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AN EVALUATION OF A 2-KM WALKING TEST IN PATIENTS WITH CHRONIC OBSTRUCTIVE PULMONARY DISEASE (COPD)

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ABSTRACT

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The major purpose of this study was to evaluate the feasibility of a 2-km walking test presented by Oja and coworkers (1991), in male patients with chronic obstructive pulmonary disease (COPD). This study also considered the pathophysiologic mechanism limiting exercise capacity in COPD.

The test subjects consisted of 13 men aged 63 ± 8 years, with a moderate COPD (FEV_1 = 1.46 ± 0.27 L). Each subject performed a graded treadmill walking test to exhaustion for the determination of symptom-limited maximum oxygen uptake (VO_2SL). On separate days the subjects walked twice 2-kilometer distance on outdoor courses following the instructions of "Guide for The UKK Institute 2-km walking test".

Physiological strain of the 2-km walking test proved to be heavy in these subjects. Even though some differences among the individuals were observed, for most of the subjects the heart rate values at the end of the walk were close to the heart rate values measured at the end of the symptom-limited exercise test on the treadmill (86 - 99 % of HRmax in treadmill test). However, the test was well tolerated by the subjects and there were no interruptions in walk performance due to excessive dyspnea, leg muscle pain, or any other reason. Ratings of perceived exertion (RPE) expressed by the Borg 0 - 10-scale averaged 3.9 for leg effort and 4.8 for dyspnea, which correspond to perceived exertion of "somewhat severe" and "severe", respectively. Also, the subjects were able to follow the standardized test procedure. The test instructions for the walk included the use of normal walking style, and maintenance of a steady, fastest possible walking pace without risking health. The reproducibility of the walking test was high. The test-retest correlation coefficients were 0.93 both for walking times and for peak heart rates.

The correlation coefficient between walking time in the 2-km test and directly measured maximum VO_2SL ($mL \cdot kg^{-1} \cdot min^{-1}$) was -0.694, ($p < 0.01$). Variables including heart rate at the end of the walk, age, height, or pulmonary function measurement of FEV_1, or FVC did not correlate significantly with weight-relative maximum VO_2SL.

The present study provides preliminary results of usefulness of the standardized 2-km walking test in patients with respiratory disease. The results suggest that the 2-km walking test is feasible test method in assessing exercise tolerance in male patients with moderate COPD. This test provides information on the ability of a subject to sustain high intensity, prolonged exercise, and is therefore useful for an estimate of aerobic work capacity. The 2-km walking test is reproducible and easy to perform, and might be potentially useful as a supplementary test together with direct exercise tests of clinical evaluation. The results of the present study are promising, and further studies are warranted.

Key words: COPD, exercise tolerance, lung diseases, oxygen consumption, physical fitness, walking.

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ABBREVIATIONS

a-v O_2 difference	Difference in oxygen concentration between arterial and venous blood, mL O_2 /100 mL blood
BR	Breathing reserve, MVV-V_E at maximum exercise
BTPS	Body temperature and pressure, saturated with water vapour
CO_2	Carbon dioxide
COPD	Chronic obstructive pulmonary disease
ECG	Electrocardiograph
FEV_1	Forced expiratory volume in one second, L·s
FVC	Forced vital capacity, L
HR	Heart rate, beats·min^{-1}
HRmax	Maximal heart rate
%HRmax	Percentage from the maximal heart rate
La	Lactate
MaximumVO_2SL	Symptom-limited maximum oxygen uptake
MVV	Maximal voluntary ventilation
$PaCO_2$	Arterial carbon dioxide tension
RPE	Ratings of perceived exertion
STPD	Temperature 0°C, pressure one atmosphere, dry
SV	Stroke volume, mL
T_E	Expiratory time
T_i	Inspiratory time
T_{tot}	Total respiratory time
V_A	Alveolar ventilation per minute
V_A/Q	Alveolar ventilation-perfusion matching
VCO_2	Carbon dioxide output by the lungs per minute
V_D	Physiological dead space ventilation per minute
V_D/V_T	Physiological dead space/tidal volume ratio
V_E	Minute ventilation
VO_2max	Maximal oxygen uptake, L·min^{-1}, or mL·kg^{-1}·min^{-1}
V/Q	Ventilation-perfusion matching
V_T	Tidal volume

CONTENTS

1. INTRODUCTION

"The progressive improvement in ability to walk without dyspnea suggested that a physiologic response similar to a training program in athletes may have been produced" (Barach et al. 1952).

Chronic obstructive pulmonary disease (COPD) patients demonstrate exercise limitation that is primarily associated with an increased ventilatory requirement and a decreased ventilatory capacity (Wasserman 1993). However, Barach and coworkers described already in 1952 that physical training has a great potential for increasing exercise tolerance in patients with COPD (Barach, Bickerman & Beck 1952). Since 1960's a number of studies have been published which state that training has led to measurable improvements on oxygen utilization and exercise endurance in patients with COPD (e.g. Christie 1968; Nicholas, Gilbert, Gabe & Auchincloss 1970; Pierce, Taylor, Archer & Miller 1964). Recently, it has been proposed that in patients with COPD greater physiological benefits are achieved in training that elicits high levels of lactic acidosis than in training eliciting a low lactate level. High intensity endurance training has shown to result in a reduced ventilatory requirement for exercise in rough proportion to the drop in blood lactate at a given work rate. (Casaburi, Patessio, Ioli, Donner & Wasserman 1991.)

Directly measured symptom-limited maximum oxygen uptake (VO_2SL) has been used as a major evaluative criterion of the benefits of rehabilitation in several studies. The indirect field tests have also been used in the evaluation of exercise tolerance. Since the adaptation of the Cooper test as walking tests of 12- and 6-minute in 1970's, these tests have gained popularity in COPD. The advantage of walking as a test mode is that walking is a familiar type of exercise and it requires no apparatus. Walking tests are applicable to patients with disease of all grades of severity, and the tests have proved to be a useful tool in the successive evaluations of patients in rehabilitation programs. (Donner & Patessio 1989.)

The incentive for the present study was a hypothesis that patients with moderate to mild COPD might be able to successfully perform a more prolonged exercise test on field conditions than that of traditional 6- and 12-minute walking tests. Referring to the findings that in training the patients with moderate COPD have been able to sustain high intensity exercise for a prolonged time, it seems appropriate to suppose that these patients would tolerate a longer field exercise test. The aim of the present study was to evaluate the feasibility of a field test, based on 2-km walking in male patients with moderate COPD.

2. REVIEW OF LITERATURE

2.1 Chronic obstructive pulmonary disease (COPD)

Chronic obstructive pulmonary disease (COPD) is a common diagnostic term indicating the same clinical picture of airways obstruction of varied pathologic findings. According to the definition of American Thoracic Society (ATS), COPD is a disorder characterized by abnormal tests of expiratory flow that do not change markedly over periods of observation. The disorders incorporated in COPD are chronic bronchitis, emphysema, and peripheral airways disease. (American Thoracic Society 1987.)

While the common denominator of these diseases is expiratory airflow limitation due to airways narrowing, the pathophysiologic basis for the narrowing is different in each case. In chronic bronchitis the expiratory flow is decreased because of abnormalities in the central airways. Narrowing of airways in chronic bronchitis is produced intraluminally due to chronic or recurrent excess mucous secretion in the bronchial tree. Excess sputum production is related to enlargement of the mucous-secreting glands of the trachea and large bronchi. (American Thoracic Society 1987.)

In emphysema there are abnormalities in peripheral airways. Emphysema is pathologically defined as: "a condition of the lung characterized by abnormal, permanent enlargement of the airspaces distal to the terminal bronchiole, accompanied by destruction of their walls, and without obvious fibrosis." (American Thoracic Society 1987.)

A variety of morphologic abnormalities have been seen in the peripheral airways of patients with COPD, including inflammation of the terminal and respiratory bronchioles, fibrosis of airways walls with narrowing, and goblet cell metaplasia of bronchial epithelium. These lesions may precede the development of emphysema and appears to represent early COPD. Peripheral airways disease is seen to result in abnormalities in pulmonary function tests and contributes to chronic airflow obstruction. (American Thoracic Society 1987.)

There are several criteria to define the degree of respiratory impairment. The American Thoracic Society has recommended that the severity of airways obstruction should be based on forced expiratory volume in first second (FEV_1) measurements. (American Thoracic Society 1991.) Furthermore, the use of percent predicted value where ratings of impairment compares the individual's organ function with a comparable group of healthy individuals is recommended by ATS (American Thoracic Society 1982). By means of FEV_1 measurements patients with airflow obstruction are commonly divided into mild, moderate, and severe airways disease, where mild is 60 to 80 %, moderate 40 to 60 %, and severe less than 40 % of predicted FEV_1 value (Killian 1993).

In the genesis of COPD, smoking is reported to be the most important factor. The theories about the origins of COPD suggest that smoking leads to infections and structural changes in small airways in the lung. Besides, it has been reported that smoking has led to increased levels of bronchial responsiveness associated with lower levels of pulmonary function, suggesting obstruction in central airways. In the genesis of emphysema, resulted in part from smoking, there is insufficiency of alfa1-antitrypsin (alfa1-Pi), which is important in controlling the production of endogenous proteolytic enzymes. The insufficiency of alfa1-antitrypsin permits proteolytic enzymes to destroy lung tissue. (Huhti 1988.)

Besides the common feature of smoking habit of COPD patients, characteristically a great part of the COPD population is geriatric. In a literature review addressing exercise programs for COPD patients, a total of 933 patients were observed in the 37 studies. The average age of these patients was 61 years. (Casaburi 1993.)

2.2 Exercise tolerance in COPD

2.2.1 Pathophysiologic mechanism limiting exercise in COPD

Oxygen is required to generate the high-energy phosphate, adenosine triphosphate (ATP) to allow muscle contraction. Muscle respiration is geared to the rate of work being performed. The increase in external respiration must ultimately increase to match the increased gas exchange needs of the muscle cell during exercise. The gas transport mechanism between the external environment and the muscle mitochondria couples the performance of the heart, lungs, and the pulmonary and systemic circulations to cellular respiration. The coupling must follow the increased metabolic stress in order to maintain tissue O_2 supply and CO_2 elimination as well as arterial blood gas exchange (figure 1). (Wasserman, Hansen, Sue & Whipp 1987, 2.)

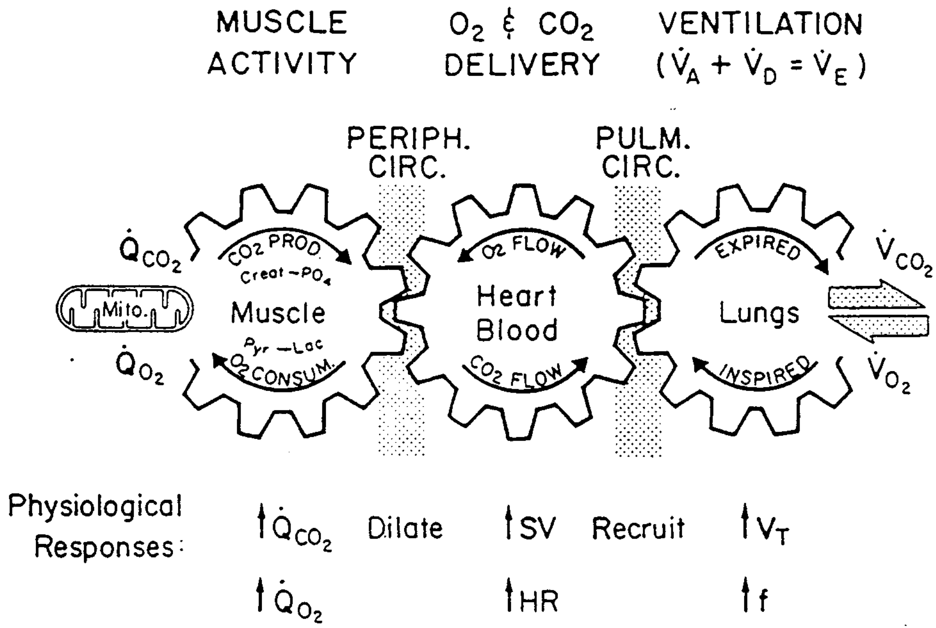

FIGURE 1. Transport of oxygen from external environment to active muscle. An increase in O_2 utilization by the muscles (QO_2) requires simultaneous cardiovascular and respiratory adjustments. Cardiovascular contributions to oxygen transport involve an increased cardiac output (Q) which is a function of heart rate (HR) and stroke volume (SV). Respiratory adjustment include an increase in ventilation (V_E) resulting from increased breathing frequency (f) and tidal volume (V_T). The increase in ventilation is determined by the newly produced CO_2 (QCO_2) arriving at the lungs and the drive to achieve arterial CO_2 and hydrogen ion (H^+) homeostasis. (Wasserman et al. 1987, 2.)

In the presence of disease states involving one or more links in the gas transport mechanism the normal metabolic-cardiovascular-ventilatory coupling needed for exercise is interfered. In patients with chronic airways obstruction the disturbed interaction of physiologic mechanisms during exercise is mainly due to the abnormal mechanical characteristics of the respiratory system. In COPD patients an increase in ventilatory requirement to perform exercise and a reduction in ventilatory capacity are characteristic features related to exercise limitation (figure 2). (Wasserman 1993.) In addition, altered cardiac function may contribute to the disability through the adverse effects of lung mechanics on cardiac performance (Morrison & Zuckerman 1993; Wasserman 1993).

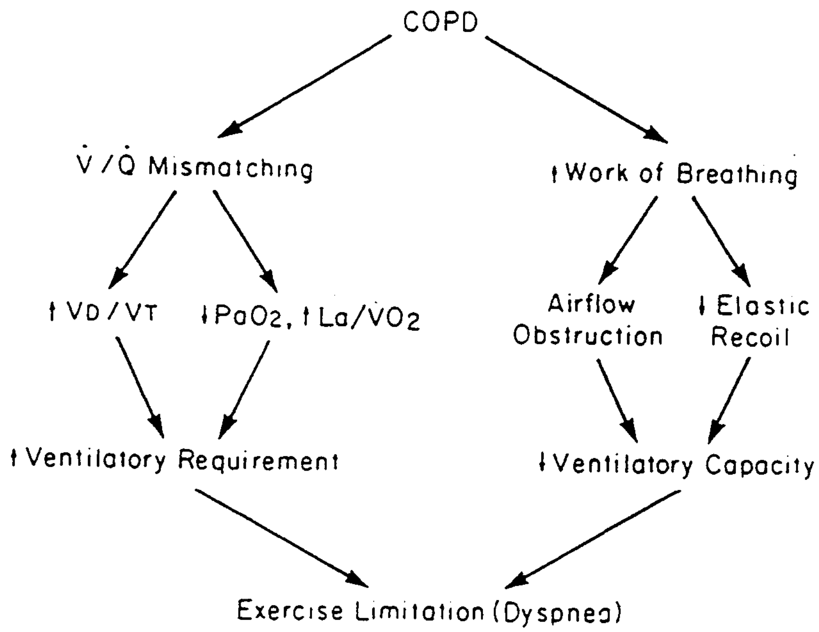

FIGURE 2. Pathophysiology of exercise limitation in patients with COPD. Factors affecting ventilation: V/Q: ventilation-perfusion ratio; V_D/V_T: dead space-tidal volume ratio; La/VO_2: ratio of lactate to oxygen consumption. (Wasserman 1993.)

Increased ventilatory requirement

Increased ventilatory requirement to exercise is a characteristic feature in patients with COPD (figure 2, left side). The ventilatory (V_E) requirement for regulation of arterial blood CO_2 partial pressure ($PaCO_2$) is defined by three physiological variables: 1) the metabolic CO_2 production (VCO_2); 2) the regulated level of arterial CO_2 ($PaCO_2$); and 3) the ventilatory efficiency for CO_2 clearance (V_D/V_T). (Brown & Wasserman 1981.)

The resulting equation is shown below and the contribution of each variable to ventilation is explained in the three following paragraphs (Wasserman et al. 1987, 17).

$$V_E\,(BTPS) = \frac{863 V_{CO_2}\,(STPD)}{PaCO_2(1 - V_D/V_T)}$$

The increment in minute ventilation (V_E) in exercise is closely related to V_{CO_2} response (Casaburi, Whipp, Wasserman, Beaver & Koyal 1977). Thus the factors that increase CO_2 output such as increased O_2 cost of breathing can demand higher ventilation (Jones, Jones & Edwards 1971). Another cause for increased cost of breathing is bicarbonate (HCO_3^-) buffering of lactic acid at low work rates in COPD. This buffering generates CO_2 that increases CO_2 output out of proportion to the aerobic CO_2 production, which causes additional stress on the ventilatory system. The early onset of lactic acidosis in response to exercise is caused by low aerobic capacity of the muscles. Thus, the state of cardiovascular fitness is an important factor when the ventilatory response to exercise is considered. (Sue, Wasserman, Moricca & Casaburi 1988.)

The second factor influencing the quantity of breathing (V_E) during exercise is the regulated level of arterial CO_2 tension ($PaCO_2$). The patients with COPD have been shown to regulate $PaCO_2$ at a reasonably constant, near resting level despite increasing work rates. Thus a patient who regulates $PaCO_2$ at a low level requires higher increase in alveolar ventilation (V_A) to eliminate a given volume of CO_2 from the body, whereas a patient with high $PaCO_2$ requires a less of a V_A response. (Wasserman et al. 1987, 52.)

The efficiency of the lung as a gas exchanger has also an influence on the ventilation. In healthy subjects ventilation and perfusion (V/Q) are closely matched (V/Q almost equals 1). (Corbridge & Irvin 1993). In patients with COPD poor ventilation-perfusion matching in certain regions of the lung contributes little to gas exchange and is thus called to wasted ventilation. When the fraction of the breath that is wasted (V_D/V_T) increases, the ventilation must be increased proportionally to maintain the $PaCO_2$ at the same value. This increases ventilatory requirement for given level of exercise. (Brown & Wasserman 1981.)

Besides these three aforementioned physiological variables, arterial hypoxemia, which may develop in patients with COPD, is also a factor causing different ventilatory requirement during exercise. This is primarily caused by the underventilation of perfused lung units (low V_A/Q) when the blood that passes through these lungs remains incompletely saturated. Hypoxia results in the stimulation of carotid body chemoreseptors, which increases ventilatory drive. (Brown & Wasserman 1981.)

Decreased ventilatory capacity

The altered mechanical properties of the lungs and chest wall impact on the ability and efficiency of the respiratory system to ventilate the alveolar air spaces in patients with airways obstruction disease (figure 2, right side). Inspiratory work is performed to overcome the inward elastic recoil force of the lungs and at very high thoracic volumes that of chest wall. During passive expiration, some of the stored energy in the elastic components is used to overcome the resistance of airflow in the airways and some is used to overcome the continued contraction of the inspiratory muscles. (Barstow & Casaburi 1993.)

In COPD expiratory airflow resistance is higher than inspiratory airflow resistance. During exercise, expiratory airflow soon reaches a limiting value and as a consequence inspiratory flow must increase simultaneously to allow time for expiration. Also, inspiratory flow reaches soon the maximum flow-volume value. The adopted pattern of breathing in COPD consists of a relatively well-maintained tidal volume (V_T), a long expiratory time (T_E), and short inspiratory time (T_i), with inspiratory/total respiratory ratio (T_i/T_{tot}) even as low as 0.15 (only 15 per cent of the breathing is spent in inspiration). This hyperinflation throws a heavy load on the respiratory muscles. (Jones & Campbell 1982, 104.)

The respiratory muscle force, the strength of respiratory muscles, and the velocity and the extend of contraction have been reported to have the main role in the genesis of respiratory effort and exercise limitation. It has been shown that intrapleural pressure, the capacity of the respiratory muscles to generate pressure, and the inspiratory flow rate and tidal volume are closely correlated with exercise capacity. (Jones & Killian 1990.) Maximal voluntary ventilation (MVV) is an index of ventilatory capacity. MVV is the ventilation that patient can voluntarily attain at rest, and it can be predicted from FEV_1. (Carter, Peavler, Zinkgraf, Williams & Field 1987.) Due to ventilatory limitation, during exercise COPD patients attain ventilation (V_E) that may equal or even slightly exceed their MVV performed at rest (breathing reserve ($BR = MVV - V_E$) is very small) whereas in normal subjects there is a large difference between exercise V_E and MVV and reflecting considerable ventilatory reserve (figure 3) (Wasserman et al. 1987, 37, 53, 79). It has been proposed that a subject can be classified as ventilatory limited if the breathing reserve during maximal exercise is less than 30 % (calculated as BR =
$(1 - V_{E}max / MVV) \times 100$) (Casaburi et al. 1991).

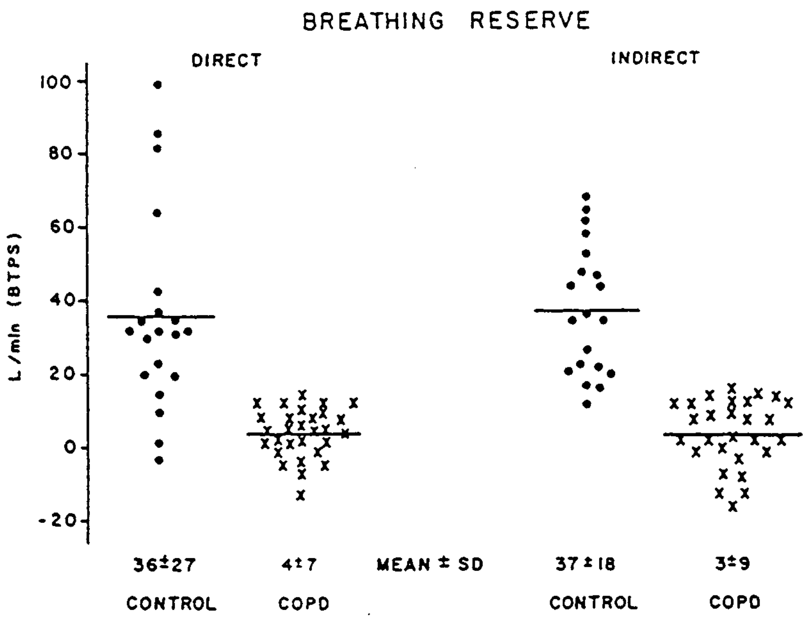

FIGURE 3. Breathing reserve (MVV - maximum V_E) in patients with COPD and in normal subjects. The values under the columns are the mean ± standard deviation. MVV is measured directly, and indirectly by calculating FEV_1 x 40. (Wasserman et al. 1987, 37, 53.)

As with other skeletal muscles, the respiratory muscles fatigue at prolonged strenuous exercise. Ventilatory muscle endurance has been defined as the capacity for sustaining high levels of ventilation for relatively long periods. A study of Wilson, Cooke, Moxham & Spiro (1984) has shown the contribution of ventilatory muscle fatigue to exercise limitation of the walking exercise in male patients with moderately severe COPD. These authors reported that a 12-minute walking test was sufficient to generate ventilatory muscle fatigue (measured with surface electrodes placed over sternomastoid muscle). However, despite the presence of ventilatory muscle fatigue, patients were able to walk twice the 12-minute walk, when the second test was performed immediately after the first test. In that study all the COPD subjects achieved relatively high minute ventilation corresponding more than 70% of predicted maximal breathing capacity in both of these 12-minute walking tests.

Impaired cardiac output response to exercise

"It is impossible to stress only the heart or only the lungs. Rather, all exercise requires the coordinated function of both the heart and lungs as well as the peripheral and pulmonary circulation to achieve the cellular gas exchange required to live and work". (Wasserman et al. 1987, 2.)

Hemodynamic studies have reported slowed or impaired cardiac output increase during exercise in COPD patients. The reduced cardiac output response to exercise may be due to right ventricular dysfunction related in part pulmonary hypertension, and reduced pulmonary vascular bed and the bed's restricted ability to vasodilate during exercise to allow the right ventricle to drive blood through the lungs at a rate that is adequate to match the increase required by the left ventricle to support cell respiration. (Morrison & Zuckerman 1993; Wasserman 1993.)

In spite of the pulmonary and possible cardiac pathology, the VO_2-work rate relationship is seen to increase linearly with a normal VO_2-heart rate (O_2-pulse) relationship (figure 4). However, because of the ventilatory limitation the heart rate at maximum work rate is generally low (high heart rate reserve). Similarly, the maximum VO_2 is reduced in the patients with obstructive lung disease. (Wasserman & Whipp 1975.)

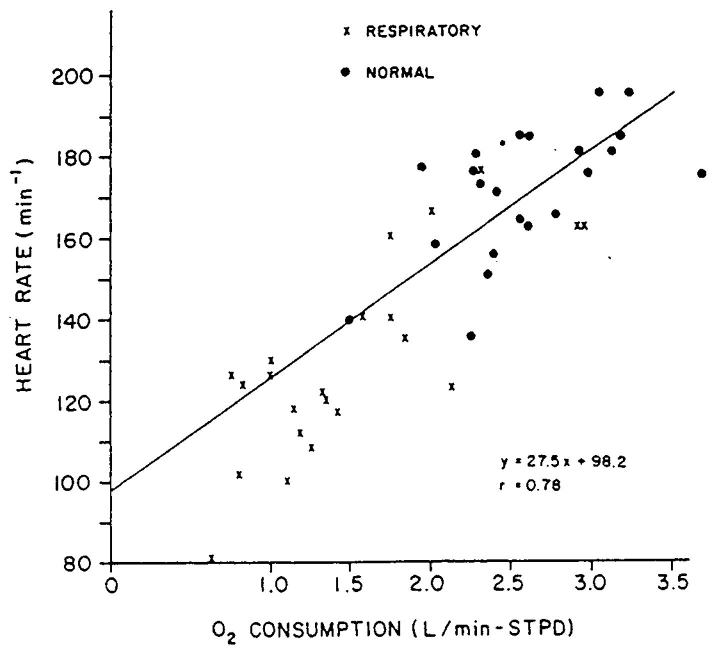

FIGURE 4. The relationship between heart rate and VO_2 in patients with chronic respiratory disease and in normal subjects (Modified from Wasserman & Whipp 1975).

Symptoms limiting exercise

Dyspnea is a conscious sensation of discomfort associated with the act of breathing, and dyspnea is explained to reflect the ventilation in relation to capacity. The sensation of dyspnea has shown to be a complex phenomenon involving both physiologic and psychological factors that contribute to the perception of dyspnea. The quality of respiratory sensation is a combination of the various receptor types that are stimulated and the magnitude of that stimulation. There are a number of different sensory receptors in pulmons, muscles, and upper airways, which are activated by breathing stimulus. The sensory nerves transmit the afferent sensory information to the central nervous system where this information is processed and further leads to the formation of a sensory impression of peripheral receptor conditions. The interpretation this sensory impression leads to the generation of respiratory sensation. (Killian 1993.)

A study of Killian, Summers & Jones (1992b) showed that the intensity of dyspnea is increased in patients with increasing impairment. It was found that in patients with severe airflow limitation (FEV_1 = 0 to 40 %) dyspnea was more frequently limiting whereas symptom limitation was not significantly different in those patients with mild (FEV_1 = 60 to 80 %) and moderate (FEV_1 = 40 to 60 %) airflow obstruction than in normal subjects.

Less commonly than sensations of dyspnea, patients with airways obstruction experience subjective muscle effort during exercise. The sense of peripheral muscle effort reflects the power output in relationship to capacity to perform work. (Killian 1993.) A study of Killian, Leblanc, Martin, Summers, Jones & Cambell (1992a) demonstrated that the exercise capacity of patients with airflow obstruction was limited by leg muscle effort and dyspnea as in normal subjects, but the limiting symptom intensity was reached at lower power output. Both normal subjects and patients with airways obstruction stopped the exercise when either leg effort or dyspnea reached intensity of 7 (very severe) an average on the Borg 0 - 10-scale.

Kearon, Summers, Jones, Cambell & Killian (1991) quantified the interaction between work intensity and duration to leg effort and dyspnea during cycle ergometer test in normal subjects. These authors found that perceived leg effort and dyspnea during exercise increased due to changes in work intensity rather than changes in duration. This data suggest that minimizing the intensity by prolonging the duration of activity have a dramatic effect on reducing muscle effort and dyspnea.

In summary, it has been showed that a number of factors affect ventilation contributing to exercise intolerance in patients with COPD. To illustrate some of the abnormal physiologic responses to exercise in COPD, Wasserman (1993) compared the metabolic cost, ventilatory requirement, and lactic acidosis that developed in response to exercise in patients with two different degree of airways obstruction due to emphysema and in normal subjects (table 1). The physiological response and work rate were measured at an O_2 consumption (VO_2) of approximately 1.0 liter per minute. The results show that the work rate for given O_2 uptake of 1.0 liter is markedly reduced in COPD patients as compared to work rate of healthy subjects. This may be resulted in part from increased work of breathing of COPD patient and in part from elevated blood lactate concentration. The increased minute ventilation (V_E) relative to VO_2 in both COPD groups reflects the inefficient gas exchange caused by V/Q mismatching. Blood lactate concentrations were markedly elevated in both COPD groups suggesting that these patients may have either a low aerobic capacity of the exercising muscles or an impaired cardiovascular function.

TABLE 1. Comparison of blood lactate concentration, minute ventilation, and an O_2 consumption of approximately 1.0 liter per minute in two groups of COPD patients and in healthy subjects (Wasserman 1993).

FEV_1 (L)	$\dot{V}O_2$ (L/min STPD)	WR (Watts)	$\dot{V}E$ (L/min BTPS)	$\dot{V}E/\dot{V}O_2$	La (mM/L)	La/$\dot{V}O_2$
1.02	0.90	35	35	39	3.03	3.37*
1.80	1.05	34	36	34	2.95	2.80†
Normal	≈1.00	50	25	25	<1.00	<1.00‡

2.2.2 Symptom-limited maximum oxygen uptake (VO_2SL)

Aerobic and anaerobic abilities are the components of cardiorespiratory fitness. In the assessment of aerobic abilities maximal aerobic power (VO_2max) is regarded as a major index. Aerobic (or endurance) capacity is another evaluative criterion of aerobic ability. Aerobic capacity is closely related VO_2max and it indicates the ability to sustain high intensity exercise for a prolonged time. (Skinner, Baldini & Gardner 1990.)

Maximal aerobic power is dependent on pulmonary ventilation, cardiac performance, peripheral blood flow, and oxygen extraction and utilization in exercising skeletal muscles. However, since in healthy subjects O_2 increases linearly with cardiac output,

VO_2max mainly represents O_2 delivery rather than O_2 utilization. (Åstrand & Rodahl 1986, 297, 373, 379.)

Maximal aerobic power (also expressed as maximal oxygen uptake or maximal oxygen consumption) has been defined as a demonstration of a plateau of oxygen uptake despite further increases in the work rate. Thus, maximal VO_2 represents the highest possible VO_2. Maximum VO_2, on the contrary, is an index of the highest VO_2 achieved without a plateau in VO_2 during maximal effort. In healthy subjects maximum VO_2 measured during incremental test closely approximates the predicted VO_2max, even when a plateau is not evident. In airways obstruction disease, the patients usually stop exercising due to limitation in ventilatory capacity, and a plateau in VO_2 may not be demonstrated. However, in clinical evaluation the maximum VO_2 in an incremental exercise test has seen to yield a good estimate of VO_2max. (Wasserman et al.1987, 28-30.) In dyspneic patients the maximum oxygen uptake is expressed as VO_2 limited by the symptoms (VO_2SL) (Gimenez 1989; Jones & Campbell 1982, 127).

Maximal oxygen uptake varies with age, sex, body size, level of activity, and the type of exercise. Of these factors sex and age have been found to be the most important factors in prediction of maximal VO_2. (Wasserman et al. 1987, 73.) Nevertheless, there is a large variability of maximal O_2 uptake in subjects of the same age and gender. It has been proposed that in healthy people maximal oxygen uptake is largely dependent on genetic factors and physical activity. (Åstrand & Rodahl 1986, 296, 334.) In the elderly people an intensive exercise training has been found to increase VO_2max by up to 30 %, suggesting that exercise habits have a large effect on aerobic power also at older age (Seals, Hagberg, Hurley, Ehsani & Holloszy 1984).

Patients with airways obstruction have been reported to have lower maximum oxygen uptake values than healthy persons (Jones et al. 1971; LoRusso, Belman, Elashoff & Koerner 1993; Punzal, Ries, Kaplan & Prewitt 1991; Wasserman & Whipp 1975). In these studies, the maximum VO_2 values in the elderly male patients have ranged from 0.46 in severe to 2.68 $L \cdot min^{-1}$ in mild COPD. Of these studies above in the study of Punzal et al. (1991) the maximum VO_2 values were also expressed in relative terms. In this intervention study the maximum VO_2 values in patients with moderate to severe COPD were 18.6 ± 6.9 $mL \cdot kg^{-1} \cdot min^{-1}$ measured in the treadmill test after rehabilitation. Nevertheless, data on maximum VO_2 in patients with airways obstruction that is precisely defined with respect to age, sex, body size, level of activity, disease severity, and the type of exercise are lacking. On the contrary, for healthy subjects there exist several studies on VO_2max. In the literature review of Shvartz and Reibold (1990), VO_2max of 62 previous studies in the USA, Canada, and 7 European countries were reported. The means of directly measured VO_2max for healthy untrained men aged 30, 50, and 75 years were 3.2, 2.7, and 1.6 L·min, respectively. The corresponding relative values for the above age groups were 48.0, 35.0 and 25.0 $mL \cdot kg^{-1} \cdot min^{-1}$, respectively. In a review of 17 studies of males, comprising 700 observations in treadmill exercise, Dehn & Bruce (1972) derived the equation for weight-relative VO_2 prediction. This equation ($VO_2max = 57 - 0.39yr\ mL \cdot kg^{-1} \cdot min^{-1}$) predicts VO_2max to be 45.3, 37.5, and 27.8 $mL \cdot kg^{-1} \cdot min^{-1}$ for healthy men aged 30, 50, and 75 years, respectively.

Maximal oxygen uptake is typically expressed in absolute ($L \cdot min^{-1}$) terms for activities such as cycle or arm ergometer, in which body weight is externally supported. For comparing VO_2 of the individuals of different body size and for assessing the energy cost of weight supported activities such as treadmill walking or running, VO_2 is preferable to be expressed in relative ($mL \cdot kg^{-1} \cdot min^{-1}$) terms. (American College of Sports Medicine 1995, 271.)

2.2.3 Effects of age and disease severity on exercise tolerance

As a great part of the COPD patients are elderly individuals there is progressive decline with advancing age in maximum VO_2 and muscle strength. The gradual decline in maximum VO_2 after the age of 25 years is about 1 % per year so that at the age of 65 the mean value of maximum VO_2 is about 70 % of the value of 25-year-old individual. This age-related decrease in aerobic power is partly caused by a reduction in maximal heart rate. Inactivity, which often accompanies aging acts also to reduce the oxygen-transporting potential: the stroke volume is reduced and the efficiency of the regulation of the circulation during exercise is interfered. (Åstrand & Rohdahl 1986, 333-336.)

The decline in muscle strength with advancing age is related to the reduction in muscle mass. There is a loss of muscle fibers down to some 60 percent of the initial number, whereas the cross sectional area remains unchanged during the life, except some diminution in the size of the fast-twitch muscle fibers. The rate of the decline in strength is greater in leg and trunk muscles than in arm muscles. (Åstrand & Rohdahl 1986, 342-343.) According to Jones and Killian (1990) the muscle weakening is mainly due to sedentary lifestyle of pulmonary patients, which over time leads to structural and physiological changes in skeletal muscles. These authors have found that many patients with chronic respiratory disorders have weak quadriceps muscles that contribute to poor exercise performance in these patients. Nevertheless, it has been shown that by exercising old people can improve their muscle functioning. For example, Frontera, Meredith, O'Reilly, Knuttgen & Evans (1988) found that elderly men (aged 60-72 yrs) whose neuromuscular and cardiorespiratory function was reduced, responded to 12-wk heavy weight training with large increases in strength in knee extensors (107 %) and flexors (227 %), and significant muscle hypertrophy (11 %).

The severity of disease as expressed in FEV_1 has been shown to influence in the exercise capacity in patients with airways disease. A decline in maximum oxygen uptake with declining FEV_1 has observed by Jones et al. (1971), and LoRusso et al. (1993). Jones and coworkers (1971) investigated the exercise tolerance of 50 men aged 43 to 73 years. They found a maximum oxygen uptake values ranging from the mean value of 0.91 $L \cdot min^{-1}$, in the most severely obstructed group (FEV_1 = 0.8 L), to 1.43 $L \cdot min^{-1}$ in the group of the mildest airways obstruction (FEV_1 = 1.6 L). In a study of LoRusso et al. (1993) data from a large sample of patients of mean age 62 years with airways obstruction was analyzed. In this study the patients were subdivided into three subgroups of increasing severity of airways obstruction. In their study population, the maximum mean VO_2 values were 0.77 $L \cdot min^{-1}$ to severe, 1.19 $L \cdot min^{-1}$ to moderate, and 1.43 $L \cdot min^{-1}$ to mild COPD. Figure 5 illustrates the relationship between disease severity as reflected in FEV_1 and exercise capacity, (and figure shows also the variability of the exercise capacity in subjects of the same disease severity) measured in cycle ergometer test (Jones & Killian 1990).

Some investigators have developed prediction equations for exercise tolerance based on pulmonary function measurements (Pineda, Haas, Axen & Haas 1984). These authors found that pulmonary function measurements *per se* can predict exercise tolerance, provided that broad range of disease severity is studied or a group of healthy subjects is included.

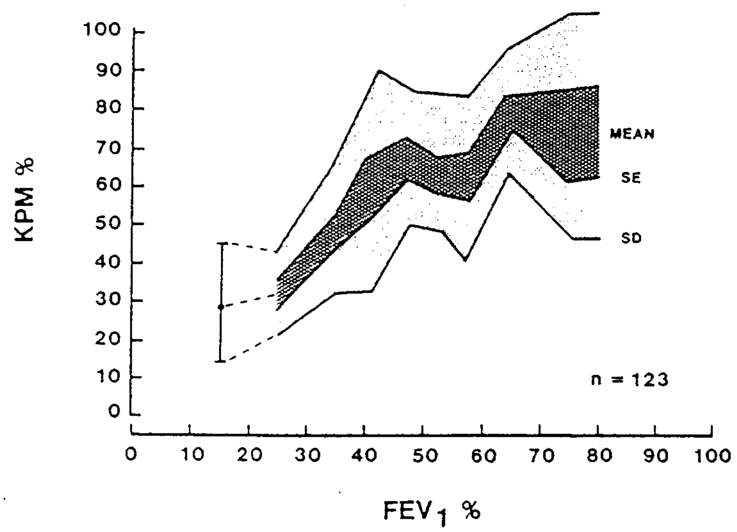

FIGURE 5. Relation between the maximum power output % predicted and the severity of airflow limitation, expressed as FEV_1 % predicted in 123 patients with COPD (Modified from Jones and Killian 1990).

2.3 Assessment of exercise tolerance in COPD

2.3.1 Direct assessment of maximum VO_2SL

Several principles and different forms of exercise are used in exercise work tests. The objectives of the testing program for clinical practice according to Andersen, Shephard, Denolin, Varnauskas & Masironi (1971) is the following: "To evaluate the effect of preventive, therapeutic and rehabilitation programmes, including the effects of medication, surgery, physical conditioning, and other means of improving health. In addition fitness tests have been used to reassure patients and motivate them to improve their health. "

Measuring VO_2max directly in laboratory conditions is the most accurate method for assessing cardiorespiratory fitness. In direct measurement VO_2 is determined from breathing gas values. In this method the volume of expired (V_E) or inspired (V_I) air over a specific time period and its oxygen (F_EO_2) and carbon dioxide (F_ECO_2) levels are measured and used to calculate VO_2. In this method VO_2 is calculated as follows:
$VO_2 = V_E \cdot [\, 0.265\, (\, 1.0 - F_EO_2 - F_ECO_2) \; - \; F_EO_2]$. (American College of Sports Medicine 1995, 272.)

In maximal oxygen uptake testing there is a need for specific working conditions and a highly motivated subject. The requirements for maximal exercise test according to Åstrand and Rodahl (1986, 367) include: exercise should involve large muscle groups; test conditions must be such that the results are comparable and repeatable; exercise should be measurable and reproducible; mechanical efficiency required for performing the task should be as uniform as possible in the population that be tested; testing must be tolerated by the individuals being evaluated.

In "normal" individuals maximal oxygen uptake during treadmill exercise is reported to be 4 to 15 % higher than during bicycle exercise (American College of Sports Medicine 1995, 108; Åstrand & Rodahl 1986, 358). Evidence from patients with mild to moderate airflow limitation has also suggested that at the highest work levels patients attained significantly higher oxygen uptake values on the treadmill than on the bicycle ergometer (Shuey, Pierce & Johnson 1969).

Since COPD is found with advancing age this should be considered when selecting testing modality. In terms of balance, the bicycle ergometer may be more convenient for older subject with poor balance. Furthermore, the bicycle ergometer provides an accurate definition of external work and the variability of the mechanical efficiency of pedaling is small among the patients. Poor muscle strength is another characteristics of older people. Some elderly have weakness in upper thighs and the pedaling leads to local muscle fatigue. For those people the treadmill is preferred. (Skinner 1987, 69-70.) When using treadmill, the stride length and cadence might be more efficient on repeated testing, thus the familiarization with treadmill is essential before exercise test (Jones & Campbell 1982, 128).

The subjective maximal effort depends upon motivation to work to exhaustion, and it may differ from the physiological maximal. Therefore a physiological criteria for maximal effort, including a plateau of oxygen consumption, a peak plasma lactate consentration of more than 8 $mmol \cdot L^{-1}$, maximal values of heart rate (220 - age), and the respiratory quotient (R) value over 1.0, is used. (Åstrand & Rohdahl 1986, 356-381.) However, Thomas, Cunningham, Rechnitzer, Donner & Howard (1987) have found that in a large sample of healthy elderly men aged 55 to 68 years only one third reached the plateau in VO_2max in treadmill exercise test, suggesting that in these persons peripheral factors such as reduced leg strength are more limiting factors than are central factors. In COPD patients maximal exercise is often stopped due to ventilatory limitation reflected by high intensity of dyspnea, before these physiological criteria are observed (Killian et al. 1992a). Due to the limitations in COPD patients the peak oxygen uptake in an exercise test is used as a measure of maximum attainable VO_2, expressed as maximum VO_2 limited by the symptoms (VO_2SL). (Gimenez 1989; Jones & Cambell 1982, 127.)

The maximal exercise protocol for evaluating the dyspneic patient should provide maximal information of the patient's pathophysiological causes of exercise limitation with the greatest accuracy, with the least stress to the patient, and in the shortest period of time. Tests that are too brief may be terminated because of the weakness or may not provide accumulation of sufficient quantity of data, whereas tests that are too long may be terminated too early because of boredom or discomfort not related to cardiorespiratory stress. Several investigators have recommended a test in which the work rate is increased by a uniform amount each minute after warming-up period. A work rate increment should be chosen so that the patient is symptom-limited in approximately 10 minutes. (Wasserman 1987, 66-68.)

2.3.2 Field tests

The indirect field tests have proved to be useful since they are more easily administered than direct VO_2max tests. A number of field tests are available, ranging from different step tests to timed walking tests. The indirect field tests are based on established relationship between test performance and/or physiological measurements and VO_2max. One of the very first investigators, who utilized this "indirect principle", were Åstrand and Ryhming already in 1954. These researchers demonstrated that there is a linear heart rate-VO_2 relationship throughout progressive exercise and thus VO_2max can be predicted from heart rate at submaximal work level. Some investigators have, however, found limitations in the accuracy of the HR-VO_2 linearity. Tests that predict VO_2max from maximum performance, such as the Cooper's test, assume similar mechanical efficiency and similar level of motivation throughout the test for all subjects. The indirect tests are much used since these tests are simple, they require minimal resource and they are generally applicable. (Laukkanen 1993, 22-23.)

One of the most popular field test modes is walking. In a literature review of Laukkanen (1993), walking was analyzed as a test mode. Walking has proved to be a good exercise mode for healthy individuals and for pulmonary, cardiac and musculoskeletal patients. Since the ground reaction forces are low in walking there is less stress on joints than if it is compared with running. The energy cost of walking is dependent on speed, body weight, stride length, the surface, clothing, and climatic conditions. Of these, the walking speed is the most important factor considering the oxygen expenditure. It has been shown that there is a direct linear relationship between oxygen uptake and walking speed within range of 50 - 100 $m \cdot min^{-1}$ (3 - 6 $km \cdot h^{-1}$). The cardiorespiratory strain of fast walking is seen to be substantial, but submaximal for most individuals. (Laukkanen 1993, 26-30.)

When regarding the test mode for COPD patients, walking has been much used. Walking is a well-known type of exercise and it is shown to be applicable to patients with disease of all grades of severity. Walking tests have particularly been used to evaluate exercise tolerance after rehabilitation treatment. (Donner & Patessio 1989.) The three following paragraphs present walking tests that have been validated for COPD patients.

The 20-meter shuttle run test (Léger & Lambert 1982) has been developed to test the functional capacity of large groups of individuals in a gymnasium at a minimal cost. Maximal speed for a 20-meter shuttle run test was shown to predict VO_2max in healthy adults ($r = 0.84$, SEE = 5,4 $mL \cdot kg^{-1} \cdot min^{-1}$). To assess functional capacity in patients with chronic airways obstruction, Singh, Morgan, Scott, Walters & Hardman (1992) developed an exercise test, which is modified from the version of Léger and Lambert.

This modified shuttle walking test requires the subjects to walk up and down a 10-meter course with walking speed dictated by a prerecorded audio signal played on a cassette recorder. The shuttle walking test has seen to provoke a graded cardiovascular response till tolerance.

Cooper (1968) developed a 12-minute running test to evaluate fitness in healthy young men. He found a close relation (r = 0.90) between distance covered in 12 minutes and the maximal oxygen uptake. McGavin, Gupta & McHardy (1976) adapted this test to evaluate exercise tolerance in patients with COPD. Since the introduction of 12-minute walking test for COPD, this walking test has been utilized to evaluate exercise tolerance after rehabilitation treatment (e.g. Cockcroft, Saunders & Berry 1981; McGavin, Gupta, Lloyd & McHardy 1977; Mungall & Hainsworth 1980; Sinclair & Ingram 1980). In this test each patient is instructed "to cover as much distance as he can on foot in 12 minutes". The patient is "told to going continuously if possible but not to be concerned if he has to slow down or stop to rest". In the study of McGavin et al. (1976) the authors compared the walking distance with some indices of lung function, finding a significant correlation with FVC (r = 0.406) and no correlation with FEV_1 (r = 0.283). A better correlation was found with maximum oxygen uptake (r = 0.52) and maximum exercise ventilation (r = 0.53). Considering the reproducibility of the 12-minute walking test varying results have been reported. McGavin et al. (1976) found a learning effect between the first and the second test, whereas no difference was found between the second and the third test. In the study of Mungall and Hainsworth (1979) the distance walked increased in the first three walks of a series of six walks carried out on different days. In a study of Swinburn, Wakefield & Jones (1985) the reproducibility of 12-minute walking test, incremental cycle ergometer test, and a fixed-rate paced step test were compared. It was found that there was a similar increase in performance in all the tests, and the increase occurred up to the last test of a series of four tests.

The 2- and 6-minute walking tests, modifications of a 12-minute walk, were developed by Butland, Pang, Gross, Woodcock & Geddes (1982). These authors demonstrated that equivalent results can be obtained with both a 2-minute and 6-minute walk. The distance walked in two, six and twelve minutes correlated well (two-minute vs. 12-minute, r = 0.86 and six-minute vs. 12-minute, r = 0.96). Butland and coworkers believe, that even though the 12-minute walking test is more discriminating than two- or six- minute tests, these tests with shorter duration are adequate in patients with more severe disability. In a recent study of Bernstein, Despars, Singh, Avalos, Stansbury & Light (1994), the relationship between different intervals in the 12-minute walk and maximum oxygen uptake was determined. The correlation coefficients between the distance walked in 2-, 4-, 6-, and 12 minutes, and the weight-relative maximal oxygen uptake were 0.55, 0.62, 0.67, and 0.65, respectively. This study considered also the predictability of these walks. It was found that changes in maximum VO_2 after exercise training correlated more closely with changes in 12-minute walk (r = 0.72) than with changes in the 6-minute walk (r = 0.64), the 4-minute walk (r = 0.59), or the 2-minute walk (r = 0.53). Considering the reproducibility of the 6-minute test, Guyatt, Pugsley & Sullivan (1984) studied the effect of encouragement on walking test performance. It was found that there was a significant improvement in the distance walked (+30.5 meters on average) when the encouragement was given to the patients by the supervisor. These data suggest that there is need for careful standardization of the test procedure to avoid the influence of learning or encouragement on the test results.

2.4 A two-kilometer walking test

A submaximal 2-km walking test was designed by Laukkanen and coworkers (1993) for determining the cardiorespiratory fitness of healthy adults. Four studies were conducted in order to develop and evaluate systematically validity, repeatability, cross-validity, and feasibility of the test.

The first study was conducted with 159 healthy women and men aged 20 to 65 years. In this study, the selection of the test distance was made on the basis of subjective experiences and physiological superiority between three distances of 1-, 1.5-, and 2-km. In a comparison, the 2-km distance was the most accurate in predicting the directly measured VO_2max, and also the 2-km distance was preferred by the subjects. The mean walking times in the 2-km walking were 16.9 min for the women and 15.2 min for the men. In the age groups of 50 -55- and 60 - 65-year-old men the mean walking times were 15.2 min and 16.1 min, respectively. In the further evaluation of the use of 2-km walking as a test mode the predictive equations were developed. Elapsed time for the 2-km walk, heart rate at the end of the walk, age, body weight or BMI were selected as the variables to construct equations for the prediction of VO_2max. The predictive equations explained 66 to 76 % of the variance in VO_2max ($mL \cdot kg^{-1} \cdot min^{-1}$) with standard errors of estimate of 9 - 15 % of the mean. (Oja, Laukkanen, Pasanen, Tyry & Vuori 1991.)

The first cross-validation of the test was studied with 77 overweight women and men ages 20- to 65-years with a BMI $(kg \cdot m^2)^{-1}$ of 27 - 40. The results showed that the test is valid for overweight men and women. The correlation coefficient between measured and estimated VO_2 max varied between 0.75 - 0.77. In a comparison of 1- and 2-km test distances, the 2-km distance was the most preferable and accurate in predicting the measured VO_2max. The 2-km test was perceived as moderately hard (RPE 3). All subjects were able to perform the walking tests, even though some subjects had mild leg symptoms. (Laukkanen, Pasanen & Vuori 1992b.)

The second cross-validation study examined criterion validity of a 2-km walking test for predicting the maximal oxygen uptake of moderately to highly active middle-aged adults. Sixty-seven 35- to 45-year old men and women and forty-four 35- to 55-year old men participated the study. These subjects, especially the group of highly active men had technical difficulties related to fast walking, which resulted in underprediction (6 - 7 %) of VO_2max. The correlation coefficient between measured and predicted VO_2max ($mL \cdot kg^{-1} \cdot min^{-1}$) for moderately active men and women and for well-trained men were 0.79, 0.55 and 0.60, respectively. (Laukkanen, Oja, Pasanen & Vuori 1993b.)

These aforementioned moderately and highly active women and men participated the study concerning the influence of walking speed on VO_2 prediction. The maximal speed and the submaximal speeds of 60 %, 70 % and 80 % of the maximal heart rate were analyzed. The results indicated that a walking speed corresponding to 80 % or more of maximal heart rate yields the most accurate prediction of maximal oxygen uptake in middle-aged adults. When the walking speed correspond to less than 80 % of HRmax, the accuracy of the prediction is seen to decrease despite fitness level or gender. (Laukkanen, Oja, Pasanen & Vuori 1993a.)

The feasibility of the walking test as a large population test was studied in Sotkamo, a rural municipality in northeastern Finland. The original population sample consisted of 665 persons. The subjects were recruited by a questionnaire and follow-up telephone calls. Of these people contacted, two-thirds volunteered to take part in the walking tests. When subjects with health or other limitation, or participation were taken into account, two thirds of them were able to walk two acceptable tests for reliable VO_2max prediction. (Laukkanen, Oja, Ojala, Pasanen & Vuori 1992a.)

The results of these studies suggest that the 2-km walking test is a valid, reliable, and feasible method for estimating the cardiorespiratory fitness of the majority of healthy adults. The test is socially acceptable, practical, and safe to perform. (Laukkanen 1993.) To my knowledge the use of the 2-km walking test has not been reported for any disease state.

2.5 Validity, reliability, and feasibility of a test

Validity of measurements refers to the extent to which test measures what it claims to measure. Maximal oxygen uptake is seen to be valid measure of cardiorespiratory fitness. Since VO_2 measurements in laboratory conditions are costly and time consuming, simpler field tests for VO_2 max prediction have been developed. The results of a valid field test correlate significantly with the results of direct VO_2 max assessment. Validity is accompanied with reliability, which indicates the consistency, or repeatability of a measurement. Repeatability of measurements depends on the subject, the testing, the scoring, and the instrumentation. Measurement error from subjects includes factors as motivation, previous practice, and familiarity with the test. Errors in testing refers to the lack of clarity in the directions and a poor instruction following. The competence, experience, and dedication of the scorers are associated with errors in scoring. The scorer should be familiar with the behavior being tested and test items in order to achieve accurate test results. Errors from instrumentation relate to inaccuracy and lack of calibration of mechanical and electronic equipment. Thus, there are several error sources, which may affect the repeatability of a test. High reliability of measurement indicates a high degree of repeatability of test results. However, this consistency of results is not same as validity, because repeatable results may be repeatedly wrong. But, if a test over repeated trials yields the same true results a test can be considered valid. (Thomas & Nelson 1990, 349-356.)

The reliability of measurement is often expressed by correlation coefficient. Intraclass correlation (R) is a statistical technique for examining systematic differences among trials of the same variable. Intraclass correlation is determined through analysis of variance (ANOVA) procedures. Interclass correlation, referred as Pearson r, is used in correlating two different variables (bivariate statistic). (Thomas & Nelson 1990, 350-353.) This correlation is commonly used in studies of predictive fitness test, where correlation coefficient shows the relationship between test performance and/or physiological measurements and VO_2max (e.g. Cooper 1968; Laukkanen et al. 1992a, 1992b, 1993a, 1993b; Léger & Lambert 1982; McGavin et al. 1976; Oja et al. 1991). Correlation coefficient is largely dependent on the number of observations, so that only one exceptional observation can affect the value of the coefficient. Therefore, in a small sample size, correlation coefficient alone is not a sufficient measure of the accuracy of the prediction. Together with correlation coefficient, the standard error of estimate (SEE) is commonly used as statistical quantity in predictive fitness tests. (Laukkanen 1993, 21.)

In the evaluation of cardiovascular fitness, term feasibility refers to the suitability of a test in population assessment. According to Rose (1968, 96), there is a need for a carefully standardized procedures in exercise testing. The feasibility requirements of an exercise test are the following: the task should be simple and brief requiring no special skill for its performance; the task should be safe and within the capacity of most ambulatory subject whether patients or active healthy persons; the task should activate large muscle masses of the body; the task should permit steady-state periods for physiological measurements; the task should provide repeatable results; the task should estimate energy expenditure related to body mass and permit the calculation of the physical work; the task should provide estimates of maximal responses and work capacity.

In the assessment of exercise tolerance it is important to consider the reason for doing a test and a population to be evaluated. For elderly and people with lung and heart diseases tests should be such that they are related to those factors that are important for health, well-being, and independence. (Skinner et al. 1990.) Andersen and coworkers (1971, 113) have proposed that submaximal tests are feasible methods for patients and elderly people since these tests allow the physician to give functional evaluation of the subject's physical working capacity, and comparison with similar data obtained in healthy subjects of the same sex, age, and body built.

3. PURPOSE OF THE STUDY

The purpose of the present study was to evaluate a 2-km walking as a test mode in male patients with moderate COPD.

The specific aims of this study were:

1. to describe the pathophysiologic mechanism limiting exercise tolerance in COPD,

2. to assess the exercise tolerance of the study group reflected by symptom-limited maximum VO_2, V_E, and HR at maximum exercise,

3. to evaluate the walk performance in respect to the instructions of the 2-km walking test,

4. to evaluate the relationship between maximum VO_2SL, the 2-km walk performance, and pulmonary function.

4. METHODOLOGY

4.1 Subjects

The sample of this study consisted of thirteen male subjects with COPD, aged 63 ± 8 years. All subjects were living in southern France. They were recruited from among the out-patients of the pulmonary rehabilitation center, Clinique de Jour Le Carlit, at Perpignan and from in-patient pulmonary rehabilitation center, Centre Les Escaldes, at Angoustrine. The aim of the selection of study population was to obtain representative number of subjects comparable with respect to the severity of disease, age, and gender. The studied population consisted of male subjects whose respiratory impairment was moderate (FEV_1 = 40 % - 60 %). In addition the subjects had to fulfill the following inclusion criteria: clinical diagnosis of COPD confirmed by history, physical examination and spirometry evaluation; stable clinical condition; no other significant lung disease; no primary cardiac disease; no neurological or locomotor disorders. The medications remained unchanged during the study including theophylline and steroids. All subjects gave their informed consent for the study. The subject characteristics and resting pulmonary function are shown in table 2.

At the time of the study the subjects were taking part in rehabilitation program which included disease evaluations, breathing exercises and physical activity at least three times a week. The subjects were not allowed to do vigorous exercise training for 24 hours before each exercise test. Most of the subjects were familiarized with a treadmill during rehabilitation phase.

TABLE 2. Subject characteristics and resting pulmonary function.

No.	Age yrs	Height cm	Weight kg	FVC, L (% pred)	FEV_1, L (% pred)	FEV_1/FVC % pred	MVV $L \cdot min^{-1}$
1	52	177	85	3.79 (84)	2.01 (56)	53	75.4
2	55	157	65	2.03 (61)	1.12 (41)	68	42.0
3	72	178	80	3.08 (77)	1.30 (43)	42	48.8
4	68	165	75	2.62 (77)	1.17 (45)	45	43.9
5	67	170	80	2.67 (72)	1.38 (48)	78	51.8
6	64	171	96	1.92 (49)	1.42 (47)	74	53.3
7	68	165	83	2.60 (77)	1.52 (58)	58	57.0
8	61	175	74	3.52 (84)	1.92 (58)	55	72.0
9	67	167	74	2.54 (72)	1.50 (55)	76	56.3
10	58	166	80	2.38 (63)	1.28 (43)	54	48.0
11	70	175	77	3.00 (76)	1.69 (56)	56	63.4
12	65	158	68	2.01 (66)	1.21 (50)	50	45.4
13	46	167	52	2.35 (57)	1.42 (42)	60	53.3
Mean	62.5	168.5	76.1	2.65 (70.4)	1.46 (49.4)	59.2	54.6
SD	7.7	6.7	10.6	0.57 (10.6)	0.27 (6.5)	11.6	10.3

FVC: forced vital capacity; FEV_1: forced expiratory volume in one second; MVV: maximal voluntary ventilation (calculated as 37,5 x FEV_1); % pred: percentage predicted.

4.2 Assessment of pulmonary function

Lung function tests were applied to characterize the patients forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1), measured by a flow-volume spirometer (V6200, Sensor Medics, USA; and Body Plethysmograph for Med Graphics, USA). Maximal voluntary ventilation (MVV) was calculated by multiplying FEV_1 by 37,5 (Carter et al.1987; Casaburi et al. 1990). Resting pulmonary function and anthropometric measurements are shown in table 2.

4.3 Direct assessment of maximum VO_2SL

To determine maximum VO_2SL and related variables, a treadmill (Power Jog M10, USA; and Gym Roll Super 2500, France) test was carried out. The test was performed according to the method described by Wasserman (Harbor protocol) at normal room temperature and humidity (Wasserman et al. 1987, 66-68). The subjects were lightly dressed. After 3 minutes warm-up at a comfortable walking speed at zero grade there was a constant grade increment at 1-minute intervals to the patient's symptom-limited maximum. According to Harbor protocol speed and grade were scaled so that the test ended approximately 10 minutes after the work rate increment had begun.

Respiratory gas exchange was collected and analyzed throughout the test with telemetric oxygen consumption system (K2, Cosmed, Italy). Before every test the gas analyzer was calibrated with a precision reference gas. During the tests heart rate was recorded by the K2, and arterial oxygen saturation (SaO_2) was measured by finger oxymetry. In addition, in some patients blood pressure was taken at periodic intervals. The peak value of VO_2 was used for symptom-limited maximum VO_2 (VO_2SL). Table 3 shows the treadmill test results.

4.4 Field test

The 2-km walking tests were conducted outdoors in February - April. The weather conditions during the tests were good: the temperature ranged from +18 to +22 °C and there was not much wind.

The test facilities were a 400-meter track for 10 subjects and a stretch of flat dirt road for 3 subjects. Each subject walked twice the two kilometer distance on separate days. Before the test the subjects prepared for the test doing warming up and stretching exercises. The subjects walked the distance in groups of 2 - 5 subjects, each individual starting in 1-minute intervals. The tests were administered following the instructions of "Guide for The UKK Institute 2-km walking test" by Laukkanen and Hynninen (1990). The instructions for the walk were to "Walk the distance as fast as you can, but do not risk your health". In addition the subjects were asked to walk at a steady pace using normal walking style. The time of walk was recorded to the nearest second. During the test heart rate was recorded by heart rate monitor (Sport Tester PE 3000, Polar Electro, Finland). The heart rate at the finish line was defined as the walking heart rate. Immediately upon crossing the finish line the ratings of perceived exertion (RPE) for leg effort and dyspnea of the subjects were assessed on the Borg 0-10-scale (Borg 1980). On the Borg scaling the subjects were asked to select a number on a paper (between 0, nothing at all, and 10, maximal) to estimate the intensity of discomfort with breathing and the intensity of leg effort (Appendix 1). In addition the subjects were asked to mention if they had symptoms or factors that limited their walk performance. The data from second 2-km test is used in results presented in table 4.

4.5 Statistical analyses

All analyses were made using the SPSS program for PC. Data are expressed as mean (M) ± standard deviation (SD). In the study the following statistical tests were applied: An analysis of variance (ANOVA) to determine test-retest repeatability of 2-km walk; Pearson's product-moment correlation to evaluate the relationship between maximum VO_2SL, walking performance, and selected variables; Student's t-test or the F-test to evaluate the statistical significance of the correlation coefficients; A regression analysis to construct a predictive maximum VO_2SL equation. The results were considered significant if p-value was less than 0.05.

5. RESULTS

5.1 Performance in the treadmill test

At the maximum exercise (table 3) maximum VO_2SL was 23.8 ± 3.4 $mL \cdot kg^{-1} \cdot min^{-1}$ (1.80 ± 0.29 $L \cdot min^{-1}$) for the group. The mean maximum exercise V_E was 51.0 ± 8.7 $L \cdot min^{-1}$. The group mean of maximum heart rate was 139.5 ± 20.9. Using a predicted value of (220 - age), the maximum heart rate in the test averaged 88.8 ± 14.4 % of predicted maximal heart rate whereas maximumV_E values during the test averaged 94.4 ± 12.1 % of the predicted maximal ventilatory capacity (MVV) calculated as FEV_1 x 37,5.

TABLE 3. The physiological variables measured in the maximum treadmill test.

No.	VO_2SL $mL \cdot kg^{-1} \cdot min^{-1}$	VO_2SL $L \cdot min^{-1}$	V_E $L \cdot min^{-1}$	V_E/MVV %	HR $beats \cdot min^{-1}$
1	24.4	2.07	63.5	84	150
2	23.9	1.55	41.2	98	118
3	27.1	2.17	48.7	100	171
4	24.8	1.86	45.2	103	135
5	23.4	1.87	42.9	83	123
6	21.3	2.04	56.9	108	117
7	18.6	1.54	44.7	78	96
8	28.5	2.11	66.5	92	142
9	24.1	1.78	55.2	98	146
10	25.3	2.02	54.4	113	153
11	20.2	1.56	48.9	77	159
12	18.6	1.26	38.2	84	158
13	29.3	1.52	57.3	108	146
Mean	23.8	1.80	51.0	94.4	139.5
SD	3.4	0.29	8.7	12.1	20.9

Weight-relative maximum O_2 uptake (VO_2SL, $mL \cdot kg^{-1} \cdot min^{-1}$); absolute maximum O_2 uptake (VO_2SL, $L \cdot min^{-1}$); minute ventilation (V_E), ventilation/maximal voluntary ventilation-ratio (V_E/MVV, %); and heart rate (HR) in the maximum treadmill test.

The walking times in the treadmill tests ranged between 8 to 13 minutes. The subjects complained both general fatigue and dyspnea on stopping the exercise. One subject had also leg muscle pain. None of the subjects interrupted the test because of objective evidence of low arterial oxygen saturation. However, two of the subjects had arterial oxygen saturation values close to the "critical" value of 85 % at the end of their final grade during the maximal treadmill test.

5.2 Performance in the 2-km walking test

The walking time ranged from 17 min 30 s to 25 min 33 s in the first and from 17 min 7 s to 25 min 11 s in the second 2-km test with a mean time 21 min 26 s and 20 min 45 s for test 1 and 2. The mean pace for the first and the second walk was 94 and 98 $m \cdot min^{-1}$, respectively. The heart rate ranged from 90 to 145 $beats \cdot min^{-1}$ in the first and from 92 to 153 $beats \cdot min^{-1}$ in the second two kilometer walk. The maximum heart rate at the end of the second walk represented 93.4 ± 3.9 % (range 86 to 97 %) of maximum heart rate recorded in the treadmill test. The results of analysis of variance (ANOVA) showed that either the walking times or the heart rates of the two 2-km walks were not significantly different. The test-retest correlation coefficients were 0.93 both for walking times and for heart rates.

No subject had to interrupt the walking tests due to excessive dyspnea, leg muscle pain, or any other reason. The dyspnea during the second 2-km walk was perceived as "severe" (mean RPE 4.8) whereas leg effort was perceived as "somewhat severe" (mean RPE 3.9). Two of the subjects reported leg symptoms during walking, one subject in thigh area and one subject in calves. The data from the second 2-km walk is used in the results presented in table 4.

TABLE 4. The results from the second 2-km walking test.

No.	Time min	HR $beats \cdot min^{-1}$	% HRmax	RPE dyspnea	RPE leg effort
1	19.90	142	95	4	2
2	19.32	114	96	9	9
3	19.36	149	87	4	2
4	23.52	126	93	3	3
5	19.43	119	97	4	2
6	22.50	113	96	4	4
7	25.18	92	96	4	4
8	18.93	125	88	3	5
9	18.40	140	96	8	6
10	20.96	132	86	5	4
11	18.87	153	96	6	4
12	25.00	145	92	4	3
13	17.12	140	99	4	3
mean	20.65	130.0	93.4	4.8	3.9
SD	2.59	17.4	3.9	1.8	1.9

Performance times for a 2-km walking; heart rates (HR); heart rate relative to maximum measured in the treadmill exercise test (% HRmax); and ratings of perceived dyspnea and leg effort (RPE) on the Borg 0 - 10-scale, at the end of the walk.

5.3 Relationship between maximum VO_2SL, the 2-km walking performance, and pulmonary function

Weight-relative maximum VO_2SL ($mL \cdot kg^{-1} \cdot min^{-1}$) correlated positively with 2-km walking time ($r = -0.694$, $p = 0.004$) (table 5). No other significant correlation were found between maximum VO_2SL ($mL \cdot kg^{-1} \cdot min^{-1}$) and other variables examined including age, body height, body weight, heart rate at the finish line for the 2-km walk, FEV_1, FVC, and MVV. Absolute maximum VO_2SL ($L \cdot min^{-1}$) showed significant positive correlation with body weight and height variables but not with walking time.

In the regression analysis, after walking time was entered none of the other variables remained significant in the estimation of aerobic power. Walking time alone explained

48% of the total variance of maximum VO_2SL in $mL \cdot kg^{-1} \cdot min^{-1}$ ($F = 10.2$, $p = 0.008$), with a standard error of estimate (SEE) of 10.9 % of the VO_2SL mean. The regression analysis yielded the following weight-relative maximum VO_2SL prediction equation: VO_2SL ($mL \cdot kg^{-1} \cdot min^{-1}$) = 42.768 - 0.918(2-km time in minutes). Scattergram between predicted and measured VO_2SL ($mL \cdot kg^{-1} \cdot min^{-1}$) is illustrated in appendix 2, according to the prediction equation seen above.

TABLE 5. Correlation coefficients between symptom-limited maximum oxygen uptake (VO_2SL), and selected variables.

Variables	VO_2SL ($mL \cdot kg^{-1} \cdot min^{-1}$)	VO_2SL ($L \cdot min^{-1}$)	2-km walking time
1.Walking time	-.69**	-.27	
2.Heart rate	.26	.02	-.44
3.Age	-.46	.08	.38
4.Weight	-.39	.58*	.37
5.Height	.34	.71**	-.42
6.FEV_1	.13	.34	-.30
7.FVC	.35	.52	-.34
8.MVV	.13	.34	-.30
9.maximum VO_2SL ($mL \cdot kg^{-1} \cdot min^{-1}$)		.52	

*. Correlation is significant at the 0.05 level.
**. Correlation is significant at the 0.01 level.

6. DISCUSSION

6.1 Methodology

6.1.1 Subjects

The subjects in this study were selected to represent a homogeneous COPD study group. Entry criteria included: only male patients with moderate airways obstruction (FEV_1 = 40 % - 60 %) and an absence of other disorders which are likely to affect exercise capacity. The age range of the study was defined to correspond to age distribution of characteristic COPD population. Due to this selective inclusion criteria there was a difficulty to obtain a large sample of subjects in the rehabilitation centers the study was carried out.

Although the study population in the present study was modest it comprises defined subgroup, thereby reducing variability found in exercise tolerance within the definition of COPD. The results of the current study should be considered as "disease-specific", representing only male patients with moderate degree of airways obstruction. However, due to the limited sample size the subjects were not grouped or analyzed by differences within age, body composition, or disease description (emphysema vs. chronic bronchitis).

At the time of the study all subjects were participating in rehabilitation program to improve their physical fitness. Subjects had high motivation and there were no exclusions due to submaximal effort or lack of co-operation in the exercise tests.

6.1.2 Direct assessment of maximum VO_2SL

In the present study treadmill test was used instead of bicycle test, for the aim of the study was to evaluate a field test based on walking as a test mode. The use of treadmill has been criticized in some respects. One problem is that in the elderly, uncoordinated subjects, a sudden exhaustion during the treadmill test may cause injury. (Skinner 1987, 69-70.) In this study, the patients were familiarized with the treadmill during their rehabilitation period. If a patient was not accustomed with the treadmill, a familiarization was provided before an exercise test. During the test, the spotter was standing behind the subject to prevent falls, and another person was ready to press the emerge stop button making the subjects feel secure. In case of losing balance, the subjects were advised to use the handrails to regain the balance. In general, the subjects performed well in the tests and there were no exclusions due to loss of balance. Nevertheless, two of the subjects had some coordination difficulties at the end of the walks and they had to use the handrails.

In treadmill exercise testing it is technically demanding to measure VO_2 for there is need for mouthpiece (often also ECG, arterial oxygen saturation, and blood pressure measuring devices) connected outside the belt. In the present study we used the Cosmed K2 oxygen uptake measuring equipment. This system enabled us to measure VO_2 telemetric way without connection outside the belt. Another favorable effect of K2 is that in this device a face mask is utilized instead of mouth piece (which may provoke dyspnea in these patients). None of the subjects felt the face mask to be too uncomfortable. Furthermore all subjects had been familiarized with K2 in two 6-minute field walk tests. In a previous study concerning the reliability of measurement of oxygen uptake, K2 equipment, similar to that used in our study, has shown high accuracy and reproducibility (Kawakami, Nozaki, Matsuo & Fukunaga 1992).

The elderly COPD subjects in this study stopped exercising due to dyspnea and general fatigue. In healthy subjects performance is judged as maximal if a plateau in VO_2 is reached and maximal values of heart rate (HR), respiratory exchange ratio (R), and blood lactate (La) concentration are attained (Åstrand & Rodahl 1986, 356-381). However, it has been found that in the elderly healthy men a plateau in VO_2 is reached by minority of the subjects (Thomas et al. 1987). Also in patients with airways obstruction exercise is often stopped due to ventilatory limitation and these aforementioned criteria are not attained (Killian et al. 1992a). In this study, as an objective mark for maximal effort, V_E during the treadmill exercise test was near or equaled the predicted ventilatory capacity in majority of subjects at their maximum work rate. Using the predicted value of maximum ventilatory capacity (MVV = 37.5 x FEV_1) % predicted, V_E at the end of the treadmill test averaged 94 ± 12 %. Using predicted value of (220 - age) % predicted heart rate averaged 89 ± 14 and in three subjects maximum HR was over the predicted value. There was some variability in the results and it is possible that at least in subjects number 5 and 7, who had relatively low V_E/MVV ratio (83 and 78 %, respectively), together with submaximal heart rates (80 and 68 % of predicted, respectively), the performance on the treadmill could have improved with treadmill experience. However, based on these objective findings it seems that most of the subjects performed their symptom-limited maximal effort.

6.1.3 Field test

The subjects in this study had slower mean walking time than the healthy men of the same age in the study of Oja et al. (1991). In this study the mean walking time in the 2-km walking test was 21.4 min for the subjects of 63 ± 8-year-old, an average. In the original study of Oja and coworkers (1991) the mean walking times were 15.2 and 16.1 min for the healthy men of 50 - 55-, and 60 - 65-year-old, respectively.

Previous researches have shown that in healthy subjects there is a linear relationship between oxygen uptake and walking speeds of 50 - 100 $m \cdot min^{-1}$ (Laukkanen 1993, 27). In the present study subjects with moderate COPD walked twice two kilometer walking test. The walking speeds ranged from 78 to 116 $m \cdot min^{-1}$, with a mean speed of 98 $m \cdot min^{-1}$ in the second walk. The subjects were able to maintain even walking pace, which was seen from the small variance in 400-m lap times. The mean walking heart rate in the 2-km test in the current sample corresponded to 93.4 ± 3.9 % (range 86 to 97 %) of HRmax measured in the treadmill test (using a predicted value of (220 - age), the maximum heart rate in the 2-km walking test averaged 82.5 % (range 61 to 100%) of predicted maximal heart rate). The results of the study of Laukkanen et al. (1993a) showed that walking speed corresponding to 80 % or more of maximal heart rate yields the most accurate prediction of VO_2 in healthy active adults. In this study the walking speed and in most of the subjects also the heart rate corresponded these aforementioned criteria.

In the studies of Oja et al. (1991) and Laukkanen et al. (1992a, 1993b) inspite that identical instructions "walk as fast as you can but do not risk your health", was given before both of the two tests, faster walking speeds were consistently attained in the second trial. The reliability of field tests has been seen to be dependent on habituation, especially among those who are not accustomed to strenuous physical activity. In testing adults with the 2-km walking test, a zero walking is recommended to familiarize subject with a test procedure. It has been shown that in this test there is no further significant improvement in walking times after the second test. (Laukkanen 1993.) Studies in COPD population have demonstrated that in repeated testing of 6- and 12-minute walking test, there has been an improvement in distance walked due to the learning effect (Guyatt et al. 1984; McGavin et al. 1976; Mungall & Hainsworth 1979; Swinburn et al.1985). These data suggest that there is need for careful standardization of the test procedure to avoid the influence of learning or encouragement on the test results. The findings of the present study demonstrated that slightly faster walking speed (mean walking time 20.7 min vs. 21.4 min) and higher heart rate (mean HRmax 126 vs. 130 $beats \cdot min^{-1}$) were attained in the second walk. However, the individual test-retest variation of walking time and heart rate were very small. The correlation coefficients were 0.93 both for walking time and heart rate. It seems likely that standardized test procedure including pretest preparation, proper warm-up, good walking conditions, and clear test walk instructions yielded reproducible test results after one walk.

When regarding a test mode for COPD, a 12-minute walking has been reported to be feasible for patients with mild to moderate disease, whereas for patients with a severe disease a test with shorter duration is recommended (Butland et al. 1982). These recommendations are not in agreement with the findings of Punzal et al. (1991) who investigated high intensity endurance training with moderate to severe COPD. It was found that these subjects were able to exercise at higher intensity than typically recommended. Also, in the endurance exercise test the patients were able to walk 22 minutes on the treadmill with workload corresponding 85 % of maximum. The scores of effort induced dyspnea at the end of the test were 3.7 an average. Similar results have been reported also by Wilson et al. (1984) who found that the patients with moderately severe airways obstruction were able to walk two consecutive 12-minute walking test and maintain relatively high minute ventilation. In accordance with these two studies, the present data showed that for moderate COPD, contrary to expectation, relatively high intensity 2-km walking test, lasting 20 - 25 minutes an average, was well supported by the subjects. Two of the subjects complained of mild leg symptoms. The leg effort scores after the test were 3.9 (somewhat severe), an average. Another interesting finding was that none of the subjects had to stop the walk performance due to dyspnea. The scores of effort induced dyspnea after completing the test were 4.8 (severe), an average. The findings of relatively low dyspnea and leg effort scores of these studies support the observation of Kearon et al. (1991), who found that in healthy subjects decreasing the intensity by prolonging the duration of exercise has a great effect on reducing dyspnea and muscle effort.

In the present study, however, there was some variability in dyspnea and leg effort results. The subjects had similar, high heart rates (% HRmax) at the end of the walks, and the differences in RPE values may be explained by the fact that RPE is a subjective measure which is affected by individual symptom tolerance and motivation. Also, it is possible that in these subjects the instructions related to self-reported RPE were not similarly understood. These results suggest that neither dyspnea nor leg effort were limiting or excluding factors in the 2-km walking tests. As a consequence the attendance rate for the tests was good. All the subjects who participated the study attended the two walking tests.

One explanation for the continuous walking performance without severe dyspnea in this study, might be the nature of the test. The 2-km test is a test of free walking, with an instruction of walking as fast as you can and maintaining even pace. Perhaps the subjects pace their walking speed close to their sustained ventilatory limit, which is high enough to yield substantial cardiorespiratory strain evidenced by high HR response. A similar study with a telemetric oxygen uptake system would provide exact information about the level of ventilation during the test.

The encouraging test environment could have influenced on good walk performance. The test facilities were a 400-m track for 10 subjects and a stretch of flat dirt road for 3 subjects. Both walking places were quiet and private. The weather conditions were ideal since there was no wind and the temperature ranged from +18 to +22 °C. Testing procedures was not rushed. The test administration was clearly explained and supervised. There were only 2 - 5 persons at the same time on a track. When comparing this kind of test environment with a hospital corridor as a testing place it seems likely that there are less anxiety and emotional problems in outdoor conditions. Actually, one finding in this study was that all the subjects preferred the 2-km walking test to the 6-minute corridor walking test. During the rehabilitation the subjects were participated twice this test of shorter duration (with K2 oxygen uptake measuring device). The subjects reported that the 2-km walking test on a track was preferable because in this test "you can pace your own continuous walking speed, and you do not have to be concerned about turning points". None of the subjects considered the 2-km distance too long when asked their opinion of the walking distance.

6.2 Exercise tolerance of the subjects

Some authors have reported that besides pulmonary limitation COPD patients may have impaired cardiac output during exercise (Morrison & Zuckerman 1993; Wasserman 1993). The patients in this study had previously, in the beginning of their rehabilitation undergone cycle ergometer test with ECG measurements to distinguish pulmonary disease from heart failure. Thus, the patients were suspected to represent only chronic obstructive pulmonary disease without concomitant heart disease.

In healthy men the exercise ventilation at their maximum work rate is about 70 % of their ventilatory capacity reflected as maximal voluntary ventilation (MVV) (Wasserman et al. 1987, 79). In this study % predicted maximal V_E averaged 94 % (range 77 - 113 %) at the end of the treadmill test. According to Casaburi et al. (1991) all subjects in our study can be classified as ventilatory limited in their maximum exercise performance since the breathing reserve (BR) (calculated as: (1 - $V_E$max/MVV) x 100) of these patients was below 30 % at the maximum treadmill exercise test. In spite of the ventilatory limitation, the maximum heart rate in most of the subjects were high representing 89 ± 14 % of predicted maximal heart rate (220 - age) value, an average. Low values of maximum heart rate in subjects number 2 (118 beats·min^1) and 6 (117 beats·min^{-1}) accompanied by very high V_E/MVV ratio (98 and 108 %, respectively), may indicate, that heart rate values in these subjects were affected by ventilatory limitation. The lowest value of heart rate was found in subject number 7 (96 beats·min^{-1}). Together with the finding of lower V_E/MVV (78 %) value it seems to be possible that in this subject the ventilatory limitation together with sensitive dyspnea perception were the factors to low exercise heart rate value. Based on these findings it seems that ventilatory limitation was playing the major role in limiting exercise in these subjects.

In this study the subjects, an average, failed to achieve the maximal VO_2 predicted for the healthy men of this age. Using the predicted values of Dehn and Bruce (1972), % predicted VO_2max for the study group averaged 73 ± 10 %. When comparing the results of the present study with earlier COPD reports, the maximum VO_2SL values in this study are higher in men with similar age and disease severity (Jones et al. 1971; LoRusso et al. 1993; Punzal et al. 1991; Wasserman & Whipp 1975). However, the maximum VO_2SL values should be compared cautiously with earlier studies since there may be number of methodological differences.

6.3 Relationship between maximum VO_2SL, the 2-km walking performance, and pulmonary function

Previous studies in patients with COPD have shown significant correlation between maximum VO_2SL and distance walked in the 2-, 4-, 6-, and 12-minute walks. McGavin et al. (1976) demonstrated the correlation of 0.52, ($p < 0.01$) between absolute maximum VO_2SL and 12-minute distance. In the study of Bernstein et al. (1994), the correlation coefficients between weight-relative maximum VO_2SL and the 2-, 4-, 6-, and 12-minute walking distance were 0.55, 0.62, 0.64, and 0.67, ($p < 0.01$ for all values), respectively. In the present study no significant correlations were found between absolute maximum VO_2SL (L·min^{-1}) values and walking time in the 2-km test. Nevertheless, the absolute values of maximum VO_2SL (L·min^{-1}) correlated significantly with weight ($r = 0.58$, $p < 0.05$) and height ($r = 0.71$, $p < 0.01$) indicating the significancy of body size in weight bearing activities such as walking. When comparing the weight-relative maximum VO_2SL with walking time the 2-km test the correlation, $r = -0.694$, ($p < 0.01$) was similar to the values of study of Bernstein et al. (1994).

When McGavin et al. (1976) developed the 12-minute walking test the correlation between walking distance and lung function were studied. They found that the distance walked correlated significantly with FVC ($r = 0.41$, $p < 0.05$) but not with FEV_1 ($r = 0.28$, $p > 0.05$). Bernstein et al. (1994) found no correlation between the distance walked in 12 minutes and lung function values of FEV_1 ($r = 0.15$), or FVC ($r = 0.26$). The results in this study are in agreement with the study of Bernstein et al. (1994) for no correlation were found between walking time and FEV_1 ($r = - 0.31$), or FVC ($r = - 0.34$). The lack of correlation between lung function measurements and maximum VO_2SL and walking tests may be due to homogeneity of the samples. In the present study and as well as in the study of Bernstein et al. (1994) and McGavin et al. (1976) the subjects had similar degree of moderate COPD. LoRusso et al. (1993) suggest that pulmonary function measurements *per se* can predict exercise tolerance provided that a broad range of disease severity is studied or a normal group is included.

In the present study a regression analysis was applied to further evaluate the relationship between maximum VO_2SL, the 2-km walking test performance, and selected variables. In the regression analysis, after walking time was entered none of the other variables remained significant in the estimation of aerobic power. Walking time alone explained 48% of the total variance of maximum VO_2SL in $mL \cdot kg^{-1} \cdot min^{-1}$ with a standard error of estimate (SEE) of 10.9 % of the VO_2SL mean. An interesting finding was that the relationship between heart rate in the 2-km walking test and the maximum VO_2SL was not significant. These results suggest that in patients with COPD the maximum oxygen uptake could not be predicted from the heart rate response to submaximal walking exercise like in healthy individuals. However, since a wide range of maximum heart rate values (92 to 153 $beats \cdot min^{-1}$) were found in a small sample this could account for the insignificant correlation between exercise performance and heart rate.

From the results of the regression analysis in 13 subjects, it is not possible to draw any definitive conclusions about the predictability of the 2-km walking test. However, the findings of significant correlation between walking time and weight-relative maximum VO_2SL values suggest that the 2-km walking test is of value in estimating aerobic capacity in male subjects with moderate COPD. With aerobic work capacity, the performance in the 2-km test was probably related to various psychological and physiological factors such as motivation, anxiety, muscular endurance, and ventilatory function.

7. CONCLUSIONS

In the present study the use of a 2-km walking as a test mode in patients with moderate COPD has been evaluated. Also, the exercise tolerance of COPD patients has been described. The results of this study support the following:

1) Patients with COPD are exercise limited and have lower maximal aerobic power values than healthy individuals. The major factors contributing to exercise limitation are increased ventilatory requirement and a decreased ventilatory capacity, demonstrated by high V_E/MVV ratio during maximum exercise:

- in this study the % predicted VO_2max for 13 male subjects with moderate COPD averaged 73 ± 10 %, and the mean exercise ventilation at the maximum work rate was 94.4 ± 12.1 % of the predicted (V_E/MVV).

2) A two-kilometer walking test is a feasible method for fitness assessment in patients with moderate COPD:

- the 2-km walking test was easy to perform. The subjects were able to follow the test instructions including: walking as fast as possible using a normal walking style, and maintenance of a steady walking pace,

- physiological strain of the 2-km walking test was high. Heart rate values corresponded 86 to 97 % of the maximum heart rate values in the treadmill test. Ratings of perceived exertion (RPE) expressed by the Borg 0 - 10-scale were 3.9 for leg effort and 4.8 for dyspnea which correspond to a perceived exertion of "somewhat severe" and "severe", respectively. However, the 2-km walking test was well tolerated by the subjects and there were no interruptions of the walking test due to dyspnea, leg muscle pain, or any other reason,

- the test-retest reliability for walking time was high (R = 0.93). This suggests that following the standardized 2-km test procedure, reproducible test results were provided after one familiarization test walk,

- the time for a 2-km walk had a significant correlation with weight-relative maximum VO_2SL. This suggests that the 2-km walking performance is of value in predicting the aerobic capacity of these subjects. Also, the performance in the 2-km test was probably related to various psychological and physiological factors such as motivation, anxiety, muscular endurance, and ventilatory function,

- these preliminary results of a use of the 2-km walking test in patients with COPD are promising and further validation studies are warranted.

Future perspectives

In the further validation of the 2-km walking test there are certain issues that should be taken into the consideration. Since there is a wide variation in patient impairment within the definition COPD, there is a need to minimize heterogeneity within a study group. By dividing the patients to well-defined subgroups reduces variability in exercise tolerance within a group. Large sample sizes are needed to reduce the risk of a wrong result due to chance. The appropriate sample size should be calculated to provide results that are applicable to other populations. Furthermore, the random samples with the control groups are needed to minimize selection bias.

In patients with COPD endurance training based on walking is the recommended mode of exercise in many rehabilitation programs. Intervention studies should be done to evaluate the effectiveness of the 2-km walking test in reflecting changes in exercise capacity after carefully designed walking training program. The "mode specificity principle" of training suggests that this relatively long field test could be sensitive in showing physiological changes after endurance training. In addition, the use of the 2-km walking test also as a "target heart rate test" when the walking speed is adjusted according to known HR of ventilatory threshold or maximum VO_2SL, could provide useful information on changes in exercise capacity. For some subjects using a test as "a target heart rate test" could avoid the discomfort associated with the maximal exercise tests.

Good patient motivation and compliance are critical factors in exercise programs. To maintain motivation the exercise training should be convenient and enjoyable. For that, variety and success in training are important factors. Exercise tests have also proved to be beneficial in reassuring the patients' improvement of fitness and motivating them to continue exercising. Regarding the usefulness of the 2-km walking test in motivating and promoting healthy exercise habits in patients with COPD, a further study is of interest.

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APPENDIX 1.

Maximal	**10**
Very, very severe	**9**
	8
Very severe	**7**
	6
Severe	**5**
Somewhat severe	**4**
Moderate	**3**
Slight	**2**
Very slight	**1**
Very, very slight	**0.5**
Nothing at all	**0**

FIGURE 1. Ratings of perceived exertion (RPE) for dyspnea and leg effort in the 2-km walking test according to the Borg 0 - 10-scale.

APPENDIX 2.

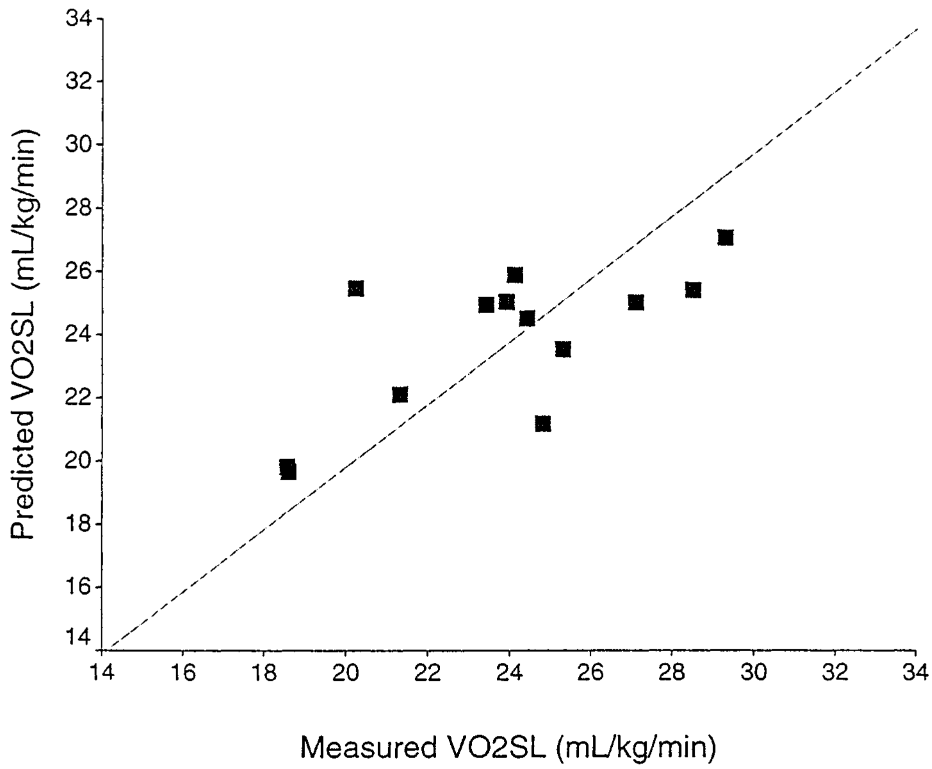

FIGURE 1. Scattergram for predicted and measured maximum VO_2SL according to the prediction equation of: VO_2SL ($mL \cdot kg^{-1} \cdot min^{-1}$) = 42.768 - 0.918(2-km walking time in minutes).