Classification of physical independence in older occupants with chronic lung disease at home - a pilot study

Mariëlle C. L. Snijders MSc PhD
Department of Architecture, Building and Planning, Technische Universiteit Eindhoven, Eindhoven, The Netherlands
e-mail: m.c.l.snijders@hetnet.nl

Ludovicus G. H. Koren MSc PhD
Allergo-Consult BV, Beusichem, The Netherlands
e-mail: l.g.h.koren@allergo.nl

Helianthe S. M. Kort MSc PhD
Netherlands Institute of Care and Welfare / NIZW, Utrecht, The Netherlands
e-mail: h.kort@nizw.nl

M.C.L. Snijders, L.G.H. Koren, H.S.M. Kort, Classification of physical independence in older occupants with chronic lung disease at home - a pilot study, Gerontechnology 2002; 1(3): 163-174. **Objective:** Chronic lung problems often constrain physical independence of older occupants. The usefulness and practicality of an existing physical independence level assessment has been studied. **Methods:** Nine independently living older occupants (aged 52-73) with chronic lung disease participated in a pilot study. Physical performance in daily activities was determined from heart-rate and body-movement registrations during a seven-day period at home and a standardised cycle ergometer test in hospital. The individual's baseline for physical independence was deduced from physical performance outdoors. **Results:** The highest actual energy expenditure at a relative physical strain of 40% allowed us to assign subjects to physical independence levels 3 (4 subjects) or 4 (5 subjects). At level 3 activity accommodations, technical aids, and informal assistance are required; at level 4 professional assistance is needed too. Subjects at level 4 had lower values of body weight, body height, peak oxygen uptake, and peak minute ventilation than subjects at level 3. The severity of airflow limitations did not predict physical independence level. Physical performance during outdoor walking showed a higher relative physical strain (above 40%) at physical independence level 4 as compared to 3. This high strain limits duration of performance as a way of activity accommodation. **Conclusion:** Physical independence level assessment is suited to distinguish baselines for physical independence levels 3 and 4 under daily living conditions in older occupants with chronic lung disease. In the future, the assessment method may give insight into the influence of efficacious interventions on physical performance parameters.

Key words: ADL, lung diseases, obstructive, health indicators, classification

Older occupants with chronic lung disease experience limitations in physical independence in daily life. Lung functionality is reduced, which sets an upper limit to physical independence[1]. As long as self-maintaining activities of daily life (ADL), such as personal care and management of the household, are possible, individuals can live independently[2]. Such activities are markers of the potential for physical independence or the need for assistance[3]. Chronic Obstructive Pulmonary Disease (COPD) is associated with an added difficulty or dependence in ADL activities, especially mobility and household activities[4].

In previous studies, physical ADL performance was only measured with self-reported inventories and with physical performance and capacity tests in the laboratory[2,3,5-8]. Pulmonary function tests may evaluate the severity of COPD[9], but do not predict to what extent persons may execute ADL activities[8]. Quantitative measures under daily living circumstances may be more representative. These may also allow identification of short-term environmental influences on physical performance, for example due to air-pollution exposure[10].

An existing system of physical independence levels has been adapted. The scale runs from full independence (level 1) to non-independence (level 5). These levels have been related to the required energy expenditure with accessory discriminating physical activities[11]. Extra-individual factors, such as technological adaptations and assistance by others have not been investigated.

The aim of this pilot study is to examine the usefulness and practicality of assessment of physical independence levels under daily living conditions in older occupants with chronic lung disease.

MATERIALS AND METHODS

Data were collected in subjects' home environments. The method to describe physical independence, the measurement protocol, and the data analysis are described below.

Subjects

Criteria for inclusion of subjects were as follows: living independently, between 50 and 75 years of age, a diagnosis of symptomatic COPD by a pulmonologist, no sensitization to inhalant allergens (total IgE < 100 kU·l^{-1} and negative Phadiatop), and a stable clinical condition. Subjects with evidence of cardiovascular disease, rheumatism, obesity, neurological or locomotor disease, or other disabling diseases were excluded. Maintenance medication of subjects could include theophylines, $ß_2$-agonists, and oral or inhaled corticosteroids.

Fourteen elderly persons (4 females, 10 males) with chronic lung disease were selected from outpatient clinics of the department of lung diseases in the Elkerliek Hospital Helmond, The Netherlands. In daily practice subject's level of physical independence was estimated.

All subjects gave written informed consent to participate in the pilot study after procedures were explained to them. This study was approved by the Medical Ethical Committee of the Elkerliek Hospital Helmond and by the Ethical Committee of the Technische Universiteit Eindhoven.

Physical independence

From the first meeting with the subjects, the potential for physical independence was described qualitatively from subject's perspectives in terms of the experienced problems in physical performance.
In addition, the corresponding physical independence level was assessed for each subject by quantifying indicators of the physical performance in daily activities[11].

Protocol for quantifying physical performance

The measurement protocol consisted of a one-week period during which the physical performance was monitored in the subject's home environment. The exercise tests and pulmonary function tests in hospital preceded or followed the field measurements. Measurements were conducted from March 1997 to September 1997.

The physical performance in daily activities was quantified by the actual energy expenditure (AEE), relative physical strain (%VO_{2r}), and body movement in daily life, using an ambulatory physical performance monitor. This monitor consisted of a heart-rate monitor (Vantage NV™, Polar Electro Oy, Finland) and a body-movement monitor (Tracmor-1, developed by the Technische Universiteit Eindhoven, Eindhoven, and University of Maastricht, Maastricht, The Netherlands).

Individual's actual energy expenditure AEE and relative physical strain were estimated from known quantitative relationships between oxygen uptake, heart rate, body movement, and personal characteristics[11]. Mean values of oxygen uptake recorded over the final two minutes of sub-maximal exercise on a cycle ergometer in hospital at 20% and 40%, respectively, combined with peak oxygen uptake, were used as calibration points to determine the individual's heart-rate versus energy-expenditure regression equation during daily life. A conversion factor of 20.19×10^3 [$J \cdot l^{-1}$] was used to convert the oxygen uptake (VO_2) to the energy expenditure and vice versa[12]. The actual energy expenditure AEE was estimated from the energy expenditure during a certain activity with a correction for a changed metabolic rate in COPD individuals. The changed metabolic rate is estimated as a ratio of the resting metabolic rate for a healthy adult relative to the resting metabolic rate for an individual with chronic lung disease. The degree of relative physical strain is assessed by the quotient of the difference between oxygen uptake during activities in daily life and during sitting quietly on a cycle ergometer in hospital, and the difference between peak oxygen uptake and oxygen uptake during sitting quietly on a cycle ergometer in hospital. This relative physical strain –as distinct from the physical strain- provides an equivalent relative exercise intensity for individuals with different resting energy expenditure, as found in COPD. In an activity log subjects recorded the type of daily activity and time engaged in it. Most daily activities were covered and could be scored in a standardised way. The time resolution of the log was 15 minutes.

Prior to actual recording, subjects practised the use of the physical performance monitor and activity log under supervision of the researcher and consecutively two or three days during daily life. Subjects were instructed to wear the monitors from day 1 to day 7 during all waking hours, except during bathing, taking a shower, or swimming. Subjects were asked not to alter their lifestyle, in spite of daily monitoring.

Data analysis

The characteristics of subjects are given as median. The values for pulmonary function and physical performance were expressed as a percentage of a reference value[13]. Physical independence level was deduced from physical performance in outdoor activities during 7 weekdays. All physical activities with dynamic properties were included for the classification. An activity is defined dynamic, when during the current minute or either of the two previous minutes body movement during a task is larger than zero counts per minute and heart rate is larger than heart rate while sitting quietly. An individual's highest actual energy expenditure (AEE) at a relative physical strain of 40% allows us to assign subjects to one of the five physical independence levels: at least 419 $J \cdot kg^{-1} \cdot min^{-1}$ for level 1, at least 279 $J \cdot kg^{-1} \cdot min^{-1}$ for level 2, at least 174 $J \cdot kg^{-1} \cdot min^{-1}$, and at least 105 $J \cdot kg^{-1} \cdot min^{-1}$ for level 4. The boundary values of these levels are deduced from the average energy expenditure required for performance in accessory discriminating physical activities in daily life[11]. For example, going upstairs carrying a 7 – 10 kg load or cycling at 16 km per hour are discriminating activities for level 1. The assumption was made that outdoors only a minimal exposure to air pollutants was present that could influence physical performance. For this reason indoor activities were excluded from analysis. At least 15 minutes of activity in the outdoor air was assumed necessary to exclude any effect of earlier exposure to indoor air pollution. A body movement versus actual energy expenditure (BM/AEE) ratio was introduced to gain additional insight into activity accommodations.

Statistical analysis was performed by use of SPSS, release 7.5. Differences between groups with different severity of COPD were calculated using the Kruskal-Wallis test. Differences between groups with a different physical independence level were calculated using the non-parametric Mann-Whitney U-test (one-tailed) because of small group sizes. The confidence level was set at 5%.

RESULTS

Characteristics of the group of subjects, as well as the results of the assessment for physical independence are presented below.

Table 1. Description of subjects, m: male; f: female; FEV_1:forced expiratory volume in one second; subject 1 had asthma as a child.

Subject	Age [y]	Gender	Severity of COPD[9]	FEV_1 [l]	History of COPD	Reported problems in physical performance	Physical independence level
1	61	f	No	2.02	5	Changing sheets, washing windows, walking, walking while talking	4
2	73	f	Mild	1.15	21	Carrying groceries while walking, walking while talking	4
3	59	m	Moderate	1.91	2	Put on shoes, walking, going upstairs, cycling	3
4	56	m	Moderate	1.94	7	Dressing, bathing, care for hair, general decline in intensity, lifting up things, gardening more than 1 hour, going upstairs	3
5	67	m	Moderate	1.57	2	General decline in intensity, cycling uphill	3
6	69	m	Severe	0.75	2	Bending forwards, going upstairs, carrying materials while walking, gardening, walking, cycling	
7	52	m	Severe	1.08	10	Sequential activities during morning, general decline in intensity, washing hair, going upstairs, lifting up things, feeding pigs	4
8	53	m	Severe	1.32	< 1	Walking, going upstairs, cycling, farming	4
9	70	f	Severe	0.63	30*	Cleaning floor, walking, going upstairs, sequential cleaning activities on one day, cycling	4 3

Accompanying physical performance in outdoor activities is described.

Characteristics of subjects

Five subjects were excluded from the pilot study because of missing data: body-movement sensor appeared out of order (three subjects), exercise tests and lung function tests were unavailable (one subject), or maximal cycle ergometer test was unavailable (one subject). The remaining nine subjects completed the whole pilot study (Table 1). Body data included body height h (median 1.65 m), body weight w (median 76 kg) and body mass index w/h^2 (median 27 $kg{\cdot}m^{-2}$). Pulmonary function was expressed as forced expiratory volume (FEV_1) before (median 1.45 l) and after bronchodilation (median 1.54 l), as FEV_1 percent predicted, i.e. 100·observed/predicted (FEV_1%pred, median 53%, range 30% to 86%). Physical performance during a maximal exercise test on a cycle ergometer was expressed as peak load (median 125 Watt, corresponding to 90% predicted), peak oxygen uptake (VO_{2peak}, median 1.7 $l{\cdot}min^{-1}$, corresponding to 93% predicted), peak minute ventilation (V_{Epeak}, median 52.8 $l{\cdot}min^{-1}$, corresponding to 61% predicted) and peak heart rate (HR_{peak}, median 149 min^{-1}, corresponding to 86% predicted). Defined by the consensus statement of the European Respiratory Society[9], eight subjects had a mild to severe COPD and one subject was without obstruction. No significant differences in age and physical characteristics were found between

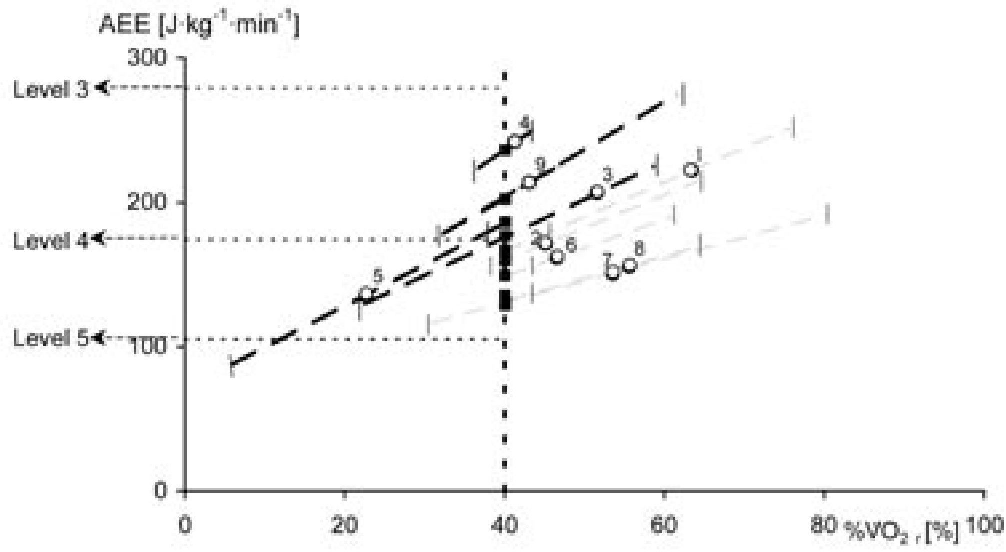

Figure 1. Physical independence level of elderly persons with chronic lung disease (n=9) according to actual energy expenditure (AEE) at a relative physical strain (%VO_{2r}) of 40% for outdoor activities (only activities with dynamic properties) during 7 weekdays. Physical independence levels 3, 4, and 5 are indicated by dashed horizontal lines; level 5 is the lowest level of physical independence, including non-independence. The dashed vertical line corresponds to 40 %VO_{2r}. Numbers refer to subjects. Subject 1 was without irreversible airway obstruction; subject 2 had mild COPD; subject 3, 4 and 5 had moderate COPD; subject 6, 7, 8 and 9 had severe COPD[9]. Weekly median value (o) and the range of daily median values (—l) are given. Subject's level of physical independence is indicated by the oblique AEE-%VO_{2r} line: level 3 is indicated by a bold dashed line and level 4 by a normal dashed line

subjects with no, mild, moderate or severe COPD (Kruskal-Wallis test).

Physical independence level assessment
All subjects indicated activity accommodations (Table 1), thus excluding physical independence level 1. A decrease in intensity or duration was mentioned for one or more activities in the field of personal care, management of the household, mobility, and recreation. The speed of walking was also decreased in all subjects, thus excluding physical independence level 2 (extra technical aids or activity accommodations needed). Subject's perspective on experienced problems could not characterise subjects to either physical independence level 3 (additional informal assistance needed) or level 4 (professional assistance needed).

Quantitatively the physical independence level was established from the actual energy expenditure (AEE) on outdoor activities with the accompanying relative physical strain (%VO_{2r}). Median actual energy expenditure was 171 $J \cdot kg^{-1} \cdot min^{-1}$, and ranged widely from 136 $J \cdot kg^{-1} \cdot min^{-1}$ (subject 5) to 242 $J \cdot kg^{-1} \cdot min^{-1}$ (subject 4). Median relative physical strain was 47% and ranged from 23% (subject 5) to 63% (subject 1). In Figure 1, the AEE is

*Table 2. Characteristics of subjects completing the whole pilot study (n=9), differentiated by physical independence level. Data are presented as median (range). n-values denote number of subjects. Significantly different between the levels: * = $p < 0.05$, ** = $p < 0.01$, NS = not significant (one-tailed Mann-Whitney U-test). For abbreviations see Materials and Methods*

	Physical independence level				p-value
	Level 3, n=4		Level 4, n=5		
	n	median (min – max)	n	median (min – max)	
Age [yr]	63	(56 – 70)	61	(52 – 73)	NS
Body weight [kg]	83	(75 – 90)	60	(50 – 75)	**
Body height [m]	1.80	(1.62 – 1.81)	1.64	(1.50 – 1.76)	*
Body mass index [$kg \cdot m^{-2}$]	27	(24 – 29)	22	(18 – 31)	NS
FEV_1, before bronchodilation [l]	1.74	(0.63 – 1.94)	1.15	(0.75 – 2.02)	NS
FEV_1, after bronchodilation [l]	1.86	(0.91 – 2.57)	1.32	(0.79 – 1.71)	NS
FEV_1 [%pred]	53	(30 – 53)	37	(34 – 86)	NS
Forced vital capacity [%pred]	76	(42 – 92)	91	(65 – 102)	NS
Total lung capacity [%pred]	93	(66 – 134)	115	(101 – 155)	NS
Peak load [Watt]	140	(76 – 170)	91	(55 – 129)	NS
Peak load [%pred]	82	(61 – 97)	103	(69 – 127)	NS
Peak oxygen uptake [$l \cdot min^{-1}$]	1.95	(1.44 – 2.22)	1.27	(0.94 – 1.61)	*
Peak oxygen uptake [%pred]	91	(86 – 94)	73	(58 – 110)	NS
Peak minute ventilation [$l \cdot min^{-1}$]	73.35	(40.30 – 87.40)	42.10	(33.60 – 47.30)	*
Peak minute ventilation [%pred]	61	(56 – 85)	57	(41 – 68)	NS
Peak heart rate [min^{-1}]	151	(125 – 152)	126	(113 – 150)	NS
Peak heart rate [%pred]	89	(76 – 94)	83	(69 – 90)	NS
f_{COPD}	0.9	(0.7 – 1.0)	0.5	(0.5 – 1.0)	NS

plotted against the $\%VO_{2r}$. Three hierarchical levels of physical independence are shown. A dashed vertical line at 40 $\%VO_{2r}$ indicates a threshold of comfort for the physical performance. The intersection of the individual's AEE - $\%VO_{2r}$ line with this vertical 40 $\%VO_{2r}$ line assigns subjects to one of the five physical independence levels. An extrapolation of the measured AEE - $\%VO_{2r}$ line is used in case of absence of an intersection with the vertical 40 $\%VO_{2r}$ line (subject 1, 5, 6, 8). Four subjects (subject 3, 4, 5, 9) are at level 3 and five subjects (subject 1, 2, 6, 7, 8) at level 4. Physical independence levels 1, 2 and 5 were not present. Only subject 5 (level 3) performed outdoor activities at a daily median physical strain below 40%. In subjects 1, 6 and 8 (level 4), the daily median relative physical strain was continuously above 40%.

Subjects at physical independence level 4 had a significantly lower body weight, lower body height, lower peak oxygen uptake ($VO_{2\ peak}$) and lower peak minute ventilation ($V_{E\ peak}$) than subjects at level 3. Body mass index was comparable between the two groups. At level 4, two subjects (subject 6 and 8) had a body mass index below 21 $kg{\cdot}m^{-2}$, indicating underweight[14]. There was

*Table 3. Physical performance in subjects (n=9) during outdoor activities in daily life: walking, cycling and gardening (only activities with dynamic properties). Data are presented as median (range). Performance is differentiated by physical independence level and based on weekly medians. n-values denote number of subjects who performed this activity. Significant differences between levels: * = p < 0.05, NS = not significant (one-tailed Mann-Whitney U-test)*

Outdoor activity	Physical independence level						p-value
	Level 3, n=4			Level 4, n=5			
	n	median	(min – max)	n	median	(min – max)	
Walking	3			5			
Actual energy expenditure [J·kg-1·min-1]		160	(107 – 238)		168	(151 – 213)	NS
Relative physical strain [%]		34	(13 – 40)		54	(50 – 60)	*
Body movement [counts·min-1]		30	(14 – 38)		29	(11 – 34)	NS
BM/AEE ratio [counts·min-1 / J·kg-1·min-1]		0.12	(0.07 – 0.40)		0.16	(0.08 – 0.23)	NS
Cycling	4			3			
Actual energy expenditure [J·kg-1·min-1]		218	(143 – 231)		168	(161 – 222)	NS
Relative physical strain [%]		40	(25 – 61)		59	(50 – 63)	NS
Body movement [counts·min-1]		19	(18 – 20)		26	(23 – 28)	*
BM/AEE ratio [counts·min-1 / J·kg-1·min-1]		0.09	(0.08 – 0.12)		0.15	(0.09 – 0.15)	NS
Gardening	4			4			
Actual energy expenditure [J·kg-1·min-1]		194	(178 – 223)		194	(151 – 217)	NS
Relative physical strain [%]		37	(32 – 52)		57	(53 – 65)	*
Body movement [counts·min-1]		11	(5 – 13)		24	(11 – 26)	*
BM/AEE ratio [counts·min-1 / J·kg-1·min-1]		0.05	(0.03 – 0.07)		0.12	(0.05 – 0.16)	NS

no significant difference in age, lung function, and other physical characteristics between level 3 and 4 (Table 2).

Accompanying physical performance

Depending on the type of activity, physical performance in outdoor activities differed on one or more parameters between subjects classified at level 3 and level 4. At level 4, the relative physical strain (%VO_{2r}) was significantly higher than at level 3, both during walking and gardening. It was above 40%. For both cycling and gardening, body movement was higher at level 4 as compared to level 3 ($p < 0.05$) (Table 3).

DISCUSSION

The present pilot study was performed to establish usefulness and practicality of physical independence level assessment in older occupants with chronic lung disease. Subjects were classified according to the actual energy expenditure and relative physical strain during the performance of physical tasks outdoors. Results show that objective assessment made it possible to distinguish baselines of physical independence at levels 3 and 4. The accompanying physical performance in outdoor activities provided information about the presence of activity accommodations.

Physical independence, here deduced from physical performance in daily activities, is one of the better indicators for health quality of buildings and their surroundings, because it has a rather direct relationship with design choices made by architects and urban planners. Also, these health indicators may allow identification of short-term changes in health due to environmental impact factors. These changes can be quantified in terms of inefficiency in physical performance, as indicated by the body movement versus actual energy expenditure BM/AEE ratio. The assessment method will give insight into actual versus optimal combination of physical performance parameters and efficacious interventions. In the future, application of this method may benefit home-care programmes for coaching subjects with a building-related disease such as older occupants with chronic lung disease. It may deliver an indirect control option to achieve optimal daily functioning and insight in the effectiveness of environmental interventions.

Usefulness and practicality

First of all, methodology needs attention. Since all subjects were classified at levels 3 and 4 on the physical independence scale, only this part of the physical independence level system could be validated. It will be of importance to examine the usefulness and practicality of the method in its full range. Additional information might be delivered by performance level over a prolonged period[15]. Another informative parameter is the frequency of certain activities. Our pilot study was not long enough for taking these into account. Although subjects did not complain about wearing the physical performance monitor, integration and miniaturisation in a single, small and lightweight device with easy user interfaces could enhance the user-friendliness and allow for long-term measurements. A warning signal in case of sampling errors will minimise the number of missing data. Data collection from the monitor by remote communication (telephone, broadband) will also be needed.

Two minutes of body movement were required to allow sufficient time for shifting from the inactive to the active period. Only active periods were taken into account. This achieves improved precision in the oxygen uptake estimates[16]. Although this method will probably never be as accurate as the use of doubly labelled water over a two week period in measuring the individual's energy expenditure, it can give a fair estimate of the energy expenditure in time[17]. The conversion from the oxygen uptake to the energy expenditure made use of the value 20.19×10^3 $J \cdot l^{-1}$, as metabolic processes were assumed to be essentially aerobic. The critical boundary between the aerobic and anaerobic process may be at 64% of the peak oxygen uptake during one hour of continuous activity[18]. At higher values, the estimated actual energy expenditure (AEE) should be considered with caution.

Body movement registration has been used earlier to provide an objective estimate of the energy expenditure in healthy adults during daily life[19]. A validation for elderly persons with chronic lung disease is not yet available. Unfortunately, the quantity of body movement measured in this pilot study is hardly comparable to earlier findings, because previous evaluations of body-movement monitors used healthy young adults and an earlier version of the monitor[19]. Additionally, the activities producing these body movements were not standardised. Walking could mean walking alone, with a spouse, with a dog, or with grandchildren.

A relative physical strain of 40% (40 $\%VO_{2r}$) instead of 40% of peak oxygen uptake ($VO_{2\ peak}$) was used as a threshold for comfort, since the oxygen uptake during sitting quietly ($VO_{2\ sitting}$) and peak oxygen uptake ($VO_{2\ peak}$) may differ substantially among elderly persons with chronic lung disease[20]. The use of relative oxygen uptake rather than absolute values resulted in more valid observations of physical strain. The assumption that a relative physical strain of 40% (40 $\%VO_{2r}$) is a reasonable average upper limit for the physical performance in daily activities without discomfort or fatiguing will need further validation in elderly persons with chronic lung disease.

Energy requirements for the different levels of physical independence were based originally on healthy adults with a resting metabolic rate equalling 69.77 $J\cdot kg^{-1}\cdot min^{-1}$ [21]. For using this scale for elderly persons with chronic lung disease, in which a disturbed metabolism might be present, an individual correction factor for the changed metabolic rate (f_{COPD}) was introduced[11]. The underlying mechanism for the disturbed metabolism, both during rest and during activity, is not yet clear. A disease-related increase in the resting metabolic rate develops in a number of patients with severe COPD[22]. Elderly persons with COPD show an increase in total daily energy expenditure as compared to healthy elderly persons[23]. Variation in the total daily energy expenditure is associated with differences in energy expenditure for activities[24], perhaps because of a decreased efficiency of energy expenditure[25]. The factor f_{COPD} has to be investigated in relation to quantity of change in the resting metabolic rate versus the energy expenditure during a certain task (EE_{task}). We estimated the changed metabolic rate f COPD as a ratio of resting metabolic rate for a healthy adult relative to resting metabolic rate for an individual with chronic lung disease and assumed that changes in metabolic rate during rest and during activity are similar. The value for the resting metabolic rate was obtained from sitting quietly (without movement) on a cycle ergometer. The resting metabolic rate values, obtained from laying down and sitting quietly in a chair, standing, sitting quietly on the bicycle ergometer, were similar to measurement for the resting metabolic rate in a calorimeter during most of the awake, inactive portion of the day[17].

Physical independence level

Levels 3 and 4 were expected from the self-reports for physical independence because of the perceived disabilities in mobility, household management, personal care and occupation. However, from a subject's description of limitations in physical performance, a differentiation in independence levels was impossible to make. Earlier it was found that COPD patients score 53 for management of the household, 83 for personal care and 65 for social activity, where 100 represents the highest level of ability[7]. In this qualitative description only some of the limitations were mentioned. Reasons for not mentioning others could be unawareness, already adopted behaviour or the idea that all elderly persons are confronted with these limitations. Intensity of performance was not described qualitatively by the subjects. Differences in functional status could be significant as well[26], but were not observed by the present subjects.

In contrast to disability from self-reports, the semi-quantitative assessment for physical independence distinguished two levels: 3 and 4. At level 3 activity accommodations in personal care and household activities, technical aids, and informal assistance by relatives are required to optimise physical independence; at level 4 professional assistance is needed too[11]. Peak oxygen uptake ($VO_{2\,peak}$) and peak minute ventilation ($V_{E\,peak}$) differed between these levels. This is in accordance with a report in the literature[27] that peak oxygen uptake plays an important role in task performance. In elderly persons with chronic lung disease a reduced lung ventilatory capacity is assumed to be the main factor limiting physical independence[28]. A difference in physical independence among groups could not be explained by possibly disturbing factors such as age and severity of COPD (FEV_1%pred), since these variables were not significantly different among groups. On the other hand, the additional impact of ageing was taken into account by this physical independence level assessment. Subject 2, who had a mild COPD and was 73 years old, was classified at level 4. Subject 9, who had a severe COPD and was 70 years old, was classified at level 3. Both subjects had a normal metabolism, i.e. the factor f_{COPD} was 1. In accordance with other studies[7,8], the disease-related changes in lung function, as reflected in FEV_1%pred, did not play a significant direct role. Subjects with no, mild, moderate or severe COPD were similar in age and physical characteristics. A severity assessment of COPD evaluates the degree of respiratory impairment as compared with standard data[9].

The difference between level 3 and level 4 in body weight disappeared, when body weight was related to body height, expressed as body mass index. However, body weight and body mass index do not take into account differences in body composition between subjects. Subjects with COPD can suffer from a marked depletion of fat-free mass despite a normal body weight[14,29]. The fat-free body mass should be included in future studies.

Activity accommodations

Large within-group differences in the relative physical strain during activity indicate that physical performance not only depends on demand made by an activity and on the available capacity, but also on strategies by which activities were deployed to meet demands. Personal decisions on activity accommodations are probably made by weighing the anticipated satisfaction derived through an activity against the discomfort that may occur. Activity accommodations refer to a lower intensity or frequency, pacing, planning, or termination of that activity[3]. Activity accommodations in personal care and management of the household were expected at physical independence levels 3 and 4. Physical performance in cycling leisurely caused a relative physical strain at or above 40% at both levels. This high strain indicates that activity accommodation is needed. Only at a higher independence level (level 2 or above) is cycling leisurely possible without discomfort or fatiguing. Remarkably, body movement during cycling of subjects at level 4 was significantly higher than of those at level 3, although actual energy expenditure (AEE) and relative physical strain (%VO_{2r}) were similar. This increase in body movement was probably not referring to an increase in velocity, but might refer to a decrease in efficiency in the less independent subjects[30]. Such inefficiency might also cause an increased body movement at level 4 during gardening. Walking leisurely or gardening at a relative physical strain below 40% was impossible at level 4, as predicted by the assessment method for physical independence. Walking leisurely is a discriminating task for level 3, and gardening for level 2[11]. A supposedly sub-maximal exercise, like 12 minute walking, results in a ventilatory and metabolic response close to a peak physiological training effect in subjects with COPD[6]. The high relative physical strain during walking is an indirect indication for activity accommodation at level 4, because the duration of performance would be limited. The body movement versus actual energy expenditure (BM/AEE) ratio did not differ between levels 3 and 4, meaning that a decline in the level of physical independence appears as a change along the same AEE-BM line. A comparison with the physical performance in healthy subjects in the same age group could give insight into activity accommodation strategies in elderly subjects with chronic lung disease.

Recommendations

Before the assessment method can be applied in for example home-care programmes for older occupants with chronic lung disease, further studies are needed on a larger number of subjects distributed over all levels of physical independence. In addition to activity accommodations, technical aids, technological adaptations, and assistance are used to optimise independence[7]. Ideally, the environment should be made optimal such that the occupant's physical independence is the limiting factor. Furthermore, it is of importance to study the impact of activity accommodations in interaction with enabling environmental interventions on the level of physical independence.

Acknowledgements

We thank all subjects and their spouses for participating in this study. Their interest, hospitality and help are sincerely appreciated. We thank H.J.H.M. van Dijk MD, and the lung function laboratory staff (Elkerliek Hospital, Helmond, The Netherlands) for their technical assistance.

References

1. Jones NL, Killian KJ. Limitation of exercise in chronic airway obstruction. In: Cherniack NS, editor. Chronic obstructive pulmonary disease. Philadelphia: Saunders; 1991. p. 196-206.
2. Sonn U. Longitudinal studies of dependence in daily life activities among elderly persons; Methodological development, use of assistive devices and relation to impairments and functional limitations. Scan J Rehabil Med 1996;Suppl 34:1-35.
3. Leidy NK, Haase JE. Functional performance in people with chronic obstructive pulmonary disease: A qualitative analysis. Adv Nurs Sci 1996;18(3):77-89.
4. Isoaho R, Puoliuoki H, Huhti E, Laippala P, Kivela S. Chronic obstructive pulmonary disease and self-maintaining functions in the elderly - a population-based study. Scand J Prim Health Care 1995;13:123-7.
5. Garrod R, Bestall JC, Paul EA, Wedzicha JA, Jones PW. Development and validation of a standardized measure of activity of daily living in patients with severe COPD: the London Chest Activity of Daily Living scale (LCADL). Respir Med 2000;94:589-96.
6. Baarends EM, Schols AMWJ, Mostert R, Janssen PP, Wouters EFM. Analysis of the metabolic and ventilatory response to self-paced 12-minute treadmill walking in patients with severe chronic obstructive pulmonary disease. J Cardiopulmonary Rehabil 1998;18:23-31.
7. Jette DU, Manago D, Medved E, Nickerson A , Warzycha T, Bourgeois MC. The disablement process in patients with pulmonary disease. Phys Ther 1997;77(4):385-94.
8. Leidy NK. Functional performance in people with chronic obstructive pulmonary disease. Image J Nurs Sch 1995;27(1):23-34.
9. Siafakas NM, Vermeire P, Pride NB, Paoletti P, Gibson J, Howard P, Yernault J-C, Decramer M, Higenbottam T, Postma DS, et al. Optimal assessment and management of chronic obstructive pulmonary disease (COPD); a consensus statement of the European Respiratory Society (ERS). Eur Respir J 1995;8:1398-420.
10. Spirduso WW. Physical dimensions of aging.Champaign: Human Kinetics; 1995.
11. Snijders, M.C.L. Indoor air quality and physical independence; an innovative view on healthy dwellings for individuals with chronic lung disease [dissertation]. Technische Universiteit Eindhoven: Eindhoven; 2001.
12. McCrory MA, Molé PA, Nommsen-Rivers LA, Dewey KG. Between-day and within-day variability in the relation between heart rate and oxygen consumption: effect on the estimation of energy expenditure by heart-rate monitoring. Am J Clin Nutr 1997;66:18-25.
13. Jones NL; Campbell EJM; Edwards RHT, et al.

Clinical exercise testing.Philadelphia: Saunders; 1975.
14. Baarends EM, Schols AMWJ, Marken Lichtenbelt WD van, Wouters EFM. Analysis of body water compartments in relation to tissue depletion in clinically stable patients with chronic obstructive pulmonary disease. Am J Clin Nutr 1997;65:88-94.
15. Stones MJ, Kozma A. Physical performance. In: Charness N, editor. Aging and Human Performance. Chichester: Wiley; 1985. p. 261-91.
16. Moon JK, Butte NF. Combined heart rate and activity improve estimates of oxygen consumption and carbon dioxide production rates. J Appl Physiol 1996;81(4):1754-61.
17. Spurr GB, Prentice AM, Murgatroyd PR, Goldberg GR, Reina JC, Christman NT. Energy expenditure from minute-by-minute heart-rate recording: comparison with indirect calorimetry. Am J Clin Nutr 1988;48:552-9.
18. Wiedemann HP, Gee BL, Balmes JR, Loke J. Exercise testing in occupational lung diseases. Clin Chest Med 1984;5(1):157-71.
19. Bouten CVC, Verboeket-van de Venne WPHG, Westerterp KR, Verduin M, Janssen JD. Daily physical activity assessment: comparison between movement registration and doubly labeled water. J Appl Physiol 1996;81(2):1019-26.
20. Swain DP, Leutholtz BC. Heart rate reserve is equivalent to %VO2Reserve, not to %VO2max. Med Sci Sports Exerc 1997;29(3):410-4.
21. Ainsworth BE, Haskell WL, Leon AS, Jacobs DS, Montoye HJ, Sallis JF, Paffenbarger RS. Compendium of physical activities: classification by energy costs of human physical activities. Med Sci Sports Exerc 1993;25(1):71-80.
22. Schols AMWJ, Fredrix EWHM, Soeters PB, Westerterp KR, Wouters EFM. Resting energy expenditure in patients with chronic obstructive pulmonary disease. Am J Clin Nutr 1991;54:983-7.
23. Baarends EM, Schols AMWJ, Pannemans DLE, Westerterp KR, Wouters EFM. Total free living energy expenditure in patients with severe chronic obstructive pulmonary disease. Am J Respir Crit Care Med 1997;155:549-54.
24. Baarends EM, Schols AMWJ, Westerterp KR, Wouters EFM. Total daily energy expenditure relative to resting energy expenditure in clinically stable patients with COPD. Thorax 1997;52:780-5.
25. Baarends, E.M. Effort related energy expenditure in patients with chronic obstructive pulmonary disease [dissertation]. Universiteit Maastricht: Maastricht; 1997.
26. Redelmeier DA, Bayoumi AM, Goldstein RS, Guyatt GH. Interpreting small differences in functional status: the six minute walk test in chronic lung disease patients. Am J Respir Crit Care Med 1997;155(1278):1282
27. Rejeski WJ, Foley KO, Woodard CM, Zaccaro DJ, Berry MJ. Evaluating and understanding performance testing in COPD patients. J Cardiopulmonary Rehabil 2000;20:79-88.
28. Cotes JE, Reed JW, Elliott C. Breathing and exercise requirements of the workplace. In: Whipp BJ , Wasserman K, editors. Exercise: Pulmonary physiology and pathofysiology. New York: Dekker; 1991. p. 495-548.
29. Schols AMWJ, Mostert R, Soeters PB, Wouters EFM. Body composition and exercise performance in patients with chronic obstructive pulmonary disease. Thorax 1991;46:695-9.
30. Baarends EM, Schols AMWJ, Akkermans MA, Wouters EFM. Decreased mechanical efficiency in clinically stable patients with COPD. Thorax 1997;52(11):981-6.