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The aim of this study was to determine whether results from the RSI QuickScan questionnaire on risk factors for arm, shoulder and neck symptoms can predict future arm, neck and shoulder symptoms in a population of computer workers. For this prospective cohort study, with a follow-up of 24 months, 3383 workers who regularly worked with a computer were approached. Generalised estimating equations (GEE) with 6, 12, 18 and 24 months time lags were used to determine whether high exposure was related to symptoms at follow-up. The results showed that high scores on 9 out of 13 scales, including previous symptoms, were significantly related to arm, shoulder and neck symptoms at follow-up. These results provide support for the predictive validity of the RSI QuickScan questionnaire.

Practitioner Summary: The results showed that high scores on 9 out of 13 scales, including previous symptoms, were significantly related to arm, shoulder and neck symptoms at follow-up. The RSI QuickScan questionnaire may be recommended as a tool in the identification of computer workers who should be targeted with interventions aimed at prevention of future symptoms.

Keywords: office ergonomics; ergonomics tools and methods; musculoskeletal disorders; upper limb disorders; risk assessment and management

1. Introduction

Information and communication technology (ICT) plays an ever more important role in the current workplace and as a result computer use has greatly increased in recent decades (IJmker *et al*. 2007, Straker *et al*. 2008, Yoshioka *et al*. 2008). Unfortunately, arm, shoulder and neck symptoms are common amongst computer workers and are suggested to be work-related (Punnett and Bergqvist 1997, Ekman *et al*. 2000, Palmer *et al*. 2001, Brandt *et al*. 2004, Wahlstrom 2005, Woods 2005, Robertson *et al*. 2009). These symptoms vary in severity, from mild to very severe, and have become one of the most important causes of work disability (Morken *et al*. 2002, Rahman and Atiya 2009). The total yearly costs of arm, shoulder and neck symptoms are high (Bongers 2001, National Research Council, Institute of Medicine 2001, European Commission 2004, Blatter *et al*. 2005), and employers are trying to reduce these costs by implementing interventions aimed at reducing exposure to risk factors and, thereby, the prevalence of symptoms.

Some employers are concerned that screening, education and focused attention on work-related musculoskeletal symptoms will cause an increase in these symptoms and the incidence of workers' compensation claims. However, a prospective cohort study (Melhorn 1999) demonstrated that there was no increase in the number of reported work-related injuries and no increase in the incidence of workers' compensation claims after completion of an individual risk screening program that included education and employee awareness about work-related musculoskeletal pain. Moreover, incidence of cumulative trauma disorders has been most effectively reduced by use of individual risk-screening programs (Melhorn 1999).

Several programmes have, therefore, been developed that include individual risk screening aimed at either asymptomatic or symptomatic workers. A screening tool, targeting asymptomatic assembly workers based on objectively measured work characteristics, was successful at identifying workers at risk (Melhorn 1996) and

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ergonomic posture training in high-risk workers reduced risk levels. Targeting symptomatic workers, a tool to identify workers at risk for poorer outcome, based on ergonomic and psychosocial stress, pain severity, pain coping style and medical history was shown to allow prediction of clinical outcomes (Feuerstein *et al.* 2000). In addition, scores on an upper-extremity specific self-report index of ergonomic exposures were shown to correlate with upper extremity pain, symptom severity, and functional limitations.

In the present study, the predictive validity of the questionnaire of the RSI QuickScan intervention programme is investigated (Speklé *et al.* 2010).The RSI QuickScan intervention programme differs from the three aforementioned programmes, in that it is designed specifically for computer workers, but for asymptomatic as well as symptomatic workers. Its goal is to identify individuals with high risks and/or symptoms, reduce exposure to presumed risk factors and, consequently, the prevalence of arm, shoulder and neck symptoms (Speklé *et al.* 2010). The intervention starts with the assessment of the presence or absence of potential risk factors in a company or organisation. The risk factors that are assessed have previously been recognised in etiological studies, such as work posture and movement, job decision latitude, relation with management and colleagues, work pace and load, work environment factors and furniture (Houtman *et al.* 1994, Toomingas *et al.* 1997, Aarås *et al.* 1998, 2001, Van der Windt *et al.* 2000, Ariëns *et al.* 2001, Harkness *et al.* 2003, Korhonen *et al.* 2003, Sluiter *et al.* 2003, Cook *et al.* 2004, Gerr *et al.* 2004, Juul-Kristensen *et al.* 2004, Punnett *et al.* 2004, Woods 2005, Bongers *et al.* 2006, Hughes *et al.* 2007). Furthermore, research showed that having had previous arm, shoulder and neck symptoms is associated with future symptoms (Cole and Hudak, 1996, Fredriksson *et al.* 1999, Leclerc *et al.* 1999). Arm, shoulder and neck symptoms at baseline are, therefore, also assessed with the RSI QuickScan questionnaire, as this information can be used in identifying workers at risk of also having symptoms at a later date. The assessment of risk factors and symptoms using this internet-based instrument was found to be reliable and valid and can be used as a means to rapidly collect data on a large population of office workers (Speklé *et al.* 2009). After the worker has filled out the questionnaire, the total score of the individual worker on each scale is classified into two categories: low to medium or high risk. For workers with a high level of exposure to risk factors and/or with arm, shoulder and neck symptoms individual feedback and advice on the specific actions that they can personally take in order to reduce their risk, are offered (Speklé *et al.* 2010).

The assumption underlying the approach described is that high exposure and previous symptoms as scored with the questionnaire predict future symptoms. The aim of the present study was to test this assumption. Much research has been done on risk factors for arm, neck and shoulder symptoms (Jensen *et al.* 2002, Marcus *et al.* 2002, Hakala *et al.* 2006, Chang *et al.* 2007). Ideally, such etiological studies are performed in a population without symptoms at baseline to evaluate subsequent incidences. The present study was designed to stay close to the aims of the RSI QuickScan intervention programme as it is used in practice. We therefore did not select a study population without symptoms at baseline. Populations in most organisations are a blend of workers with and without arm, neck and shoulder symptoms. Since the prevalence of arm, neck and shoulder symptoms is high, secondary as well as primary prevention are important and the RSI QuickScan programme is targeted at all workers with a high risk of having symptoms at a later date. The RSI QuickScan questionnaire has been used as a screening tool for several years, but the predictive validity of the scales in the questionnaire has not previously been determined. Therefore, the aim of this study was to determine whether results from the RSI QuickScan questionnaire can predict future arm, shoulder and neck symptoms in a population of computer workers.

2. Methods

2.1. Study design and follow-up

This study was designed as an observational, prospective cohort study. None of the participants was involved in any intervention whatsoever. Data on exposure to risk factors for arm, shoulder and neck symptoms and the prevalence of arm, shoulder and neck symptoms were collected with the RSI QuickScan questionnaire at baseline, and after 6, 12, 18 and 24 months. The internet-based RSI QuickScan investigates the presence or absence of potential risk factors, such as work posture and movement, job decision latitude, relation with management and colleagues, work pace and load, work environment factors, and furniture (Speklé *et al.* 2009). A detailed description of the questionnaire can be found at www.rsiquickscan.com/research/questionnaire.pdf.

Participation was voluntarily and all participants electronically provided informed consent before filling out the baseline questionnaire. In case of non-response, participants received a maximum of two reminders by e-mail. The study design, protocols, procedures and informed consent form were approved by the Ethics Committee of the Faculty of Human Movements Sciences of the VU University Amsterdam.

2.2. Population

At the start of the two-year study, the source population (N = 3383) consisted of office staff, consultants, health care personnel, researchers and managers of an Occupational Health Service (Arbo Unie), with offices throughout the Netherlands. This population works considerably more than 2 h with the computer per day (data not presented) and is, therefore, termed computer worker. Workers with and without arm, shoulder and neck symptoms were included.

At baseline, all 3383 workers of the source population were contacted by e-mail and were given time during work to fill out the questionnaires. The workers were informed about the study using the Intranet site of the organisation and through the companies' magazine. In addition, all these employees received an e-mail with information on the objectives of the study, privacy as well as required effort for participation. As incentive for participation, workers who participated in all five measurements were included in a lottery for a weekend holiday in Paris.

2.3. Response

Of the 3383 workers who were contacted at baseline, in total 2660 workers participated in one or more of the five measurements. Of the 3383 workers, 2049 (61%) workers filled out the questionnaire at baseline (T0), 1485 (44%) at the second (T1), 1278 (38%) at the third (T2), 1195 (35%) at the fourth (T3) and 1043 (31%) workers filled out the questionnaire at the fifth (T4) measurement (Table 1). In total, 7050 completed questionnaires were received over the two-year period. Of the 2660 workers who participated in one or more of the five measurements, 872 (32.8%) workers filled out only one questionnaire, 543 (20.4%) workers filled out two questionnaires, 401 (15.1%) workers three, 331 (12.4%) workers four, and 513 (19.3%) workers filled out all five questionnaires. In total 1788 workers answered two or more questionnaires and entered into the investigation.

2.4. Data collection procedure

The workers were informed about the study using the Intranet site of the organisation and through the companies' magazine. In addition, all these employees received an e-mail with information on the objectives of the study, privacy as well as required effort for participation. Data on exposure to risk factors and the prevalence of arm, shoulder and neck symptoms were collected using an internet-based questionnaire. The workers were contacted by e-mail and were given time during work to fill out the questionnaires. Participants received an e-mail containing a link to the questionnaire, their ID-number and password. The questionnaire consisted of several items on work, work place and musculoskeletal health (98 items in total). By request, they were sent a hard copy of the questionnaire by regular post.

2.4.1. *Assessment of risk factors*

The internet-based RSI QuickScan investigates the presence or absence of potential risk factors, such as work posture and movement, job decision latitude, relation with management and colleagues, work pace and load, work environment factors, and furniture (Speklé *et al.* 2009). The questionnaire included scales, with each scale consisting several yes/no questions, on: information on computer work and health, work hours, work posture and movement, work tasks, job decision latitude, work relation with management and colleagues, work pace and load, recovery time, work environment factors, furniture, and computer workstation physical attributes. For each of these scales, a risk score was determined by calculating the percentage of answers on questions within the scale that were indicative of a high risk. In accordance with the rationale for intervention allocation in the RSI QuickScan programme, a low to medium risk was defined as a score of 60% or less and a high risk was defined as a score of 61% or more. For example, the scale on work tasks consists of six questions, if the respondent indicates a risk on four or more of these questions a high risk for this scale is assumed. The questionnaire has been described in more detail previously (Speklé *et al.* 2009) and can be found at www.rsiquickscan.com/research/questionnaire.pdf. In addition to the separate scales of the potential risk factors, also a combined risk factor was created that was defined as high risk when a participant scored a high risk on four, or more, potential risk factors.

2.4.2. *Assessment of symptoms*

The 6-month prevalence of arm, shoulder and neck symptoms was assessed using modified questions of the Standardised Nordic questionnaire (Kuorinka *et al.* 1987), which specifies seven (instead of five in the Nordic

Table 1. Characteristics of the study population for each of the five measurements.

	T0 ($N = 2049$)	Non-response T0–T1 p-value***	T1 ($N = 1485$)	Non-response T1–T2 p-value***	T2 (N = 1278)	Non-response T2–T3 p-value***	T3 ($N = 1195$)	Non-response T3–T4 p-value***	T4 ($N = 1043$)
Gender (male)	648 (31.6%)	0.19	491 (33.1%)	0.51	409 (32.0%)	**0.00**	452 (37.8%)	0.51	402 (38.5%)
Age (years) (mean, SD)	42.6 (9.3)	0.20	43.0 (9.1)	0.94	43.1 (9.2)	**0.05**	43.7 (8.9)	**0.01**	44.0 (8.9)
Risk factors									
Information	49.3%**	**0.03**	44.2%**	**0.00**	41.0%**	0.40	46.0%**	0.00	46.7%**
Work hours	6.2%**	0.96	5.4%**	**0.04**	5.1%**	0.73	6.6%**	0.60	7.6%**
Work posture and movement	15.1%**	0.14	12.4%**	0.71	10.3%**	0.42	11.0%**	0.12	8.7%**
Work tasks	19.1%**	**0.02**	15.8%**	0.69	16.1%**	**0.01**	14.5%**	**0.04**	16.6%**
Job decision latitude	6.9%**	**0.00**	6.9%**	0.12	7.5%**	0.43	9.5%**	0.50	9.5%**
Work relation with management and colleagues	13.5%**	**0.00**	13.3%**	0.28	16.3%**	0.21	22.0%**	0.38	18.7%**
Work pace and load	38.3%**	0.69	34.7%**	0.51	35.3%**	0.82	36.9%**	0.23	45.8%**
Recovery time	8.8%**	0.11	7.5%**	0.22	10.0%**	0.10	11.6%**	0.59	12.3%**
Work environmental factors	7.2%**	0.74	8.0%**	0.74	5.8%**	0.94	5.2%**	0.87	5.5%**
Furniture	5.5%**	0.07	3.2%**	0.24	4.4%**	0.19	3.5%**	0.28	4.0%**
Computer workstation physical attributes	3.5%**	0.44	3.9%**	0.40	3.8%**	0.35	3.1%**	0.56	4.5%**
Eyesight	37.0%**	0.05	32.8%**	0.37	29.9%**	0.81	30.1%**	0.22	30.7%**
Neck, shoulder and arm symptoms									
Prevalence symptoms	59.1%	0.27	51.3%	0.37	48.4%	0.07	48.0%	0.63	61.5%

Note: N represents the numbers of workers who participated in this measurement.**Percentage workers with a high risk score.***Group differences were tested with the chi-square test. Significant results are presented in bold face.

Questionnaire) areas in the upper extremity region (neck, upper back, shoulder, elbow, forearm, wrist, hand), as suggested by Sluiter *et al*. (2001). Workers had to answer the question: 'Have you had trouble (aches, pain, discomfort) in the neck, upper back, shoulders, elbows, lower arms, wrist or hand in the previous 6-months?', with one of the following four response options: 'No, never'; 'Yes, sometimes'; 'Yes, regularly'; 'Yes, prolonged'. A case of arm, shoulder and neck symptoms was defined as reporting regular or prolonged symptoms, in one or more of the seven regions, in the previous 6 months. A case did not had to be preceded by a symptom free period of time or an increase in symptom severity to become a case.

2.5. *Statistics*

To determine whether the RSI QuickScan questionnaire is able to predict the future prevalence of arm, shoulder and neck symptoms in a population of computer workers, generalised estimating equations (GEE) were used, which is an extension of generalised linear models that accounts for correlated repeated measurements within individuals (Zeger and Liang, 1986, Zeger *et al*. 1988, Twisk *et al*. 2000, Ballinger 2004), with 6, 12, 18 and 24 months time lags. At all five time points, exposure to risk factors and the prevalence of arm, neck and shoulder symptoms were measured. The GEE time lag model was used to evaluate whether high scores on risk factors and the prevalence of arm, neck and shoulder symptoms were related to the arm, neck and shoulder symptoms were reported 1, 2, 3 or 4 surveys later, thus taking into account the temporal sequence of cause and effect (Twisk 1997, Hoogendoorn *et al*. 2002). Figure 1 shows the 6-, 12-, 18- and 24-month time lag models, where the dependent

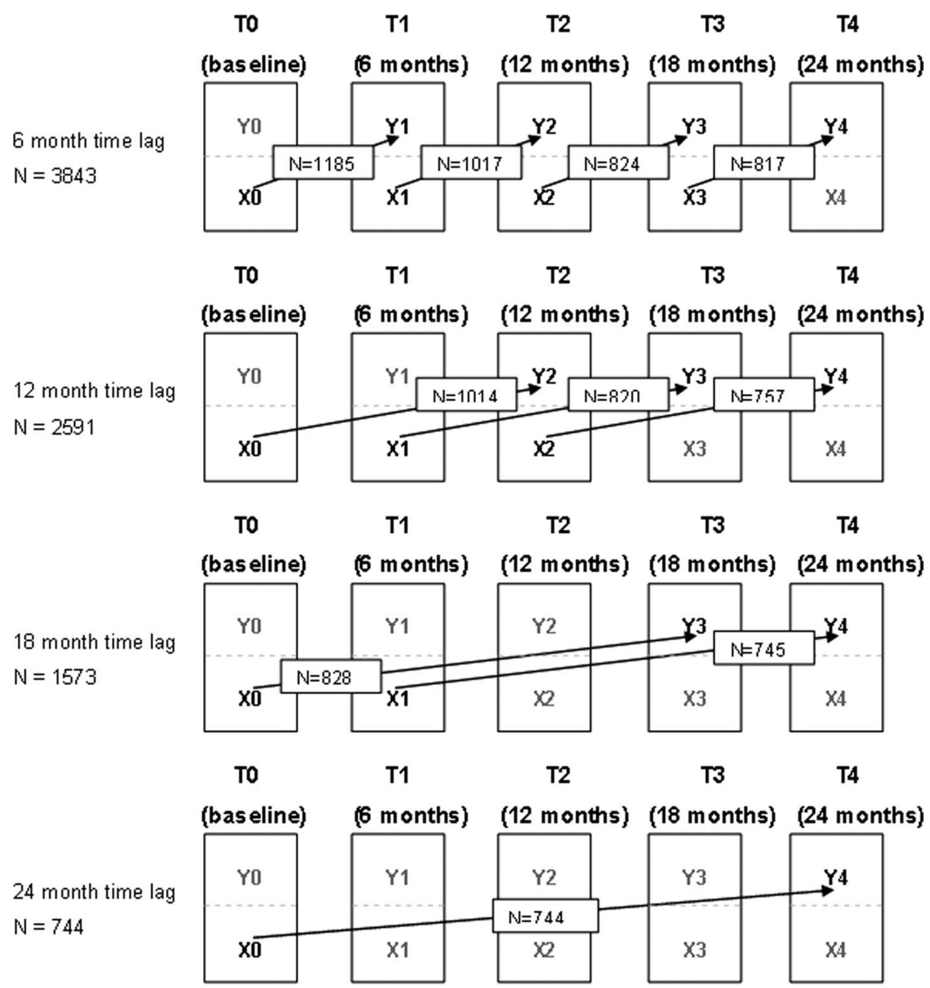

Figure 1. Illustration of the generalised estimating equations (GEE) with 6-, 12-, 18- and 24-month time lag models. Note: The number of workers is represented for each of the tested associations. Y is the dependent variable and *X* is the independent variable. T0 = baseline, T1 = 6 months, T2 = 12 months, T3 = 18 months and T4 = 24 months, after baseline.

variable (Y) is arm, shoulder and neck symptoms, and the independent variables (X) are the risk factors and previous arm, shoulder and neck symptoms. The figure illustrates that if a worker participates at all five measurements, he or she contributes with four associations between X and Y six months later. As these four associations are not independent observations but related, a regression technique for repeated measurements is called for, thus requiring the use of GEE. The dependent variable was dichotomous ('yes' or 'no' symptoms) and therefore a binary logistic model was applied. In univariate analyses crude odds ratios (OR) with corresponding 95% confidence intervals (95% CI) were calculated for all risk factors studied, including previous symptoms, for all time lags.

The odds ratio is a way of comparing whether the probability of a certain event is the same for two groups (a high risk group and a low risk group). An odds ratio of 1 implies that the event (symptoms) is equally likely in both groups. An odds ratio greater than one implies that the event is more likely to occur in the high risk group compared to the low risk group and an odds ratio less than 1 implies that the event is less likely to occur.

Differences between the respondents and non-respondents at T1 were examined with the chi-square analyses. An alpha level of 0.05 was used. All analyses were conducted using SPSS version 16 (SPSS 2007).

3. Results

3.1. *Non-response analysis*

Of the 2049 participant who filled in the questionnaire, 1485 also filled in the questionnaire at T1. Comparing the characteristics of those 1485 participants (respondents) to the 564 participants who did not fill in the questionnaire at T1 (non-respondents) gives some indication whether the non-response at T1 was selective. There were no significant differences between the respondents and non-respondents at T1 with regard to the outcome variable prevalence of arm, shoulder and neck symptoms in the previous 6 months, nor were there significant differences in age and gender between respondents and non-respondents. However, there were significant differences between respondents and non-respondents with regard to 4 of the 12 risk factors. Non-respondents at follow-up (T1) had significantly lower risk scores on the scales 'information', 'work tasks', 'work relations with management and colleagues', but a higher risk score on 'job decision latitude'. Figure 1 shows the number of workers represented in each of the tested associations.

3.2. *Associations between high exposure and the 6 months prevalence of symptoms with arm, shoulder and neck symptoms at follow-up*

The binary logistic GEE analyses with 6-, 12-, 18- and 24-month time lags (Table 2) showed a significantly higher probability of reporting future arm, neck and shoulder symptoms, with ORs at different time lags ranging from 1.3 to 3.1, for the scales: work posture and movement, work tasks, job decision latitude, work relation with management and colleagues, work pace and load, recovery time, work environmental factors, furniture, eyesight, and previous arm, shoulder and neck symptoms. The workers with a combination of four high risk scores also showed a significantly higher probability of reporting future arm, neck and shoulder symptoms, with ORs at different time lags ranging from 1.5 to 2.1. For the remaining scales (information, work hours, and computer workstation physical attributes) having a high risk score on these factors did not increase the risk of reporting arm, neck and shoulder symptoms in the future.

3.3. *Associations between previous symptoms and future arm, neck and shoulder symptoms*

Results of the GEE analyses with a 6, 12, 18 and 24 month time lag (Table 2) showed that previous arm, shoulder and neck symptoms were significantly related, to a higher risk (ORs ranging from 4.1 to 6.6) of future arm, neck and shoulder symptoms.

3.4. *Comparison of the results with different time lags*

The GEE analyses (Table 2) showed consistent results for all four time lags, except for the scale on work environment factors and the scale on furniture. The scales on work posture and movement, work tasks, work pace and load, recovery time, work environment factors, eyesight and symptoms showed ORs greater than 1 for all four time lags. The risk estimates for the scales work posture and movement, works tasks and recovery time showed a

Table 2. Results of four different time lags concerning the relation between risk factors and previous symptoms on the one hand and for future arm, shoulder and neck symptoms on the other.

GEE time lag model	6 months OR (95% CI)	12 months OR (95% CI)	18 months OR (95% CI)	24 months OR (95% CI)
Risk factors				
Information	0.95 (0.83–1.08)	0.95 (0.82–1.12)	0.89 (0.73–1.08)	1.08 (0.80–1.45)
Work hours	1.21 (0.94–1.56)	1.21 (0.87–1.68)	1.03 (0.68–1.55)	0.75 (0.43–1.32)
Work posture and movement	1.27 (1.20–1.69)	1.55 (1.25–1.91)	1.74 (1.29–2.37)	2.04 (1.26–3.31)
Work tasks	1.42 (1.06–1.52)	1.41 (1.14–1.76)	2.06 (1.53–2.77)	2.41 (1.45–4.00)
Job decision latitude	1.29 (1.00–1.65)	1.58 (1.14–2.19)	1.68 (1.09–2.57)	1.30 (0.65–2.62)
Work relation with management and colleagues	1.33 (1.13–1.57)	1.57 (1.27–1.95)	1.07 (0.81–1.43)	1.08 (0.68–1.72)
Work pace and load	1.26 (1.11–1.44)	1.30 (1.11–1.52)	1.23 (0.99–1.52)	1.34 (0.99–1.82)
Recovery time	1.70 (1.36–2.12)	1.81 (1.37–2.40)	1.82 (1.26–2.61)	3.15 (1.57–6.32)
Work environment factors	1.34 (1.06–1.69)	1.06 (0.79–1.43)	1.50 (1.00–2.27)	1.76 (0.92–3.38)
Furniture	0.95 (0.69–1.32)	1.87 (1.22–2.88)	0.94 (0.57–1.55)	1.27 (0.59–2.73)
Computer workstation physical attributes	1.20 (0.84–1.71)	1.06 (0.73–1.54)	0.84 (0.51–1.39)	0.71 (0.35–1.43)
Eyesight	1.38 (1.20–1.59)	1.71 (1.44–2.03)	1.63 (1.32–2.03)	1.59 (1.15–2.20)
Combination of four high risk scores	1.50 (1.25–1.79)	1.82 (1.47–2.26)	1.75 (1.31–2.33)	2.06 (1.31–3.25)
Previous symptoms				
Arm, shoulder and neck symptoms	6.63 (5.61–7.83)	4.49 (3.72–5.41)	4.05 (3.24–5.06)	4.71 (3.43–6.48)

Note: The GEE analyses with a 6, 12, 18 and 24 months time lag model, show the odds ratios (OR) with 95% confidence intervals (95% CI) for arm, shoulder and neck symptoms after 6, 12, 18 and 24 months of follow-up.

steady increase over time. However, the overall number of significant ORs for the scales decreased with longer, 18- and 24-month time lags (Table 2).

4. Discussion

4.1. *Summary and interpretation of findings*

The aim of this study was to determine whether results from the RSI QuickScan questionnaire on risk factors for arm, shoulder and neck symptoms can predict the future prevalence of arm, neck and shoulder symptoms. The results indicate that most scales of the RSI QuickScan questionnaire are valid tools to predict future prevalence of arm, neck, and shoulder symptoms in computer workers.

4.2. *Non-response analysis*

To analyse the non-response in our study population, we compared the baseline values of the outcome variable arm, neck and shoulder symptoms as well as age, gender and risk factors of the participants that also filled in the questionnaire at T1 with the baseline values of the participants that did not fill in the questionnaire at T1. We also analysed non-response between T1–T2, T2–T3, and T3–T4. Since the non-response between T0 and T1 was larger than the combined non-response of T2, T3 and T4, we focused on the non-response between T0 and T1. We found no differences in the prevalence of arm, neck and shoulder symptoms between any of the consecutive measurements, suggesting that there was no health-based selection in our study population. Nor were there differences in age and gender between T0 and T1. However, the workforce did appear to be getting older and more male during the study. This can be explained by the fact that the workers who joined the organisation in the last decennia were primarily female and younger workers and the participating organisation downsized considerably during the study. The organisation terminated the contract of the last person engaged in employment ('Last In First Out'), first. This resulted in an increased non-response of younger and female workers. Therefore, the non-response was non-differential and did not affect the associations of exposure and effect. The non-respondents at follow-up had significantly lower risk scores on the scales 'information', 'work tasks', 'work relations with management and colleagues', but a higher risk score on 'job decision latitude', suggesting that there might have been some selection in our study population. This may have violated the 'missing completely at random' (MCAR: missing, independent of both unobserved and observed data) assumption in our analyses and may have caused some bias to our estimates (Zeger and Liang 1986, Zorn 2001). However, since the pattern on the occurrence of arm, neck and shoulder symptoms during follow-up is assumed to be random, the effect of this potential bias is believed to be limited. Missing data because of non-response were not imputated, because when GEE are used to analyse a longitudinal dataset with missing data, imputing missing data with longitudinal imputation methods (i.e. last value carried forward, longitudinal interpolation, and longitudinal regression) or multiple imputation, may lead to an under- or overestimating of the standard errors, depending on the chosen imputation method. Therefore, not imputing at all may be better than any of these imputation methods (Twisk and De Vente 2002).

During the two years of the study, the participating organisation downsized considerably and reduced its workforce by approximately 30%. This process, which was independent of the predictor and outcome variables, caused many participants to involuntarily leave the study and was a major contributor to the non-response. Pilkington *et al.* (2001) identified restructuring as major contributor to stress and there is scientific evidence indicating that work organisation and psychosocial work factors are associated with the development of arm, shoulder and neck symptoms (Buckle and Devereux 2002). Furthermore, organisational instability owing to restructuring, expansion and downsizing has been associated with ill-health and increased sickness absence (Leka and Jain 2010). Moreover, significant relations between downsizing and long periods of sick leave, irrespective of cause, and separately with regard to absence because of musculoskeletal disorder and trauma were found (Vahtera *et al.* 1997). Older individuals and those in workplaces with a high proportion of older employees were at greatest risk of long periods of sick leave, especially sick leave due to musculoskeletal disorders. In workplaces with a high proportion of older employees, major downsizing by workplace may lead to a 10-fold increase in the risk of an individual developing musculoskeletal disorders compared with minor downsizing. Since our study took place during a period of downsizing and approximately half of our population consisted of older workers, we expect that our results show a higher than normal prevalence of arm, shoulder and neck symptoms. However, it is uncertain whether this would affect the presented ORs. Downsizing might not only increase the prevalence of symptoms, it might also lead to higher exposure to high risks and higher subjective reports of exposure.

4.3. Strengths and limitations of the study

An important strength of our study is its prospective design, with five measurements over a two-year period, which allowed for repeated measurements of exposure that adjust for changes in the workplace that might occur. To study the predictive validity of our method of assessment we needed to stay as close as possible to the intervention programme as used in practice, i.e. identify workers with high risks. As such, the predictive validity of the questionnaire is defined as the extent to which a high-risk score on one (or a combination) of the scales predicts reporting symptoms at a later time. This is conceptually different from an etiological study, which aimed at trying to explain the actual cause(s) of the symptoms Therefore, we have chosen not to adjust for the influence of variables, such as previous arm, neck and shoulder symptoms, as might be preferable for an aetiological study and we refrained from drawing conclusions on aetiology.

The scale on previous symptoms was used both as a risk factor and as an outcome measure. This may be considered a flaw in the design of the study. However, previous symptoms can be predictors of current symptoms either because symptoms have become chronic or because they are recurrent. In this context, using the same measurement tool to assess the predictor and outcome actually seems preferable. It could also be argued that previous questions in the RSI QuickScan may bias later questions. However, there is no conclusive evidence that question-order affects response (Bradburn and Mason 1964). In the online questionnaires of the RSI QuickScan, the 'screen-by-screen approach' provides less context than people normally have for answering questions, when compared to paper questionnaires and consequently respondents may have lost sense of context (Dillman *et al.* 1999), which would prevent bias. In addition, it is debatable whether the respondents will perceive their answers as high risk (and therefore are more likely to report symptoms in order to be consistent). Furthermore, measuring symptoms separately may introduce negative effects, i.e. an increased non-response rate.

For practical reasons, we performed this study in one company and one could argue that it might have been better for the generalisation of the results if more organisations had been included. However, the organisation was fairly large ($N = 3383$), with offices throughout the Netherlands and a broad range of computer workers with diverse educational levels, ranging from intermediate to university education. The respondents were representative with respect to exposure (Speklé *et al.* 2010) and age (21–66 years). Even though females were overrepresented compared to the general population, with two-thirds being female, this is representative for many organisations with computer workers.

One final limitation may be that the GEE method does not correct for feedback bias that may occur with repeated measurements of exposures and outcome variables, where earlier outcomes may affect subsequent exposure (Eisen 1999). However, such effects are likely to be limited given the 6 months period between filling out questionnaires.

4.4. Risk factors and symptoms

Little research has been done on the predictive validity of risk factors and previous symptoms for arm, neck and shoulder symptoms (Viikari-Juntura *et al*. 2000). Unfortunately, no comparable studies were found, in which the predictive validity of a questionnaire on risk factors and previous symptoms to arm, neck and shoulder symptoms at follow-up was investigated in a population of computer workers with and without symptoms.

In a previous reliability study (Speklé *et al*. 2009), each item of the subscales was tested separately and consequently no reliability study was performed with the cut-off scores for the sub-scales that are used at present. However, multi-item scales, even short ones, are more reliable than the single items (Duncan *et al*. 1999). Therefore, the results in our previous study are likely to be conservative and no additional analysis was performed.

The results with regard to the risk factors: work posture and movement, work tasks, job decision latitude, work relation with management and colleagues, work pace and load, recovery time, work environmental factors and eyesight, were found to be statistically significant and indicate that these scales can be helpful in predicting which workers are at risk of having future arm, neck and shoulder symptoms. The scales were constructed based on evidence from aetiological studies several years ago. However, present results on the predictive validity of the questionnaire compare well with aetiological findings in more recent systematic reviews on occupational risk factors for arm, neck and shoulder symptoms (Fagarasanu and Kumar 2003, Hadler 2003, Visser and Van Dieën 2006, IJmker *et al*. 2007, Waersted *et al*. 2010), which strengthens our results. It seems likely that arm, neck and shoulder symptoms are the result of many factors; including physical load and the psychosocial work environment and that these factors can reinforce each other (Van der Windt *et al*. 2000, Bongers *et al*. 2006). Several studies found that having had previous symptoms is a strong predictor of future symptoms and it can be concluded that musculoskeletal symptoms are persistent (Juul-Kristensen *et al*. 2004, Nordlund and Ekberg 2004, Silverstein *et al*. 2006, Descatha *et al*. 2008). Results in our study also indicate that current symptoms can be helpful in identifying workers at risk of future arm, neck and shoulder symptoms. This information can subsequently be used to allocate tailored interventions, aimed at the prevention of symptoms in the future. The results indicate that the scales on information, work hours, and computer workstation physical attributes neither predicted arm, neck and shoulder symptoms at 6 months, nor at the other three longer time periods of 12, 18 or 24 months. The scale on furniture showed inconsistent results over the four time periods. When we combine these results with previous results on the internal consistency of the scales (Speklé *et al*. 2009), we find that all of these scales also scored poorly on internal consistency. The scale on work hours and the three scales on workplace ergonomics (work environment factors, furniture, and computer workstation physical attributes), all scored Cronbach's alpha between 0.30 and 0.45, whereas the other six scales scored 0.70 or higher. Since the scale on information consists of only one question, no Cronbach's alpha was calculated. We therefore suggest the removal of these three scales, which previously also have shown to have poor internal consistency, from the RSI QuickScan questionnaire. Even though the scale on information did not predict future symptoms arm, neck and shoulder symptoms, it does provide important information for organisations, since informing their employees on healthy computer use and the risks involved with computer work is a requirement by law in the Netherlands. Further research to determine the optimal cut-off points of each of the scales by calculating optimal sensitivity and specificity, would be useful. The goal of this study was to evaluate its usage and not its aetiological strength. Nevertheless, the available data might be used for more aetiological studies in the future.

Does the RSI QuickScan tool work as well or better than simply monitoring arm, neck and shoulder symptoms alone? Table 2 shows that having had regular or prolonged symptoms, in one or more of the seven regions, in the previous 6 months was the strongest predictor of future symptoms. However, focusing solely on previous symptoms would only be helpful in identifying workers with previous symptoms (and a high risk of future symptoms). It would not provide any guidance on primary preventative measures for workers without symptoms. The scales on risk factors and symptoms in the RSI QuickScan complement each other. Therefore, the RSI QuickScan tool works better than simply monitoring arm, neck and shoulder symptoms alone.

An effective intervention must exist for screening to reduce exposure and/or prevalence of symptoms. Therefore, the programme must not only consist of a screening instrument with sound psychometric properties, but also offer effective interventions. In a related study on the effectiveness of a questionnaire based intervention programme on the prevalence of arm, shoulder and neck symptoms, risk factors and sick leave in computer workers, the effects of the RSI QuickScan intervention programme were small (Speklé *et al*. 2010). This may have been the result of difficulties with the implementation process of the proposed interventions. Some significant positive effects were found as to an increase in receiving education and a decrease in exposure to adverse postures and movements. With regard to symptoms and sick leave, only small and non-significant effects were found.

4.5. *Recommendations for use of the RSI QuickScan*

The RSI QuickScan questionnaire gives individual feedback to the respondents and advice on the specific actions that they can personally take in order to reduce their risk of arm, shoulder and neck symptoms. Furthermore, organisations are advised to undertake specific interventions. Ergonomic professionals use the RSI QuickScan as a primary prevention tool and integrate it in their periodical WHS, or use it as a secondary prevention tool in case of a high incidence or prevalence of arm, neck and shoulder symptoms in a population of computer workers. When the instrument is used periodically, it is suggested to do so annually, if financial resources are available. The results from the effectiveness study (Speklé *et al*. 2010) imply that the RSI QuickScan intervention programme can be used to increase the level of education and to decrease the exposure to adverse postures and movements. Although this study did not find evidence to support the claim that the RSI QuickScan intervention programme can be used to reduce symptoms or sick leave, it cannot be ruled out that the RSI QuickScan intervention programme could be effective, especially in the secondary prevention of arm, neck and shoulder symptoms, with a more successful implementation of the interventions. Therefore, it is recommended that professionals in the field should pay close attention to the implementation of proposed interventions, since interventions will only be potentially effective if they are successfully implemented.

5. Conclusion

In conclusion, the majority of the scales (work posture and movement, work tasks, job decision latitude, work relation with management and colleagues, work pace and load, recovery time, work environmental factors, eyesight and previous arm, shoulder and neck symptoms) in the RSI QuickScan questionnaire provides valid predictions of the risk of having future arm, neck and shoulder symptoms. However, the scale on work hours, and the one on computer workstation physical attributes did not predict arm, neck and shoulder symptoms at any of the investigated time lags. The scale on furniture showed inconsistent results. The RSI QuickScan questionnaire may be recommended as a tool in the identification of computer workers who should be targeted with interventions aimed at prevention of future symptoms.

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