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Development of a decision model to identify workers at risk of long-term disability in the construction industry

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Objective This study presents a decision model that predicts long-term disability among construction workers.
Methods Risk factors were identified in two cohort studies among construction workers and evaluated in validation samples of smaller cohort studies among Dutch construction workers. The risk estimates (odds ratios) were used in a logistic regression model to calculate the probability of long-term disability in the next 4 years for a particular construction worker, subject to a specific combination of risk factors. The a priori probability was set equal to the overall long-term disability risk among the youngest construction workers (<30 years) with a relatively short exposure history.
Results According to literature findings, the risk estimate for work ability was set with the odds ratio at 2.0 for good work ability, 5.0 for moderate work ability, and 10.0 for bad work ability. Age-dependent risks were set at odds ratios of 1.5, 2.0, and 3.0 for the age groups of 30–34 years, 35–44 years, and 45–54 years, respectively. A sickness absence period of ≥3 months had an odds ratio of 2.0, and severe musculoskeletal complaints had an odds ratio of 3.0. Since the number of construction workers older than 55 years was rather small and heavily biased by a healthy worker effect, it was decided to limit the applicability of the decision model to workers aged 20–55 years. The decision model used four risk factors and predicted a 40-fold difference in disability risk between construction workers with all four risk factors present (0.79) and those without any risk factor (0.02).
Conclusions The decision model presented the combined effect of different risk factors on the risk of an individual worker becoming disabled within 4 years. Evaluation studies will need to demonstrate whether the application of this decision model is helpful in identifying workers at risk for long-term disability and will facilitate appropriate intervention at the individual level.

Key terms construction worker; decision model; disability; prediction.

Musculoskeletal complaints, especially low-back pain, have long been recognized as an important source of morbidity and disability in many occupational populations (1, 2), especially in the construction industry, where musculoskeletal disorders are the primary reason for long-term sickness absence and associated disability (3). Since most musculoskeletal complaints are usually self-limiting conditions in which recovery without medical treatment occurs for most episodes, it has been argued that prevention and treatment should focus on preventing chronicity and disability rather than on preventing the onset of pain (4, 5). It is largely unknown whether the work-related risk factors for the occurrence of musculoskeletal complaints are similar to those that cause an aggravation of these complaints and associated long-term disability.

In working populations, a disability may limit the worker's ability to perform the usual tasks required in a job and may, as a consequence, prompt spells of sickness absence. Although work disability and sickness absence are different entities, sickness absence is being used as a health parameter of interest in studies of the

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consequences of disability in occupational groups. Most workers with musculoskeletal sickness absence return to work within a few weeks, and the small proportion of workers with long-term sickness absence is responsible for the largest share of all the costs incurred (2, 4). Hence it is important to identify the prognostic factors that make the difference between those with absence spells of a few weeks and those absent for long periods, especially workers who are at risk of becoming disabled for their regular job on a long-term level. However, prognostic factors for long-term sickness absence and associated disability are not well documented (6).

Early identification of the group of workers at risk of long-term sickness absence seems to be an essential tool in establishing appropriate and cost-effective intervention (4). Although health surveillance programs among workers have been used to identify emerging health problems at the population level, these programs have seldom been adopted to identify and target particular populations for prevention and intervention. In theory, regular medical examinations within occupational health care may provide unique opportunities to evaluate individual and work-related predictive factors for long-term sickness absence and disability. So far, decision models with a high predictive value for long-term disability are almost completely absent. One of the first attempts to forecast early retirement due to disability demonstrated that a work-ability index for middle-aged construction workers was highly predictive of disability pensions during the 4-year follow-up with a relative risk of 10 for workers with a poor work ability compared with those with excellent work ability (7).

In order to combine the sparse information in the scientific literature on risk factors for long-term disability, a decision model can be applied that captures the combined effect of different risk factors on future disability. On request of the construction industry, this approach was adopted in a newly developed health surveillance program, with a focus on musculoskeletal complaints, given their importance in long-term sickness absence and disability. The aim of our paper is to present a decision model to predict the probability of work-related long-term disability in the future among construction workers.

Methods

Data sources

The available literature on risk factors for long-term disability among construction workers was evaluated. Long-term disability was defined as early retirement resulting from disability or prolonged sickness absence of >1 year. The literature was included when information on risk factors for disability was derived from longitudinal studies with a sufficient follow-up period among cohorts of construction workers. In addition, a trend analysis was required presenting risk estimates across different levels of exposure. A formal meta-analysis on risk factors for disability was not conducted since there were too few cohort studies among construction workers. Two cohort studies (7, 8) were identified that could be used for the purpose of our paper with respect to information on risk factors for long-term disability among construction workers.

The risk factors identified in the selected studies were used for the model development by extracting the risk estimates as odds ratios or relative risks. The dose-response relationships for single risk factors were evaluated in validation samples, consisting of two cohort studies among Dutch construction workers (3, and unpublished data: De Zwart BCH, Frings-Dresen MHW, Groothausen J, Van Duivenbooden JC. Two-year prospective study on work, work ability and health among construction workers in the Netherlands. Presented at the 4th International Scientific Conference on Protection of Work-related Musculoskeletal Disorkers PREMUS 2001). These two cohort studies were primarily used for validation purposes since their sample sizes were limited and consequently their risk estimates were not precise enough to be used in the model development.

Model development

The decision model calculates the probability of long-term disability in the next 4 years for a particular construction worker, subject to a specific combination of risk factors. The basis of the decision model is the probability of long-term disability for a construction worker not exposed to the established risk factors. This a priori probability was set equal to the overall long-term disability risk among the youngest construction workers (<30 years) with a relatively short exposure history, who, in this study, were regarded as unexposed workers. The probability of long-term disability increases when one or more risk factors are present. The estimates per risk factor derived from the literature (odds ratios) were rounded off before inclusion in the decision model. A logistic regression model to predict long-term disability was constructed whereby the a posteriori probability equals the mathematical expression 1 over 1 plus *e* to minus the linear combination of the intercept and risk parameters (9). The intercept reflects the a priori probability, and the risk parameters are equal to the natural logarithms of the odds ratios derived from the literature. Hence, for any given combination of risk estimates, the calculated probability represents the likelihood for the occurrence of long-term disability within 4 years for the specific combination of risk factors for an individual worker.

The decision model and underlying risk estimates were discussed with a small group of experts in occupational health from the participating organizations in this study in order to agree upon the final estimates to be used in the decision model.

Results

Work ability

The estimated effect of the work-ability index is described in table 1. In a Finnish study among 736 middle-aged construction workers, a work-ability index was calculated for each participant at baseline, and actual work status was determined after 4 years of follow-up. This work-ability index was a weighted sum of seven items, constructed to include self-reported work ability in relation to work demands, health status, and psychological resources, and its total score relates to excellent work ability (44–49 points), good work ability (37–43 points), moderate work ability (28–36 points), or poor work ability (7–27 points). Adjusted for age, the work-ability index was highly predictive of a worker receiving a disability pension during the 4-year follow-up (7). In a validation sample of 601 Dutch construction workers with a similar design but only 2-year follow-up, the work-ability index was also highly predictive of long-term disability. Due to the smaller number of cases, adjustment for age was not possible in this validation sample (unpublished data: De Zwart BCH, Frings-Dresen MHW, Groothausen J, Van Duivenbooden JC. Two-year prospective study on work, work ability and health among construction workers in the Netherlands. Presented at the 4th International Scientific Conference on Protection of Work-related Musculoskeletal Disorkers PREMUS 2001).

Age

The association between age and disability risk is presented in table 2. This analysis is based on all long-term disability pensions granted in the construction industry in The Netherlands over the period 1995–1998. The 4-year disability risk increased with age, but workers 55 years and older had a risk comparable to the observed risk in the age group of 30–34 years. The number of cases in the oldest age group was much lower than in the other age groups, illustrating that this age group consists of healthy survivors (8).

In a validation sample, the effect of age on disability was evaluated in a dynamic cohort of 288 scaffolders who worked in the same company between 1998 and 2001 (3). During the 3-year follow-up, 23 cases experienced a sickness absence period of 1 year and,

Table 1. Predictive value of the work-ability index on long-term disability among construction workers in Finland (7) and The Netherlands (9). (RR = relative risk, 95% CI = 95% confidence interval)

Work-ability-index score	Liira et al (7)				De Zwart et al (9)			
	N [a]	%	RR [b] (4-year)	95% CI	N [a]	%	RR (2-year)	95% CI
Excellent	3	2.0	1.0	·	2	1.0	1.0	·
Good	26	5.6	2.5	0.9–8.8	2	0.7	0.7	0.1–4.8
Moderate	44	15.9	5.4	1.8–18.5	5	4.6	4,5	0.9–23.1
Poor	21	35.6	10.7	3.1–36.0	3	21.4	20.8	3.5–124.4

[a] Cases with long-term disability and associated cumulative incidence.
[b] Adjusted for age.

Table 2. Predictive value of age for long-term disability among construction workers in The Netherlands. (RR = relative risk, 95% CI = 95% confidence interval, NA = not available)

Age group	Ploeger (8)				Elders et al (3)			
	N [a]	%	RR [b] (4-year)	95% CI	N [a]	%	RR (3-year)	95% CI
20–29 years	1810	2.0	1.0	·	2	1.5	1.0	·
30–34 years	1114	3.3	1.6	1.5–1.7	5	8.1	5.6	1.1–29.8
35–44 years	2625	4.2	2.1	2.0–2.2	9	13.2	9.8	2.1–46.6
45–54 years	3576	6.6	3.2	3.1–3.4	7	15.9	12.1	2.4–60.8
55–64 years	521	3.5	1.7	1.6–1.9	..	..	..	..

[a] Cases with long-term disability and associated cumulative incidence.

consequently, received a long-term disability pension. A stronger trend in disability by age was observed, and the overall disability among scaffolders was the highest of all occupations in the construction industry (3, 8).

Sickness absence

In a study population of approximately 200 000 construction workers, it was found that workers with a sickness absence period of 3 months or longer in a given year had a relative risk of 2 for becoming disabled on a long-term basis in the following 2 to 7 years (8). In the validation sample, this finding could not be corroborated due to the small numbers (3).

Musculoskeletal complaints

In a preliminary analysis of a dynamic cohort study among 288 scaffolders, severe back pain in the 12 months prior to the start of the study was a strong risk factor (OR 3.8) for long-term disability during the 2-year follow-up period. Severe back pain was defined as a spell of back pain that resulted in functional disability with limitations in the capabilities to perform daily activities at work and at home. The analysis after a 3-year follow-up demonstrated that severe back pain was highly predictive of sickness absence longer than 2 weeks (OR 4.5) (3). An additional analysis of this dataset showed that severe back pain was highly associated with long-term disability (OR 3.0) and that co-morbidity between severe back pain and other severe musculoskeletal complaints was high.

Table 3. Estimated probability of long-term disability in the next 4 years among construction workers, based on work ability, age, previous sickness absence, and history of musculoskeletal complaints.

Work-ability index	Age	Sickness absence and age	Musculo-skeletal complaints and age	Sickness absence, musculo-skeletal complaints and age
	P-value	P-value	P-value	P-value
Good work ability				
<30 years of age	0.04	0.08	0.11	0.20
30–34 years of age	0.06	0.11	0.16	0.27
35–44 years of age	0.08	0.14	0.20	0.33
45–54 years of age	0.11	0.20	0.27	0.42
Moderate work ability				
<30 years of age	0.09	0.17	0.23	0.38
30–34 years of age	0.13	0.23	0.32	0.48
35–44 years of age	0.17	0.29	0.38	0.55
45–54 years of age	0.23	0.38	0.48	0.65
Poor work ability				
<30 years of age	0.17	0.29	0.38	0.55
30–34 years of age	0.23	0.38	0.48	0.65
35–44 years of age	0.29	0.48	0.55	0.71
45–54 years of age	0.38	0.55	0.65	0.79

Model development

The decision model was built upon the probability of long-term disability for a construction worker not exposed to the established risk factors. This a priori probability was set equal to the overall long-term disability risk among construction workers younger than 30 years (ie, P=0.02 in the next period of 4 years) (9). The additional presence of work ability, age, sickness absence history, and severe musculoskeletal complaints raises the probability of becoming disabled.

The risk estimates for work ability were set at OR=2.0 for good work ability, OR=5.0 for moderate work ability, and OR=10.0 for poor work ability. The risk estimates from the Finnish study (7) were preferred to those of the Dutch study (unpublished data: De Zwart BCH, Frings-Dresen MHW, Groothausen J, Van Duivenbooden JC. Two-year prospective study on work, work ability and health among construction workers in the Netherlands. Presented at the 4th International Scientific Conference on Protection of Work-related Musculoskeletal Disorkers PREMUS 2001) since the latter study had a smaller sample size and a shorter follow-up period. The age-dependent risks were taken from the analysis of the total construction industry in The Netherlands (8) with OR values of 1.5, 2.0, and 3.0 for the age groups 30–34, 35–44, and 45–54 years, respectively. Since the number of construction workers above 55 years of age was rather small and the estimated risk for long-term disability was heavily biased by a healthy worker effect, it was decided to limit the applicability of the decision model to workers between 20 and 55 years of age. Although the age effect on the validation set among the scaffolders was much stronger (3), it was not considered representative for the construction industry since the scaffolders had a twofold risk for long-term disability when compared with the average risk of all construction workers (8). The risk of workers with a sickness absence period of 3 months or longer was set at OR=2.0 (8). The risk factor "severe back pain" was translated into the risk factor "severe musculoskeletal complaints" due to the strong overlap between various musculoskeletal complaints. The effect of this risk factor was set at OR=3.0 (3).

For the given combination of risk factors, table 3 presents the calculated probability of long-term disability within 4 years for an individual worker. Since work ability and age are risk factors always present for each worker, they were taken into account when the additional effects of sickness absence and severe musculoskeletal complaints were calculated. The estimated probabilities varied between P=0.04 and P=0.79. The effect of specific risk factors on the probability for long-term disability partly depends on the presence of other risk factors, but table 3 clearly demonstrates the profound impact of the work-ability index and, to a less extent, that of age, sickness absence, and severe musculoskeletal complaints.

Discussion

In order for the probability of future long-term disability among construction workers to be predicted, a prediction model was developed based on the sparse epidemiologic information from the literature. Techniques from clinical decision modeling were adapted to construct a model that may help the occupational health physician to determine the risk for long-term disability for an individual worker, given his personal profile of well-established risk factors. The decision model used four risk factors and predicted a 40-fold difference in the disability risk between the construction workers with all four risk factors (P=0.79) and those without any risk factor (P=0.02).

Performance of the model

The basis of the model is the age-dependent disability risk among construction workers when not exposed. The a priori probability for long-term disability was estimated to be approximately 2%. The sensitivity of the decision model for this assumption was evaluated using a priori probabilities of 1% and 3%. A lower a priori probability of 1% resulted in substantially lower disability risks (eg, the risk of disability for a young worker with an index rating indicating poor work ability decreased from 17% to 9%, whereas the risk for a worker with all four risk factors changed from 79% to 64%). The effects of a higher a priori probability of 3% were less profound, with estimated increases for the same persons of 17% to 24% and 79% to 85%.

The performance of the model is strongly influenced by the chosen values of the risks incorporated in the decision model. Since the available epidemiologic information was limited, it is difficult to evaluate the appropriateness of the weights in the model. The available validation datasets illustrated that risk estimates may vary across different populations. The findings among scaffolders demonstrated that this occupational group is not representative of the heterogeneous population of construction workers in general and, hence, has restricted value for validation purposes. They also suggest that, for particular occupations, the decision model may not sufficiently reflect the effects of different risk factors on disability. Hence, in these situations, an occupation-specific decision model should be considered. The decision model presented could be improved if the estimated risks could be derived from a meta-analysis on a sufficient number of studies reporting on the same risk estimates in the construction industry.

An important assumption in the decision model is that the distinguished risk factors have an independent effect on disability. This independent effect may lead to overestimation of the disability risks when these risk factors overlap to some extent and thus do not constitute an independent effect and hence a downward adjustment would be required. The four risk factors were derived from separate studies since no studies were available that reported both unadjusted and adjusted risk estimates for all four risk factors in the same population. In the Finnish cohort study the work-ability index was corrected for age, and the age-adjusted risk estimates were used as input in the decision model (7). Since the work-ability index combines subjective experiences of one's ability to work with the self-reported occurrence of various diseases and sickness absence, this index may already capture, to some extent, the independent effects of the predictive factors musculoskeletal complaints and sickness absence. In order to evaluate the potential overestimation due to including these interrelated factors as independent predictors in the decision model, in the validation sample of Dutch construction workers, we corrected the work-ability index (maximum score 49 points) for the contribution of sickness absence (maximum score 5 points). This adjusted work-ability index showed similar relative risks, which may be explained by the fact that sickness absence contributes ≤10% in the work-ability index. Hence, given the strength of the predictive value of prolonged sickness absence in the past in other studies, it seems reasonable to include this factor as a separate predictor in the decision model. Since the presence of severe musculoskeletal complaints may change the work-ability index by a maximum of 3 points (≤6%), the likelihood of overestimation will be small if both work ability and severe musculoskeletal complaints are included. Although potential overestimation of the disability risk certainly cannot be ruled out, additional evaluation of the risk of overestimation was not possible due to the lack of a validation dataset with available information on all risk factors simultaneously. However, the potential magnitude of overestimation will not exceed the difference between the prediction model based on work ability, age, and musculoskeletal complaints (table 3, column 4) and the full prediction model (table 3, column 5). The potential relative overestimation is largest for people with a good work ability (56–82%) and smallest for those with a poor work ability (22–45%). The appreciation of this potential overestimation depends highly on the practical use of the model, especially the consequences for workers deemed to be at high risk for future work disability.

The estimated risks will be affected by the healthy worker effect, but this effect is difficult to estimate. There are some indications for a substantial healthy worker effect among construction workers since the proportion of workers over 55 years of age is small (8) and in the Finnish cohort study the work-ability index at baseline was also associated with unemployment during the follow-up (7). This healthy worker effect probably underestimates the risk of future long-term disability.

The overall sensitivity of the decision model for other definitions of risk factors and other estimates of their effects is difficult to evaluate, since empirical evidence is lacking. For further development of the model, it would be advised to include the risk factors in future epidemiologic studies and evaluate their impact on disability when adjusted for each other. The sensitivity of the model will also be influenced by measurement bias with respect to the risk factors of interest and may ultimately result in the poor performance of the decision model. In a study on the work-ability index, repeated measurements with a 4-week interval showed that less than 66% of the construction workers were classified into the same work-ability category in both measurements (10).

Practical implications of the model

The decision model was designed to be used in existing health surveillance programs, and the time span of 4 years coincided with the largest gap between two consecutive health examinations among construction workers. A model with a shorter time span of prediction will have lower estimated probabilities of future disability and thus may complicate the distinction between those with and without risk. In order to determine which construction workers need additional occupational health care, we have proposed to use cut-off points at P=0.20 and P=0.38. Workers with a probability between P=0.20 and P=0.38 should be examined more carefully and evaluated as to whether it is possible to increase the person's work ability by specific intervention programs or whether workplace adjustments or modified worktasks are necessary. Workers with a probability of over 38% should be offered the opportunity to change to a less strenuous job. This distinction is currently put into practice and, in the upcoming years, will be evaluated as to its effect on disability rates in the construction industry.

It must be emphasized that the decision model is not an etiologic model for long-term disability, but is instead an attributive model for the effect of different risk factors on the risk of becoming long-term disabled in the next 4 years. As such, this model gives an estimate for the individual worker and can be used as a potential tool to direct intervention strategies. Evaluation studies will demonstrate whether the application of this decision model is helpful in identifying workers at risk of long-term disability and will facilitate appropriate intervention at the individual level.

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