Evaluating pulmonary impairment: appropriate use of pulmonary function and exercise tests

HERBERT P. WIEDEMANN, MD

■ Pulmonary impairment in patients with occupational lung diseases can frequently be detected and quantified simply by measuring spirometric values (forced vital capacity, forced expiratory volume in 1 second), or single breath-diffusing capacity. When the results of such pulmonary function tests are equivocal or inconsistent with clinical symptoms, cardiopulmonary exercise testing provides helpful ancillary information. Published guidelines are available to assist in grading the severity of respiratory impairment based on pulmonary function and exercise testing.
□ INDEX TERMS: LUNG DISEASE, OCCUPATIONAL; PULMONARY FUNCTION TESTS □ CLEVE CLIN J MED 1991; 58:148–152

OCCUPATIONAL lung diseases have concerned mankind throughout recorded history. In ancient times, Pliny (61 to 114 AD) noted that people involved in the production and wearing of asbestos cloth often developed a lung sickness.[1] More recently, in 1943, a landmark article by Dr. VanOrdstrand, to whom this symposium is dedicated, reported the first recognized cases of pneumonitis in workers exposed to beryllium.[2] Asbestos and beryllium, however, are just two of many agents, both organic and inorganic, that are capable of causing lung disease in occupationally exposed workers.[3]

In recent years, the legal, social, and medical issues of job-related pulmonary disease have become increasingly complex. The detection and measurement of impairment is the physician's first and primary task. Specifically, physicians are often asked to address a variety of questions related to impairment and disability, such as: (1) Is the patient physiologically impaired? (2) If so, is the impairment related to occupational factors or to problems unrelated to the workplace, such as smoking-induced pulmonary disease, heart disease, and so on? (3) Is the patient physically able to perform a specific job? This article reviews the role of pulmonary function testing and cardiopulmonary exercise testing in the objective evaluation of impairment.[4]

From the Department of Pulmonary Disease, The Cleveland Clinic Foundation, Cleveland, Ohio.

Address reprint requests to H.P.W., Head, Section of Medical Intensive Care, Department of Pulmonary Diseases, The Cleveland Clinic Foundation, One Clinic Center, 9500 Euclid Avenue, Cleveland, Ohio 44195.

IMPAIRMENT *V* DISABILITY

The distinction between impairment and disability is important.[5–7] *Impairment* refers to reduced organ function, usually indicated by deviation from predicted normal values. The detection and measurement of impairment is a medical issue and the physician's responsibility.

Disability is the overall effect of impairment on a person's working ability. The rating of disability requires the assessment of many factors including age, motivation, educational background, and job demands. Two individuals with identical impairment may have vastly different disabilities. For example, a file clerk and a heavy construction worker may have identical reductions in pulmonary function, with the same physiologic impairment, but the construction worker is clearly more disabled.

Disability assessment and Workers' Compensation decisions are complex problems that are usually adjudicated through legislative and administrative processes, rather than by the medical profession. In some circumstances, disability determinations have become quite removed from the supposed impairment, leading some to argue for a more scientific foundation to disability ratings.[8]

ASSESSING PULMONARY IMPAIRMENT

Dyspnea grades

Pulmonary disease of any type almost uniformly leads to the sensation of dyspnea, or shortness of breath, at abnormally low levels of exertion or even at rest. Although subjective grades of breathlessness correlate reasonably well with objective measures of lung function in some studies, subjective judgments have some readily apparent limitations. Not surprisingly, disability claimants have higher dyspnea scores than do workers matched for physiologic characteristics who are not applying for disability.[9–11] Furthermore, dyspnea is a nonspecific symptom which may be caused by nonpulmonary disorders including, most importantly, cardiac disease.

The limitations of dyspnea scoring were evident in a recent study of 120 asbestos-exposed workers who complained of breathlessness and impaired exercise tolerance and who were involved in pending litigation for asbestos-related injuries.[12] Half of the workers had no detectable limitation of exercise performance, whereas 37% had a limitation resulting from cardiac rather than ventilatory factors. Assessment of occupational lung impairment clearly requires the use of objective measurements, such as those obtained through pulmonary function testing and exercise testing.

Pulmonary function tests v exercise tests

Contemporary cardiopulmonary exercise testing permits the direct and accurate measurement of maximum oxygen consumption (VO_2max).[4] In a sense, determination of VO_2max is the most important "lung function test" for assessing pulmonary impairment, because "the major function of the lung is to meet the oxygen requirements of the body as these vary from rest to maximum exercise."[13] However, universal routine exercise testing is limited by practical considerations, including time and cost. Thus, traditional evaluation of resting lung function, including mechanical properties (lung volumes and airflow rates) and gas-exchange capacity (diffusing capacity, or DL_{CO}), is an appropriate first step in the evaluation of lung disease. Often, such pulmonary function tests are adequate to detect and quantify pulmonary impairment. However, in certain circumstances, as when pulmonary function test results are equivocal or inconsistent with the degree of symptoms, cardiopulmonary exercise testing may provide important ancillary information.

PULMONARY FUNCTION TESTS

To evaluate respiratory impairment, the American Thoracic Society recommends that the first pulmonary function tests include forced spirometric measurements (forced vital capacity, or FVC, and forced expiratory volume in 1 second, or FEV_1) and tests for single-breath diffusing capacity (DL_{CO}).[6]

Spirometric measurements assess mechanical function of the airways and lung parenchyma. Spirometric values can be decreased by either obstructive or restrictive pulmonary disorders. A low FEV_1 causes exercise impairment through a reduction in maximum minute ventilation.

Measurement of DL_{CO} is also important because some pneumoconioses (particularly asbestosis) can cause a profound decrease in DL_{CO}, even in the absence of significant mechanical lung dysfunction. A low DL_{CO} is associated with functional limitation for at least two reasons. First, clinically significant arterial oxygen desaturation during exercise is likely if the DL_{CO} is less than about 55% of predicted, and the severity of such desaturation generally increases in relationship to the degree of reduction in DL_{CO}.[14,15] Second, a low DL_{CO} is a marker for a constricted or obliterated pulmonary microvasculature, which may cause pulmonary hypertension, especially during exercise.

Arterial blood gases at rest or during exercise generally do not provide helpful independent information regarding impairment in patients with lung disease, including the pneumoconioses.[4,16–18] Patients with significant resting or exercise-induced hypoxemia (or

TABLE 1
RATING OF IMPAIRMENT BY PULMONARY FUNCTION TESTS (% predicted value)*

Pulmonary function test	Mild	Moderate	Severe
Forced expiratory volume in 1 sec (FEV_1)	60–79	41–59	≤40
	or	*or*	*or*
Forced vital capacity (FVC)	60–79 *or*	51–59 *or*	≤50 *or*
DL_{co}	60–79	41–59	≤40

*From the American Thoracic Society.[6]

hypercapnia) caused by respiratory disease will also have spirometry or DL_{CO} values that indicate impairment.[6,14,19]

Table 1 provides a scheme by which the degree of impairment can be appropriately categorized in most individuals.[6] If resting lung function is markedly abnormal (FEV_1 less than 40% predicted, FVC less than 50% predicted, or DL_{CO} less than 40% predicted), then aerobic capacity is significantly impaired. Such patients are usually unable to meet the physical demands of even sedentary occupations (including travel to work).

On the other hand, normal resting lung function (FEV_1, FVC, and DL_{CO} 80% of predicted value or greater) essentially rules out a pulmonary cause for exercise limitation. The major exception is asthma, in which intermittent attacks of bronchospasm, sometimes triggered by occupational exposures, may cause functional impairment. The grading of impairment and disability in occupational asthma is made difficult by the variable nature of the airflow obstruction. Although widely accepted standard criteria are not available, an approach to the assessment of functional impairment in asthmatic patients has recently been proposed.[20]

EXERCISE TESTING

Information from exercise testing

Most clinical exercise tests measure physiologic responses during short-term, progressive incremental work up to the symptom-limited maximum. Noninvasive technology (including expired gas analysis) makes it possible to answer two pertinent questions: (1) What is the maximum aerobic power (VO_2max)? (2) Is aerobic power limited by pulmonary disease or by cardiovascular factors?[21]

In normal individuals, maximum exercise is limited

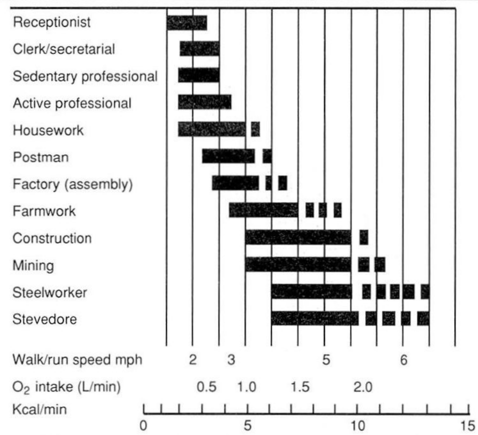

FIGURE 1. Estimated oxygen and energy demands of selected occupations (solid bars) compared with various running and walking speeds. Short-term or "peak" requirements are also indicated (broken bars).

by cardiac output rather than ventilation (at peak exercise, the minute ventilation is only about 70% of the maximum voluntary ventilation). As a consequence, mild lung disease usually does not reduce VO_2max, but reduces the "ventilatory reserve" that normally exists at peak exercise.

Indications for exercise testing

Many patients being evaluated for respiratory impairment do not require exercise testing. This is especially true if spirometry and DL_{CO} values are normal or only mildly reduced, indicating that impairment from pulmonary disease is extremely unlikely, or if such pulmonary funcion tests are severely reduced, making occupational disability almost inevitable.

Exercise testing is helpful when lung function tests indicate intermediate degrees of impairment or when the patient's symptoms are discordant with results of lung function tests. As shown by several studies of asbestos-exposed individuals,[12,22–25] exercise testing in such circumstances may provide a more precise assessment of functional capacity than is achieved by lung function tests alone and often uncovers clinically unsuspected cardiovascular disease.

Impairment measured by exercise testing

Although many factors influence work capacity, an individual's maximum aerobic power plays a critical role.[26] Because exercise testing is a measure of maximum aerobic power, it is often assumed that the results of such testing would easily determine whether a

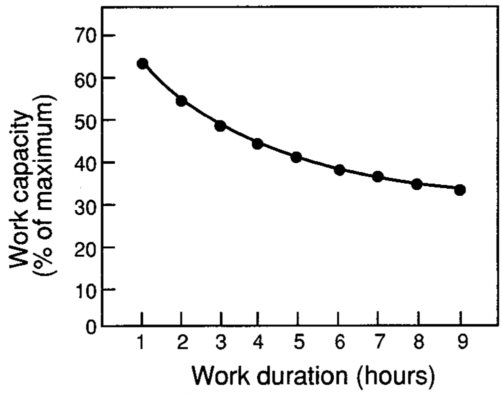

FIGURE 2. Approximate percentage of maximum work capacity that can be maintained for given work durations (adapted from Erb[27]).

TABLE 2
RATING OF IMPAIRMENT BY VO_2 MAX (mg/kg/min)

	Mild	Moderate	Severe
Canadian Thoracic Society[7]	15–25	7–15	<7
American Medical Association[30]	20–25	15–20	<15
American Thoracic Society[6]	—	—	<15 or average job demand >40% VO_2max

patient is physically able to perform a particular job. In fact, arriving at such a conclusion is more difficult than might be suspected. It is difficult to assess reliably the energy demands of a specific job. In addition, there is a complex relationship between short-term maximum aerobic power and the ability to meet submaximal and intermittent energy demands over a period of time.

Portable gas collectors and analyzers have allowed the oxygen cost of many activities to be estimated for a variety of situations. The oxygen demands of selected occupations are shown in *Figure 1*.

The physician who is assessing impairment usually must resort to this or similar published data to estimate the energy demand of a patient's job. However, such data provide only a rough guideline, because few jobs are characterized by well-defined standard activities. Furthermore, variations in training skills and anthropometric characteristics among individuals may alter the aerobic demands even for those doing an identical task.[26]

Several aspects of applied work physiology also need to be considered when evaluating the adequacy of a patient's aerobic power in relation to job energy demands. One important feature of normal exercise physiology is the inability to sustain peak levels of oxygen consumption for long periods (*Figure 2*).[26–28] About 50% of VO_2max is the most that can be maintained during 3 hours of exertion.[28] According to Astrand,[26] a worker involved in manual labor who is more or less free to set his own pace normally accepts working at an energy output up to approximately 40% of his maximum aerobic power.

Another important aspect of work physiology is that peak energy demands of short duration (such as a few seconds of heavy lifting) can be achieved "anaerobically" if subsequent rest is allowed for replenishment of muscle energy stores. Thus, heavy work can be performed with minimal peak aerobic demand if an individual can adopt an intermittent schedule with frequent short bursts of work, followed by intervening rest or light activity. In such circumstances, a worker is not "limited" by his aerobic power. This fact may help explain why one study found that 25% of successfully employed miners had VO_2max values that should have caused severe functional impairment.[29]

Clearly, the results of exercise testing cannot always provide an absolute determination of an individual's ability to meet the energy demands of a particular occupation. Nevertheless, the measurement of VO_2max does provide helpful and objective information. *Table 2* summarizes three different schemes for the rating of impairment by exercise testing, as officially accepted by the American Thoracic Society,[6] American Medical Association,[30] and Canadian Thoracic Society.[7]

REFERENCES

1. Selikoff IJ, Lee DHK. Asbestos and Disease. New York: Academic Press; 1978.
2. VanOrdstrand HS, Hughes R, Carmody MG. Chemical pneumonia in workers extracting beryllium oxide. Cleve Clin Q 1943; **10**:10–18.
3. Cullen MR, Cherniak MG, Rosenstock L. Occupational medicine. N Engl J Med 1990; **322**:594–601, 675–683.
4. Wiedemann HP, Gee JBL, Balmes JR, Loke J. Exercise testing in occupational lung diseases. Clin Chest Med 1984; **5**:157–171.
5. Richman SI. Meanings of impairment and disability. The conflicting social objectives underlying the confusion. Chest 1980; **78(suppl)**:367–371.
6. American Thoracic Society. Evaluation of impairment/disability secondary to respiratory disorders. Am Rev Respir Dis 1986; **133**:1205–1209.

7. Ostiguy GL, et al. Summary of task force report on occupational respiratory disease (pneumoconiosis). Can Med Assoc J 1979; **121**:414–421.
8. Richman SI. Why change? A look at the current system of disability determination and Workers' Compensation of occupational lung disease. Ann Intern Med 1982; **97**:908–914.
9. Cotes JE. Assessment of disablement due to impaired respiratory function. Bull Physiopathol Respir 1975; **11**:210P–217P.
10. Epler GR, Sober FA, Gaensler EA. Determination of severe impairment (disability) in interstitial lung disease. Am Rev Respir Dis 1980; **121**:647–659.
11. Morgan WKC. Disability or disinclination? Impairment or importuning? Chest 1979; **75**:712–715.
12. Agostoni P, Smith DD, Schoene RB, et al. Evaluation of breathlessness in asbestos workers. Am Rev Respir Dis 1987; **135**:812–816.
13. Becklake MR. Respiratory impairment including assessment of disability. I. Summary of the conference. Bull Physiopathol Respir 1975; **11**:203P–209P.
14. Owens GR, Rogers RM, Pennock BE, et al. The diffusing capacity as a predictor of arterial oxygen desaturation during exercise in patients with chronic obstructive pulmonary disease. N Engl J Med 1984; **310**:1218–1221.
15. Sue DY, Oren A, Hansen JE, Wasserman K. Prediction and monitoring of oxygen desaturation during exercise testing. N Engl J Med 1987: 316:1301–1306.
16. Gimenez M, Salinas W, Candina R, et al. Blood gases at rest and exercise for assessment of respiratory impairment in pneumoconiosis. Eur J Respir Dis 1981; **62(suppl)**:30–31.
17. Morgan WKC, Lapp NL, Seaton A. Respiratory disability in coal miners. JAMA 1980; **243**:2401–2404.
18. Refsum HE. Pulmonary gas exchange during and after exercise of short duration in silicosis. Scand J Clin Lab Invest 1972; **S121**:1–48.
19. Risk C, Epler G, Gaensler EA. Exercise alveolar-arterial oxygen pressure difference in interstitial lung disease. Chest 1984; **85**:69–74.
20. Chan-Yeung M. Evaluation of impairment/disability in patients with occupational asthma. Am Rev Respir Dis 1987; **135**:950–951.
21. Wasserman K. Dyspnea on exertion. Is it the heart or the lungs? JAMA 1982; **248**:2039–2043.
22. Pearle J. Exercise performance and functional impairment in asbestos-exposed workers. Chest 1981; **80**:701–705.
23. Zejda J. Diagnostic value of exercise testing in asbestosis. Am J Indust Med 1989; **16**:305–319.
24. Howard J, Mohsenifar Z, Brown HV, et al. Role of exercise testing in assessing functional respiratory impairment due to asbestos exposure. J Occup Med 1982; **24**:685–689.
25. Oren A, Sue DY, Hansen JE, et al. The role of exercise testing in impairment evaluation. Am Rev Respir Dis 1987; **135**:230–235.
26. Astrand PO. Quantification of exercise capability and evaluation of physical capacity in man. Prog Cardiovasc Dis 1976; **19**:51–67.
27. Erb BD. Applying work physiology to occupational medicine. Occup Health Saf 1981; **50**:20–24.
28. Michael ED Jr, Hutton KE, Horvath SM. Cardiorespiratory responses during prolonged exercise. J Appl Physiol 1961; **16**:997–1000.
29. Roemmich W, Blumenfeld HL, Moritz H. Evaluating remaining capacity to work in miner applicants with simple pneumoconiosis under 65 years of age under Title IV of Public Law 91-173. Ann NY Acad Sci 1972; **200**:608–616.
30. Guides to the evaluation of permanent impairment. Chicago: American Medical Association; 1984:28–34.