

Preventive effectiveness of pre-employment medical assessments

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Abstract

Objectives and methods—Health gain, prevention of health loss, and avoidance of financial risk all seem to be driving forces for the use of pre-employment medical assessment. An attempt is made to measure the effect of implementing the pre-employment medical assessment on these end points. The anticipated maximum preventive effect (preventive effectiveness) of selection by means of pre-employment medical assessments for work related risks and the potential for disablement in individual workers can be calculated or estimated. Necessary parameters include test validity characteristics and epidemiological data for both the adverse outcome to be prevented, and risk factors of concern.

Results—The preventive effectiveness can be expressed as the effort (number of actions) needed to prevent one adverse event—for example, one case of occupational disease or one case of long term disablement. Actions include: a pre-employment health assessment, rejection of the candidate, individual precautions, adjustments of the job, and adjustments of the job environment. It seems that the preventive effectiveness of many actions can be low, implying that large numbers of actions are needed to prevent one adverse outcome.

Discussion—The medical assessment should consist of no more questions and tests than are required relevant to the stated aim. Particularly, when the pre-employment medical assessment is used to reject candidates at risk, the use of tests should be carefully weighed. If the preventive effectiveness is considered to be too low, then the question or test should not be incorporated for selection purposes. The application of a so called “expert judgment” should be based on professional guidelines wherever possible and should be made clear. The benefit of reducing the incidence of a serious adverse event by one may outweigh the costs of rejecting many candidates.

Conclusions—The concept of preventive effectiveness may help to reach evidence based occupational medicine, which starts at the pre-employment medical assessment.

Keywords: pre-employment health assessment; preventive effectiveness; risk avoidance

To produce substantive policy in occupational medicine, it is necessary to gain insight into the quality aspects of the methods to be used.¹ An important one of these is the pre-employment medical assessment. This assessment will, among other functions, be a means of personnel selection and as such it is essential that assessment is both sufficiently accurate and reliable. The contents of the pre-employment medical assessment differ widely and may include a history (often taken by questionnaire), a medical examination, and additional (laboratory) tests. A pre-employment medical assessment may include all of these items extensively, or may merely consist of a simple self administered questionnaire.² This article focuses on methodological aspects of such a screening process. More specifically, attention will be given to the anticipated maximum preventive effect (preventive effectiveness) of selection by such medical assessments on work related health risks, risks to others, the potential for absenteeism, and disablement in individual workers.

Pre-employment medical assessment

The content and the relevance of pre-employment medical assessment of fitness for work have held centre stage since the emphasis was placed on the possible contribution that such an assessment could make to the prevention of occupational disease, absence through sickness, and work disablement. The pre-employment medical assessment is used to assess whether a candidate is sufficiently skilled to perform the job adequately from a medical point of view. Moreover, the pre-employment medical assessment presents an opportunity to ease the entrance to the work force for people with certain health risks, medical impairments, or handicaps. When the results of a pre-employment health examination show a lack of balance between job demands and anticipated performance of the candidate, measures to lower risk can be taken. Such measures may be aimed at the candidate (rejection or not; individual precautionary adjustments), the job, or the job environment. However, health gain is not the only motivation for the use of pre-employment medical assessment. The involvement of the employer, the insurance companies, and pension funds with the growing cost containment problems of sick leave

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and work disablement has led to the notion that pre-employment medical assessment can present a method of (financial) risk avoidance.

A relevant factor in this setting is the existence in various countries of legislation—such as, the Dutch “Arbeidsomstandighedenwet” (Working Environment Act)—which has allowed pre-employment medical assessments when certain work is to be performed. Despite the general renunciation by numerous governmental and international bodies, including professional associations, of a purely economically based risk avoidance, the pre-employment medical assessment is still commonly used by many, including some of these international bodies.³ The attention of the media focuses on disorders in which hereditary tendencies may play a part (with the help of so called genetic screening) and checking aspiring employees for the use of alcohol or other (illicit) drugs and for possible infection by human immunodeficiency virus (HIV).

Codes of practice

When a person has a certain endogenous or acquired tendency, it may imply that in a particular working environment he or she will perform less effectively than average, or will run an above average risk of injury or detrimental health effects—such as occupational disease, incapacity, or disablement. Such a risk can also denote risks for third parties. In epidemiological terminology, such a person is spoken of as being susceptible, or having an individual risk factor. The pre-employment medical assessment is a means of identification and selection for a risk factor, but before reaching a conclusion about this, several aspects should be considered. In 1968, Wilson and Jungner, in a World Health Organisation publication, focused attention on the principles on which the establishment of a screening programme for the general population could be based.⁴ Employees of the National Institute for Occupational Safety and Health have suggested ways of translating these into the field of occupational health care.⁵ This translation places a focus on specific characteristics of the population of workers and on some less conventional possibilities for intervention. In occupational health, one does not always immediately speak of disease or disorder, but much more often of a risk factor in the form of a tendency or of noticeable non-pathological variables. Also, the working environment offers conditions which are more readily and more specifically open to intervention than conditions in the general environment or at home.

Individual authors,⁶⁻⁸ textbooks,⁹⁻¹¹ professional organisations,¹² and governmental or international bodies,¹³⁻¹⁷ do present well formulated advice or guidelines for medical assessments, but only briefly refer to the generally accepted principles already mentioned. They do not generally take into account, or do so only in passing, the limitations of the tests and the methods to be used. In particular, the actual or possible preventive effect of certain

pre-employment medical policies is not taken into consideration. Yet, a discussion on limitations of medical testing is important, because a lack of precision or absence of predictive value may leave too much room for personal interpretations, if not intentional or unintentional, discrimination.

Recently the Dutch “Koninklijke Nederlandse Maatschappij ter bevordering van de Geneeskunst” (Royal Dutch Medical Association) has published a code of practice for pre-employment medical assessment.¹⁸ The impetus for this protocol included a Dutch Bill on pre-employment medical assessments, and research carried out in The Netherlands.^{19,20} This code of practice also only contains generally formulated goals and deals with procedural aspects. Briefly, it states that the pre-employment medical assessment should aim at judging the balance between the ability of a certain candidate to sustain a work load and the presumed work load of the job in question. Conditionally, the pre-employment medical assessment must be performed: (a) before work is started; (b) on the one remaining candidate; (c) by an independent sufficiently trained physician; (d) if, and only if, there are job demands which can be translated into medical terms of reference; (e) if the contents of the medical assessment (questions, physical examination, laboratory tests, etc) are relevant to the stated aim; and (f) while respecting physical and psychological integrity of the candidate’s privacy. Also, the code of practice deals with important other procedural aspects, such as those about exchange of information, the reporting of results, the access to documents, the possibility of a re-examination, and the procedure for dealing with complaints.

Preventive effectiveness of a pre-employment medical assessment

The preventive effectiveness of a pre-employment medical assessment can only be estimated with the validity characteristics of the tests to be used, and with the epidemiology of the risk factors of the effects of concern. Thus, the preventive effectiveness is expressed as the effort—the number of actions—needed to prevent one adverse event—for example, one case of occupational disease or one case of long term disablement.

VALIDITY CHARACTERISTICS OF THE TESTS USED; POSITIVE PREDICTIVE VALUE

Validity and reliability (reproducibility) of tests vary enormously. Hardly any of the tests for showing a particular risk factor are entirely valid. People are missed who do carry the risk factor, whereas others are wrongly designated as risk carriers. Mostly use is made of the test attributes sensitivity and specificity to ascertain the validity of a given test. In combination with the actual prevalence of a risk factor in a given population the test standards give an indication of the certainty that the risk factor identified is actually present in a given person; this is the prognostic or positive predictive value (PPV). The PPV is thus the proportion

of those people with a positive test result who actually carry the risk factor. It should be noted that the description of PPV used in the scientific literature is unfortunate as what is meant here is not an attempted prognosis of a possible subsequent appearance of a work related ailment, but only the correct prediction of the presence of a risk factor.

A general equation can be derived from which the PPV can be calculated for a positive test result—that is, a result which predicts the presence of a risk factor (Kleinbaum *et al*, 1982²¹).

$$PPV = \frac{a \cdot p}{a \cdot p + (1 - b) \cdot (1 - p)} \quad (1)$$

where: a = sensitivity of the test; b = specificity of the test; p = prevalence of the risk factor.

Example 1

Imagine that the atopy of people applying for the job of technician responsible for laboratory animals needs to be ascertained, as those with atopic reactions are especially at risk of allergic reactions in this work environment. The identification of people as atopic or non-atopic may thus be used as a selection criterion. Both sensitivity and specificity of the test used to identify these people—namely, a questionnaire in combination with an evaluation of the IgE concentration in blood, are 90% under optimal conditions. The prevalence of atopy in the general population of the Netherlands is about 5%. A positive test result implies that somebody is identified as being atopic. When the details of this example are filled in in equation 1, the outcome is that of those with a positive result, 32% are correctly identified with atopy and thus are excluded from the selection process. It follows that 68% of the test positive candidates will incorrectly be identified as atopic, but will nevertheless be excluded from the selection process.

The table shows the PPV for several specificity and prevalence values. If, for example, the prevalence of the risk factor is 1% and the test specificity is 95%, then a positive test result will point correctly to the presence of a risk factor in 15.4% of cases, whereas a test specificity of 99% gives a PPV of 47.6%. The value of PPV seems to depend strongly on the specificity of a test and only to a limited extent

on the sensitivity between 60% and 100%. The PPV will only slightly improve with sensitivity values > 90%.

EPIDEMIOLOGY OF THE RISK FACTOR IN RELATION TO THE EFFECT OF CONCERN: POPULATION ATTRIBUTABLE RISK

By rejecting applicants after a medical assessment on the grounds of a certain risk factor, it would be expected that the number of cases of occupational disease will be reduced. In theory, such a selection should reduce the incidence of work related disorders by up to the proportion that can be attributed to the risk factor in question. For the sake of simplicity, it is assumed that no competing or interacting risk factors exist for the work related disorder and that maximum effect will be attained when all candidates carrying the risk factor are identified. An equation can be derived in which the proportion of the work related disorder attributable to the risk factor, or population attributable risk (PAR), can be calculated.²¹

$$PAR = \frac{p \cdot (RR - 1)}{1 + p \cdot (RR - 1)} \quad (2)$$

where: p = prevalence of the risk factor; RR = relative risk.

In equation 2 only the prevalence of the risk factor, p , and the relative risk, RR , are included as variables. The incidence, I , of the work related disorder is not included because PAR concerns a proportion of I . If, for example, a risk factor appears in 1% of the population, and the accompanying RR amounts to 5, then about 3.8% of the instances of disease can be attributed to the risk factor.

Example 1 (continued)

When atopic people run a threefold greater risk of developing allergies to laboratory animals than people who are considered normal, selection on the basis of being atopic (population prevalence around 5%) can reduce the number of new cases of work related animal allergies by 9.1% at the most. When the sensitivity of the test is 90%, the actual reduction will be 10% lower—that is, around 8.2%.

PREVENTIVE EFFECTIVENESS

The contribution that selection through pre-employment medical assessment makes to the prevention of occupational disease is determined by the interplay of the aspects mentioned. One aim of selection through such a process can be a reduction in the incidence of work related disease. In part, this aim may be achieved by rejecting those with specific risk factors found at the selection process. In assessing the contribution of selection at the pre-employment medical assessment, it can be useful to measure the results of such a process. In particular, the (health) benefits of selection must be weighed against the input of effort and costs. This is possible in various ways. For example, it can be calculated how many medical assessments need to be performed to

Positive predictive value (PPV) calculated from equation 1 for various values of the test specificity (b) of the prevalence (p) of the risk factor investigated, with the test sensitivity (a) fixed at 90%

Prevalence (p %)	Specificity (b %)					
	80	90	95	97.5	99	99.9
0.1	0.4	0.9	1.8	3.5	8.3	47.4
0.5	2.2	4.3	8.3	15.3	31.1	81.9
1.0	4.3	8.3	15.4	26.7	47.6	90.1
5.0	19.1	32.1	48.6	65.5	82.6	97.9
10.0	33.3	50.0	66.7	80.0	90.9	99.0
20.0	52.9	69.2	81.8	90.0	95.7	99.6

reduce the number of new cases of a specific occupational disease by one. How many candidates need to be rejected to reduce the number of new cases of a certain work related ailment by one can also be calculated. The appendix shows a derivation of the equations used in these calculations. With formula (8') from the appendix, the necessary number of medical assessments to reduce the number of new cases by one, K , amounts to:

$$K = \frac{1}{a \cdot \text{PAR} \cdot I} \quad (8')$$

and the necessary number of rejections, K_{rejected} , amounts to:

$$K_{\text{rejected}} = \frac{p}{\text{PPV} \cdot \text{PAR} \cdot I} \quad (9')$$

Where a = sensitivity of the applied test; PAR = population attributable risk; I = (cumulative) incidence of the disease or adverse career outcome; p = prevalence of the risk factor; PPV = positive predictive value. The equations can be calculated quickly and easily.

Example 1 (continued)

The cumulative incidence I for the acquisition of an allergy to laboratory animals amounts in some investigations to around 100/1000 animal technicians. With values for p , PAR, and PPV it can be calculated by means of equations 8' and 9' that for each avoided case of allergy 122 medical assessments must be performed and 17 candidates must be rejected. Twelve of the group of 17 rejected candidates will have been diagnosed incorrectly as being atopic.

Example 2

When appointing nurses for a general hospital the occupational physician wishes to prevent sick leave periods due to low back pain lasting four weeks or more during the 10 years after the health assessment. Previous chronic episodes of back pain are regarded as a valid predictor. Therefore, the use of a questionnaire asking for absence due to back pain for at least four weeks in the past is considered. To apply equations 8' and 9', some critical values have to be estimated.

In a first estimation, values close to reality will be used. Also, more or less extreme estimations will be presented to stimulate the discussion.

Firstly, sensitivity of the question on sickness absence in the past is expected to be low, 0.70, as some applicants will deny problems. Being a rather straightforward question, a high specificity of 0.95 is presumed. In this mostly young population the prevalence of an absence for four weeks or more due to back pain in the past has been reported to be 3%. People with such absence in the past may show a relative risk for three for future periods of sickness absence of four weeks or more.

The cumulative incidence of sickness absence for four weeks or more during 10 years has been estimated to be 10% of the applicant population.

The results of the calculations are a K value of 252 and a K_{rejected} value of 18. In other words, to prevent one case 252 examinations have to be organised with 18 candidates rejected, including 12 incorrectly diagnosed risk carriers.

In a second estimation, a situation more favourable for pre-employment medical assessments is presented. Here, a sensitivity of 0.90, a specificity of 0.975, and a prevalence of the personal risk factor of 6% are assumed. As some publications report a high relative risk, we decided for this example on a relative risk of five in combination with a cumulative incidence of 20%. Now, 29 pre-employment assessments are necessary and two candidates have to be rejected for every prevented case. In a third estimation, a more extreme situation in the opposite direction has been chosen with a sensitivity of 0.70, a specificity of 0.80, a prevalence value of 2%, a relative risk of two, and a cumulative incidence of 5%. From this, K is 1457 and K_{rejected} is 306, including 286 incorrectly diagnosed risk carriers.

Preventive effectiveness of pre-employment medical assessments is not restricted to preventing work related diseases but can be generalised to other goals. Subsequently, the results of the calculated preventive effectiveness can be applied to estimate the extent of the anticipated avoidance of economic risk. However, it is necessary to keep in mind the substantial social influences on outcomes such as sickness absence. Moreover, the pre-employment medical itself is likely to only make a small (if any) contribution to safe working practices, hazard control, and indeed, sickness absence during the course of employment.

Example 3

Assume that 5% of the population of candidates run a twofold risk of health related sick leave or some other health related adverse career outcome—such as premature retirement for health reasons—which would occur in 5% of the working population. Given these assumptions, the risk carrying candidates account for about 4.8% additional sick leaves or premature retirements for health reasons. Assume also that sensitivity and specificity are both 90% with the available methods of identifying the risk carriers. Then 467 candidates must be examined, of which about 65 (14%, including about 44 non-risk carriers) must be rejected to prevent one person from experiencing the adverse outcome of concern. The justification of adopting such a selection policy could be that it is considered more profitable to examine 467 candidates and to reject 65 (including 44 non-risk carriers) than to

accept one person who will experience an adverse outcome, presupposing that the adverse outcome could not have been prevented otherwise.

Decision making

The previous section should offer a rationale for the use of a test in a pre-employment medical assessment but also for use of all the pre-employment medical assessments as a means of personnel selection. Thus it is crucial to develop assessments of job specific pre-employment medicals. Job demands should dictate the contents of the medical assessment. In our view, this automatically leads to the setting of conditions on the contents of a pre-employment medical assessment.

Firstly, the medical assessment should consist of no more questions and tests than are needed. This implies that the preventive effectiveness of the questions or tests must be known or be estimated from available knowledge. If the preventive effectiveness is considered to be too low, then the question or test should not be incorporated for selection purposes—for example, questions involving the “general impression” of the physician in decision making, a medical test that cannot be reproduced, should be avoided. Moreover, the general impression of the physician involved is unlikely to be an appropriate selection criterion for any job. Ultimately, if no acceptable medical questions or tests are at hand, there should not be a pre-employment medical assessment to select personnel. During this decision making process a wide range of K values may occur that are highly dependent on the estimation of some basic values. Some results may not indicate the adoption of the pre-employment medical examination to select personnel, but others would strongly support it. One possible solution for narrowing the wide range of K values is to ask a professional panel to present an evidence based (more narrow) range of K and K_{rejected} values for several common situations. To foster efficiency and to stimulate implementation, these activities can be incorporated in the development of professional guidelines.

Secondly, criteria for rejection must be set in advance. If set afterwards, criteria may easily be distorted by personal views and subjective and variable standards. As a corollary, test validity decreases, thus lowering preventive effectiveness, simply because the reproducibility of the test will be lower.

Thirdly, although emphasis on preventive effectiveness remains of utmost importance, a low preventive effectiveness can be acceptable whenever the impact of the risk to be avoided is considered large—for example, if the safety of colleagues, customers, or the public in general is at stake—or if the health effect is very serious. As a matter of course, serious risks do not improve preventive effectiveness. However, the benefit of reducing the incidence of a serious adverse event by one may outweigh the costs of rejecting many candidates—for example, in the selection of aircrew.

Fourthly, it is unlikely that experience and knowledge of the individual occupational physician will not play a part in performing pre-employment medical assessments and thus in the outcome. This unavoidable “expert judgment”, notwithstanding its subjective nature, can be considered justified in situations where general guidelines are not applicable or simply not available because of the uniqueness of the situation. If such a situation occurs, the preventive effectiveness cannot be calculated or estimated. The use of expert judgment, therefore, remains a decisive tool in assessing medical fitness for a job. The application of expert judgment should be based on professional guidelines wherever possible and should be made clear. An unequivocal registration of the results of the medical assessment is required for evaluation. Therefore, the arguments for the decision must be made explicit.

Fifthly, unexpected or coincidental findings must be treated properly. That is, serendipitous discoveries should not be denied and must be treated carefully. However, finding such cases cannot justify the use of pre-employment medical assessments to select personnel although, in individual cases, rejection of the candidate involved might just be the actual outcome of the procedure.

Conclusion

The pre-employment medical assessment aims at reducing adverse health related career outcomes and job related safety risks by identifying risk carriers and taking subsequent appropriate measures. From a different point of view, it may sometimes be used for lowering absenteeism, long term disablement, or financial risks to the health insurance company or the pension fund.

We suggest that a balanced policy in occupational medicine should be pursued and that the concept of preventive effectiveness may be helpful in attaining evidence based occupational medicine, which starts at the pre-employment medical assessment.

Appendix: Derivation of equations for the number of medical assessments and rejections needed to reduce the number of adverse career outcomes by one

Suppose, a company needs Z new employees for a particular type of job within a given time span. Without selection, it can be expected that ultimately a proportion I of the employees will contract a certain occupational disease—that is, the cumulative incidence of this disorder is I . From equation 2, it follows that, in this situation, in the group of Z employees there are:

$$N_{\text{factor}} = \text{PAR} \cdot I \cdot Z \quad (3)$$

employees who will get this disorder and for whom the disorder can be attributed to the fact that these employees have a certain risk factor. With the risk factor as a selection criterion, the number of cases of this particular occupational disease should decline. If a is the test sensitivity, then by means of the pre-employment medical policy there are:

$$N_{\text{avoided}} = a \cdot \text{PAR} \cdot I \cdot Z \quad (4)$$

less new cases of the work related disease. As this risk factor is used as a selection criterion at the medical assessment, several candidates will be rejected from the

selection process. If Z new workers are ultimately required to be taken into service, then more than Z candidates must be screened, namely Z' candidates. Z' can be determined as follows.

The expected proportion with a positive test result, and therefore the expected proportion to be rejected by the medical assessment, F_{rejected} amounts to (equation 1):

$$F_{\text{rejected}} = a \cdot p + (1 - b) \cdot (1 - p) = \frac{a \cdot p}{\text{PPV}} \quad (5)$$

It holds that:

$$Z' - F_{\text{rejected}} \cdot Z' = Z \quad (6)$$

From equation 6 it follows that:

$$Z' = \frac{Z}{(1 - F_{\text{rejected}})} \quad (7)$$

candidates must be subjected to a pre-employment medical assessment to eventually appoint Z new employees. The number of medical assessments to avoid one case, K (equations 4 and 7), then amounts to:

$$K = \frac{Z'}{N_{\text{avoided}}} = \frac{1}{a \cdot \text{PAR} \cdot I \cdot (1 - F_{\text{rejected}})} \quad (8)$$

By multiplying equation 8 by equation 5 it is possible to calculate the number of rejections per case avoided, K_{rejected} :

$$K_{\text{rejected}} = K \cdot F_{\text{rejected}} = \frac{p}{\text{PPV} \cdot \text{PAR} \cdot I \cdot (1 - F_{\text{rejected}})} \quad (9)$$

If F_{rejected} is very small, then equations 8 and 9 can be reduced to:

$$K = \frac{Z'}{N_{\text{avoided}}} = \frac{1}{a \cdot \text{PAR} \cdot I} \quad (8')$$

and:

$$K_{\text{rejected}} = K \cdot F_{\text{rejected}} = \frac{p}{\text{PPV} \cdot \text{PAR} \cdot I} \quad (9')$$

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