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A Comparative Study of Objective and Subjective Assessment of Occupational Risk

Danuta Koradecka
Małgorzata Pośniak
Maria Widerszal-Bazyl
Danuta Augustyńska

Central Institute for Labour Protection – National Research Institute (CIOP-PIB), Poland

Piotr Radkiewicz

Polish Academy of Sciences, Poland
Central Institute for Labour Protection – National Research Institute (CIOP-PIB), Poland

Measurements of dangerous, harmful and annoying factors in the working environment are used to assess occupational risk. Surveys on workers' subjective perception of risk are used, too. This study aimed to compare subjective assessment of work-related factors with their objective measurements and a national database on occupational risk. Spearman's correlation analysis, stepwise regression analysis and structural modelling were used to determine the relationship between subjective and objective risk assessment and to acquire knowledge about the role of psychosocial job characteristics as predictors of subjective assessment. Subjective assessment of hazards was related not only to their objective measurements but also to psychosocial job characteristics, workers' individual characteristics and work load. Even though subjective and objective assessments of hazard are strongly related, they are distinct phenomena. Hence, risk assessment should be carried out with both objective and subjective methods.

subjective assessment objective assessment perception measurements working environment risk DCS model

1. INTRODUCTION

Assessment of occupational risk is indispensible in preventing its negative effects on employees' life and health [1][1]. There are three groups of factors in the working environment that have a detrimental effect to human's body: dangerous, harmful and annoying ones [2, 3, 4, 5, 6, 7].

Dangerous factors, which are a hazard to life, are regulated by safety standards on work while

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Correspondence and requests for offprints should be sent to Danuta Koradecka, CIOP-PIB, ul. Czerniakowska 16, 00-701 Warszawa, Poland. E-mail: <dakor@ciop.pl>.

[1] Also other directives: Council Directive 98/24/EC of 7 April 1998 on the protection of the health and safety of workers from the risks related to chemical agents at work. OJ. 1998;L131:11–23...

exposed to, e.g., electric current or explosive atmosphere. Harmful and annoying factors are a hazard to health; they are regulated by obligatory health standards (harmful factors) [6, 8] or recommendations (annoying factors).

Measurement results (objective assessment) or questionnaires (subjective assessment) are used to assess occupational risk. Accredited laboratories measure the values of risk factors using procedures that are mostly standardized. If the measurements show that maximum admissible concentrations or intensities of harmful factors in the working environment have been exceeded, in Poland employers report this annually to the Central Statistical Office [9] (for enterprises with over 9 persons) and, of course, they have to reduce the risk. At the same time, professional surveys on workers' subjective perception of risk in their working environments are increasingly common in Europe [10, 11, 12, 13, 14, 15, 16]. WHO's definition "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity"[2] explains the importance of subjective assessment. Thus, subjective risk assessment is an indirect way of assessing workers' awareness of occupational risk and its effect on their health and life.

Three questions need to be asked, (a) To what extent are the three sets of data on working conditions, i.e., national statistics database, measurement results and workers' assessment, in step with one another? (b) What are the relationships between them? (c) Why are the relationships what they are? There do not seem to be any studies that would directly analyse these relationships.

A possible discrepancy between objective measurements of hazards in the working environment and workers' subjective perception of them might result from mental stress caused by bad psychosocial job characteristics. Research presented in this article tests such a possibility, too.

2. AIM

The aim of this research was to compare subjective assessment of work-related factors with their objective measurements (related to occupational safety and health standards) and the national database on occupational risk.

Thus, analyses were conducted to determine to what extent subjective assessment of physical and chemical hazards could be explained with an objective level of those hazards and to what extent with stress-inducing psychosocial job characteristics with special stress put on the dimensions in the demand–control–support (DCS) model [17, 18].

3. METHODS

3.1. Study Population

A population of workers employed in sectors of the economy with highest rates of occupational risk, i.e., the construction sector, the processing industry and transport, were studied. In 2008, the Polish national statistics database on working conditions covered 5 358 500 persons (i.e., 46.2% of workers in national economy, excluding private farms and enterprises with under 9 employees). This study considered data on 9 225 persons exposed to occupational hazards from those sectors (Figure 1).

Figure 2 illustrates the age of the subjects. Their tenure was as follows: 29% had worked for under 5 years, 30% for 6–14 years and 40% for over 15.

[1] *continued*

Directive 2004/37/EC of the European Parliament and of the Council of 29 April 2004 on the protection of workers from the risks related to exposure to carcinogens or mutagens at work (codified version). OJ.2004;L229:23–34.

Directive 2002/44/EC of the European Parliament and of the Council of 25 June 2002 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration). OJ. 2002;L177:13–9.

Directive 2003/10/EC of the European Parliament and of the Council of 6 February 2003 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise). OJ. 2003:L42:38–44.

Directive 2004/40/EC of the European Parliament and of the Council of 29 April 2004 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields). OJ. 2004;L184:1–9.

Directive 2006/25/EC of the European Parliament and of the Council of 5 April 2006 on the minimum health and safety requirements regarding the exposure of workers to risks arising from physical agents (artificial optical radiation). OJ. 2006;L114:38–59.

[2] http://www.searo.who.int/EN/Section898/Section1441.htm

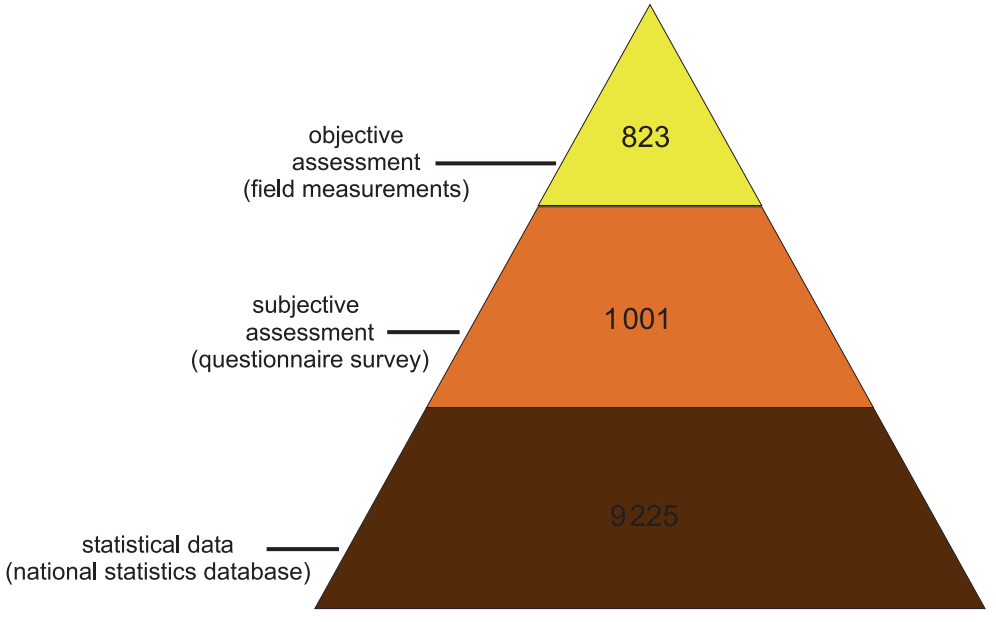

Figure 1. The number of employees studied and sources of data.

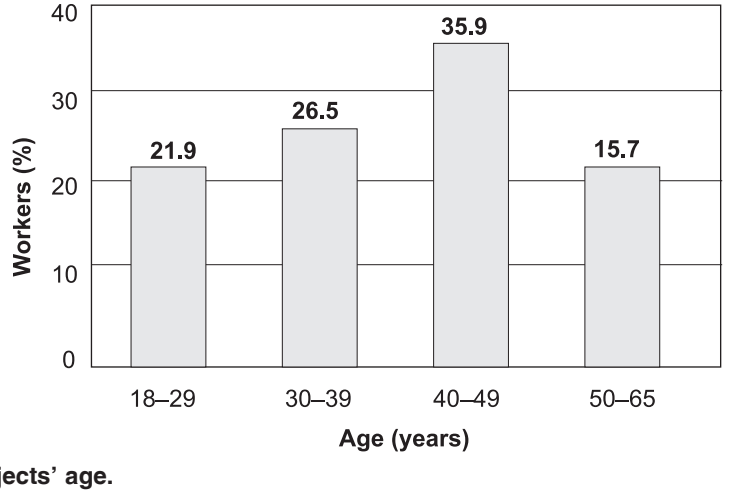

Figure 2. The subjects' age.

3.2. Questionnaire

The questionnaire for a subjective assessment of working conditions was an adaptation of the questionnaire used in the European Working Conditions Surveys [11, 12] It was supplemented with the risk factors that are included in Polish statistics. The analysis discussed in this paper considered questions on

- subjective assessment of physical and chemical hazards, including vibration, noise, chemicals, optical radiation, electric current, manual material handling, mechanical factors and repetitive tasks. Respondents answered the question "Are you exposed to (this factor) at work?" on a 7-point scale (7—*all the time*, 6—*almost all the time*, 5—*around 3/4 of the time*, 4—*around half of the time*, 3—*around 1/2 of the time*, 2—*almost never*, 1—*never*). Analyses included a subjective assessment of those hazards because their objective measurements were available;
- workers' individual characteristics: age, gender, tenure and position;
- psychosocial and organizational job characteristics;
  - quantitative demands (pace of work, tight deadlines),

  - control (4 questions on control over the order of tasks, work method, pace of work, breaks),
  - social support (2 questions),
  - responsibility (3 questions),
  - discrimination (10 questions),
  - and one question each on the kind of employment, training in the past year and being informed on risk,
- time load: the number of work hours, commuting time and additional work (the latter factor was measured with 5 questions on the need to work at night, in the evening, on Saturday, on Sunday and over 10 h a day);
- health and satisfaction;
  - considering work a health risk, "Do you think your health or safety is at risk because of your work, or not? If yes, how does it affect your health?" There were 18 possible answers that reflected various disfunctions (e.g., problems with hearing, problems with sight, anxiety),
  - job satisfaction, "On the whole, are you very satisfied, fairly satisfied, not very satisfied or not at all satisfied with working conditions in your main paid job?",
  - expected work ability, "Do you think you will be able to do the same job you are doing now when you are 60 years old?".

The variables that were measured with more than one question each (control, social support, responsibility, additional work, health risk) had summary indexes. Internal consistency was calculated; Cronbach's α is given in Table 1. In all cases, consistency was satisfactory; Cronbach's α was greater than the acceptable value of .70 or was very close to it (additional work).

TABLE 1. Cronbach's α for the Summary Indexes of the Questionnaire

Index	No. of Questions	Cronbach's α
Control	4	.77
Responsibility	3	.80
Social support	2	.90
Additional work	5	.69
Health risk	18	.91

Workers from 10 enterprises (n = 1001, out of the 9 225 employees in the national statistics database; Figure 1) took part in a questionnaire survey (a direct interview):

- two rubber enterprises (100 subjects);
- a furniture factory (127 subjects);
- two cast iron foundries (160 subjects);
- copper works (150 subjects);
- zinc works (100 subjects);
- a bus and tram municipal transport company (300 subjects);
- a construction enterprise (64 subjects).

3.3. Measurements of Risk Factors at the Workstation

Hazards posed by dangerous, harmful and annoying factors were measured at the workstations of 823 persons (out of the 1001 of those who filled in the questionnaire). The measurements were done for harmful factors (chemical substances and industrial dust, noise, whole-body and hand–arm vibration, and hot and cold microclimates), annoying factors (excessive physical load and repetitive tasks) and dangerous factors (mechanical hazards and electric current).

Dangerous factors were measured in accordance with occupational safety standards [19, 20]. Most harmful factors were measured in accordance with Polish standards [6, 21, 22, 23, 24, 25, 26, 27, 28, 29] and measurement procedures [30, 31, 32, 33, 34, 35, 36, 37, 38, 39]. Annoying factors were measured in accordance with health standards, i.e.,

- physical effort was measured on the basis of energy expenditure calculated from the measurement of minute ventilation [40] $E = 0.21\ V_{E(STPD)}$, where E—energy expenditiure (kJ/min), $V_{E(STPD)}$—ventilation (L/min), at standard conditions for temperature and pressure (STPD), i.e., at a temperature of 0 ºC and an absolute pressure of 101.3 kPa;
- annoyance related to physical load (including repetitive tasks) was assessed on a 1–10 scale on the basis of measurements of forced posture, manual material handling and imposed frequency of repetitive tasks [4];

- improper lighting of a workstation was measured in accordance with Standard No. EN 12464:2004 [41].

3.4. A Method of Determining the Relationship Between Subjective and Objective Risk Assessment

Three kinds of statistical analyses were used to determine the mutual relationship between subjective and objective risk assessment and to acquire knowledge about the role of psychosocial job characteristics as predictors of subjective assessment:

- Spearman's correlation analysis;
- stepwise regression analysis for vibration, noise, chemical hazards, optical radiation, electric current, mechanical factors, physical load and repetitive tasks. In those regressions subjective assessments of hazards were the explained variables, whereas the following were the explanatory ones;
  - an objective measurement of a hazard (first step),
  - a worker's individual characteristics (second step),
  - time load (third step),
  - psychosocial and organizational job characteristics, including quantitative demands, control and support (fourth step),
  - health risk and job satisfaction (fifth step),
- structural modelling that tests mutual relationships among the indexes of the subjective assessment of risk; the results of regression analyses were used to build the model to be tested.

4. RESULTS

4.1. Questionnaire Results

In the enterprises studied a considerable percentage of workers complained of exposure to dangerous, harmful and annoying factors *all the time* or *almost all the time*. Figures 3–5 illustrate data on complaints of chemical and physical hazards.

Sixty-eight percent of workers complained of repetitive tasks, whereas 20% of excessive work load. Workers in the copper works, cast iron foundries, rubber enterprises and the municipal transport company mostly complained of exposure to environmental factors.

However, there were considerable differences in the assessment of risk factors between enterprises in the same sector, e.g., in the two cast iron foundries (Figure 6). Those differences may have been caused by, e.g., various technologies (automated foundry process in foundry 1, manual in foundry 2) or more crowded conditions and older machinery in foundry 2.

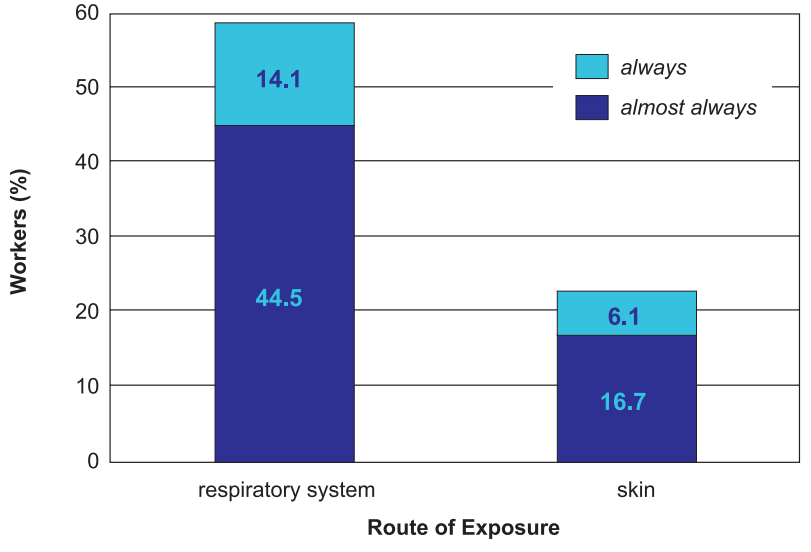

Figure 3. Workers reporting chemical hazards in the working environment.

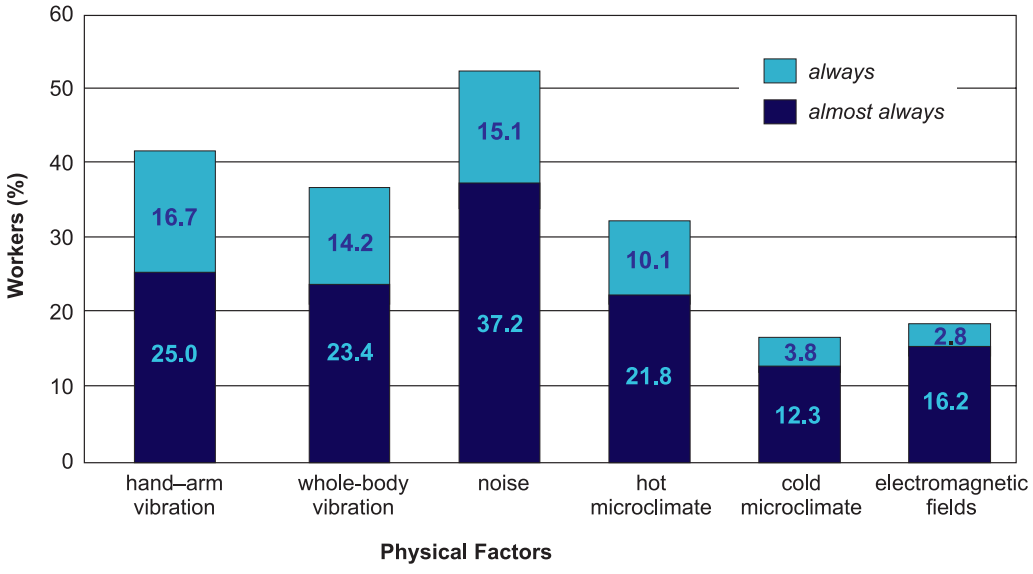

Figure 4. Workers reporting physical hazards in the working environment (%).

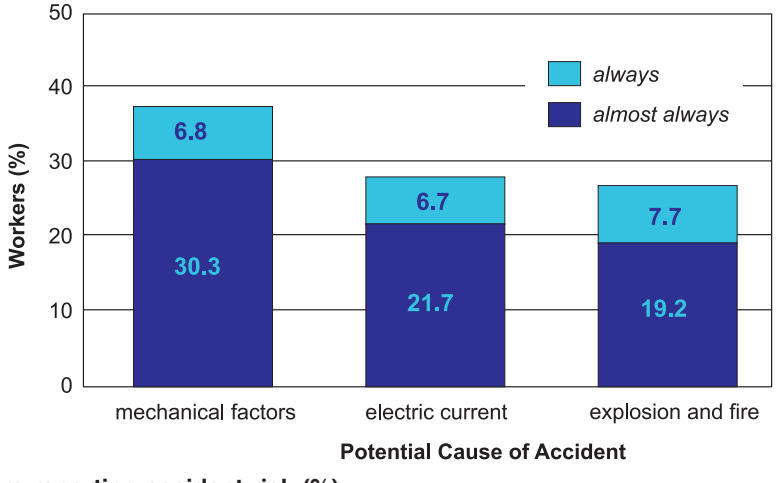

Figure 5. Workers reporting accident risk (%).

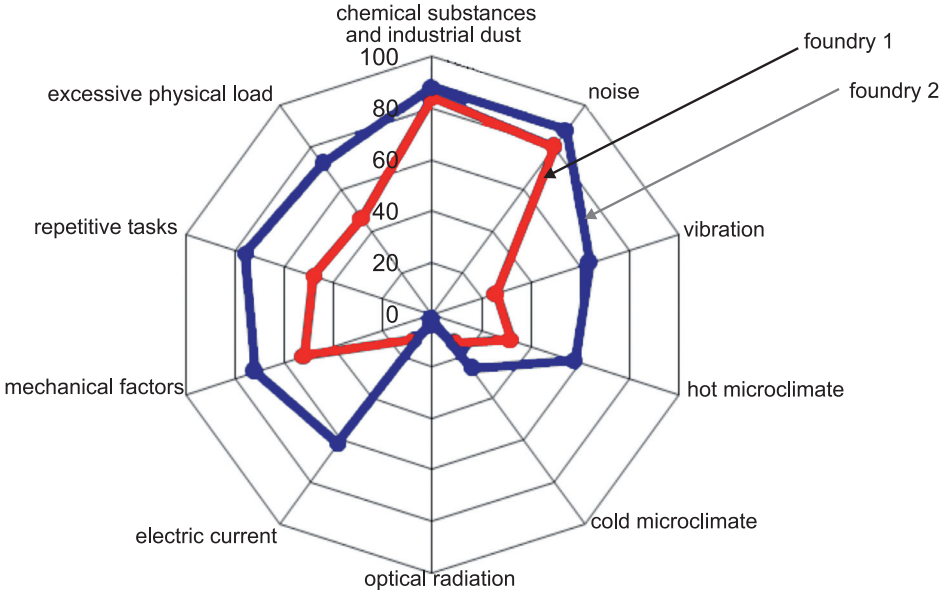

Figure 6. Workers reporting exposure to environmental factors (%). A comparison of the results of a questionnaire survey in cast iron foundries 1 and 2.

4.2. Results of Measurements of Risk Factors

Field measurements showed that maximum admissible values were exceeded for chemical substances and industrial dust at 24% of workstations, noise at 23%, vibration at 7% and optical radiation at 5% of workstations. Occupational risk posed by electric current was considered high at 11% of workstations, mechanical factors at 4%, excessive physical load at18% and repetitive tasks at 3% of workstations. Measurements showed that maximum admissible values and other criteria of assessing hazards posed by dangerous and annoying factors were predominantly exceeded at workstations in the copper works, cast iron foundries, a furniture factory, rubber enterprises and the zinc works.

The level of noise annoyance was exceeded at 52% of the workstations. In the furniture factory this was the case at all workstations. Eighteen percent of workers were exposed to physical load. The situation was worst in the cast iron foundries, where 67% of the workers experienced it.

Dangerous, harmful and annoying factors of the working environment were registered at 13–84% of workstations; however, when they were measured neither admissible nor other values were exceeded. At the same time the fact that those factors were present at so many workstations means that they are a potential health risk.

When the results of field measurements in enterprises from the same sector were compared, greatest differences in the working conditions were found in cast iron foundries 1 and 2 (Figure 7). Exposure to noise, vibration, chemical substances and industrial dust, mechanical factors and electric current was greater in foundry 2 than in foundry 1.

Differences were also recorded in the two rubber enterprises for exposure to noise, electric current, mechanical factors and excessive physical load. Objective assessment conducted on the basis of the measurement of those factors showed that the working conditions in enterprise 2 were worse than in enterprise 1 (Figure 8).

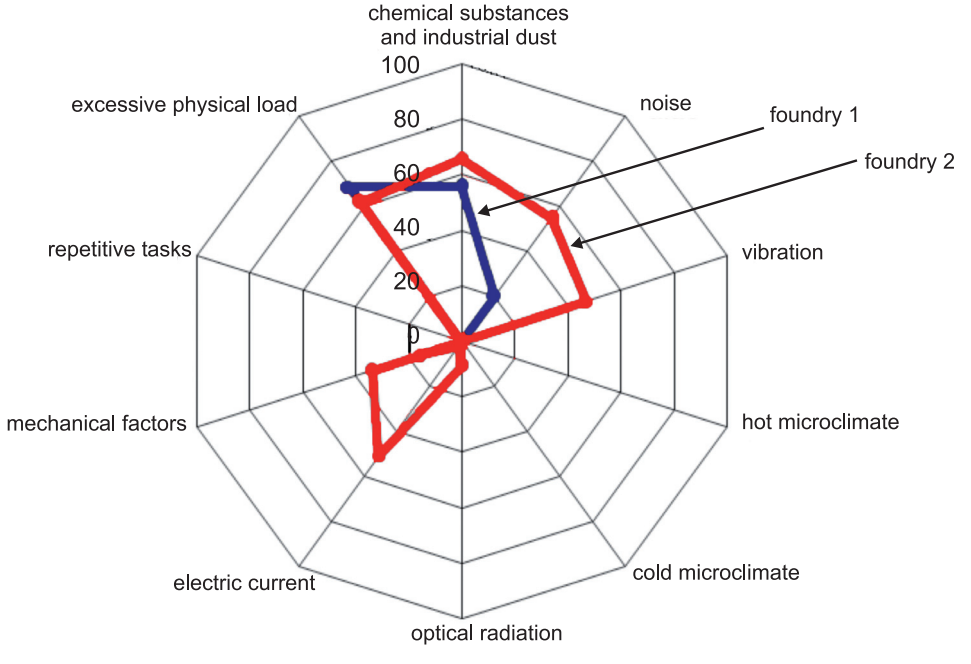

Figure 7. Employees exposed to environmental factors (%). A comparison of field measurements in cast iron foundries 1 and 2.

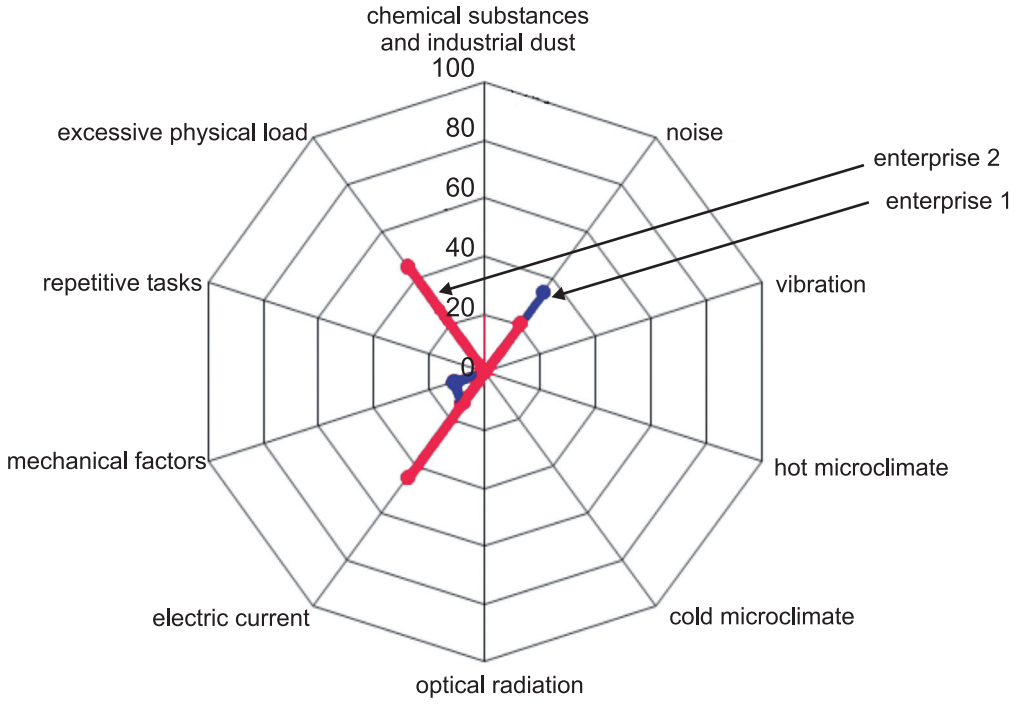

Figure 8. Employees exposed to environmental factors (%). A comparison of field measurements in rubber enterprises 1 and 2.

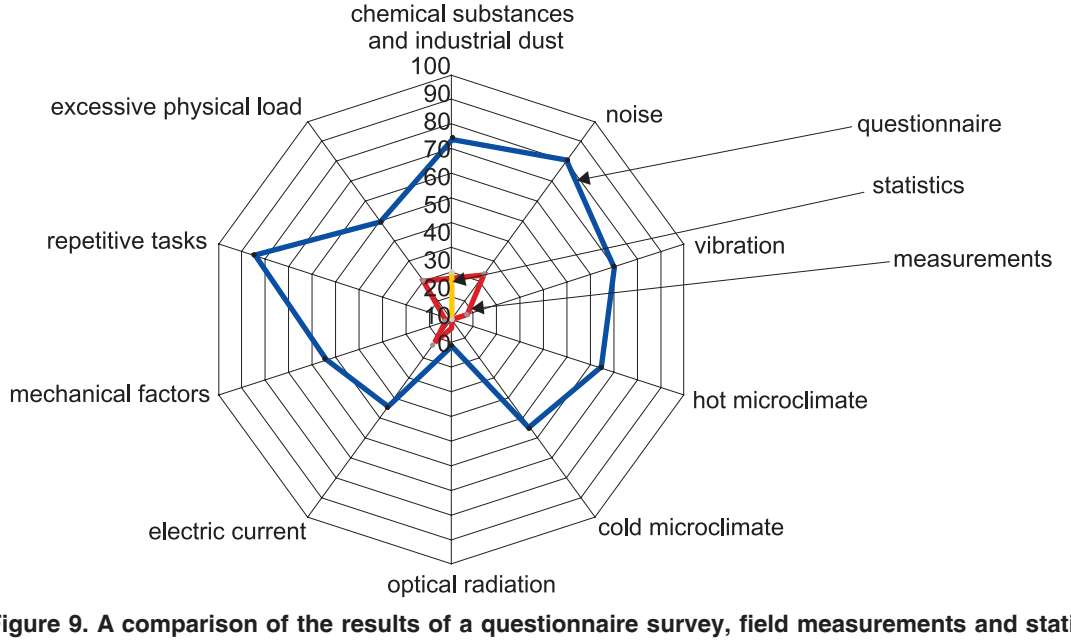

Figure 9. A comparison of the results of a questionnaire survey, field measurements and statistical data. Employees exposed to environmental factors (%).

Statistical data on occupational risk reported by enterprises are lower than measurements at workstations, and much lower in comparison with workers' subjective assessment of hazards reported in questionnaires (Figure 9).

This means that data might not be correctly reported from the level of the enterprise to the level of the state. Whether this process is credible depends on the competence and reliability of the responsible services in the enterprise and on the efficiency of state control and supervision bodies.

4.3. A Comparison of Mean Subjective and Objective Assessment of Risk Factors in the Working Environment

The analysis of subjective and objective assessment began with a comparison of mean subjective assessment in three categories of objective measurement: (a) a risk factor is not present, (b) a risk factor is present but values set in standards or other criteria are not exceeded and (c) a risk factor is present and values set in standards or other criteria are exceeded.

Figure 10 shows that workers assessing exposure to vibration where this factor was present, considered the duration of the exposure as significantly longer than where there was no vibration ($t = -13.42$, $p < .01$). There were no statistically significant differences between assessments of vibration at workstations where the values of this factor did not exceed admissible ones and those where those values were exceeded. The objective measurement of vibration was compared with its subjective perception; Spearman's ζ was .42 ($N = 573$, $p < .01$). This means there was a strong positive relationship between workers' subjective perception and objective measurements.

As expected, the means in Figure 11 show that workers who assessed noise where this factor was present, considered its duration as much longer than where it was not ($t = -2.17$, $p < .05$). It is necessary to remember, however, that this result could be distorted by the very small size of the first subgroup. There was no statistically significant difference between that assessment of noise at workstations where it did not exceed admissible values and those where those values were exceeded. The relationship between objective measurements of noise and their subjective perception was calculated, too. Spearman's ζ was not statistically significant ($\zeta = .03$, $N = 803$, $p > .05$).

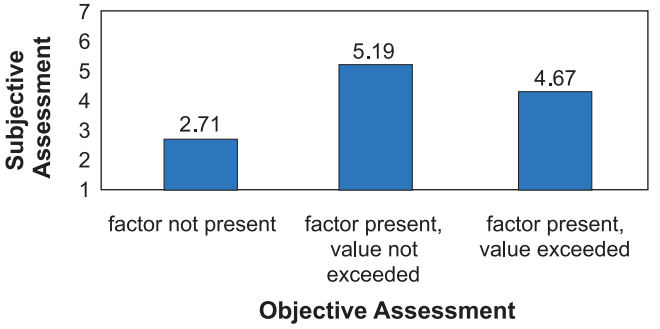

Figure 10. Mean subjective assessment of exposure to vibration and its objective measurement. *Notes.* 1—*never*, 7—*all the time.*

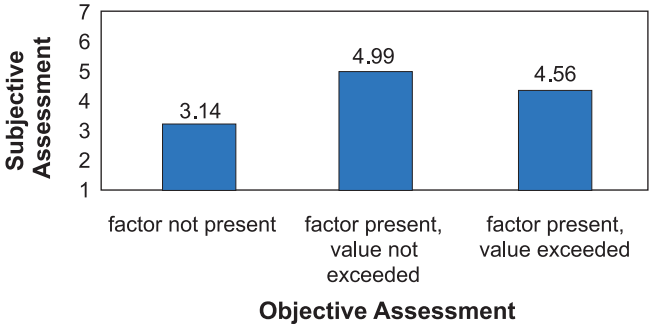

Figure 11. Mean subjective assessment of exposure to noise and its objective measurement. *Notes.* 1—*never*, 7—*all the time.*

Workers who assessed chemical airborne substances and industrial dust where those factors were present but their values were not exceeded considered the duration of exposure as identical to the places where admissible values were exceeded (Figure 12). The relationship between objective measurements of the presence of chemical airborne substances and industrial dust and their subjective perception was calculated with Spearman's ζ; $\zeta = .04$ ($N = 772$, $p > .05$), which means it was not statistically significant.

Workers who assessed optical radiation where it was present, considered its duration as slightly longer than where it was not ($t = -8.8$, $p < .01$) (Figure 13). There was no statistically significant difference in the assessment of exposure to optical radiation between workstations where its admissible value was and was not exceeded. The relationship between objective measurements of optical radiation and its subjective perception was calculated with Spearman's ζ. As $\zeta = .30$ ($N = 563$, $p < .01$), there was quite a strong positive relationship between workers' subjective perception and objective measurements of optical radiation.

Workers' assessment of exposure to electric current where it was present considered the duration of potential exposure to it as distinctly

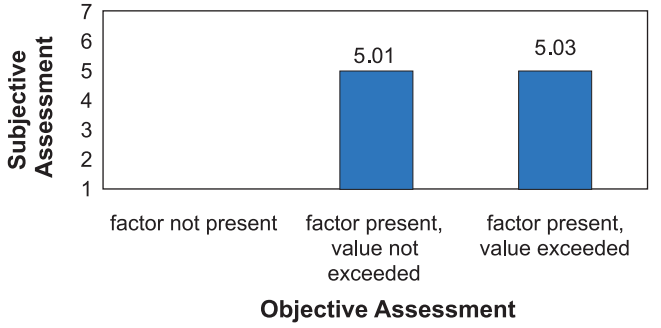

Figure 12. Mean subjective assessment of exposure to chemical hazards and their objective measurement. *Notes.* 1—*never*, 7—*all the time*.

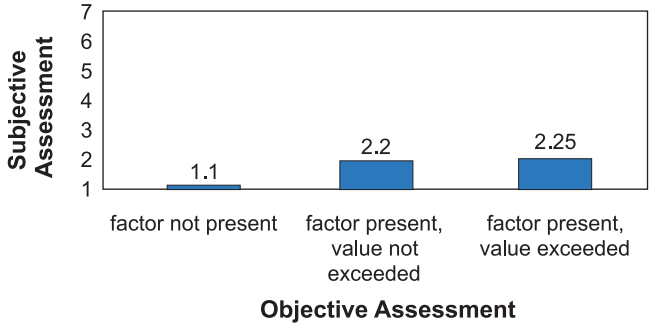

Figure 13 Mean subjective assessment of exposure to optical radiation and its objective measurement. *Notes.* 1—*never*, 7—*all the time.*

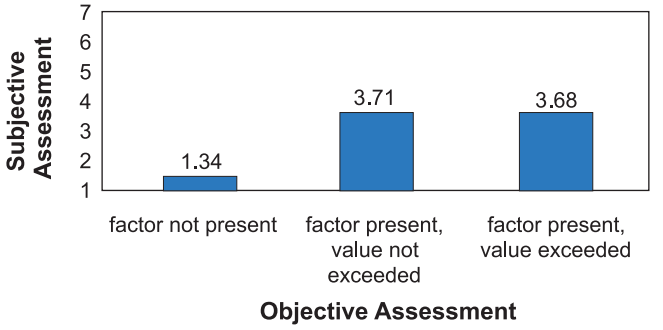

Figure 14. Mean subjective assessment of exposure to electric current and an objective assessment of the risk of electric shock. *Notes.* 1—*never*, 7—*all the time.*

bigger than when there was none (t = –12.03, p < .01) (Figure 14). There was no difference in the assessment of the risk of electric shock among the workstations where safety requirements were or were not met. The relationship between objective measurements of the risk of electric shock and its subjective perception was calculated. Spearman's ζ of .35 (N = 699, p < .01) showed there was quite a strong positive relationship between workers' subjective perception and objective measurements.

Workers assessing physical load where it was present considered its duration as distinctly shorter than where admissible values were exceeded (t = –12.15, p < .01) (Figure 15). The relationship between objective measurements of physical load and its subjective perception was calculated. Spearman's ζ of .42 (N = 773, p < .01) showed there was quite a strong positive relationship between workers' subjective perception and objective measurements.

All workstations carried risk of mechanical injury (Figure 16). Workers assessing exposure to mechanical factors where they were present perceived its duration as distinctly shorter than where these factors posed a hazard (t = –5.96, p < .01). Spearman's ζ was used to calculate the relationship between the objective assessment of exposure to mechanical factors and their subjective perception; ζ = .20 (N = 580, p < .01). Thus, there was a positive relationship between workers' subjective perception and objective measurements.

Workers who assessed repetitive tasks where they were not present, considered their duration as shorter than where they were present (t = –2.92, p < .05) (Figure 17). The relationship between objective measurements of repetitive tasks and their subjective perception was calculated, too. Spearman's ζ of .15 (N = 497, p < .01) proved there was a weak relationship between the

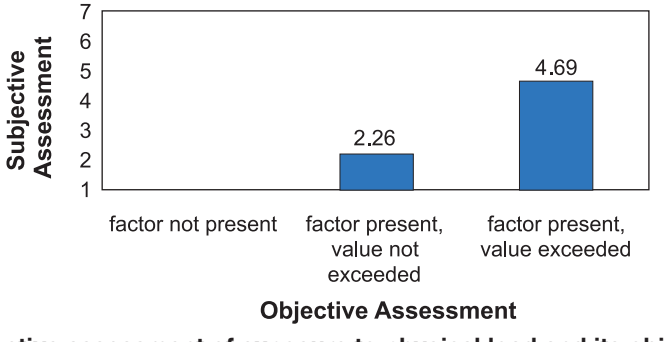

Figure 15. Mean subjective assessment of exposure to physical load and its objective measurement. *Notes.* 1—*never*, 7—*all the time.*

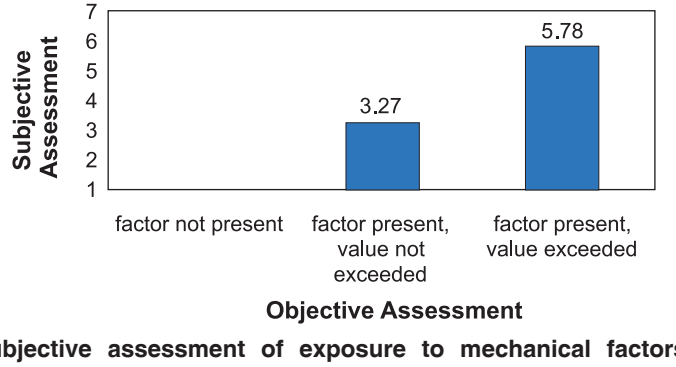

Figure 16. Mean subjective assessment of exposure to mechanical factors and its objective measurement. *Notes.* 1—*never*, 7—*all the time.*

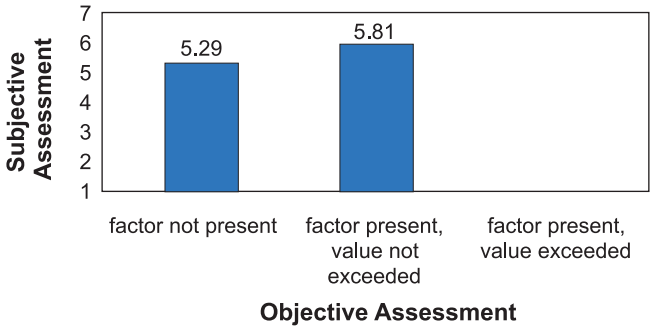

Figure 17. Mean subjective assessment of exposure to repetitive tasks and its objective measurement.
Notes. 1—*never*, 7— *all the time.*

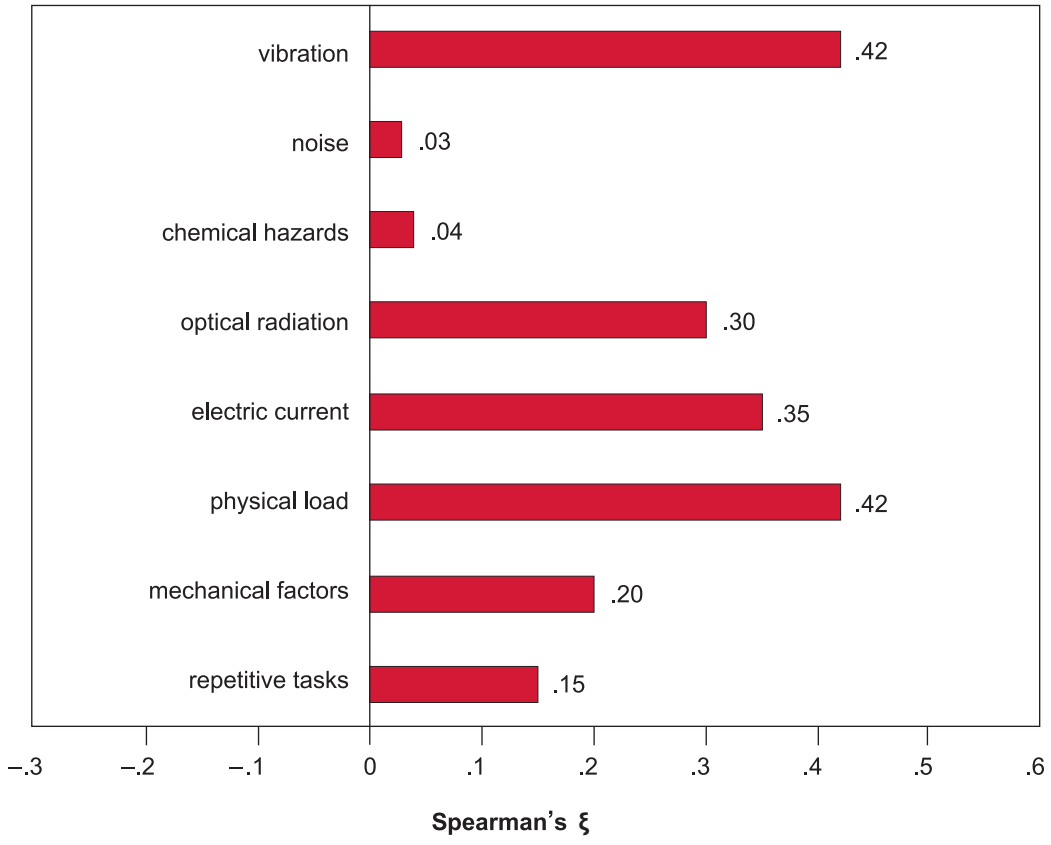

Figure 18. Correlation between subjective assessment of risk and its objective measurement.

workers' subjective perception and objective measurements.

4.4. The Results of Correlations Between Subjective and Objective Assessment of Risk in the Working Environment

An analysis of the direct relationships between subjective and objective assessment of risk showed that they were almost always statistically significant and usually distinct (Figure 18). Lack of correlation between subjective and objective assessment of exposure to noise ($\zeta = .03$) and chemical vapours, gas, exhaust fumes and industrial dust ($\zeta = .02$) was an exception. The coefficients were not statistically significant.

4.5. The Results of Regression Analyses

Table 2 summarizes the eight stepwise regression analyses. The results reveal that objective measurements of risk explained significant

percentages of variance of subjective assessment. This was especially true for vibration, for which the objective measurement explained 18% of variance of subjective assessment, for physical load 16% and for electric current 11%. It was only in two cases (noise and chemical hazards) that objective measures were not significant predictors of subjective assessments. In those two cases, and also in the case of mechanical hazards (where, at 4%, the percentage of variance explained by objective measurements was also low, though statistically significant), individual variables were important predictors. They explained 12% of the variance of the subjective assessment of mechanical hazards, 10% of variance for chemical hazards and 8% of variance for noise. From among the individual variables that were considered, tenure was most often significant. It was a predictor of the subjective assessment of five hazards. The longer the tenure, the greater the perception of risk was true for noise ($\beta = .28$, $p < .01$); chemical hazards ($\beta = .19$, $p < .01$); optical radiation ($\beta = .10$, $p < .05$) and mechanical hazards ($\beta = .21$, $p < .01$). For physical load, though, the longer the tenure, the lower the perceived risk.

The psychosocial job characteristics that were introduced in the fourth step of the

TABLE 2. A Summary of Regression Analyses of Subjective Risk Assessment: Coefficient β in the Last Step of Regression

		Subjective Assessment of:							
Steps	**Predictors**	**Vibration**	**Noise**	**Chemical Hazards**	**Optical Radiation**	**Electric Current**	**Physical Load**	**Mechanical Factors**	**Repetitive Tasks**
1	objective assessment	.27**	.03	.02	.21**	.35**	.28**	.09*	.07
	ΔR^2 (%)	18			6	11	16	4	1
2	individual characteristics								
	age		–.12**					–.14**	
	tenure		.28**	.19**	10*	.07	–.16**	.21**	
	position						–.14**	.14**	
	ΔR^2 (%)		8	10	3	1	5	12	
3	time load								
	number of hours			.14**					
	additional work	.04		.10*	–.13**	.14**		.08*	
	commuting time								
	ΔR^2 (%)	1		6	1	3		3	
4	psychosocial job characteristics								
	control	–.17**	.13**	–.14**		.15**	.14**	.17**	–.27**
	discrimination	.08*					–.16**	.22**	
	tight deadlines	.17**	.06	–.11**	.08*		.08*		
	pace of work						.10*	.19**	.12**
	ΔR^2 (%)	6	3	5	1	5	9	14	10
5	health and satisfaction								
	expected work ability						–.12**	.12**	
	health risk	.23**	.29**	.36**	.32**	.25**	.24**	–.20**	.27**
	ΔR^2 (%)	5	7	10	10	6	8	6	7
	R^2 (%)	29	17	29	19	25	8	36	17

Notes. Only statistically significant values are given. Increases in explained variance (ΔR^2) apply to the step, in which a given group of variables was introduced; R^2—explained variance.

regression explained significant percentages of the subjective assessment of all eight hazards. Mechanical hazards, repetitive tasks and physical load were the best predictors (14, 10 and 9% of variance explained, respectively). However, their direction often differed from that the DCS model would suggest [15]. Control was a significant predictor of seven subjective assessments with an expected direction of relationship for three risks: vibration ($\beta = -.17$, $p < .01$), chemical hazards ($\beta = -.14$, $p < .01$) and repetitive tasks ($\beta = -.27$, $p < .01$). Thus, the greater the control, the lower the subjective assessment of those hazards. In the other cases, the direction of the relationship was unexpected, i.e., the higher the control, the higher the subjective perception of risk. This was true for noise, electric current, physical load, and mechanical factors.

The relationship between additional work and the subjective assessment of hazards was mostly in step with expectations; high pace of work was related to a higher subjective assessment of three hazards: physical load, mechanical factors and repetitive tasks. Tight deadlines were related to a higher assessment of three risks: noise, optical radiation and physical load; however, here, too, two relationships were unexpected. For vibration and chemical hazards, the shorter the notice, the lower the subjective assessment of risk. The last dimension of the DCS model [17, 18], i.e., social support, was never a predictor of subjective assessments (that is why it has not been included in Table 2). When looking at the results in Table 2, it is important to note that subjective assessment of some hazards was more closely related to psychosocial job characteristics than to objective measurements of hazards. This was so for mechanical factors, where objective measurements explained 4% of variance of subjective assessment, whereas psychosocial job characteristics 14%. In the case of repetitive tasks, objective measurements explained 1% of variance whereas psychosocial job characteristics 10%.

In the health and satisfaction group of variables, which were introduced in the last step of regression, work-related health risk was a particularly consistent predictor of subjective assessment. This factor explained significant percentages of variance of the subjective assessments of all hazards (6–10% depending on the hazard). Moreover, with the exception of mechanical hazards, the greater the perception of health risk, the greater the perception of hazard posed by that factor.

4.6. Path Analyses of Models Explaining the Relationship Between Subjective Assessment of Hazards and Its Psychosocial Determinants, and Objective Hazards

The enormity of the varied research material required special tools for analysing the relationships between them. On the basis of the preliminary assumptions on the role of psychosocial job characteristics as predictors of subjective assessment of hazards and the results of the correlation and regression analyses, a model was developed to illustrate the relationship between the main variables (Figure 19). The subjective assessment of hazard was the main explained variable. It was endogenous, i.e., it did not explain other variables; it was only explained within the model. It was assumed that subjective assessment of hazard depended on its objective assessment and on perceived health risk. It was also assumed that it depended on job satisfaction, which in turn depended, according to DCS, on the three dimensions of demands, control and support [17, 18]. This model also assumed that the three dimensions affected the subjective assessment of hazard not only indirectly (i.e., through job satisfaction), but also directly. Regarding individual variables, it was assumed that they affected subjective assessment of hazard both indirectly and directly, through job satisfaction. This model also assumed that job satisfaction was predicted by objective hazards and by perception of health risk; perception of health risk being affected by objective measurements of hazard and by age.

Eight such models were tested; they corresponded to the eight subjective assessments of hazards. The empirical results are illustrated in Figure 20; vibration was the example.

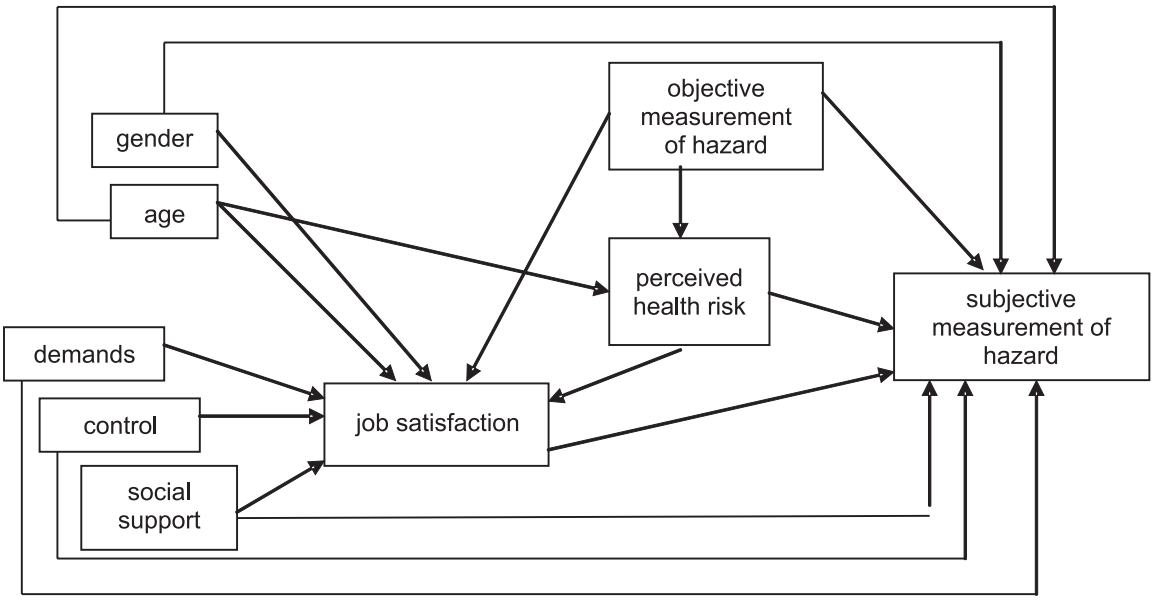

Figure 19. The assumed model of the relationship between subjective assessment of risk and the related variables.

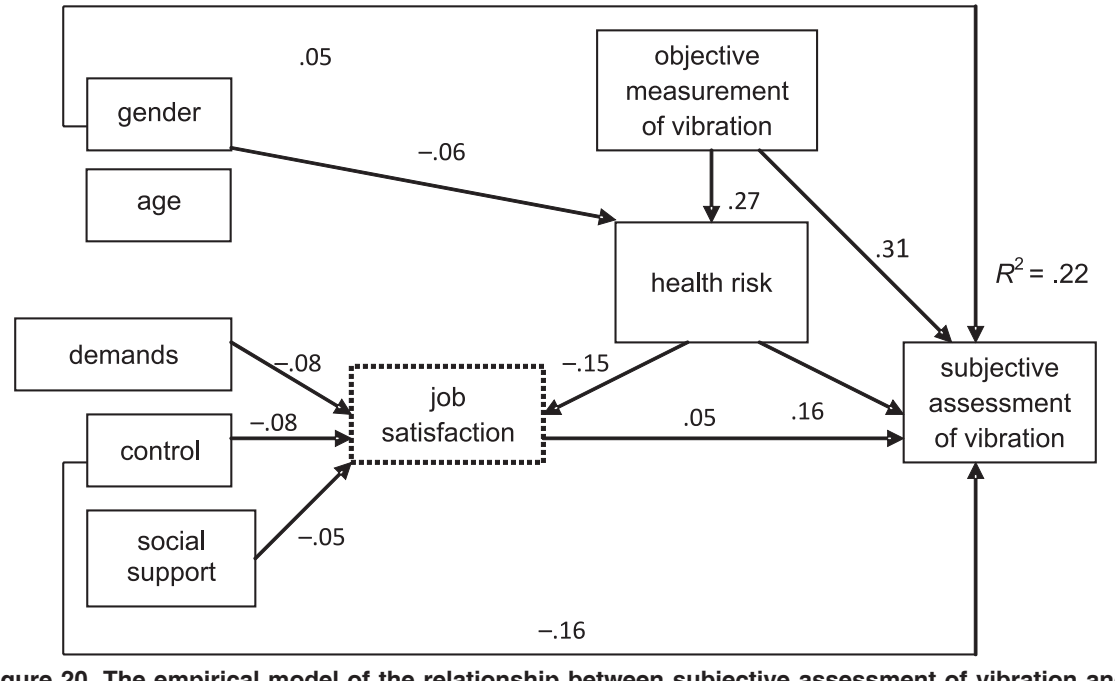

Figure 20. The empirical model of the relationship between subjective assessment of vibration and the related variables. *Notes.* R^2—explained variance; GFI = .999, NFI = .998, RMSEA = .039.

The measures of fit that were used proved that the model and empirical data fit (GFI = .999, NFI = .998, RMSEA = .039)[3]. The explained variance of the subjective assessment of exposure to vibration was 22%. In the model the direct influence of psychosocial job characteristics on

[3] Three measures of fit were used to test the fit of the theoretical model with empirical data: (a) GFI (goodness of fit index): one and values close to one signify goodness of fit; the lower the value, the worse the fit; (b) NFI (normed fit index): a value over .90 signifies goodness of fit; (c) RMSEA (root mean square error of approximation): a value lower than .05 signifies good fit, a value of ~.08 means the fit is quite good and values higher than .01 signify lack of fit.

job satisfaction was expressed through demands ($\beta = -.08$, $p < .01$), control ($\beta = -.08$, $p < .01$) and support ($\beta = -.05$, $p < .05$). It was only for demands that the direction of the relationship was expected: the higher the demands, the lower the job satisfaction. For control and support the direction was unexpected: the higher the two factors, the lower the satisfaction. Relationships of job satisfaction with subjective assessment of vibration were also unexpected: the greater the satisfaction, the higher the assessment of hazard. In other words, as expected, job satisfaction mediated the relationship among the three dimensions of work and the subjective assessment of work. However, the direction of those relationships was unexpected. On the other hand, for the direct influence of psychosocial job characteristics on the subjective assessment of vibration, there was an expected influence of control ($\beta = -.16$, $p < .01$): the higher the control, the lower the perception of hazard ($\beta = .05$, $p < .05$). Objective measurements of vibration were a significant predictor of subjective assessment ($\beta = .31$, $p < .01$), which earlier regressions had already shown. Moreover, path analysis showed that objective measurements affected subjective assessment not only directly but also through the influence on perception of health risk ($\beta = .27$, $p < .01$). In turn, perceived heath risk was strongly related to subjective assessment of hazard.

The results of path analyses of other factors were to a large extent similar to the results on vibration. In particular they confirmed the important role played of objective assessment of hazards as a predictor of subjective assessment, both through its direct and indirect influence, through an increase in perceived health risk, which in turn significantly affected subjective assessment.

5. DISCUSSION

Comparison analyses of the subjective assessment of exposure to hazards done by 823 workers (mostly labourers) and objective measurements of those hazards, showed that subjective assessment was to a large extent a consequence of the objective level of hazards (in regression analyses this applied to six and in path analyses seven of the eight analysed hazards). Objective measurements explained, depending on the hazard, 1–18% of variance of subjective assessments. Path analyses also showed that objective hazards affected subjective assessment not only directly (as has already been explained) but also indirectly, through perceived health risk. This means that objective hazard increases perceived health risk (this was so in six of the eight analysed hazards) and that in turn increases the subjective assessment of hazard (confirmed for all hazards) and expected work ability (also in path analyses of all hazards).

Numerous psychological studies showed that some psychosocial job characteristics could cause severe mental stress (cf., e.g., Leka and Cox [42]; European Agency for Safety and Health at Work [43]; de Lange, Taris, Kompier, et al. [44]; Widerszal-Bazyl [45]; Sauter and Murthy [46]). Negative emotions are a constituent characteristic of stress. Some researchers even refer to emotions when defining stress. For example, Strelau [47] defined stress as "a condition characterized by negative emotions of high intensity (such as, e.g., fear, anxiety, anger, hostility or other conditions defined as mental discomfort), which is accompanied by physiological and biochemical changes that clearly exceed a base level of activation"[4]. Negative emotions caused by stress influence the perception of the physical and social world, thus probably also the perception of risk in the working environment. They cause workers to perceive them as greater than they are according to objective measurements. In other words, it can be supposed that the psychosocial environment, through the mechanism of stress, causes a distortion of the subjective perception of risk. The model of stress developed by Karasek [17] and Karasek and Theorell [18] implies that an especially great role is played by excessive job demands, limited job control and limited social support. There are many empirical proofs that those characteristics cause deterioration of

[4] M. Widerszal-Bazyl's translation.

health, and physical and mental well-being. Thus, it was logical to assume that those stress-inducing dimensions of work would support a negative assessment of physical and chemical hazards in the working environment.

Even though the results showed strong relationships between objective and subjective assessment of hazards, at the same time they revealed that significant percentages of variance of subjective assessment were also explained by psychosocial job characteristics. In individual cases they even explained greater percentages of variance of that assessment than objective measurements. This was so for mechanical hazards (14% of variance explained by psychosocial job characteristics, 4% by objective measurements) and repetitive tasks (10% of variance explained by psychosocial job characteristics, only 1% by objective measurements). Thus, even though the influence of psychosocial factors on subjective assessment of risk was clear, the mechanisms of that influence are not unambiguous. According to the DCS model [15] high demands, low control and low social support are important sources of work-related stress; thus they should be related to a higher subjective assessment of risk. However, the results of both regression and path analyses showed this was so in few cases.

For control, the expected direction of direct relationships with subjective assessment was found in path analyses of five hazards: the higher the workers' control, the lower the subjective assessment of vibration, noise, exposure to optic radiation, chemical hazards and repetitive tasks. However, for demands and support, the expected direction was rare. We can thus suppose that mental stress is only one of the possible mechanisms explaining the relationships of psychosocial characteristics with subjective assessment of risk. Other possible explanations of those relationships lie in the connection between psychosocial characteristics with position at work and the related higher or lower awareness of risk. High degree of control usually characterizes people at higher professional and organizational levels. We can thus expect that because of their higher general level, they are more aware of risk; thus, their subjective assessment of those risks is higher. This means that we can expect the result that came up a few times in this research, that the higher the control, the higher the subjective assessment of those risks (this was the case for electric current, mechanical factors and physical load).

It is important to regard cautiously the results on demands, because the results of regression and path analyses differed. Regression analysis showed an expected relationship: the higher the quantitative demands (work pace), the higher the subjective assessment of several risks. On the other hand, path analysis showed that the higher the quantitative demands, the lower the subjective assessment of demands.

The models that were analysed predicted not only direct relationships of psychosocial characteristics with subjective assessment of risk but also indirect ones, through job satisfaction. It was expected that psychosocial job characteristics, demands, control and support would affect satisfaction. That indirect effect of psychosocial job characteristics turned out to be quite weak, mainly because of the weak relationships between job satisfaction and subjective assessment of risk.

6. CONCLUSIONS

- The comparative objective and subjective assessment of occupational risk in sectors of the economy with highest rates of occupational risk (the construction sector, the processing industry and transport) showed significant differences between workers' subjective assessment and the results of objective assessment (i.e., measurements of all the physical and chemical hazards that were studied).
- Worse subjective assessment of hazards was related not only to their objective measurements but also to psychosocial job characteristics, workers' individual characteristics and work load.
- Objective occupational hazards affect, however, subjective assessment not only directly, but also indirectly, by increasing perceived health risk.

- Despite subjective and objective assessment of hazard being strongly related, they are distinct phenomena. That is why risk assessment in the working environment should be carried out with both objective and subjective methods.

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