and healthy subjects showed that subjects with COPD had the lowest level of physical activity, i.e 84% of the patients had an activity level too low to maintain good health (Arne, Janson et al. 2009). Pitta and Troosters et al. (2006) saw a reduction in physical activity after admission with acute exacerbation in COPD patients with a mean walking time of 6–7 $\text{min}\cdot\text{day}^{-1}$ and fails to recover even 1 year after to levels observed in stable outpatients with equally severe COPD. The duration of the rehabilitative exercise programs is much discussed and the evidence is clear that longer duration have better long-terms effect compared with short-term (Troosters, Gosselink et al. 2000), while the number of training sessions have an effect on strength improvement, and near daily training has shown less effect than 2-3 sessions a weeks (McArdle, Katch et al. 2007, p.523). Another challenge for COPD patients is to maintain the effects from a rehabilitation program. Home-based exercise training studies have not shown convenience evidence; McMurdo and Johnstone (1995) followed 69 elderly people in 6 month. There was a trend toward improvement, but not significantly. This is supported by Emery and Shermer (2003), who showed that the gains achieved during a 10 week pulmonary program were maintained in only 39% of the COPD patients after 1 year. There are few studies including muscle strength as an outcome in home-based training studies for COPD patients, and further work is required to identify the optimal strength exercise in a home-based training program.

The challenge for a physiotherapist working with COPD patients is to design training programs that is not limited by respiratory impairments before achieving physiological adaptations. Bjorgen et al. (2009) revealed that COPD patients cycling by using one leg at 85-95% of peak heart rate, increased significant whole body VO_2peak and peak work rate. This shows that COPD patients have great advance of exercising with reduced muscle mass, which should indicate muscle strength training being an effective method for this patient group.

Muscle strength training

Maximal strength training has not been common in rehabilitation, especially not in training for elderly people even if several studies show good indications for doing it. The increase in muscle strength is greater when higher loads are used. McDonagh and Davies (1984) stated that loads lower than 66% of one repetition maximum (1RM) confirmed no increase in muscle strength, while loads higher than 66% with few repetitions gave significant improvement, giving indication of the recommend intensity. Of clinical importance is the finding of Swallow and coworkers (2007), showing that a reduction in quadriceps strength is a better predictor for survival amongst patients with advanced COPD than the spirometric value FEV_1. A recent study by Leite Rodrigues et al. (2009) support the importance of quadriceps muscle strength, revealing that muscle strength in quadriceps is the only variable among FEV_1 and PaO_2 that can predict the distance COPD patients walk in 6 minutes, 6 minutes walking distance (6MWD). The effects of strength training in COPD patients is well documented; Dourado et al. (2009) revealed 58% improvement in muscle strength after 12 weeks, while Simpson (1992) and Hoff et al. (2007) showed changes of 16% and 27% respectively, in muscle strength after 8 weeks of strength training. The evidence of the effects after home-based training in COPD patients is weak (McMurdo and Johnstone 1995; Emery, Shermer et al. 2003). Because the long-term effects after pulmonary rehabilitation decline after 1 year, it is important to find exercises which easily can be followed up by the patients.

There are two mechanisms for developing muscular strength; hypertrophy and neural adaptation. Hypertrophic training put emphasis on execution changes from slow to fast, and the eccentric phase is particularly slow. 8 to 12 repetitions with submaximal resistance in series are recommended. Increased strength is associated with a large increase in the myofibril content of fibers caused by the connection between cross-sectional area of the muscle and its potential for force development (Tesch 1982; McArdle, Katch et al. 2007). Neural adaptation is a broad description involving a number of factors. To develop maximal force a muscle is dependent on as many active motor units as possible, and to activate the fast-twitch motor units which develop the highest force. To activate as many motor units as possible and to train the fastest motor units, Behm and Sale (1993) suggested to work against high loads (85-90% of 1RM) with rapid action, supported by Schmidtbleicher (1992) saying few repetitions (3-7) and explosive movements in concentric phase which would be the most effective way to increase muscle strength by improving the rate of force development (RFD). Rutherford (1988) reveal that the ability to coordinate other muscle groups involved in the movement is a large part of the improvement of muscle strength.

Studies with focus on neural adaptations, few repetitions and high load showed significant improvements in muscle strength (Hoff, Tjonna et al. 2007) compared with studies using lower intensities and more repetitions (Simpson, Killian et al. 1992). This indicates that strength training with focus on neural adaptations and few repetitions seems to suit COPD patients well without loading the ventilatory system and gaining good effects.

To improve endurance capacity Pate and Kriska (1984) described three major factors determining success; VO_{2max}, anaerobic threshold and work economy. Because COPD patients are ventilatory limitated they will not be able to stress the VO_{2max} and in that way improve endurance capacity. Maximal strength training has shown to give improvement in endurance capacity by improving the work economy, and might be a more suited method for COPD patients to improve exercise intolerance. Work economy is defined as the ratio of work output to oxygen cost and is commonly defined as the steady-state VO2 in $mL \cdot kg^{-1} \cdot min^{-1}$ at a standard velocity, in terms of running or walking economy (Hoff 2002). The improved work economy seems to be a result of improved RFD. In a study by Hoff, Gran et al. (2002) cross-country skiers showed improved work economy after maximal strength training were the improvement in RFD was greater than 1RM (Hoff, Tjonna et al. 2007). The average-age in COPD patients participating in a rehabilitation program at Glittreklinikken in Norway is 65 years. In consideration to the age-related loss of muscle strength and the knowledge of average-age in COPD patients participating in rehabilitation programs, it is important to note that the ability to develop rapid muscle power declines more rapidly than does maximal muscle strength (Bassey, Fiatarone et al. 1992). The ability to develop a rapid increase in RFD is important to prevent a fall, and several studies have shown that elderly fallers have a low RFD compared with non-fallers (Fleming, Wilson et al. 1991; Aagaard, Simonsen et al. 2002). This indicates the importance to emphasis on maximal mobilization of force in the concentric movement when training elderly and COPD patient.

The transformed effect from increased muscle strength into functional endurance capacity is not well documented. Simpson, Killian et al. (1992), Skumlien, Skogedal et al. (2007) and Dourado et al. (2009) all showed significant improvement in muscle strength without significant changes in 6MWD, while Spruit, Gosselink et al. (2002) showed significant improvement in 6MWD after strength training. The shortages of evidence in supervised studies are in line with other home-based strength training studies were only small effects on muscle strength and endurance performance are revealed (McMurdo and Johnstone 1995; Emery, Shermer et al. 2003). Further studies are required to give convincing evidence of the impact of strength training on endurance capacity.

Furthermore, it seems hard to find appropriated exercises which can improve and/or maintain muscle strength in self-monitored training, which is very important because most of the COPD patients are not following a supervised pulmonary rehabilitation program.

The FEV_1-value is widely regarded as the most common value describing the severity of COPD, and both patients and professionals are familiar to $FEV_{1.}$ Most of the studies including interventions in COPD patients have FEV_1 as an outcome measure, but the significance of this value is still no clear. In the review by O'Shea, Taylor et al. (2004), no change in respiratory function did appear after strength training. These findings are in line with other studies; Skumlien, Skogedal et al. (2007) showed a change of 8% in FEV_1 after 4 weeks of strength training while Simpson, Killian et al. (1992) got the same change after 8 weeks. Thus, it was very sensational when Hoff, Tjønna et al. (2007) revealed a significant improvement in FEV_1 of 22% after 8 weeks of maximal strength training. The finding in the latter study makes it necessary to have FEV_1 as an outcome measure in further experiments.

Actually, few COPD patients are participating in rehabilitation programs, and studies with home-based strength training programs are using low intensities and show smaller effects, while studies using a seated leg press with high intensities reveal to be effective. Therefore, it is important to find exercises which might give the same increase in muscle strength as seated leg press, but without special equipments. Current studies have shown conclusive evidence that maximal strength training with few repetitions improve muscle strength in COPD patients, but the influence on other parameters like work economy and pulmonary function are not well documented. The aim of this study was to compare two different strength exercises for the muscles of ambulation to investigate whether the effects on muscle strength would be the same for both interventions, and to see if the improved muscle strength will enhance work economy and pulmonary function. Following hypotheses were tested: 1) COPD patients performing maximal strength training in a seated leg press and on a step device will improve muscle strength after 4 weeks; 2) Improvements in muscle strength will directly translate into improved work economy, measured during a standard workload on a treadmill; 3) The parallel training effects on respiratory muscles during maximal strength training will improve pulmonary function, measured by FEV_1.

3. MATERIALE AND METHODS

3.1 Setting

The study was performed at Glittreklinikken, Nittedal, Norway between January and Mai 2009. Glittreklinikken is a hospital for diagnosis, treatment and rehabilitation for persons with lung disease. Patients attend a four week in-clinic interdisciplinary program, consisting of medical diagnosis, treatment, training and education. There are 96 patient rooms distributed over six units and about 50% of the patients have been there more than one time, 65 % of all patients hospitalized at Glittreklinikken have the diagnosis COPD and the average age of the patients is 65 years.

3.2 Subject characteristics

In total, 24 patients were included in the study, 12 in leg press (LP) and 12 in step device (SD). All the subjects were recruited at the first day they arrived to Glittreklinikken. Inclusions criteria were a clinical definition of COPD according to GOLD guidelines (Celli and MacNee 2004), $FEV_1/FVC < 0.70$ and $FEV_1 \leq 80$ % of predicted and ability to perform a seated leg press exercise and a step device exercise. Exclusion criteria were smokers or other lung diseases combined with COPD. Two subjects in each group dropped out. In LP one subject had a FEV_1 value > 80 % predicted, were the spirometric results was received the third day of his stay and after inclusions tests were performed. The second fell in the canteen and impaired her ankle two weeks after start, and was not able to perform any exercise for a week. Two subjects in SD got exacerbations on their last days of the 4 weeks and could not be tested before leaving. The subjects were randomly assigned to LP or SD by drawing a lot. Randomization within genders facilitated groups that were balanced for gender (four females in both groups). Medication was monitored and seven in the LP group and six in the SD group adjusted their medication during the 4-weeks. The baseline characteristics of the subjects are presented in *Table 1.*

Table 1 – Baseline characteristics

	Leg Press n = 10		Step Device n = 10	
Age (yr)	65.2	(± 8.7)	69.9	(± 6.2)
Height (cm)	173.4	(± 8.7)	170.3	(± 5.6)
Body mass (kg)	76.9	(± 18.6)	75.6	(± 12.5)
BMI (kg ·m ^{2})	25.2	(± 4.7)	26.0	(± 3.5)
FEV$_1$ (L)	1.38	(± 0.75)	1.31	(± 0.5)
predicted %	45.6	(± 19.1)	49.7	(± 15.9)
FVC (L)	2.76	(± 1.0)	2.58	(± 0.5)
predicted %	74	(± 16.7)	79.3	(± 18.6)
FEV$_1$/ FVC (%)	47.5	(± 10.9)	50.2	(± 15.3)

Data are presented as mean (± SD); BMI, body mass index; FEV$_1$ forced expiratory volume in one second; FVC, forced vital capacity; No significant differences between groups (p>0.05).

3.3 Testing procedures and apparatus

Pre- and posttests were performed with identical protocols.

Maximal strength

Maximal muscle strength was measured dynamic using 1RM, "refers to the maximum amount of loads lifted *one time* during a standard weight-lifting exercise" (McArdle, Katch et al. 2007), s. 511. 1RM had to be measured on two different horizontal leg press apparatus, Selection (Techno Gym, Italy) shown in *figure 2* and Legpress 190849, Steens Physical, Steens Industrier, Ski, Norway), because the Selection apparatus was brand new and had to be adjusted by a serviceman from Techno Gym for two days when 4 subjects arrived and had to be tested. The 4 subjects, 2 in LP and 2 in SD, continued on the Legpress from Steens Industrier during the study, including 1RM tests and training sessions for LP. They performed the 1RM test with a knee angle of 90°. All subjects performed the 1RM test twice on two following days due to the learning effect, validated through a pilot work. The first trial was performed after the work economy test where the subjects had walked on a treadmill for five minutes. Before the second trial they warmed up walking on a treadmill for 5 minutes with a speed corresponding to their habitual walking speed. The 1RM test started after 2 - 4 minutes rest. The first attempt was adjusted by the test leader to be around 70 % of the assumed maximal strength or around the subjects' bodyweight. The load was increased until 1RM was achieved, 2 minutes rest between each attempt and maximum five to six attempts were performed.

Figure 2. – Illustrating a 1RM test on the Selection apparatus.

Work economy

Work economy was tested as a constant load test on a treadmill (Jaeger LE2000CE). From an initial pilot work, a walking speed that was equivalent to 40 Watt (W) work rate was tested. Because 40 W was corresponding to maximal work rate for some of the subjects, and a workload they could maintain for 5 minutes was chosen. The mean W was 25 (±12). The work economy was determined by measuring the steady state consumption of oxygen (VO_2), using the mean VO_2 -values noted after 4:40, 4:50 and 5:00 minutes measured as $mL \cdot min^{-1}$. To measure the oxygen consumption, an Oxycon Pro. Apparatus (Jaeger, Wûrtzburg, Germany) was validated initially in a pilot test. Unfortunately, after testing the first six subjects, the Oxycon Pro had to be delivered for service. Therefore the rest of the pre- and posttests had to be performed by using Schiller CS-200 (Schiller, Baar, Switzerland) (*Figure 3* and *figure 4*). To be aware of the differences between the two apparatus test-values from measurements taken routinely of the staff working at the respiratory physiology laboratory were used. Four tests were performed between January and Mai 2009. Standardized procedures with randomization between the apparatus each time were followed and the same person walked at different speeds for 5 minutes on both Oxycon and Schiller at the same day. The test at 4.8 km/t was chosen because it corresponded closest to the tests performed by the subjects in this study, revealed mL-values in mean (±SD) for Oxycon at 856.25 (± 29.83) and Schiller CS-200 1057.75 (± 146.15). A non-parametric Wilcoxon Signed Rank test showed no significant difference between the apparatus, p= 0.068. Prior to all tests, a manual of calibrating was followed from the producer.

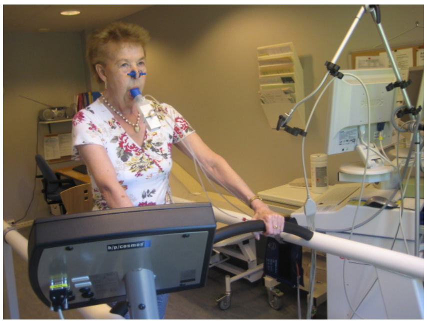


Figure 3. - Work economy test performed on a Schiller CS-200.

Figure 4. – The treadmill and Schiller CS-200 apparatus.

Walking capacity

Six-minutes walking test (6MWT) is routinely performed by all patients at income and at the end of the rehabilitation program at Glittreklinikken (ATS 2002). 1st day, the test was performed twice and 6MWD was recorded from the test with the longest distance. The 6MWT performed after 4-weeks were done as a single test. 6MWT is accomplished by nurses or auxiliary nurses at the unit were the patients belong.

Pulmonary function tests

All patients perform lung function tests as part of the income-routine in the rehabilitation program at Glittreklinikken, and the subjects in this study performed a new lung function test after 4-weeks. Forced expiratory volume in 1 second (FEV_1) and forced vital capacity (FVC) were measured, and FEV_1/FVC ratio calculated. The pulmonary function tests were accomplished by the staff at the unit of Respiratory Laboratory and the equipment used for all tests were Jaeger Master Screen (Jaeger, Würzburg, Germany). The tests were performed according to the standardization criteria from the American Thoracic Society (ATS) and European Respiratory Society (ERS) (Miller, Hankinson et al. 2005).

3.4 Scaling

Scaling is a mathematical procedure to establish a proper relationship between a body size variable and factors like endurance capacity or muscle strength (McArdle, Katch et al. 2007, p. 517). When comparing both muscle strength and work economy at submaximal exercise, heavier subjects will be overestimated and the lighter subjects underestimated (Hoff 2002). A unit of $mL\cdot kg^{0.75}\cdot min^{-1}$ has shown to be convenient when comparing subjects with different body mass in endurance exercises (Helgerud 1994), while body mass raised to the power of 0.67 is more indicative when comparing strength performance, expressed $kg\cdot m_b^{-0.67}$ (Wisloff, Helgerud et al. 1998).

3.5 Training intervention

Both LP and SD performed a four weeks training regime, a total of 20 training sessions. Each session consisted of four sets of five repetitions with a focus on maximal mobilization in the concentric movement. Both groups did five minutes light warm up on a treadmill before the training session. The LP group performed all strength training on the same seated leg press machine they used during 1RM testing with loads corresponding to 85-90% of 1RM. The subjects were instructed to stop the eccentric movement at an angle of 90° in knees, a full stop before emphasis on maximal mobilization to straight legs. When the subject was able to perform more than five repetitions in a set, load was increased by 5 kg until five repetitions were the maximal repetitions being achieved. Some subjects needed a rest between some of the repetitions, which was determined individually dependent on ventilation limitations. All subjects rested for 2 minutes between each set. The SD group performed a strength exercise by using a metal step device (Steens Industrier, Ski, Norway), where the height of the step could be altered up and down (*Figure 5*). The training was performed standing on a step with one leg, performing a backward step down until the tiptoe of the other leg touched the floor. Then full stop without letting the tiptoe leg take any bodyweight before maximal concentric movement to straight leg using the muscles of the leg standing on the step. The step device was placed in front of a naked wall to avoid the possibility to use the arms to grab and drag up (*Figure 6*). The height of the step was adjusted up until the subjects managed to perform maximum five repetitions. Five repetitions with one minute rest before changing leg. Two minutes rest between each set. All the strength training sessions in both groups were supervised to ensure enough loads/height and correct execution. As participant in a rehabilitation program the subjects took part in other activities during the four weeks, including gymnastics in groups, individual training programs on treadmills and strength training programs for upper body.

Figure 5. – The step device.

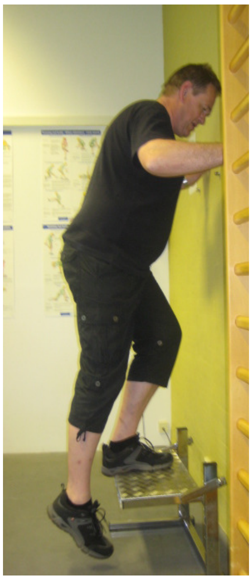


Figure 6. – Illustrating a backward step in front of a naked wall.

3.6 Statistical analysis

The software program SPSS 16.0 was used to do the statistical analyses and construct the figures and tables. The main outcomes; strength, walking economy and lung function were measured twice and characterized as repeated measurements. There are several techniques that can be used to test the difference between groups. Due to the low number of subjects, a nonparametric test was adopted for the statistical analyses. A Wilcoxon Signed Rank test was used to analyze the changes within the groups from pre- to posttest. Delta values (i.e. the difference from pre- to posttest) was calculated and used in a Mann-Whitney U test to analyze the changes from pre- to posttest between groups.

Non-parametric tests use median and range values as measures of central tendency, but in order to compare the results with other studies the parameters presented are as mean and standard deviation. A p-value of less than 0.05 was considered to be statistically significant. Relationship between variables were assessed with Spearman`s Rank Order Correlation in order of being a non-parametric.

4. RESULTS

Baseline values as age, physical characteristics and pulmonary function reveal no significant difference between the LP group and SD group. Neither group experienced a significant change in body weight during the 4 week period. Both groups completed the study protocol without any adversity, and the LP and SD completed 97% and 97.5%, respectively of the planned 20 sessions.

4.1 Exercise data

Muscle strength

4 weeks of maximal strength training were significantly associated with increased muscle strength in both LP ($p< 0.005$) and SD ($p<0.05$). 1RM increased by 26.5 kg (19%) in LP and 13.5 kg (10%) in SD. There was no significant difference between the groups ($p>0.05$). (*Table 2, Figure 7*).

Table 2. – Alterations in strength parameters measured before and after 4 weeks of training.

	Leg Press group **n = 10**		**Step Device group** **n = 10**	
	Pre	Post	Pre	Post
Body mass (kg)	76.9 ± 18.6	77.3 ± 18.9	75.6 ± 12.5	5.6 ± 12.4
1RM (kg)	142.5 ± 56.4	169.0 ± 60.3 **	127.0 ± 45.0	140.5 ± 50.8*
1RM (kg · $m_b^{-0.67}$)	7.59 ± 2.05	9.00 ± 2.04 **	6.95 ± 2.16	7.70 ± 2.51*

Data are presented as mean ± SD. 1RM, one-repetition maximum with a knee angle at 90°; m_b, bodyweight.. Significant difference before and after training within group (* $p<0.05$, ** $p< 0.005$). No significant difference between groups ($p>0.05$)

Work economy

Both groups significantly improved their work economy during a steady state treadmill test with a reduction in oxygen consume in liters of 0.16 $L·min^{-1}$in both LP and SD, 17% and 18% reduction respectively ($p<0.005$).There was no significant difference between groups (*Table 3, Figure 7*).

Table 3 – Physiological responses to a steady state treadmill exercise test after 4 weeks maximal strength training

	Leg Press Group n = 10		**Step Device group** n = 10	
	Pre	Post	Pre	Post
VO_2 ($L \cdot min^{-1}$)	1.12 ± 0.34	0.96 ± 0.26**	1.03 ± 0.36	0.87 ± 0.20**
VO_2 ($mL \cdot kg^{-1} \cdot min^{-1}$)	14.3 ± 1.8	12.5 ± 1.7**	13.6 ± 3.3	11.5 ± 2.0**
VO_2 ($mL \cdot kg^{0.75} \cdot min^{-1}$)	42.6 ± 6.5	36.9 ± 5.5*	39.9 ± 11.2	34.0 ± 5.9*

Data are presented as mean (± SD). VO_2, Oxygen uptake. Significantly difference before and after training for both groups (* $p<0.05$; ** $p< 0.005$). No significantly difference between groups ($p >0.05$).

Walking capacity

Only 10 subjects were included in the results of the 6MWT, LP n = 6 and SD n = 4. Four subjects, two from each group had to be excluded because they performed 6MWT with supplementary oxygen at posttest. One in SD had an exacerbation at posttest which influenced the 6MWT by decreasing the distance with 150 m. and was excluded, and three subjects in SD whilst two in LP did not perform the posttest. LP had a significant improvement in 6MWD with 85 meters (19%) $p<0.05$, while SD improved 6MWD with 14 meter (3%) which was not significant. No significant difference between groups (*Table 4, Figure 7*).

Table 4. – Changes in distance walked in 6MWD after 4 weeks of maximal strength training.

	Leg Press group n = 6		**Step Device group** n= 4	
	Pre	Post	Pre	Post
6MWD, m	457 ± 97	542 ± 66*	444 ±74	457 ± 38

Data are presented as mean (± SD). M, meter, Significant difference within LP after 4 weeks (*$p<0.05$).

Pulmonary function

There were no significant changes within the groups or between the groups. FEV_1 increased with 0.12 L (8%) in LP and 0.01 L (0.7%) in SD. FVC increased with 0.13 L (5%) in LP and 0.09 L (4%) in SD 2.9% of predicted (4%). FEV_1/ FVC % increased by 5 % for both LP and SD with 2.2% and 2.7% respectively (*Table 5, Figure 7*).

Table 5 - Spirometric responses to 4 weeks training at the leg press machine and the step device.

	Leg Press group		**Step Device group**	
	n = 10		**n = 10**	
	Pre	Post	Pre	Post
FEV$_1$ (L)	1.37 ± 0.75	1.49 ± 0.75	1.31 ± 0.5	1.32 ± 0.5
Predicted %	45.6 ± 19.1	49.2 ±18.7	49.7 ± 15.9	50.1 ± 17.1
FVC (L)	2.76 ± 1.0	2.89 ± 1.02	2.58 ± 0.5	2.49 ± 0.7
Predicted %	74 ± 16.7	77.4 ± 20.5	79.3 ± 18.6	76.4 ± 23.4
FEV$_1$/ FVC (%)	47.5 ± 10.9	49.7 ± 9.2	50.2 ± 15	52.9 ± 15.6

Data are presented as mean (± SD). FEV$_1$, forced expiratory volume in one second; FVC, forced vital capacity. No significant differences within groups or between groups before and after training (p>0.05).

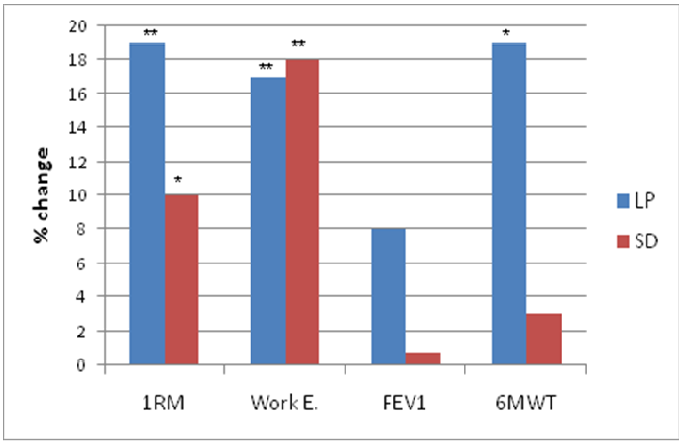


Figure 7.- The percent change in maximal strength (1RM), work economy (Work E.), six minutes walking test (6MWT) and pulmonary function (FEV$_1$) after 4 weeks of maximal strength training for the leg press group (LP) and the step device group (SD). *Significant difference between pre- and posttest ($p < 0.05$); ** ($p < 0.005$).

4.2 Correlation analyses

At baseline there was a significant correlation between FEV$_1$ and 1RM ($r = 0.66$) and VO$_2$ ($r = 0.78$), and between 1RM and VO$_2$ ($r = 0.81$) for all subjects (n=20). In LP the improvement in VO$_2$ correlated significantly with both improvement in 1RM ($r = 0.73$) and FEV$_1$ ($r = 0.70$). The correlation was significant at the 0.05 level. No significant correlation of improvements in SD.

5. DISCUSSION

The aim of this study was to compare two different ways to perform a maximal strength training exercise of the legs in COPD patients; one performed in a seated leg press machine using loads in kg. as a resistance, and the other way by using the subjects own bodyweight on a step devise combined with increasing the height of the step as increased intensity. Outcome were the effect on 1RM, walk economy and pulmonary function measured as FEV_1. The major finding in this study is that both strength training with loads in a seated leg press, and without load performed in a step device significantly increased 1RM and walk economy during 4 weeks of training, components which are related to increased exercise tolerance, quality of life and survival (Nici, Donner et al. 2006; Swallow, Reyes et al. 2007).

Leg press versus step device

In this study a comparison between maximal strength training performed in a seated leg press and on a step device reveal that both exercises have significant improvement on maximal muscle strength and walk economy. According to McArdle, (2007, p.518) it is the overload intensity and not the type of exercise that applies the overload, that give strength improvements, and therefore it is not surprising that both LP and SD improved muscle strength. Both LP and SD followed the same design; strength training with maximal mobilization in the concentric movement and high intensity with the ability to perform only five repetitions. This is a well known method to improve muscle strength revealed by Behm and Sale (1993), while working against high loads and training the fastest motor units will guarantee maximal voluntary contraction. Rapid movement is a method to increase the rate of force development. The improvement in LP and SD is of clinical importance because muscles of ambulation, and especially quadriceps, is the only evidenced based muscle group having great impact on exercise capacity and in addition being a good predictor for both survival and walking distance in COPD patients (Swallow, Reyes et al. 2007; Leite Rodrigues, Melo et al. 2009). The improvement in LP is in line with other studies using a seated leg press to strengthen the muscles of ambulation. Skumlien and Skogedal et al. (2007) showed significant improvement in a 4 weeks in-patient rehabilitation program, while two other out-patient studies have shown significant improvement in muscle strength using a seated leg press (Simpson, Killian et al. 1992; Hoff, Tjonna et al. 2007). The improvement in SD is difficult to compare with other studies because there are few studies were other exercises than leg press has been used. It is more likely to compare with home-based programs, but most of these studies do not include strength training, neither have muscle strength as an outcome been measured.

One study by McMurdo and Johnstone (1995) had a trend toward improvement in exercises like “sit-to-stand” and “Time-to-get-up” in a home-based exercises program for elderly people with poor mobility. 86 subjects were allocated to a strength exercise group, a mobility exercise group or a health education group. The subjects got verbal and written instruction and were visited for 30 minutes every 3-4 week in six month by a physiotherapist. They found no significant difference between the groups and the trend towards improvement failed to attain statistical significance. The significant improvement in SD in this study shows that this might be a convenient exercise to use as an outcome in other home-based studies in the future.

In the present study both LP and SD showed a significant improvement in muscle strength, revealing that both are well designed exercises for strengthening the leg muscles. The positive effects from pulmonary rehabilitation are well documented and the challenge for COPD-patients is to keep on training when arriving at home to maintain the effects gained during rehabilitation. Emery and colleges (2003) followed COPD patients after one year of a 10-week intensive exercise program. They were all given an individualized home exercise program and encouraged to continue exercise at an exercise facility or on their own. Only 39% of the COPD patients had followed up the exercise prescription and those were the only one who had maintained the physical effects gained during the 10-weeks exercise program. COPD patients in Norway have a good chance to get routines because they get financial support from the Norwegian social security system to do individual training under supervision of a community physiotherapist. There are some problems; physiotherapists do not have proper apparatus, like a seated leg press and do not give other strength exercises for the legs instead, and it is well known that COPD patients often get out of training routines due to exacerbations. The findings in this study show that SD is a good alternative exercise to improve muscle strength in legs for COPD patients, giving the physiotherapists and COPD patients the possibility to perform strength training independent of the available equipment. According to Rutherford (1988) the SD should be preferred before LP. Rutherford showed that improvement in strength training is very task-specific and training isolated muscle groups may not be as effective to improve function capacity. Hence, an improvement in muscle strength gained from SD is transferable in those activities which are required in daily life like rising up and walking steps.

Muscle strength

In the present study both LP and SD increased muscle strength significantly. LP showed a mean increase of 26.5 kg (19%) $p < 0.005$ and SD 13.5 kg (10%) $p<0.05$, but no significant difference between the groups. Improved strength in the muscles of ambulation is important to prevent fall in elderly subjects. This is special important for COPD patients because osteoporosis is a well known side effect of drugs like glucocorticosteroids. The improved muscle strength in this study is less compared with other studies. Hoff and colleagues (2007) showed an improvement of 27% in muscle strength in COPD patients. They had approximately the same amount of sessions compared to this study, 24 versus 20 respectively, and the same intensity of 85-90% of 1RM which could assume a more similar improvement in muscle strength between these two studies. An important explanation could be related to the initial extent of weakness of the subjects in the study by Hoff, were the mean muscle strength was 118 kg compared to 142 kg. in this study. According to the dose-response curve, subjects with initial low muscle strength would more easily improve muscle strength compared to subjects with initial higher muscle strength. This could explain the impressive improvement in leg muscle strength of 58 % in COPD patients in a study of Dourado and Tanni et al. (2009), were the subjects had initial mean muscle strength of 98 kg.

Different body weight between the subjects will overestimate muscle strength in heavy athletes and ought to be considered when comparing the different groups. By doing a dimensional scaling and compare the relative strength in term of $kg \cdot m_b^{-0.67}$ in these three studies, we can exclude body weight to contribute the difference in muscle strength. A contributor that is of importance is duration of training programs, which is supported by Green et al. (2001). They revealed that a rehabilitation program of 4 weeks shows less benefit than similar training for longer duration of 7 weeks. This might also be a factor to explain why Dourado et al. showed an improvement of 58% in 12 weeks and Hoff et al. (2007) an improvement of 27% in 8 weeks while the present study only improved 19% after 4 weeks. But to compare weeks of training may not give us any answers without counting the numbers of training sessions accomplished. Then we have to look for other explanations than duration of the great improvement revealed by Hoff et al. compared to this study. Both Hoff et al. and this study had approximately the same amount of training sessions, 24 versus 20 respectively. The difference was the distribution of sessions with 5 sessions a week in this study and 3 sessions a week in the study by Hoff et al. According to McArdle (2007, p. 523), training with multiple exercises 4 or 5 days per week may produce less improvement than training 2 or 3 times per week.

By training the same muscle near-daily, the recovery will be inadequate because of impaired muscle recovery between the training sessions, and further break down processes in both neuromuscular, structural adaptations and strength develop. The two studies included a similar amount of exercises, one leg exercise, but the subjects in this study participated in a rehabilitation program which included an individualized strength program for upper body and endurance training carried out in addition to group sessions. Thus, training 5 days a week in this study might also be a contributing factor of less improvement in 1RM compared with both Hoff et al. and Douardo et al. Both LP and SD showed a significant increase in 1RM with a p-value of 0.005 and 0.05 respectively.

The greater improvement in LP compared to SD might be due to the functionality of the exercises. SD is performed in an upright position in a way the subjects daily use their legs e.g. in a staircase, while LP is a new movement for most of the subjects, sitting and using the legs in a horizontal position. According to Rutherford and Jones (1986) one of the main improvements during strength training with neural adaptation is the ability to coordinate all the muscle groups involved in a movement. SD does not demand the subjects to coordinate other muscle groups performed in an ordinary staircase at home. LP is a movement including coordination of other muscle groups in a way we cannot compare with everyday movements, and thus we could assume a greater improvement in LP compared to SD. Sitting in a leg press, trying to move 85-90% of your 1RM five times, involves more than quadriceps, gluteus, hamstrings and calf muscles. It is necessary to stabilize the body with muscles of abdomen and truncus. Another demand when performing LP was the importance of good breathing techniques together with coordination of other muscle groups. During the study it was easy to observe subjects who performed LP with a wrong breathing pattern and thereby was not able to stabilize the body. The subjects were not able to press the weights before they were able to coordinate all the muscles involved in the movement together with expiration. The greater improvement in LP can also be explained by another study of Rutherford (1988) revealing that improvement in strength training has shown to be very task-specific to the training maneuver itself. In this study the 1RM-tests were measured on a seated leg press, which according to Rutherford would be beneficial for the subjects in LP who did 20 sessions on the leg press apparatus versus the subjects in SD who only performed the leg press in the 1RM-tests situations.

To increase muscle strength the intensity of training is of importance where higher intensities is more beneficial versus lower intensities (Dons, Bollerup et al. 1979; McDonagh and Davies 1984). It is not easy to find the optimal intensity of strength training by comparing studies (O'Shea, Taylor et al. 2004) or use recommendations from guidelines (Ries, Bauldoff et al. 2007). Both use the range from 50-85% of 1RM which make it confusing to design strength programs.

According to McDonagh and Davies (1984) load less than 66% of 1RM give no increase in muscle strength, and the discrepancies in studies may be attributable to the difference in the modalities and the intensity of training employed. In this study 1RM in LP increased 19% while SD increased 11%. The result may have been influenced by the lack of exact control of the resistance in SD which may have lead to a lower intensity compared with LP. To prove the "66%- rule" of McDonagh and Davies the subjects in SD had a mean 1RM at 127 kg., and to have significant improvement the loads had to be at least 66% of 1RM – means 83 kg. The mean bodyweight in SD is 75.6 kg. which is about 60% of 127 kg. and not enough to significantly increase strength. To increase the intensity the step was adjusted higher up until 5 repetitions were maximal they could perform, and in that way try to be at the same intensity level as the LP, 85-90% of 1RM. Anyway, this gives less control of the intensity comparing to LP were exact kg. was adjusted.

Another component that could influence the greater improvement in LP compared to SD is the strong motivation factor that accompanied the subjects in LP. In both groups most of the subjects got very positively surprised over themselves at the 1RM test at baseline, and therefore it was very easy for the subjects in LP to keep up the motivation and try to put new personal records in every session. The same kind of motivation was not observed in SD.

Work economy

Results in work economy showed a significant improvement in both LP and SD with 17% and 18% respectively ($p< 0.005$), but no significant difference between groups ($p>0.05$). It has been demonstrated that maximal strength training with emphasis on maximal mobilization of force in the concentric movement improve work economy and thus improve aerobic endurance performance both in athletes and in COPD patients (Hoff, Gran et al. 2002; Hoff, Tjonna et al. 2007). Exercise intolerance is a common hallmark in COPD and treatments which could improve endurance performance among these patients would be of great benefit, studies have shown that COPD patients have a low level of physical activity compared with other patient groups with a chronic disease (Arne, Janson et al. 2009). Activity level decreases additionally during exacerbations giving the COPD patients a mean walking time of 6-7 $\text{min}\cdot\text{day}^{-1}$ which fails to recover even after 1 month (Pitta, Troosters et al. 2006).

According to greater improvement in 1RM for LP versus SD and a significant correlation between changes in 1RM and work economy in LP, we could assume a greater difference in work economy between LP and SD as a following response. The similar improvement in work economy in LP and SD can be explained by the importance of RFD. Both groups performed their exercise with maximal mobilization of force in the concentric movement which is, according to Schmidtbleicher (1992), a method to increase RFD. RFD was not a measure outcome in this study, which is a weakness when work economy was measured, but due to shortage of equipment.

Previous studies have shown that the improvement of RFD may be the main component of increased work economy rather than improved 1RM after maximal strength training with emphasis on neural adaptation (Hoff, Gran et al. 2002). Hoff and Gran et al. showed a great improvement in RFD parallel with a small increase in 1RM, followed by improved work economy in cross-country skiers. They indicated that increased RFD was a more important factor to influence work economy than improved strength. Hoff and colleges (2002) explain the mechanisms behind improved work economy after strength training with maximal mobilization on force by a change in the power-load and load-velocity relationship, thereby making a standard workload relatively easier with a longer muscle relaxation period. Further they discuss the reduced VO_2 during a standard work load as a result of reduced blood flow during muscle contraction due to increased RFD. The exact mechanisms are not clear and should be addressed in future experiments.

The improvement in work economy in this study is not in line with Simpson and Killian et al (1992) who revealed no changes in aerobe endurance after strength training in patients with chronic airflow obstruction. The 1RM in leg press increased with 16%, which is in line with this study, but 6MWD-test was unchanged. The lack of maximal mobilization in the concentric phase of the movement might explain the unchanged 6MWT in that study. Simpson and colleges coached the subjects in their study to obtain slow smooth movement with normal breathing during the concentric phase, which increase strength via muscular hypertrophy, and not via neural adaptations and maximal mobilization in concentric phase. These findings support the theory about RFD being a main contributor to improved work economy, and theoretically an increased RFD may explain the similar improvements in work economy for both LP and SD in this study.

COPD patients will not necessarily appreciate better muscle strength or decreased oxygen consumption during a standard work load unless this leads to improved mobility. 6MWT is routinely measured at income and departure for almost all patients at Glittreklinikken. 6MWT is related to skeletal muscle dysfunction and gives an aspect of exercise performance. The problem to use the results from 6MWT in this study is due to the small numbers of subjects. Four of the patients were given supplementary oxygen during the stay, and conduct the last 6MWT with ambulatory oxygen and therefore it could not be compared to the initial 6MWT. Furthermore, sometimes the 6MWT have to be cancelled due to exacerbation or lack of nurses to accomplish the test, which happened to six other subjects in this study, making the results weak.

Although the LP showed a significant improvement with a mean increased walking distance of 85 meter which is in line with Spruit and colleges (2002) who revealed a increase of 79 meters in 6MWD after 12 weeks of strength training in COPD patients. SD showed an improvement of 14 meters (3%) which is not significant, but exactly the same results as Skumlien and colleagues (2007) showed in their study. The small changes of 14 meters in 6MWD might be a consequence of the intensity; Skumlien et al. used 10 repetitions with intensities increasing from 62% to 70% of 15RM and no focus on maximal mobilization of force in the concentric phase of the movement, while it has been shown in several studies that high intensity and rapid movements is important factors to influence work economy and thereby the endurance capacity (Hoff, Gran et al. 2002; Hoff, Tjonna et al. 2007). The impact of intensity is supported by both Dourado et al. (2009) and Simpson et al. (1992) both studies using 50-80% of 1RM, revealing small changes in 6MWD with 7% and 9% respectively.

In the present study the intensity in SD was high enough to produce improvement according to the significant improvement in work economy, so the small improvement in 6MWT for SD might be a consequence of the small amount of subjects. Skumlien et al. (2007) had calculated a sample of $n = 33$ to be necessary to detect a change of 54 meters, which has been suggested as minimal important clinical difference (Redelmeier, Bayoumi et al. 1997). Significant improvement in 6MWT has been shown in studies with smaller samples than 33 subjects. Spruit, Gosselink et al. (2002) had 24 subjects with significant improvement and in this study LP increased 6MWT with 85 meters. So it is difficult to interpret the lack of significance in SD from the small sample size alone. 6MWT is a self-paced test and might be vulnerable to each subject`s daily condition.

The self-paced nature of 6MWT might explain the small change in SD, while two of the subjects in SD were walking the last 6MWT the days preceding exacerbation and decreased their walking distance from pre- to posttest by 25 and 30 meters. The combination of small samples and the influence of other mechanisms like exacerbations make it difficult to discuss the results of 6MWT in this study. Another way to evaluate the effects from maximal strength training into endurance capacity is to calculate mechanical efficiency. Decreased mechanical efficiency is often accompany COPD (Baarends, Schols et al. 1997) and a study has revealed increased mechanical efficiency after maximal strength training by ca. 31% in COPD patients (Hoff, Tjonna et al. 2007). When calculating mechanical efficiency according to McArdle, Katch et al. (2007, p. 211-212) in this study, LP increased mechanical efficiency from 16% to 22% which correspond with the findings from Hoff et al. with improvement from 16% to 21% in the maximal strength group. SD increased even more, from 12% to 18% which is difficult to understand according to the similar improvement in work economy between LP and SD and a lower increase in 1RM in SD. To investigate the mechanisms behind improved mechanical efficiency, biopsies might be of great value. There are indications that improved mechanical efficiency is due to increased muscle strength and coupled with an increased reliance on type II fibers (Hoff, Tjonna et al. 2007). To evaluate mechanical efficiency has not been the intension in this study but because of the increased focus on mechanical inefficiency in COPD patients this should be a line of further research.

To involve patients in a study who participate in a rehabilitation program have some considerations. It is well known that exercise intolerance is a common hallmark in COPD due to inactivity as a main contributor (Rantanen, Guralnik et al. 1999; Watz, Waschki et al. 2008). Most of the patients coming to Glittreklinikken will increase their activity level in 4-weeks compared to out-patients participating in a rehabilitation program. The patients' rooms at Glittreklinikken are 2 or 3 floors above and 200-300 meters away from the canteen were the patients have to go four times a day for meals. So without doing any additional exercising the patients have increased their activity level quite a lot by walking in long halls and using the staircase compared to their activity level at home. This increased activity level might very well influence on the findings of improved endurance capacity in this study. Additionally the subjects get individualized endurance program on a treadmill and strength exercises for upper body. This may also be a contributing factor for the similar improvement for both LP and SD in work economy and is in line with Rutherford (1988) and the task-specificity of training exercises and effects.

Both LP and SD did regular training endurance by walking on treadmills and thus given them a better technique on that specific skill and therefore showing similar improvement for both groups. An initial pilot validated the work economy test but it is difficult to avoid learning effects that can influence the effects.

The findings of improved work economy in this study is in line with other studies showing that maximal strength training with emphasis on rapid force in the concentric phase is an effective method to improved work economy in both athletes and COPD patients. Other effects gained in an in-patients rehabilitation program like increased activity level and learning effects, might have influenced the results in this study. The mechanisms behind improved work economy after maximal strength training could have been identified by including RFD and monitored the activity level of the patients as outcome measures and should be addressed in future studies.

Pulmonal function

There was no significant change in pulmonary function, FEV_1, in neither LP nor SD after 4 weeks of maximal strength training. The mean improvement in LP and SD was 8 % and 0.7% respectively and no significant difference between the groups. Spirometry and pulmonary function is essential for diagnosis COPD and GOLD has developed a classification system with four stages were the stages are defined from a combination of spirometric findings and symptoms (GOLD 2008 Updated). Bernard and colleges (1998) showed a positive correlation between quadriceps strength and FEV_1 % of predicted, but it has been difficult to get evidence that strength training affect FEV_1, and the lack of significant changes in FEV_1 in this study is in line with other studies. In a trial of 8 weeks with weightlifting exercise in COPD patients Simpson and Killian et al. (1992) found significant improvement in 1RM but no significant improvement in FEV_1. The increase in 1RM was 16% and FEV_1 with 7% which is almost similar to the results found in LP in this study with 19% and 8% respectively. These two findings are supported in a review of O`Shea (2004) were 13 articles related to strength training in people with COPD are examined and no significant changes in respiratory function appear after strength training.

FEV_1 is a value of airflow limitation and seems to be hard to affect. Even medication like bronchodilators have not shown significant changes in FEV_1 (Rabe, Hurd et al. 2007), so how could strength training affect FEV_1 then? Literatures supporting the link between pulmonary function and strength training have focused on improvement in respiratory muscles, which may be challenged during maximal strength training, as a possible mechanism.

One study showed 22% increase in FEV_1 after maximal strength training in COPD patients using a seated leg press (Hoff, Tjonna et al. 2007). They explained the increased FEV_1 with parallel training adaptations of the abdominal muscles as a result of the biomechanics during the leg press machine. The significant changes in FEV_1 in their study may be explained by a greater increase in 1RM (27%) compared to both this study (19%) and Simpson et al. (16%). The difference in biomechanics during a leg press performance and a step device performance may explain the variance of FEV_1 between LP and SD in this study. LP increased more in both 1RM and FEV_1 compared to SD, 19% versus 11% in 1RM and 8% versus 0.7% in FEV_1 respectively. This reveal that performing strength training in a step device gives less challenge to the abdominal muscles compared to leg press and therefore a less change in FEV_1. The strong correlation between 1RM and FEV_1 is ratified by Bernard and colleges (1998), and improvement in 1RM correlated positively with improvement in FEV_1 in the study by Hoff and Tjonna et al. (2007), but not in this study even if both studies used the same intensity and apparatus. Before any conclusion is taken, more studies are needed.

It might be difficult to have FEV_1 as an outcome measure when the subjects are participating in a pulmonary rehabilitation program in our clinic as adjustments of the medicines are routinely done during the 4 weeks. In this study seven subjects in LP and six in SD adjusted their medication during the 4-weeks. Because nobody got new medication, it was mainly changing from one anticholinergic into another new type. This might not influence the results of FEV_1 because pharmacologic treatment is used to prevent and control symptoms and reduce the frequency and severity of exacerbations. Studies have shown that bronchodilator drugs have shown to increase exercise capacity without necessarily producing significant changes in $FEV_{1,}$ while a combination of short-acting Beta-agonist and an anticholinergic produces greater and more sustained improvements in FEV_1 than either drug alone (Rabe, Hurd et al. 2007)s. 541).

The small change in FEV_1 in this study, which is supported in other studies, combined with few studies with significant improvement in FEV_1 after strength intervention, raise the question of using FEV_1 as an outcome measure after pulmonary rehabilitation of relevance. FEV_1 is a good predictor for diagnosing airway limitations, but even GOLD have seen the reduced importance of FEV_1 and added symptoms of the disease to classify the severity of COPD (2008 Updated).

To determine physical capacity studies have revealed FEV_1 as a poor value compared to quadriceps muscle strength to predict both survival and distance walked in COPD patients (Swallow, Reyes et al. 2007; Leite Rodrigues, Melo et al. 2009). Other variables like $VO_{2\ max/peak}$ and muscle strength are highlighted in the pulmonary society to be more reliable and of greater clinical importance than FEV_1, and might replace FEV_1 in further experiments.

Methodological limitations

No control group was added to this study of two reasons. First, in another study using the same methodology as the present study, the control group showed no improvements without any interventions except from continuing their normal daily living with modest regular activity (Hoff, Tjonna et al. 2007). Second, it would be unethical to include COPD patients participating in the rehabilitation program at Glittreklinikken in a control group and not giving them any exercises for strengthening the legs while the importance of training the muscles of ambulation in COPD patients is so well documented. The present study has some methodological limitations. Although reliable equipment and apparatus were used, unfortunately both the Oxycon apparatus, measuring work economy, and the Selection leg press apparatus was out of order for a longer or shorter period during the study. This study was limitated by time, and more subjects could have been included with more time available. Then the results from the six subjects measuring work economy by the Oxycon and the four subjects using the leg press apparatus from Steens Industrier, would have been removed from this study.

6. CONCLUSION

Peripheral muscle weakness is a common hallmark in COPD patients and affects exercise performance negatively. Exercise training is widely regarded as the cornerstone of pulmonary rehabilitation and later studies have shown that COPD patients are less ventilatory taxed during strength training compared to endurance training, allowing them to increase the intensity and thereby the effects. The results from this study is in line with other studies, revealing that maximal strength training is well tolerated and give positive effects on muscle strength and work economy in COPD patients. This is illustrated both through a significant increased maximal muscle strength and improved work economy after 4 weeks of training. According to ATS/ERS guidelines, these improvements are associated with increased exercise tolerance and quality of life in this group of patients. To my knowledge, maximal strength training in a step device has never been used in a strength study for COPD patients before, and the significant increase in muscle strength in this study confirm that strength training is dependent on intensity and not the choice of exercise. This is of clinical importance because it gives physiotherapists and COPD patients the possibility to perform effective strength exercises independently of available equipment. Furthermore, performing one exercise which gives improvement in both muscle strength and work economy might be manageable for COPD patients to maintain or increase muscle strength non-supervised.

7. REFERENCE LIST

Aagaard, P., E. B. Simonsen, et al. (2002). "Increased rate of force development and neural drive of human skeletal muscle following resistance training." J Appl Physiol **93**(4): 1318-26.

Arne, M., C. Janson, et al. (2009). "Physical activity and quality of life in subjects with chronic disease: Chronic obstructive pulmonary disease compared with rheumatoid arthritis and diabetes mellitus." Scand J Prim Health Care: 1-7.

ATS, s. (2002). "Guidelines for the six-minute walk test." Am J Respir Crit Care Med **1;166**(1): 111-7.

Baarends, E. M., A. M. Schols, et al. (1997). "Decreased mechanical efficiency in clinically stable patients with COPD." Thorax **52**(11): 981-6.

Bassey, E. J., M. A. Fiatarone, et al. (1992). "Leg extensor power and functional performance in very old men and women." Clin Sci (Lond) **82**(3): 321-7.

Behm, D. G. and D. G. Sale (1993). "Velocity specificity of resistance training." Sports Med **15**(6): 374-88.

Bernard, S., P. LeBlanc, et al. (1998). "Peripheral muscle weakness in patients with chronic obstructive pulmonary disease." Am J Respir Crit Care Med **158**(2): 629-34.

Bjorgen, S., J. Hoff, et al. (2009). "Aerobic high intensity one and two legs interval cycling in chronic obstructive pulmonary disease: the sum of the parts is greater than the whole." Eur J Appl Physiol.

Celli, B. R. and W. MacNee (2004). "Standards for the diagnosis and treatment of patients with COPD: a summary of the ATS/ERS position paper." Eur Respir J **23**(6): 932-46.

Dons, B., K. Bollerup, et al. (1979). "The effect of weight-lifting exercise related to muscle fiber composition and muscle cross-sectional area in humans." Eur J Appl Physiol Occup Physiol **40**(2): 95-106.

Dourado, V. Z., S. E. Tanni, et al. (2009). "Effect of three exercise programs on patients with chronic obstructive pulmonary disease." Braz J Med Biol Res **42**(3): 263-71.

Emery, C. F., R. L. Shermer, et al. (2003). "Cognitive and psychological outcomes of exercise in a 1-year follow-up study of patients with chronic obstructive pulmonary disease." Health Psychol **22**(6): 598-604.

Fleming, B. E., D. R. Wilson, et al. (1991). "A portable, easily performed muscle power test and its association with falls by elderly persons." Arch Phys Med Rehabil **72**(11): 886-9.

GOLD, G. I. f. C. O. L. D. (2008 Updated). "Global strategy for diagnosis, management and prevention of COPD." http://www.goldcopd.org.

Green, R. H., S. J. Singh, et al. (2001). "A randomised controlled trial of four weeks versus seven weeks of pulmonary rehabilitation in chronic obstructive pulmonary disease." Thorax **56**(2): 143-5.

Helgerud, J. (1994). "Maximal oxygen uptake, anaerobic threshold and running economy in women and men with similar performances level in marathons." Eur J Appl Physiol Occup Physiol **68**(2): 155-61.

Hoff, J., A. Gran, et al. (2002). "Maximal strength training improves aerobic endurance performance." Scand J Med Sci Sports **12**(5): 288-95.

Hoff, J., A. E. Tjonna, et al. (2007). "Maximal strength training of the legs in COPD: a therapy for mechanical inefficiency." Med Sci Sports Exerc **39**(2): 220-6.

Hoff, J. J. H., U. Wisløff (2002). "Endurance training into the next millenium; Muscular strength training effects on aerobic endurance performance: A review." " Am J Med Sports **4**: 58-67.

Hoydal, K. L., J. Helgerud, et al. (2007). "Patients with coronary artery- or chronic obstructive pulmonary disease walk with mechanical inefficiency." Scand Cardiovasc J **41**(6): 405-10.

Leite Rodrigues, S., E. S. C. A. Melo, et al. (2009). "The influence of lung function and muscular strength on the functional capacity of chronic obstructive pulmonary disease patients." Rev Port Pneumol **15**(2): 199-214.

McArdle, W. D., F. I. Katch, et al. (2007). Exercise physiology energy, nutrition, and human performance. Philadelphia, Lippincott Williams & Wilkins.

McDonagh, M. J. and C. T. Davies (1984). "Adaptive response of mammalian skeletal muscle to exercise with high loads." Eur J Appl Physiol Occup Physiol **52**(2): 139-55.

McMurdo, M. E. and R. Johnstone (1995). "A randomized controlled trial of a home exercise programme for elderly people with poor mobility." Age Ageing **24**(5): 425-8.

Miller, M. R., J. Hankinson, et al. (2005). "Standardisation of spirometry." Eur Respir J **26**(2): 319-38.

Nici, L., C. Donner, et al. (2006). "American Thoracic Society/European Respiratory Society statement on pulmonary rehabilitation." Am J Respir Crit Care Med **173**(12): 1390-413.

O'Shea, S. D., N. F. Taylor, et al. (2004). "Peripheral muscle strength training in COPD: a systematic review." Chest **126**(3): 903-14.

Pate, R. R. and A. Kriska (1984). "Physiological basis of the sex difference in cardiorespiratory endurance." Sports Med **1**(2): 87-98.

Pellegrino, R., G. Viegi, et al. (2005). "Interpretative strategies for lung function tests." Eur Respir J **26**(5): 948-68.

Pitta, F., T. Troosters, et al. (2006). "Physical activity and hospitalization for exacerbation of COPD." Chest **129**(3): 536-44.

Rabe, K. F., S. Hurd, et al. (2007). "Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease: GOLD executive summary." Am J Respir Crit Care Med **176**(6): 532-55.

Rantanen, T., J. M. Guralnik, et al. (1999). "Disability, physical activity, and muscle strength in older women: the Women's Health and Aging Study." Arch Phys Med Rehabil **80**(2): 130-5.

Redelmeier, D. A., A. M. Bayoumi, et al. (1997). "Interpreting small differences in functional status: the Six Minute Walk test in chronic lung disease patients." Am J Respir Crit Care Med **155**(4): 1278-82.

Ries, A. L., G. S. Bauldoff, et al. (2007). "Pulmonary Rehabilitation: Joint ACCP/AACVPR Evidence-Based Clinical Practice Guidelines." Chest **131**(5 Suppl): 4S-42S.

Rutherford, O. M. (1988). "Muscular coordination and strength training. Implications for injury rehabilitation." Sports Med **5**(3): 196-202.

Rutherford, O. M. and D. A. Jones (1986). "The role of learning and coordination in strength training." Eur J Appl Physiol Occup Physiol **55**(1): 100-5.

Schmidtbleicher, D. (1992). Training for power event. Strength and Power in Sport. P. V. Komi. London, Blacwell Scientific Publications **3:** 381-395.

Simpson, K., K. Killian, et al. (1992). "Randomised controlled trial of weightlifting exercise in patients with chronic airflow limitation." Thorax **47**(2): 70-5.

Skumlien, S., E. A. Skogedal, et al. (2007). "Four weeks' intensive rehabilitation generates significant health effects in COPD patients." Chron Respir Dis **4**(1): 5-13.

Spruit, M. A., R. Gosselink, et al. (2002). "Resistance versus endurance training in patients with COPD and peripheral muscle weakness." Eur Respir J **19**(6): 1072-8.

Swallow, E. B., D. Reyes, et al. (2007). "Quadriceps strength predicts mortality in patients with moderate to severe chronic obstructive pulmonary disease." Thorax **62**(2): 115-20.

Tesch, P. A. (1982). Short- and long-term histochemical and biological adaptions in muscle. Strength and Power in Sport. P. V. Komi. London, Blackwell Scientific Publication**:** 381-395.

Troosters, T., R. Gosselink, et al. (2000). "Short- and long-term effects of outpatient rehabilitation in patients with chronic obstructive pulmonary disease: a randomized trial." Am J Med **109**(3): 207-12.

Watz, H., B. Waschki, et al. (2008). "Extrapulmonary effects of chronic obstructive pulmonary disease on physical activity: a cross-sectional study." Am J Respir Crit Care Med **177**(7): 743-51.

WHO (2007). "Chronic Obstructive pulmonary diseases (COPD)."

www.who.int/respiratory/copd/en/.

Wisloff, U., J. Helgerud, et al. (1998). "Strength and endurance of elite soccer players." Med Sci Sports Exerc **30**(3): 462-7.