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A comparison of the Barthel index and Nottingham extended activities of daily living scale in the assessment of disability in chronic airflow limitation in old age

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Abstract

Introduction: there is no disease-specific instrument for measuring activities of daily living (ADLs) in elderly patients with chronic airflow limitation (CAL). We assessed sensitivity, specificity and positive and negative predictive values of two ADL scales: the Barthel index and the Nottingham extended ADL scale in elderly people with and without CAL.

Methods: the Breathing Problems Questionnaire was used as a measure of quality of life (a low score indicates good quality of life) in 96 outpatients (56 men) with CAL aged 70–93 (mean 78) years and 55 community-dwelling controls (23 men) aged 71–90 (mean 78) years with normal lung function drawn from a recent community survey. CAL subjects had been clinically stable for >6 weeks. All subjects were cognitively intact.

Results: mean best 1 s forced expiratory volume/forced vital capacity was 45.5% (SE 1.4) in CAL subjects and 71.4% (SE 1.3) in controls. All CAL subjects considered themselves disabled and had higher breathing questionnaire scores [geometric mean scores: 39.5 (range 13–112) *vs* 4.8 (range 0.6–40) for controls; $t = 13.4$, $P < 0.0001$]. However, the Nottingham extended ADL index (threshold >18) discriminated better than the Barthel index (threshold >17) in terms of sensitivity (76% *vs* 19%; $\chi^2 = 60.9$, $P < 0.0001$) and negative predictive value (75% *vs* 40%; $\chi^2 = 20.2$, $P < 0.0001$). Altering the Barthel threshold did not improve its performance. Multiple regression analysis showed that variability in physiological and psychological variables related to CAL predicted variability in Nottingham extended ADL score ($R^2 = 0.71$) but not in Barthel score.

Conclusions: the Barthel index underestimates disability in CAL in old age. The Nottingham extended ADL discriminates better between normal old people and those with CAL.

Keywords: *Barthel index, chronic obstructive pulmonary disease, disability, Nottingham activities of daily living index*

Introduction

Chronic airflow limitation (CAL), mainly due to smoking-related chronic obstructive pulmonary disease and chronic asthma, is a major cause of disability in old age. Elderly community dwellers themselves rate respiratory disease as the second most common cause of disability [1]. Shortness of breath and fatigue are the most disabling symptoms of CAL, limiting exercise capacity and interfering with activities of daily living (ADLs), and this in turn may affect quality of life [2]. Physical disability in elderly, frail patients with CAL may be underestimated, at least in part because there is no close relationship between physiological measures and self-reported symptoms [3].

There is little documentation of the level of disability associated with moderate or severe degrees of airways obstruction in old people. Medical professionals frequently underestimate the problems patients face in performing daily activities [4, 5]. The need for this type of information is well recognized in most areas of geriatric practice and has been highlighted by the Royal

College of Physicians and the British Geriatrics Society in a joint report [6]. This report recognizes the difference between the so-called 'personal' ADLs (needed for self-care) and 'instrumental' ADLs (more complex functions needed to live within a wider community) [7] and recommends that those scoring high on personal ADL scales should also be assessed by instrumental scales [6].

Since there is no disease-specific ADL scale for CAL subjects, we have assessed two widely accepted ADL scales used in elderly patients in other contexts: the Barthel index and the Nottingham extended ADL index. The Barthel index [8], a personal ADL scale, has been used in many rehabilitation settings as a measure of disability and is often used for frail elderly patients. It is a useful tool in stroke rehabilitation. The Nottingham extended ADL index [9], an instrumental ADL scale, was established as a postal questionnaire to monitor patients after stroke rehabilitation in the community. It assesses 21 activities within four categories: mobility (e.g. 'do you walk over uneven ground?), kitchen activities (e.g. 'do you do the washing up?'), domestic activities (e.g. 'do you do a full clothes wash?') and leisure activities (e.g. 'do you go out socially?'). It is a simple, self-administered questionnaire which can be completed by the patient in approximately 10 min.

To be clinically useful, an ADL scale should perform well with respect to reproducibility, validity, sensitivity, practicality, acceptability and responsiveness to environmental or clinical change. The aims of the present study were to investigate reproducibility, validity, sensitivity, specificity and predictive values of these two ADL measures in elderly people with and without CAL.

Methods

Subject selection

Subjects comprised 96 outpatients (56 men) with symptomatic irreversible CAL (12 with chronic asthma and 84 with smoking-related chronic airways obstruction). Their age range was 70–93 (mean 78) years. CAL was defined as best 1 s forced expiratory volume (FEV_1) less than 70% of predicted value [10] and rising by less than 15% after 5 mg nebulized salbutamol. Subjects with CAL were included if they were clinically stable with no change in medication for 1 month and no hospital admission in the previous 6 weeks. Reasons for exclusion were: terminal illness, psychotic disease, unstable angina, uncontrolled heart failure, acute or chronic confusion (Abbreviated Mental Test Score <7/10 [11]) and limitation of exercise by factors other than respiratory disease (for example, neuromuscular disease, osteoarthritis, peripheral vascular disease, visual impairment). Subjects with other disabling conditions were not excluded if they considered their respiratory problem to be the major factor limiting their mobility.

Controls were 55 community-dwelling subjects (23 men), aged 71–90 (mean 78) years with normal lung function and no chronic respiratory symptoms, identified in a recent community survey by our department [12].

All subjects gave witnessed written informed consent. The study was approved by the medical ethics committees of Central Manchester Healthcare NHS Trust and Bury Health Authority.

Study design

The design was single blinded. History, examination and physiological measurements were performed by a consultant geriatrician and ADL scales were administered by a research physiotherapist. Subjects were seen as outpatients at the geriatric day hospital. FEV_1 and forced vital capacity (FVC) were measured using a Compact C spirometer (Vitalograph, Buckingham, UK). Three reproducible readings ($\pm 5\%$ FEV_1) were taken at 1 min intervals and the best result recorded. Inspiratory and expiratory mouth pressures (reflective of respiratory muscle strength and endurance) were measured using an MPM mouth pressure meter (Precision Medical Ltd, Pickering, UK) [13], again recording the best of three reproducible measures ($\pm 5\%$) with considerable care taken to ensure maximal patient effort. Quality of life was measured by the disease-specific Breathing Problems Questionnaire [14].

Most subjects completed the Barthel, Nottingham extended ADL and Breathing Problems Questionnaires themselves. For those who had difficulty reading or writing, the physiotherapist read out the questionnaires and recorded their responses. The physiotherapist supervised completion of the questionnaires, but gave no advice either directly or indirectly that might influence the subjects' response to the questions. A further blinded investigator repeated the questionnaires with the same protocol in a random selected population of 18 subjects with CAL on a separate day. In order to assess exercise tolerance, all those with CAL also completed a 6-min walk test [15] 30 min after the inhalation of 5 mg nebulized salbutamol and 0.5 mg nebulized ipratropium. CAL subjects also completed the Brief Assessment Depression Cards (BASDEC) test [16], a screening test with high sensitivity and specificity for depression in this age group.

Statistical analysis

Analyses were performed using the EcStatic program (SomeWare in Vermont, USA).

As Barthel and Nottingham ADL scores were not normally distributed, inter-group comparison was by Wilcoxon rank sum test. Breathing Problems Questionnaire scores were logged to achieve normal

distribution and their inter-group comparison was by grouped *t*-test. A Barthel index threshold score of ≥17/20 was arbitrarily chosen to indicate 'disabled' and 'non-disabled' subjects in both groups on Barthel index. Similarly, a threshold of 18/21 was chosen for Nottingham extended ADL. Analysis of difference in sensitivity, specificity and predictive values was by χ^2 test. Inter-investigator variability was assessed by the 95% range for agreement [17]. Multiple regression analysis was employed to identify factors predictive of Barthel and Nottingham extended ADL scores. Significance was defined at the 5% level.

Results

Baseline physiological data for subjects and controls are given in Table 1. Mean improvement in FEV_1 after 5 mg salbutamol and 0.5 mg ipratropium (nebulized) was 6.7% (range 4.4-10.5) and did not relate to either Barthel or Nottingham extended ADL score.

Table 2 shows median Barthel and Nottingham extended ADL scores for the two groups. The total theoretical range of the scores is 0-20 for Barthel and 0-21 for Nottingham extended ADL. By Wilcoxon rank sum test both Barthel and Nottingham extended ADL scores were significantly higher in controls than in those with CAL ($P < 0.0001$ in both cases). Figures 1 and 2 detail the distribution of Barthel and Nottingham extended ADL scores in the two groups.

There was no significant difference in either Barthel or Nottingham extended ADL score between investigators. Mean difference between investigators was 0.278 (SD 1.179) for Barthel scores and was 0.444 (SD 1.504) for Nottingham extended ADL. Thus, 95% confidence limits for repeatability between investigators were: (original score −2.1) to (original score +2.6) for the Barthel index and (original score −2.6) to (original score −3.5) for the Nottingham extended ADL.

Table 1. Baseline physiological data for patients with chronic airflow limitation (CAL) and controls

	Group	
	CAL	Control
FEV_1 (l)	0.95 (0.04)	1.96 (0.07)
FEV_1 (% of predicted)	51 (2.0)	108 (3.3)
FEV_1/FVC (%)	45.5 (1.4)	71.4 (1.3)
6-min walk distance (m)	212 (9.9)	373 (12.7)
IAv (cmH_2O)	33.3 (1.5)	46.1 (4.4)
EAv (cmH_2O)	49.1 (2.2)	59.8 (4.6)

EAv, average expiratory mouth pressure; FVC, forced vital capacity; FEV_1, best 1 s forced expiratory volume; IAv, average inspiratory mouth pressure.

Table 2. Barthel index and Nottingham extended ADL scale scores in patients with chronic airflow limitation (CAL) and controls

	Index			
	Barthel		Nottingham	
Group	Median	Range	Median	Range
CAL	19	12-20	13	3-21
Control	20	12-20	20	11-21

The geometric means for the Breathing Problems Questionnaire were 39.5 (range 9-83) for CAL subjects and 4.8 (range 0-41) for control subjects ($t = 13.4$; $P < 0.0001$).

Table 3 shows sensitivity, specificity and predictive values of Barthel and Nottingham extended ADL scales using the Breathing Problems Questionnaire as the 'gold standard' (i.e. all CAL subjects and no controls had abnormal Breathing Problems Questionnaire results). There was no significant difference in specificity and positive predictive value between the two questionnaires, but the Nottingham extended ADL performed better than the Barthel with regard to sensitivity and negative predictive value. Reducing the Barthel threshold to >16 and >15 tended to slightly reduce both sensitivity and negative predictive value (to 17 and 39% minima respectively). Increasing the Barthel threshold to >18 minimally improved sensitivity to 24% ($\chi^2 = 50.0$, $P < 0.0001$ *versus* Nottingham extended ADL). Increasing or lowering the Nottingham extended ADL threshold by 1 point produced minimal effects on sensitivity, specificity and predictive values.

Multiple regression analysis with Nottingham extended ADL as the dependent variable (Table 4) showed that the following variables independently predicted Nottingham extended ADL: age, FEV_1 (% predicted), 6-min walk distance, BASDEC score, average inspiratory mouth pressure and household composition (total $R^2 = 0.709$). Variance in walk-distance accounted for 24% of the variance in Nottingham extended ADL score and BASDEC accounted for 12%. In contrast, only age and previous occupation (Registrar General classification) were independently predictive of Barthel score ($R^2 = 0.42$).

Discussion

Information provided by appropriate ADL scales may help in the planning of health care provision both for individual patients and at a community-wide level. This is the first study to investigate the validity, sensitivity, specificity, positive and negative predictive values of the Barthel and Nottingham extended ADL scales in the context of CAL in old age. Our results suggest that

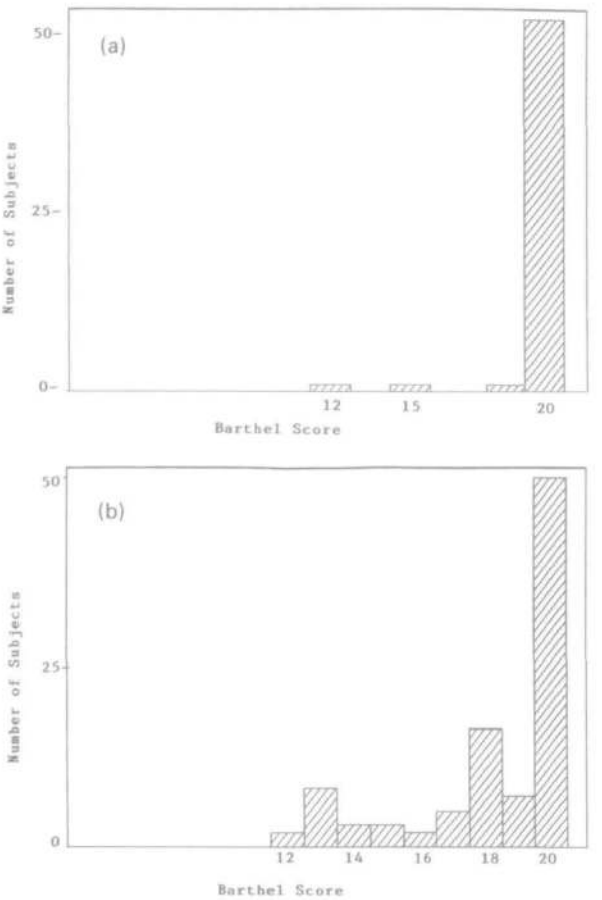

Figure 1. Distribution of Barthel index scores in **a** control subjects and **b** subjects with chronic airflow limitation.

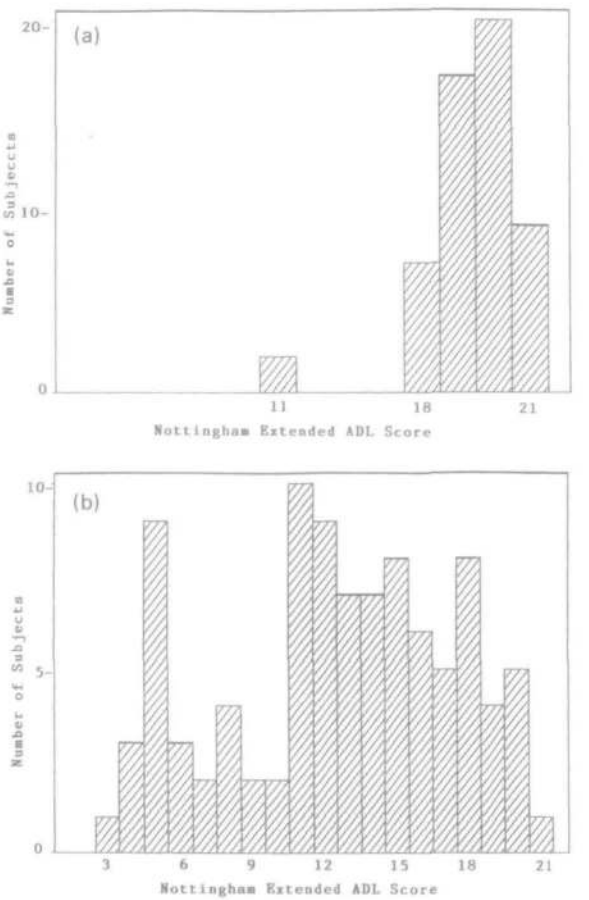

Figure 2. Distribution of Nottingham extended activities of daily living scores in **a** control subjects and **b** subjects with chronic airflow limitation.

Nottingham extended ADL is a much better clinical discriminative tool in terms of sensitivity and negative predictive value for differentiating elderly subjects with respiratory disability from those of the same age group with normal lung function. There was no difference between the tests in specificity and positive predictive values . Both scales were reproducible in CAL subjects. The choice of a 'gold standard' measure for assessing the value of disability scales is complicated by the potential for overlap between questions in this scale and those under investigation. We chose the Breathing Problems Questionnaire scale for this as the overlap between it and our chosen ADL scales is both minimal and consistent.

We did not attempt in the present study to investigate sensitivity of either scale to change in physiological or psychological state, and it would thus be invalid to suggest from our data that the Nottingham ADL is (or is not) a sensitive measure of intervention. Further work is needed in this area. However, evidence

Table 3. Analysis of sensitivity, specificity and predictive values of the Barthel index and Nottingham extended ADL scale

		%		Predictive value (%)	
	Threshold	Sensitivity	Specificity	Positive	Negative
Barthel	≥17	19	96	90	40
Nottingham	≥18	76	92	95	69
χ^2	-	60.9	-	-	20.2
P	-	<0.0001	NS	NS	<0.0001

NS, not significant.

Table 4. Factors predicting Nottingham extended activities of daily living score (multiple regression analysis with Nottingham extended ADL as the dependent variable)

Independent variable	*B*	*t* score	*P* value
Age	−0.14	−2.45	<0.001
6-min walk distance (m)	0.03	7.74	<0.001
BASDEC score	−0.39	−5.89	<0.001
Household composition[a]	0.66	3.39	<0.001
IAv (cm H_2O)	−0.08	−1.97	0.05
FEV_1 (% predicted)	0.02	2.18	0.03

Total R^2 (adjusted for degrees of freedom) = 0.709
BASDEC, Brief Assessment Depression Cards; $FEV_{1,}$, best 1 s forced expiratory volume; IAv, average inspiratory mouth pressure.
[a]1 = living with carer/spouse, 2 = living alone.

that the Nottingham extended ADL scale has superior validity comes from the fact that >70% of its variability between individuals was explained by variability in measures which intuitively could be expected to influence it. The same was not true of Barthel score, in which most of the same independent variables were not significantly predictive.

That a valid ADL measure should in part be predicted by exercise tolerance (walk-distance) is self-evident, and others have reported the importance of psychological well-being in the maintenance of physical activity [18]. Although the BASDEC depression score was negatively predictive of Nottingham extended ADL score (Table 4), this merely reflects the inverse nature of the BASDEC scale (where high scores suggest lack of psychological well-being).

That age should also be a negative predictor, however minor, of Nottingham extended ADL score (i.e. advancing age is protective) is more surprising but may reflect reduced expectation or activity level in very elderly people and/or impaired appreciation of bronchoconstriction with advancing age [19, 20]. The failure of lung function tests such as FEV_1 to predict quality of life has been reported by others [21, 22]. In the present study FEV_1 was only minimally predictive of Nottingham extended ADL score in the regression model. However, when walk-distance was removed from the model the predictive value of FEV_1 increased, although R^2 fell significantly (to 0.49). This points to exercise tolerance rather than lung function *per se* as the most important predictor of ADL.

In the present study community-dwelling control subjects who were active in their daily lives achieved clinically similar Barthel scores to frail elderly subjects with CAL (Table 2), although there was a statistical difference between group means. However, Nottingham extended ADL differentiated both statistically and clinically between subjects with CAL and active controls.

The Barthel index has been used as a disability measure after acute stroke rehabilitation, in clinical trials and in audit following rehabilitation programmes [23]. Several studies suggest that it is a reliable assessment tool [24, 25]. It is recommended by the British Geriatrics Society and the Royal College of Physicians as a measurement tool in elderly subjects [6]. Although in the present study both scales were reproducible between blinded investigators, others have suggested that the Barthel index may be unreliable when information is collected at physician interview, with patients over-estimating their abilities compared with more objective observers [26]. However, in the present study all patients were cognitively intact (a factor associated with preserved agreement between interview-based and observer-based scores [26]) and impairments reported were mobility-related and consistent with previously recorded clinical observations.

The superiority of the Nottingham extended ADL over the Barthel index in this community-based patient population is not unexpected, as it represents an 'instrumental' type of scale, identifying difficulties at a higher functional level than those revealed by a 'personal' ADL scale such as the Barthel. In addition, ceiling effects (high scorers nonetheless being disabled) and insensitivity to change at the upper end of the scale are recognized to occur in the Barthel index in areas such as extended stroke rehabilitation [7, 27–29]. Our data add weight to this view in that Nottingham extended ADL identified 76% subjects with CAL as having difficulties in their daily life whereas the Barthel index only identified 19% of the group. The choice of community volunteers (as opposed to the 'average' community-dwelling 'elderly normal' population) would tend to accentuate the difference between groups as volunteers will tend to be fitter and more active than the population mean. However it is unlikely that this would have a differential effect on the two scales under investigation. The thresholds we chose for Barthel and Nottingham extended ADL were admittedly arbitrary, but altering the thresholds in either direction did result in improved performance.

We thus suggest Nottingham extended ADL has greater clinical relevance than the Barthel index as an ADL assessment tool in elderly subjects with CAL.

Key points

- Disability in old people with chronic obstructive pulmonary disease is often underestimated.
- The Barthel index fails to distinguish clinically between the normal elderly subjects and those disabled by chronic airflow limitation.
- The Nottingham extended activities of daily living scale has greater sensitivity and negative predictive value in identifying such disability in older people.

- The most important factors contributing to respiratory-related disability in old age are: exercise capacity, depressive ideation (mood), age, household composition and baseline best 1 s forced expiratory volume.

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