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Short Communication

Proficiency in Reading Pneumoconiosis Radiographs Examined by the 60-film Set with 4-factor Structuring 8-index

Huashi ZHOU[1], Yukinori KUSAKA[1]*, Taro TAMURA[1], Narufumi SUGANUMA[2], Ponglada SUBHANNACHART[3], Somkiat SIRIRUTTANAPRUK[4], Narongpon DUMAVIBHAT[5], Xing ZHANG[6], P. K. SISHODIYA[7], Khuong VAN DUY[8], Kurt G. HERING[9], John E. PARKER[10], Eduardo ALGRANTI[11], Igor FEDOTOV[12], Hisao SHIDA[13] and Masanori AKIRA[14]

[1] Department of Environmental Health, School of Medicine, University of Fukui, 23–3 Shimoaitsuki Matsuoka, Eiheizi-cho, Fukui 910-1193, Japan
[2] Department of Environmental Medicine, Kochi University School of Medicine, Japan
[3] Chest Disease Institute, Thailand
[4] Bureau of Occupational and Environmental Diseases, Ministry of Public Health, Thailand
[5] Department of Preventive and Social Medicine, Faculty of Medicine Siriraj Hospital, Mahidol University, Thailand
[6] Institute of Hygiene, Zhejiang Academy of Medical Sciences, Hang Zhou, P. R. China
[7] National Institute of Miners' Health, India
[8] Department of Occupational Health, Ha Noi Medical University School of Public Health, Vietnam
[9] Department of Diagnostic Radiology, Radiooncology and Nuclear Medicine, Radiological Clinic, Miner's Hospital, Dortmund, Germany
[10] Pulmonary and Critical Care Medicine, Robert C, Byrd Health Sciences Center, School of Medicine, West Virginia University, Morgantown, U.S.A
[11] Divisao de Medicina, Fundacentro, San Paulo, SP, Brazil
[12] International Labor Office, Geneva, Switzerland
[13] Committee of Compensation of Asbestos Related Diseases in Ministry of Environment Protection, Kawasaki, Japan
[14] Department of Radiology, National Hospital Organization Kinki-Chuo Chest Medical Center, Japan

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Abstract: 29 physicians (A1-Group) and 24 physicians (A2-Group) attending the 1st and 2nd "Asian Intensive Reader of Pneumoconiosis" (AIR Pneumo) training course, respectively, and 22 physicians (B-Group) attending the Brazilian training course took the examination of reading the 60-film set. The objective of the study was firstly to investigate the factor structure of physicians' proficiency of reading pneumoconiosis chest X-ray, and secondly to examine differences in factor scores between groups. Reading results in terms of the 8-index of all examinees (Examinee Group) were subjected to the exploratory factor analysis. A 4-factor was analyzed to structure the 8-index: the specificity for pneumoconiosis, specificity for large opacities, specificity for pleural plaque and shape differentiation for small opacities loaded on the Factor 1; the sensitivity for pneumoconiosis and sensitivity for large opacities loaded on the Factor 2; the sensitivity for pleural plaque loaded on the Factor 3; the profusion increment consistency loaded on the Factor 4. 4-Factor scores were compared between each other of the three groups. The Factor 2 scores in A1 and A2 groups were significantly higher than in B-Group. Four factors could reflect four aspects of reading proficiency of pneumoconiosis X-ray, and it was suggested that 4-factor scores could also assess the attained skills appropriately.

Key words: Pneumoconiosis, ILO Classification, Sensitivity, Specificity, Chest X-ray, Factor analysis

*To whom correspondence should be addressed. E-mail: yukik@u-fukui.ac.jp

In the current authors' preceding paper[1], we have suggested that 8 indices reflect reading proficiency for pneumoconiosis in individuals and groups and be used appropriately for assessing examination results from reading 60-film sets: sensitivity for pneumoconiosis, specificity for pneumoconiosis, sensitivity for large opacities, specificity for large opacities, sensitivity for pleural plaque, specificity for pleural plaque, profusion increment consistency for small opacities, and shape differentiation for small opacities. The exam films, the correct answers, the criteria for 8 indices in 60 exam films, and the assessment algorithm were described in the Appendix in the literature[1].

There were 29 physicians (A1-Group) and 24 physicians (A2-Group) attending the 1st and 2nd "Asian Intensive Reader of Pneumoconiosis" (AIR Pneumo), respectively, and 22 physicians attending the Brazilian Training Course (B-Group) took examination of reading 60-film set described extensively in the authors' paper[1]. The Examinee Group included A1-Group, A2-Group and B–Group. The summary of the reading results in terms of the 8 indices for all groups was shown in Table 2 in our preceding paper[1].

Factor analysis is a statistical approach that can be used to analyze inter-relationships among a large number of variables and to explain these variables in terms of their common underlying dimensions (factors)[2]. The statistical approach involves a way of condensing the information contained in a number of original variables into a smaller set of dimensions (factors) with a minimum loss of information. In recently years, factor analysis gradually has become the most frequently used statistical method in the field of education and social psychological study[3, 4]. There has been only one paper published on pneumoconiosis concerning the research by factor analysis of the clinical data of asbestos exposed workers[5] and several papers on the study by factor analysis of respiratory diseases[6, 7].

The current study aimed at investigating the factor structure of the 8 indices of physicians reading pneumoconiosis chest X-ray, exploring the underlying factors in the physicians' proficiency of the reading chest x-ray of pneumoconiosis, and studying the appropriateness to test the proficiency of examinees in the three training courses by calculating the factor scores.

The multivariate exploratory factor analysis was performed using SPSS 16.0 for the reading results of Examinee Group (SPSS Inc., USA)**.** An initial principal component analysis was conducted to determine the final number of factors. An orthogonal rotation (Varimax rotation) was executed to yield the simple factor structure, facilitating the interpretation of the factors[8].

The correlation matrix among the 8 indices of all examinees is shown as Table 1.

For the number of factors extraction, the most frequently used criterion for retaining factors is the Kaiser's criterion (Eigenvalue >1) [9]. However, if we took this criteria, the communalities were less than 0.7 after extraction with eigenvalues more than 1, therefore, selecting factors with an eigenvalue >1 was not an accurate criterion according to the literature[10, 11], in our study, too. On the other hand, Jolliffe argued that since Kaiser's criterion might be too strict, it discards too much information. And Jolliffe suggested a cut-off of eigenvalue 0.7 for retaining factors, instead of 1[12, 13]. Based on the Jolliffe's criterion (Eigenvalue >0.7), a 4-factor structure matrix was accurately generated with a variance of more than 80%, as shown in Table 2.

Table 2 indicates that the cumulative variance from the

Table 1. The correlation matrix among the 8 indices of all examinees

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
X_1	1.000							
X_2	0.172	1.000						
X_3	0.591	0.155	1.000					
X_4	0.505	0.468	0.260	1.000				
X_5	0.264	0.370	0.307	0.372	1.000			
X_6	0.457	0.521	0.316	0.597	0.262	1.000		
X_7	0.414	0.343	0.229	0.222	0.126	0.293	1.000	
X_8	0.491	0.447	0.380	0.444	0.308	0.620	0.308	1.000

X_1: Sensitivity for pneumoconiosis, X_2: Specificity for pneumoconiosis, X_3: Sensitivity for large opacities, X_4: Specificity for large opacities, X_5: Sensitivity for pleural plaque, X_6: Specificity for pleural plaque, X_7: Profusion increment consistency, X_8: Shape differentiation for small opacities.

Table 2. Varimax rotated factor-loading matrix from factor analysis

Variable	Factor 1	Factor 2	Factor 3	Factor 4
Sensitivity for pneumoconiosis	0.378	0.792*	0.002	0.218
Specificity for pneumoconiosis	0.638*	–0.208	0.436	0.395
Sensitivity for large opacities	0.123	0.848*	0.218	0.067
Specificity for large opacities	0.762*	0.213	0.222	–0.006
Sensitivity for pleural plaque	0.175	0.212	0.925*	0.008
Specificity for pleural plaque	0.865*	0.195	0.027	0.116
Profusion increment consistency	0.143	0.215	0.016	0.943*
Shape differentiation for small opacities	0.702*	0.335	0.085	0.166
Eigenvalue	3.625	1.101	0.908	0.770
Total variance explained, %	45.31	13.76	11.35	9.62

*Variables with high loading coefficient>0.6.

Table 3. Comparative analyses for the factor scores between each other of the three groups

Factor score	A1-Group (n=29)	A2-Group (n=24)	B-Group (n=22)
Factor score 1	–0.118 ± 1.223	0.091 ± 0.650	0.056 ± 1.016
Factor score 2	0.191 ± 0.977*	0.326 ± 0.613#	–0.608 ± 1.132*#
Factor score 3	–0.103 ± 0.913	0.209 ± 0.870	–0.092 ± 1.228
Factor score 4	0.036 ± 0.990	0.026 ± 0.983	–0.076 ± 1.072

Values are Mean ± SD. *Comparison between A1 and B-Group by Bonferroni multiple comparisons test, $p<0.05$. #Comparison between A2 and B-Group by Bonferroni multiple comparisons test, $p<0.05$.

first to the fourth factor explained 80.0% of total variance. By examining the loading coefficients of the variables on each factor, the variables that had high loadings on the same factors were grouped. The larger the factor loading, the stronger the association is between that variable and that factor. The specificity for pneumoconiosis, specificity for large opacities, specificity for pleural plaque and shape differentiation consistency for small opacities were found to be loaded significantly on the Factor 1. The sensitivity for pneumoconiosis, sensitivity for large opacities loaded largely on the Factor 2. The sensitivity for pleural plaque loaded largely on the Factor 3. The profusion increment consistency loaded predominantly on the Factor 4.

A factor score is a composite score based on each variable's contribution to the factor. Each factor score of individual examinee was calculated by the regression method. The equation for calculating factor score is shown as follows[14]:

$$F_j = \beta_{j1}Z_1 + \beta_{j2}Z_2 + \beta_{j3}Z_3 + \ldots + \beta_{j8}Z_8$$
$$= \sum_{i=1}^{8} \beta_{ji} \times Z_i, (i=1, 2,\ldots,8)\ (j=1, 2,\ldots,m)$$

F_j represents the factor score of the jth factor. β_{ji} represents the factor score coefficient for the ith variable.

Z_i is the value of the ith standardized variable. $Z_i = (X_i-\overline{x}_i)/S_i$, X_i is the observed value of ith variable, S_i is the standardized deviation of variable X_i, $\overline{x}_i$ is the mean of ith variable over all observations. m is the number of the factors, m is less than or equal to the number of variables.

Factor scores were compared by the Bonfferoni multiple comparisons method in One way ANOVA test between each other of the three groups by SPSS 16.0. Table 3 shows that there was a significant difference in the Factor 2 scores between the A1-Group and B-Group, A2-Group and B-Group ($p<0.05$). There was no significant difference for the other factor scores between each other of the three groups.

Factor analysis is an analytic technique that permits the reduction of a large number of interrelated variables to a smaller number of latent or hidden dimensions. The variables that are highly correlated are likely influenced by the same factors, while those that are relatively uncorrelated are likely influenced by different factors[11]. Each factor is interpreted as a latent characteristic of the individuals revealed by the original variables[15], the original variables are expressed as linear combinations of the factors[16].

We reduced the 8 indices into 4 factors by factor analysis. Accordingly, we can make an interpretation of 4 factors as reflecting 4 different aspects of the reading skill on pneumoconiosis chest films: Factor 1 reflects the proficiency for recording negative parenchymal and negative pleural findings; Factor 2 reflects the proficiency for recording positive parenchymal findings including small and large opacities; Factor 3 reflects the proficiency recording positive pleural findings; Factor 4 reflects the proficiency as to profusion increment consistency alone.

The presence or absence of pneumoconiosis is determined by the cut-off point of profusion 1/0[17]. If more films with profusion equal to or more than 2/1 than 1/1 or 1/2 are included in the exam films, the sensitivity for pneumoconiosis by examinee is easily increased, which mimics great proficiency. Thus high sensitivity or high specificity for pneumoconiosis alone fails to associate with high profusion increment consistency. The factor analysis actually showed that the profusion increment consistency was an independent factor. If examinees originally have high profusion increment consistency, they can necessarily and comprehensively achieve both high sensitivity and specificity for pneumoconiosis. In order to obtain good profusion increment consistency, it requires the examinee to make accurate comparison of all profusions on a 12-point scale with those on the standard films.

Pleural plaque cannot necessarily be seen even in asbestosis patient, while some patients present with the pleural plaque without the parenchymal abnormalities. In our current factor analysis, there was no close relationship between the sensitivity for parenchymal abnormalities and the sensitivity for pleural plaque. It is reasonable that sensitivity for pleural plaque was seen as an independent factor.

After summarizing the 8 indices, the calculation of factor scores for each factor for individual can be helpful to simplify assessment for the proficiency of examinee[18]. The factor score of >0 of individual examinee imply that the proficiency in this aspect was better than the average proficiency of the Examinee Group, and the factor score of <0 imply that the proficiency of examinee was worse than the average proficiency of the Examinee Group. Use of factor score could identify whether the individual proficiency was worse or better than the average proficiency of Examinee Group at each aspect. And it could be helpful in deriving a comprehensive evaluation of the achievement of examinees and making comparison of the proficiency between each other of the three groups.

Factor analysis showed that the Factor 2 scores in the A1-Group and A2-Group were significantly higher than those in the B-Group, which were consistent with the results as shown in Table 2 in our previous literature that the sensitivity for pneumoconiosis of A2-Group, and the sensitivity for large opacities of both A1-Group and A2-Group were higher than those in the B-Group[1]. This indicated that A1-Group and A2-Group tended to identify much more parenchymal abnormalities than the B-Group.

One limitation of this study was that, as to the shape index, there were 20 films with purely rounded small opacity (R/R) subjected, while there were only 4 films with purely irregular small opacity (IR/IR) subjected. Since more films in the exam were in association with rounded opacities than with irregular opacities, recording for absence of small opacities (specificity for pneumoconiosis) and identifying of rounded opacities against irregular opacities might have become effective in the same factor, i.e., factor 1. Therefore including more films with irregular small opacity for the shape index may be appropriate in the future AIR Pneumo Program.

In conclusion, four factors could reflect four aspects of reading proficiency of pneumoconiosis X-ray, and factor scores as well as the 8-index could show differences in attained skills. The 60-film set providing 8-index and 4-factor was suggested to assess reading proficiency of physicians appropriately.

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References

1) Zhou H, Kusaka Y, Tamura T, Suganuma N, Subhannachart P, Siriruttanapruk S, Dumavibhat N, Zhang X, Sishodiya PK, Van Duy K, Hering KG, Parker JE, Algranti E, Fedotov I, Shida H, Akira M (2012) The 60-Film set with 8-index for examining physicians' proficiency in reading pneumoconiosis X-rays. Ind Health **50**, 84–94.
2) Hair JF, Black WC, Babin BJ, Anderson RE (2009) Multivariate data analysis, 7th Ed., Prentice Hall, New Jersey.
3) Stevens J (2002) Applied multivariate statistics for the social sciences, 4th Ed., 385, Lawrence Erlbaum Associates, New Jersey.
4) Fabrigar LR, Wegener DT, MacCallum RC, Strahan EJ (1999) Evaluating the use of exploratory factor analysis in psychological research. Psychol Methods **4**, 272–99.
5) Harber P, Lew M, Tashkin DP, Simmons M (1987) Factor analysis of clinical data from asbestos workers: implications for diagnosis and screening. Br J Ind Med **44**, 780–4.
6) Van Stel HF, Bogaard JM, Rijssenbeek-Nouwens LHM, Colland VT (2001) Multivariable assessment of the 6-min walking test in patients with chronic obstructive pulmonary disease. Am J Respir Crit Care Med **163**, 1567–71.
7) Hajiro T, Nishimura K, Tsukino M, Ikeda A, Koyama H, Izumi T (1998) Analysis of clinical methods used to evaluate dyspnea in patients with chronic obstructive pulmonary disease. Am J Respir Crit Care Med **158**, 1185–9.
8) Raykov T, Marcoulides GA (2008) Exploratory factor analysis. *In:* An introduction to applied multivariate analysis, Raykov T, Marcoulides GA (Eds.), 241–76, Taylor & Francis, New York.
9) Kaiser HF (1960) The application of electronic computers to factor analysis. Educ Psychol Meas **20**, 141–51.
10) Dawes P, Bishop DVM (2007) The SCAN-C in testing for auditory processing disorder in a sample of British children. Int J Audiol **46**, 780–6.
11) Field A (2005) Exploratory factor analysis. *In:* Discovering statistics using SPSS, Field A (Ed.), 619–80, SAGE Publications, London.
12) Jolliffe IT (2002) Chapter 6. Choosing a subset of principal components or variables. Chapter 7. Principal component analysis and factor analysis. *In:* Principle component analysis. 2nd Ed., Jolliffe IT (Ed.), 111–98, Springer-Verlag, New York.
13) Dunteman GH (1989) Principal components versus factor analysis. *In:* Principal components analysis. Series: quantitative applications in the social sciences series. Dunteman GH (Ed.), 55–64, SAGE Publications, California.
14) Gatz DF (1979) An investigation of pollution source strength-rainfall relationships at St. Louis. J Appl Meteorol **18**, 1245–51.
15) Härdle W, Simar L (2007) Decomposition of data matrices by factors. *In:* Applied multivariate statistics analysis, 2nd Ed., Härdle W, Simar L (Eds.), 203, Springer, New York.
16) Rencher AC (2002) Factor analysis. *In:* Methods of multivariate analysis, 2nd Ed., Rencher AC (Ed.), 409, John Wiley & Sons, New York.
17) International Labour Office (ILO) (2002) Guidelines for the use of the ILO International Classification of Radiographs of Pneumoconioses, Revised Edition 2000 (Occupational Safety and Health Series No.22). International Labour Office, Geneva.
18) DiStefano C, Zhu M, Mîndrilă D (2009) Understanding and using factor scores: considerations for the applied researcher. Pract Assess, Res & Eval 14, 1–11. http://pareonline.net/getvn.asp?v=14&n=20. Accessed March 10, 2011.