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THE INDUSTRIAL INJURIES ADVISORY COUNCIL

LUNG FUNCTION ASSESSMENT
INDUSTRIAL INJURIES DISABLEMENT BENEFIT
PRESCRIBED DISEASE D12
(CHRONIC BRONCHITIS AND EMPHYSEMA IN UNDERGROUND COAL-MINERS)

POSITION PAPER No 11

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INTRODUCTION

1. In 1992 IIAC recommended that chronic bronchitis and emphysema in underground coal miners should become a prescribed disease for the purposes of claiming industrial injuries disablement benefit[1]. The recommendation was accepted and the disease was prescribed from 1993.

2. IIAC recommended certain criteria that should be met before a person received benefit for this prescribed disease. One of the criteria was that a claimant's lung function, quantified by an $FEV_{1,}$ should be at least one litre below that expected for a person of the same age, height and sex. IIAC recommended that the formula to be used for calculating the expected lung function should be that published by J E Cotes[2].

3. In 1996 the prescription for these diseases was amended because of new evidence. The criteria concerning lung function remained largely unaltered except that anyone with an FEV_1 of less than 1 litre would automatically meet the lung function criterion, irrespective of his expected value.

4. The terms of the original and current prescriptions are attached at Annex A.

BACKGROUND

5. In 1992 IIAC considered the Cotes formula for lung function to be a clear, straightforward and appropriate formula for use in the context of the benefit scheme and for this prescribed disease in particular. The issue was thoroughly reviewed in 1996[3] when IIAC considered the merits of using other formulae (including the European Community for Coal and Steel (ECCS) and the Institute of Occupational Medicine (IOM) formulae) but concluded that the Cotes formula was still appropriate.

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[1] 'Chronic Bronchitis and Emphysema' Report by IIAC (reference Cm 2091) published in November 1992.

[2] "Lung Function: Assessment and Application in Medicine"

[3] Chronic Bronchitis and Emphysema (reference Cm 3240) published in May 1996.

6. Since 1996 IIAC have received representations from various sources that the Cotes formula may not be the most appropriate for use in relation to this prescribed disease. In 1998 the Sheffield Occupational Health Project contended that the formula used by the ECCS was more appropriate and should be used instead. Members of Parliament and the Trades Union Congress (TUC) also raised the issue directly with IIAC and requested that a review of the use of the Cotes formula should be undertaken.

7. The case they put was that the Cotes formula:

- was based on a small sample;
- was based on an out of date sample;
- did not represent the population at large;
- did not reflect that smoking was more prevalent at the time it was derived, and
- did not reflect that modern environmental conditions had improved and consequently the lung function of the general population had improved.

8. Following the representations received, the Council has now re-examined the issue, revisited the evidence considered in 1992 and 1996 when it produced reports on this prescribed disease, and considered whether any relevant new evidence has emerged since then. The Council has looked again at the Cotes and ECCS formulae and at other relevant formulae including that of the IOM.

REQUIREMENTS OF THE INDUSTRIAL INJURIES DISABLEMENT BENEFIT SCHEME

9. The Council reviewed the basis for using the FEV_1 criterion. Chronic bronchitis and emphysema are common in the general population, especially among smokers. When considering whether the diseases should be prescribed, IIAC had to decide whether it would be possible to attribute individual cases to work as a coal miner with reasonable confidence.

10. Before this question could be answered, a case definition was required. This posed a problem since chronic bronchitis and emphysema is not an "all or nothing" phenomenon. It occurs in a spectrum of severity from minor reductions in lung function that overlap with the normal range, through to seriously disabling and even fatal disease.

11. Any definition of lung function loss would be somewhat arbitrary, but as a pragmatic approach, IIAC adopted a criterion of 1 litre below the predicted average value for age, sex and height. This is an indication of significant impairment of lung function and is associated with disabling breathlessness

(Soutar 1993)[4].

12. To calculate predicted FEV_1 values, FEV_1 measurements are taken for a sample of a population, together with the age, height, weight and other characteristics of each subject. A 'best fit' regression (reference) equation is derived which summarises all the variation in FEV_1 which can be explained by age and other characteristic variables. This reference equation can then be used to calculate the predicted (average) values of FEV_1 for given values of age and height etc.

13. It is important to bear in mind that measuring lung function is not an exact science and that the use of spirometers will inevitably entail a margin of error reflecting personal, environmental and other factors. In addition, regression reference equations provide an average predicted FEV_1 for any given age and height. The accuracy of prediction is greatest at the mean values of age and height within the sample of people and will be least at the extremes of the physiological range, for example at older ages or smaller heights.

14. The Council noted that using formulae that had been derived for other purposes did not mean they were completely suitable for use in relation to a scheme for awarding industrial injuries disablement benefit. The need for a simple, well-understood and easily administered scheme inevitably introduced some compromise and an element of rough justice. There was an element of generosity in including everyone with an FEV of less than 1 litre. The IIDB scheme operated on the balance of probabilities and a presumption that occupation had caused the disease in question, and it was in this context that the suitability of any formula had to be judged.

15. The implications of making a relatively slight change needed to be carefully considered. Any advantages of a marginal change that would only benefit a very small number of claimants and that might also disadvantage others, had to be balanced against the effect of encouraging many miners to make a further claim. A large number of reclaims, involving re-examinations but with little or no hope of a changed decision, would succeed only in raising false expectations and result in disappointment. Much costly administrative work would be necessary for little change in benefit payments.

FORMULAE

16. There have been many published sets of reference values and regression equations. Annex B shows a selection of these, including those used to derive the Cotes and ECCS formulae and some from more recent studies. Although the regression relationships are generally similar, there is variation by year of publication, age range, sample size and selection of subjects. Many are derived from populations that may have different characteristics from those of the UK

4 Soutar C, Campbell S, Gurr D, et al. Important deficits of Lung Function in Three Modern Colliery Populations. Am Rev Respir Dis 1993; 147:797-803

population and might therefore be inappropriate for the proposed use.

17. Reference equations ideally describe results for groups of healthy people and their use for prediction for any individual depends on the assumption that this person is part of the group. In its 1996 report, the Council recommended that, for comparison with the coal industry, the population should consist of employed men, working in non-dusty occupations, and should include smokers.

18. The Council were asked to review in particular the Cotes formula in comparison with the ECCS formula. In addition, a more recent formula was published in 1994 by the Institute of Occupational Medicine (IOM), which was derived from measurements taken from British coal miners. The following sections describe the derivation of the formulae from the three sources. A comparison of predicted values from the three formulae (Annex B) is also discussed.

Cotes

19. The equation currently used was provided by Cotes. Although based on data collected in the 1960s, it fulfils the selection criteria indicated above of being derived from employed, healthy subjects aged between 20 and 74 years of age including some smokers. The equation was derived by weighting the data from four separate studies (Cotes 1965, Berglund 1963, Ferris 1965, Kory 1961).

European Community for Coal and Steel (ECCS)

20. The ECCS formula was first published in 1983 and is derived from 20 studies carried out between 1961 and 1980. The samples used in the 20 studies were selected from a variety of populations, including ‘fit’ and ‘normal’ populations, factory workers, hospital employees, religious sects, and tuberculosis patients. Country of origin, age ranges, sample size, the inclusion of smokers and method of measurement of FEV_1 also varied. The ECCS summary equation was derived from sets of values computed from each equation of 19 of the studies (see Annex B) and from tables from one study, for height and age in 5 cm and 5 year intervals respectively. No weighting of the values was carried out to take account of the differences in study size (which ranged from 50 to 2536).

Institute of Occupational Medicine (IOM)

21. The most recent reference equations available are those published in 1994 by the Institute of Occupational Medicine from a longitudinal study of the respiratory health of British coalminers at a selection of coal mines between 1958 and 1978. Data were collected at intervals using respiratory questionnaires and by carrying out lung function tests. The equations were derived using the data for miners who did not suffer from respiratory symptoms and were non-smokers. The equations include weight in addition to age and height, and are extrapolated to give expected values in the absence of dust exposure.

Comparison of the Cotes, ECCS and IOM Formulae

22. Annex B, table 2 compares the predicted values from the three formulae for three ages and four heights. In all cases the predicted values using the Cotes formula are lower than those obtained using the ECCS formula. The difference between the predicted values from these two formulae increases as both age and height increase. Similarly, the predicted values using the IOM formula are all lower than those from the ECCS formula. Although these differences also increase as age increases, they decrease as height increases. The predicted values from the Cotes and IOM formulae tend to be very close, particularly at heights at and below 1.7m. The mean height of the miners in the IOM surveys was approximately 1.72m

Choice of Formula

23. None of the formulae is ideal as they were not devised with benefit entitlement for the mining industry in mind. The IOM formula could be considered as being derived from the most appropriate reference population, that of British coalminers, although it does not include smokers. The Cotes formula is derived from a statistically weighted sample of healthy populations which included smokers. The ECCS formula is derived by an unweighted combination of sample data from a set of rather disparate populations. The values predicted from the IOM and Cotes formulae are very similar, but the inclusion of weight would make the IOM formula more complex administratively. On balance the Council does not find the case for changing to a different formula compelling.

REGULATIONS

24. The Council has been made aware that a difficulty has arisen concerning the reference in the prescribed diseases regulations to the published volume of Cotes' book containing the formula. A later edition was quoted in the amendment regulations in 1996 than that quoted in the original regulations in 1992. The Council takes the view that to avoid any misunderstandings about the content and volume referred to, it would be advisable for the regulations to be amended so that they quote the formula itself, rather than a particular edition of Cotes' book.

CONCLUSION

25. IIAC has re-examined the choice of a formula with which to predict FEV_1 for use in the prescription of chronic bronchitis and emphysema.

26. None of the formulae was devised with benefit entitlement for the mining industry in mind and none is entirely satisfactory for this purpose. All are based on data that are relatively old.

27. The ECCS formula is derived from an unweighted combination of data from several rather different populations, many of which would not be comparable with the UK population. Thus, IIAC does not consider that a change to the ECCS formula would be justified.

28. The IOM formula could be considered the most appropriate for the purposes of the Industrial Injuries Scheme, being derived from a study of British Coal Miners. However, the sample of miners on which it was based did not include smokers. Furthermore, the predicted values from the IOM formula are very similar to those from the Cotes formula. The IOM formula would be more complex to administer as it takes account of weight as well as age and height. In view of the small differences between the predicted values obtained with the IOM and Cotes formulae (well within the margin of error inherent in taking such measurements), and the administrative costs that would be entailed, IIAC does not consider that a change to the IOM formula would be justified.

29. In summary, therefore, IIAC believes that it is appropriate to continue to use the Cotes formula. Change would only be justified if the current system were clearly and importantly unfair, and in our view that is not the case. The Council would be very interested in, and would encourage, new studies on this subject particularly on British typical values. The Council will, as usual, continue to monitor and consider any new evidence, studies or publications relevant to this question. We are aware of the lung function data collected during the recent Health Survey for England[5] and would encourage analysis of these data to be carried out to derive a reference equation.

February 2000

5 Prescott-Clarke P, Primaterta P (Eds) Health Survey for England 1996, London: The Stationery Office, 1998.

Annexes

ANNEX A – Original and current prescription for D12

ANNEX B – Details of the various formulae

> **Table 1 – Comparison of some relevant reference equations of predicting FEV_1.**
>
> **Table 2 – Comparison of predicted values from Cotes, IOM and ECCS formulae.**

ORIGINAL AND CURRENT PRESCRIPTION FOR D12

Original prescription – September 1993

Prescribed Disease or injury	**Occupation**
Except in the circumstances specified in regulation 2(d), (a) chronic bronchitis; or (b) emphysema; or (c) both where there is accompanying evidence of: (i) coal dust retention demonstrated by a chest radiograph to at least the level of Category 1 in the International Labour Office's publication "The Classification of Radiographs of Pneumoconioses" Revised Edition 1980, 8th Impression 1992 published at Geneva; and (ii) a forced expiratory volume in one second at least one litre below the mean value predicted in accordance with "Lung Function: Assessment and Application in Medicine" by J.E. Cotes, 4th Edition 1979 published at Oxford by Blackwell Scientific Publications Limited (ISBN 0-632-00033-3) for a person of the claimant's age, height and sex, measured from the position of maximum inspiration with the claimant making maximum effort.	Exposure to coal dust by reason of working underground in a coal mine for a period of, or periods amounting in the aggregate to, at least 20 years (whether before or after 5th July 1948).

Revised Prescription from April 1997

Prescribed Disease or injury	Occupation
Except in the circumstances specified in regulation 2(d), (a) chronic bronchitis; or (b) emphysema; or (c) both where there is accompanying evidence of a forced expiratory volume in one second (measured from the position of maximum inspiration with the claimant making maximum effort) which is- (i) at least one litre below the mean value predicted in accordance with "Lung Function: Assessment and Application in Medicine" by J. E. Cotes, 5th Edition 1994 published at Oxford by Blackwell Scientific Publications Limited (ISBN 0-632-03926-9) for a person of the claimant's age, height and sex; or (ii) less than one litre.	Exposure to coal dust by reason of working underground in a coal mine for a period or periods amounting in aggregate to at least 20 years (whether before or after 5th July 1948) and any such period or periods shall include a period or periods of incapacity while engaged in such an occupation.

ble 1 Comparison of Some Relevant Reference Equations of Predicting FEV_1

uthor	Country	Year	Age	Sample Size	Population/ Selection Criteria	Regression Equation*	R (where available)	Predicted Value (Man aged 65, height 1.75m, weight 76kg)
erglund	Sweden	1963	20-65	152	Normal, with yearly checkup naval officers, clerks, bankers, medical students	3.75H-0.036A-1.09	-	3.1325
lack	USA	1974	16-59	83	Not stated, includes smokers	2.7H-0.032A+0.6	0.69	3.245
herniack	Canada	1972	15-79	780	Not stated, non smokers	3.59H-0.023A-1.51	-	3.2775
otes	UK	1965	20-64	275	Random samples, factory workers, includes smokers	3.46H-0.033A-1.12	0.83	2.79

e Kroon	Netherlands	1964	20-60	1076	Factory workers	antilog (2.12logH-0.00425A+0.219)	0.67	2.87
ickman	USA	1969	mean 38.7	604	Blood donors, volunteers respiratory disease program	3.70H-0.031A-1.501	0.70	2.959
rouet	France	1980	30-59	480	Factory workers	4.22H-0.034A-2.14	-	3.035
ricsson	Sweden	1969	51-71	56	Randomly selected population	1.9H-0.045A+0.021W+0.9	-	2.896
erris(a)	USA	1965	25-74	157	Random sample, non smokers and ex smokers	2.9H-0.028A-0.7	0.61	2.555
erris(b)	USA	1965	25-74	298	Random sample, smokers only	3.6H-0.027A-1.65	0.71	2.895
udson	USA	1976	25-79	128	Non Mexican white population, non smokers	5.2H-0.027A-4.2	0.82	3.145
ory	USA	1961	18-66	389	Hospital employees, patients	3.7H-0.028A-1.59	0.63	3.065
orris	USA	1971	20-80	517	Religious sect, non smokers	3.62H-0.032A-1.26	0.73	2.995

ıanjer	Netherl ands	1977	21-64	189	Normal populations in rural and urban areas, non smokers	4.05H-0.031A-2.1	0.73	2.972
ıanjer	Netherl ands	1977	20-64	1006	Normal populations in rural and urban areas, smokers, non smokers and ex smokers	4.06H-0.038A-2.0	0.76	2.635
ıanjer	Netherl ands	1977	20-64	586	Normal populations in rural and urban areas, smokers only	4.17H-0.040A-2.17	0.76	2.527
ılorinne	Finland	1976	20-69	69	Visiting tuberculosis dispensary, non smokers only	5.43H-0.0273A-3.98	0.75	3.748
ılorinne	Finland	1976	20-69	50	Visiting tuberculosis dispensary, smokers only	4.56H-0.0286A-2.75	0.69	3.371
choenberg	USA	1978	18-70	194	Rural and semirural town, non smokers	-0.064W-0.00033AHW+0.064HW-0.00016W^2+0.75⌊nA -0.05	0.80	2.952
CCS ombined from bove equations nd tabled igures from ECA						4.301H-0.029A-2.492	0.93	3.15

otes combined quation	UK	1966			Combination of Cotes, 1965 Berglund, 1963, 1965, Ferris(b), 1965, Kory, 1961	3.62H-0.031A-1.41	-	2.91
ther Studies								
chmidt	USA	1973	55-94	368	Volunteers from USA senior citizens groups and world war I veterans. Included smokers	85H(inches)-31A-897	0.80	2.953
aclaren IOM)	UK	1958-78	15-75 (mean 38)	771 men (1755 measurements)	Working coal miners, lung function measurements at 5, 5-year intervals, non smokers, non respiratory symptoms, no chest illness	4.71H-0.03196A-.008521W-2.48735 4.741H-0.00919A-0.00026A^2-0.00848W-2.982	- -	3.03 2.974
rapo	USA	1981	15-91	125	Non smoking, Caucasian	4.14H-0.024A-2.205	-	3.48
nudson	USA	1983	25-84	86	Non smoking, Caucasian	6.65H-0.029A-6.5225	-	3.23
iller	USA	1986	18-85	176	Non smoking, Caucasian	5.66H-0.023A-4.93	-	3.48
aoeletti	Italy	1986	29-64	263	Family cluster sample, never smokers,	4.94H-0.0275A-3.5763	0.59	3.281

oca	Spain	1986	20-70	443	Volunteers in Barcelona metropolitan area, non smokers	4.99H-0.0211A-3.837	0.75	3.524
oberts	UK	1991	18-86	83	Never smokers. White urban dwellers. UK	3.961H-0.033A-1.558	0.82	3.229
molej-Narancic	Yugoslavia	1991	18-86	327	Non smokers	4.37H-0.0374A-2.2732	0.76	3.118
lindmeyer	USA	1995	18-65	2844 White	Black and white paper workers, never smokers. No history of occupational exposure dust	4.53H+0.00895A-0.000489A^2-3.445	0.63	2.998

* A age in years
H standing height in metres

Table 2
Comparison of Predicted Values from Cotes, IOM and ECCS Formulae

		Cotes	IOM*	ECCS
Age 55	**Height**			
	1.65	2.86	2.88	3.01
	1.7	3.04	3.11	3.22
	1.75	3.22	3.35	3.44
	1.8	3.40	3.59	3.65
Age 65	**Height**			
	1.65	2.55	2.56	2.72
	1.7	2.73	2.79	2.93
	1.75	2.91	3.03	3.15
	1.8	3.09	3.27	3.36
Age 75	**Height**			
	1.65	2.24	2.23	2.43
	1.7	2.42	2.47	2.64
	1.75	2.60	2.71	2.86
	1.8	2.78	2.94	3.07

* Using weight of 76kg.

REFERENCES

Berglund E, Birath G Bjure J, et al. Spirometric studies in normal subjects. I. Forced expirograms in subjects between 7 and 70 years of age. Acta Med Scand 1963; 173: 185-192.

Black LF, Offord K, Hyatt RE. Variability in the maximal expiratory flow volume curves in asymptomatic smokers and in non-smokers. *Am Rev Respir Dis* 1974; 110:282-289.

Cherniack RM, raber MB. Normal standards for ventilatory function using automated wedge spirometer. *Am Rev respir Dis* 1972; 106:38-46.

Cotes JE, Rossiter CE, Higgins ITT, Gilson JC. Average normal values for the forced expiratory volume in white caucasian males. B*r Med J* 1966; 23 April: 1016-1019.

Crapo RO, Morris AH, Gardner RM. Reference spirometric values using techniques and equipment that meet ATS recommendations. *Am Rev Respir Dis* 1981; 123:659-664.

De Kroon JPM, Joosting PE, Visser BF. Les valeurs normales de la capacite vitale et du volume expiratoire maixim seconde. Recherche chez les ouvriers d'une acierie aux Pays-Bas. *Arch Mal Prof* 1964; 100:780-790.

Dickman ML, Schmidt CD, Gardner RM, Marshall HW, Day WC, Warner HR. On-line computerized spirometry in 738 normal adults. *Am Rev Respir Dis* 1969; 100: 780-790.

Drouet D, Kauffmann F, Brille D, Lellouch J. Valeurs spirographiques de reference. Modeles mathematiques et utilisation pratique. *Bull Europ Physiopath Resp* 1980; 16:747-767.

Ericsson P, Irnell L. Spirometric studies of ventilatoryu capacity in elderly people. *Acta Med Scand* 1969; 185: 179-184.

Ferris BG, Anderson DO, Zickmantel R. Prediction values for screening tests of pulmonary function. *Am Rev Respir Dis* 1965; 91:252-261.

Ferris BG, Higgins ITT, Higgins MW. Chronic nonspecific respiratory disease in Berlin, New Hampshire, 1961-1967: A follow-up study. *Am Rev Respir Dis* 1973; 107:110-122.

Glindmeyer HW, Lefante JJ, McColloster C, Jones RN, Weill H. Blue-Collar Normative Spirometric Values for Caucasian and African-American Men and Women Aged 18 to 65. *American Journal of Respiratory Critical Care Medicine* 1995; 151:312-422.

Knudson RJ, Slatin RC, Lebowitz MD, Burrows B. The maximal expiratory flow-volume curve. Normal standards, variability and effects of age. *Am Rev Respir Dis* 1976; 113:587-600.

Knudson RJ, Lebowitz MD, Holberg CJ, Burrows B Changes in the Normal Maximal Expiratory Flow-Volume Curve with Growth and Aging1-3 *Am Rev Respir Dis* 1983; 127:725-734.

Kory KC, Callahan R, Boren HG, Syner JC. The Veterans Administration – Army co-operative study of pulmonary function 1. Clinical spirometry in normal men. *Am J Med* 1961; 30:243-258.

Maclaren WM, Miller BG, Hurley JF, Love RG. *Reference Values for Lung Function Decline in Working Coalminers.* Edinburgh: Institute of Occupational Medicine, 1994:

Miller A, Thornton J C, Warshaw R, Berstein J, Selikoff IJ, Teirstein AS. Mean and instantaneous expiratory flows, FVC and FEV1: prediction equations from a probablity sample of Michigan, a large industrial state. *Bull Europ Psysiopath Resp* 1986; 22:589-597.

Morris JF, Koski A, Johnson LC. Spirometric standards for healthy non smoking adults. *Am Rev Respir Dis* 1971; 103:57-67.

Paoletti P, Pistelli G, Fazzi P. Reference values for vital capacity and flow-volume curves from a general population study. *Bull Europ Physiopath Resp* 1986; 22:451-459.

Quanjer PH. Standardisation of Lung Function Tests. *Bull Europ Physiopath Resp* 1983; 19 Suppl 5:7-95.

Quanjer PH. Unpublished observations 1977.

Roberts CM, MacRae KD, Winning AJ, Adams L, Seed WA. Reference values and prediction equations for normal lung function in a non-smoking white urban population. *Thorax* 1991; 46:643-650.

Roca J, Sanchis J, Augusti-Vidal A. Spirometric reference values for a Mediterranean population. *Bull Europ Physiopath Resp* 1986; 22:217-224.

Salorinne Y. Single-breath pulmonary diffusing capacity. Reference values and application in connective tissue diseases and in various lung diseases. *Scand J resp Dis* 1976; Suppl 96:

Schmidt CD, Dickman ML Gardner RM, Brough FK. Spirometric Standards for Healthy Elderly Men and Women 1-3 *Am Rev Respir Dis* 1973; 108:933-643.

Schoenberg JB, Beck GJ Bouhuys A. Growth and decay of pulmonary function in healthy blacks and whites. *Respir Physiol* 1978; 33:781-790.

Smolej-Narancic N, Pavlovic M, Rudan P. Ventilatory parameters in healthy non-smoking adults of Adriatic islands (Yugoslavia). *European Respiratory Journal* 1991; 4:955-964.

Soutar C, Campbell S, Gurr D, et al. Important deficits of Lung Function in Three Modern Colliery Populations. *Am Rev Respir Dis* 1993; 147: 797-803.