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Preparedness for peer first response to mining emergencies with injuries: a cross-sectional study

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ABSTRACT

Objective Identify factors of importance for being prepared for a peer first response to underground mining emergencies with injuries.

Design Cross-sectional questionnaire study of Swedish underground mineworkers.

Setting Seven out of nine Swedish underground mines.

Participants 741 mineworkers out of 1022 (73%) answered the questionnaire.

Outcome measures Level of preparedness for emergencies with injuries in underground mines.

Results Three factors emerged that influenced the preparedness of mineworkers' to peer first response; 1) *Familiarity with rescue procedures during emergencies with injuries*, 2) *Risk perception of emergencies with injuries*, 3) *Experience of using self-protective and first aid equipment*. Mineworkers of the opinion that they know how to handle emergencies with injuries and also have been trained in the use of self-protective and first aid equipment considered themselves to be better prepared for a peer first response compared to those not familiar with the rescue procedures or who had not used the self-protective and first aid equipment. However, mineworkers who rate the risk for emergencies with injuries as high considered themselves to be less prepared compared to those who rate the risk as low.

Conclusion In spite of mandatory training in first aid, mineworkers were only to some extent prepared to give first aid to their injured peers. To increase preparedness for peer first aid response in mine emergencies, a systematic program approach with contextualized and adapted first aid courses, and training the mineworkers in relevant emergency scenarios, might be used to allow the mineworkers to become confident in how to perform peer first aid.

Strengths and limitations of this study

- The study included seven out of nine underground mines in Sweden.

- High response rate (73%).
- Although the questionnaire was evaluated with a face validity test with mineworkers with relevant experience, a more comprehensive pilot study may have improved the questionnaire, as would a test/retest or random response test.
- This study is based on data from the mineworkers' self-assessed level of preparedness. A knowledge test or observation at a full-scale practical exercise could have been performed to obtain more objective measures, but was considered too resource intensive in the present study.

Keywords: Trauma management, Medical education & training, Accident & Emergency medicine.

INTRODUCTION

Mining emergencies are infrequent but may have severe consequences for mineworkers (see Table 1 for definition), thus they require an efficient and timely response.[1 2] The most common emergencies in mineral and metalliferous underground mines are fires, vehicle incidents and rock-falls.[3] Mine rescues take time regardless of whether the mining companies have their own mine rescue teams, as in most European countries, or if it is the responsibility of the local rescue services and emergency medical service (EMS), which is common in Sweden.[4 5] Time is lost as the rescue service has a long distance to travel to the remote mine[5] and furthermore, the rescue personnel must reach the site of the incident, which could be far underground.[6] Time-consuming rescue operations could be fatal for severely injured victims.[7] Reaching the incident site in a mine will consume time for the rescue organizations[7], which is why mineworkers close to the injured have to act as peer first responders. In a worst-case scenario, mineworkers might be inside a refuge chamber within a smoke-filled area several hundred meters underground with a severely injured peer. The only option might be to wait for the rescue service or mine rescue team. Thus, they have to be prepared to take care of the moderately or severely injured peer until help arrives. Essential knowledge, skills and equipment are of utmost importance.[8] The combination of being a peer to the victim and being unskilled at handling injuries may lead to emotional distress that might impede their actions.[9]

Strong recommendations have been made in order for mineworkers to be able to escape or be rescued during emergencies[10], because a lack of knowledge may have fatal consequences. For example, in the Sago mine explosion in 2006[11], 12 mineworkers died. These workers lacked knowledge of how to use self-contained self-rescuers.[12] Prior training or experience of incidents have each been shown to result in a better state of preparedness, and to influence action during the infrequent incidents that have had severe consequences.[2] Those with prior

experience of escaping from a smoke-filled mine reported feeling less stress during an exercise under similar conditions, while mineworkers lacking this experience generally act more on intuition than prior knowledge.[13]

Swedish mining companies aim to prevent and mitigate incidents, by focusing on risk management, evacuation technology, and routes.[14] Preparedness to respond to incidents is thus an essential element of any underground mine's strategic plan.[15] However, articles with focus on the medical aspects and peer first response in mining emergencies with injuries are scarce in literature.[3] This study aimed to identify factors of importance for being prepared for peer first response to underground mining emergencies with injuries.

METHOD

Design

The design of this study is a national cross-sectional survey.

Sample

Questionnaires (n=1,022) were distributed to seven participating mines between November 2016 and February 2017. The response rate was 73% (n=741) after excluding 29 individuals not working underground and 11 with more than ¼ internal missing variables. Table 1 describes the participants' characteristics.

INSERT TABLE 1 ABOUT HERE

Questionnaire

The study-specific questionnaire in Swedish was purposely designed and constructed based on preparedness literature.[16] [17] [3] The questionnaire was constructed to capture the preparedness of the mineworkers for peer rescue and peer first aid of moderately or more severely injured peers until they were rescued during emergencies. Thus, the questions focused on the mineworkers' self-perceived knowledge of injuries and first aid, their first aid

training and equipment, and the presumed risks of mining incidents, particularly concerning fires, vehicle incidents and rock-falls. Answers to the questions were either yes/no or on a five-item Likert scale (Table 2). The face validity of the questionnaire was tested on three mineworkers. The relevance and validity of the items and the questionnaire were discussed during several seminars in an iterative process by the research group.

INSERT TABLE 2 ABOUT HERE

Data collection

Sweden has 14 mineral and metal mines, nine of which are underground. Contact was made with the nine underground mine managers. Written information about the study and the questionnaire was sent to the managers for their informed consent. The main unions were also notified about the study. Seven out of nine mine managers agreed to participate and were sent questionnaires for all employed mineworkers working underground. The mine managers were responsible for the distribution and collection of the questionnaires. A letter was attached to each questionnaire informing the mineworkers that their participation was voluntary. By completing the questionnaire, the respondents gave their informed consent.

Analysis

Descriptive analysis and data management

First, a descriptive analysis of the data was performed, including minimum and maximum, mean, standard deviation, skewness and kurtosis. The descriptive analysis indicated that all questions had less than 10% missing values. Imputation with an expectation maximisation estimation was performed to impute the missing data.[18]

A significance level of 0.05 was used throughout the study. In this study, SPSS Statistics Version 24[19] was used to impute the data with an expectation maximisation estimation, and Stata Statistical Software Release 14[20] was used for all other analyses.

Exploratory factor analysis

Exploratory factor analysis was performed for data reduction purposes and to find the latent factors that make the manifest variables covary.[21] When conducting the exploratory factor analysis, six factors had eigenvalues >1. However, when comparing the constructs, and studying the resulting scree plot (Figure 1), a decision was made to retain the three factors with an eigenvalue >2. This decision was made due to the opportunity to form relevant and meaningful factors and that the scree plot starts to level out after three factors. The three retained factors were rotated using Promax and a threshold of 0.5 was chosen for the factor loadings. A value of 0.5 indicates a strong loading for the items.[21]

INSERT FIGURE 1 ABOUT HERE

Thereby, the items with a minimum loading of 0.5 from the first, second and third factors were added together. The three factor solution is shown in Table 3. Cronbach's alpha and average inter-item correlation was for Factor 1 0.86 and 0.41, for Factor 2 0.87 and 0.41 and for Factor 3 0.80 and 0.37.

INSERT TABLE 3 ABOUT HERE

The three factors illustrate mineworkers' medical peer response preparedness. They were: 1) *Familiarity with rescue procedures during emergencies with injuries*, containing the questions Q3, Q4a-Q4d and Q5a-Q5d 2) *Risk perception of emergencies with injuries*, covering the questions Q2, Q6a-Q6e and Q7a-Q7d, and 3) *Experience of using self-protective and first aid equipment* containing questions covering Q1a stretcher, bandages, splints, eye rinse, defibrillators, self-contained self-rescuers and fire extinguishers.

Multiple logistic regression

In the multiple logistic regression, the three factors were used as independent variables and "Do you consider yourself prepared to respond (before the EMS or rescue personnel arrive at the incident site) to emergencies, e.g. fire, explosions or rock-falls in the mine?" was used as

the global dependent variable. The post-estimation tests of the Pearson $\chi 2$ goodness-of-fit test as well as the Hosmer-Lemeshow test were performed and were insignificant, indicating a good model fit.[22]

Participant and public involvement statement

Neither the public, nor the participants were involved in the design of this study. However, the questionnaire was tested for face validity both from a mining employer and employee perspective.

RESULTS

Below are some highlights of how the mineworkers answered the questionnaire (Table 2). Eighty-one percent of the mineworkers consider there to be some risk to a very high risk to injure themselves at their workplace. When asked what kind of major incident scenarios they thought were likely, eighty percent of the mineworkers considered there to be some risk to a very high risk of a major fire incident that would require the rescue service to be contacted. One fourth (25%) of the mineworkers consider there to be a high or very high risk for moderate or more serious injury during major fire incidents. While major fires were considered to be probable, explosions were not considered as likely. Sixty-eight percent of the mineworkers consider there to be a low or very low risk of major explosions involving injury and 57% of the mineworkers think there is a low or very low risk of major explosions leading to moderate or more serious injury or death. The mineworkers also answered whether they considered their mine to be prepared for an underground incident involving multiple injured mineworkers. Eighty-six percent of the mineworkers believed their mine to be prepared from some extent to a very high extent.

Seventy-nine percent of the mineworkers considered themselves to be prepared to respond in the event of an emergency. A third of the mineworkers (33%) considered that they to a high or very high extent would know how to act if they witness a peer crashing a vehicle and

become moderately or more seriously injured. Thirty-eight percent would also to a high or very high extent know what to do if a truck catches fire with the driver being trapped in the vehicle and 56% would to some extent know what to do. Forty-three percent of the mineworkers knew how to act if a peer would suffer cardiac arrest. Almost all (91%) of the mineworkers reported that they had received first aid training and 22% of the mineworkers had experience in helping an injured peer. However, if a peer was moderately or more severely injured, only 27% considered themselves to a high or very high extent be able to help. Nearly two-thirds (60%) of the mineworkers thought that they to some extent would know how to give peer first aid response and help a moderately or more severely injured peer.

In order to be able to help injured peers, the mineworkers have to have knowledge, access to and confidence in using several different kinds self-protective and first aid equipment. Just to name a few, 68% had access to a stretcher, about one fourth (24%) of the mineworkers had ever used one and 55% considered themselves comfortable using it. Seventy-five percent of the mineworkers considered themselves to be comfortable using bandages and 25% considered themselves to be comfortable using splints. Eighty-five percent of the mineworkers had access to a defibrillator, 44% had ever used one and 60% considered themselves comfortable using it. Seventy-three percent of the mineworkers had used a fire extinguisher and almost all (95%) of them felt comfortable using it.

These highlights show that a lot of interesting data has been collected. Therefore, the choice was made to further analyse the data through finding some encompassing factors, which could find the essence of the necessary preparedness of the mineworkers for peer first response.

The three constructed factors illustrate aspects and relevance of mineworkers' medical peer first response preparedness. *Familiarity with rescue procedures during emergencies with injuries* include if the mineworkers know how to act during stressful situations when there has been an emergency, and a peer has been injured in the vicinity. *Risk perception of*

emergencies with injuries includes how the mineworkers interpret the perceived risk for emergencies with injuries at their workplace. *Experience of using self-protective and first aid equipment*, includes if the mineworkers have used/know how to use equipment, such as a stretcher, bandages, splints, self-contained self-rescuers and fire extinguishers.

If the mineworkers were familiar with the rescue procedures during emergencies with injuries, they also felt more prepared to respond before the rescue services and EMS arrive, compared to those not familiar with the rescue procedures (OR = 1.30, 95% CI 1.22-1.38). If the mineworkers considered there was a great risk of emergencies with injuries occurring there was also less probability that they felt prepared to respond, compared to those considering there was a low risk of incidents (OR= 0.95, 95% CI 0.91-0.98). If the mineworkers had experience of using their self-protective and first aid equipment, they were also more prone to respond, compared to those not having any experience in using their self-protective and first aid equipment (OR = 1.19, 95% CI 1.07-1.32). Thus, there were significant associations between the three factors of preparedness and the global variable of self-reported preparedness. The perceived level of preparedness increased if they were familiar with rescue procedures and had experience in using self-protective and first aid equipment, but their perceived level of preparedness decreased if they perceived there was a great risk for incidents.

DISCUSSION

(i) *Familiarity with rescue procedures during emergencies with injuries*, (ii) *risk perception of emergencies with injuries* and (iii) *experience of using self-protective and first aid equipment* were of importance for mineworkers perceived level of preparedness for emergencies with injuries.

This study showed that 30% of the mineworkers considered there to be a high or very high risk and 51% considered there to be a moderate risk of sustaining injuries at their workplace. Although 79% of mineworkers considered themselves to be prepared to respond in the event of emergencies – and although virtually all of them had received first aid training – the majority of them (60%) considered that they merely to some extent would know how to help an injured peer. There might be a risk that this is an overestimation of their knowledge in performing first aid.[23] However, other authors have also shown that, in general, people tend to help but may have a low confidence in their first aid skills and training and have several other barriers for delivering first aid, e.g. the worry of making mistakes, which could further harm the injured person.[23-25] In line with our findings, training responders in first aid as recommended by other authors,[24 25] could improve their self-confidence and willingness to respond. The first aid training might focus on typical injuries and illnesses relevant for the underground environment.

In this study, mineworkers familiar with the rescue procedures, also considered themselves to be more prepared to respond to incidents before the rescue services and emergency medical service arrive, compared to those not familiar with the rescue procedures. For example, at least nine out of ten mineworkers knew partly or completely what to do if a vehicle crashes and/or if it catches fire and the driver is moderately or more seriously injured. Preparing mineworkers includes training them in e.g. using their self-contained self-rescuers or in solving complex dilemmas during emergencies.[2 26] The Mine Safety Technology and Training Commission[10] suggest that there are three skills that mineworkers must have in order to be able to self-escape or be rescued: (i) have knowledge of escape/rescue technologies; (ii) have mine-specific knowledge in order to be able to find the evacuation routes; and (iii) have escape/rescue conceptual knowledge in order to be able to make difficult decisions in an emergency situation. Therefore, in order to respond to and survive emergencies with injuries,

they need to have comprehensive knowledge about rescue procedures and technologies. To facilitate the rescue of the injured, it would be an advantage if the mineworkers and the rescue personnel were training together.

The mineworkers in the present study were asked if they knew how to act in several difficult situations involving an injured peer (Table 2). Their answers indicate that the majority of the mineworkers considered themselves to be prepared to respond only to some extent. Their ability to respond includes also making sound decisions and judgements during stressful situations.[27] As in the present study, training the mineworkers in their emergency skills has been shown to increase their preparedness for handling emergencies.[27] However, the efficacy of the self-escape training in communication, collaboration, leadership development, responsibility and accountability may be limited due to both structural and individual factors.[28] Mineworkers responding to dilemmas about critical self-rescue and escape skills did not always choose the safest option, even though they understood the consequences of their choices. [26] Two difficult dilemmas included (i) leaving an injured mineworker behind and (ii) trying to rescue missing mineworkers during unsafe conditions.[26] Because mineworkers often respond to emergencies as a group,[10] they also have to make optimal decisions for the whole group to escape. Training the mineworkers to collaboratively make decisions and self-escape in simulated smoke may improve their ability to escape.[10] To further increase preparedness, testing the entire emergency response system would be beneficial.[29] Training the mineworkers may include both table top-exercises where the mineworkers can discuss different dilemmas and best practice when handling injuries, as well as full-scale scenario training.

In the present study 30% of the mineworkers consider that there is a high or very high risk of sustaining injury at their workplace. The mineworkers also considered that major fires were more likely to occur than uncontrolled explosions. Mineworkers who consider there to be a significant risk of emergencies with injuries assess themselves as being less prepared to act

before the rescue and emergency medical services arrive, compared to those that consider there is a low risk. This is in line with the results of a study showing that first aid training can make the workers more aware of the hazards in their work-place.[30] Training has been shown to increase the likelihood of optimal behaviour and decrease the risk of injury,[31] but it needs to be context sensitive and consider the specific conditions at different mines,[32] as well as providing each mineworker with sophisticated training in evacuation strategies.[12] Thus, mining companies may consider this, particularly as mineworkers onsite are not only first responders, some of them also have duties as guides for the rescue services.[33] Although most of the mineworkers in present study have attended regular first aid courses, the connection to the underground mining incident panorama might not have been evident. Included in the first aid course could also be discussions of the psychological strain that emergencies with injuries could impose on the mineworkers. It may be necessary for the mineworkers to help a moderately or more severely injured peer in a rescue chamber for a long time before the rescue and emergency services arrive. The peers may feel helpless because they are unable to provide the appropriate level of care to the injured.[12] Although 60% of the mineworkers in the present study felt comfortable using a defibrillator, if they would have to perform cardiopulmonary resuscitation they may feel exposed and powerless.[34] Therefore, adjusting the first aid course to become more relevant to the mining context including the psychological aspects needs to be further explored.

Present results show that mineworkers who had experience in using self-protective and first aid equipment, e.g. self-contained self-rescuers (50%), bandages (52%) or defibrillators (44%), also considered themselves to be more prepared to respond during emergencies with injuries. It has been shown that hands-on training with first aid equipment improved lay person skills.[35] Other authors have recommended that the mineworkers practice using their self-contained self-rescuers because, on several occasions, mineworkers have claimed that

their equipment did not work in a real emergency.[2] The equipment used during emergencies needs to be easy to use even in highly stressful situations.[5] To increase the preparedness of the Swedish mineworkers, the regulation require annual evacuation training[14] which preferably may include use of self-protective and first aid equipment.

The present study identified three important factors for preparedness. These factors may be considered to be implemented in first aid courses. The mine companies have, according to the law, great responsibility to train their personnel for emergency scenarios and the personnel need to practice realistic and relevant scenarios during both table-top and practical exercises. This may improve confidence in how to act in case of emergencies with injuries.

CONCLUSIONS

Although the companies continuously work on incident prevention, emergencies with injuries still occur. Therefore, a systematic focus on peer first response is necessary to deliver aid within a limited timeframe. It might be necessary to review and revise the content of the first aid courses to better adapt them to a mining context, as well as including both theoretical and practical elements. Therefore, a program approach focusing on peer first response with well-structured and systematic table-top exercises, followed by well-defined skills training exercises, and finally full-scale realistic scenario trainings including all different rescue organizations might have the potential to mitigate the consequences of emergencies with injuries.

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Contributors: The study was initiated, conceptualized and supervised by BIS, UB, LG and SK. SK collected and analysed the data as well as drafted the manuscript. The manuscript was reviewed and revised by SK, BIS, UB, MH and LG. All authors read and approved the final manuscript.

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Patient and public involvement: Neither patients nor the public were included in the design, or conduct, or reporting, or dissemination plans of the research.

Ethical considerations: The study has been performed in accordance with the Helsinki declaration.[36] The subject area and methods of this study are excluded from ethical wetting according to the Swedish Act concerning the Ethical Review of Research Involving Humans (SFS 2003:460)[37] and therefore no ethical permission has been sought. Measures have been taken to protect the anonymity and free will of the participants. The participating mines were sent paper questionnaires and information letters. The information letters informed the participants about the study and that it was completely voluntary to participate. They were also informed that the results were to be presented at the group level and no one would be able to identify individual answers. Although the participants were encouraged to answer all questions, they were free to hand in a blank questionnaire or only partly answer the questionnaire. No sensitive personal information was collected. The participants gave their informed consent by anonymously answering the questionnaires. The participants were completely anonymized to the researchers as the data collection method made it impossible to create code-lists.

Data availability statement: All data relevant to the study are included in the article.

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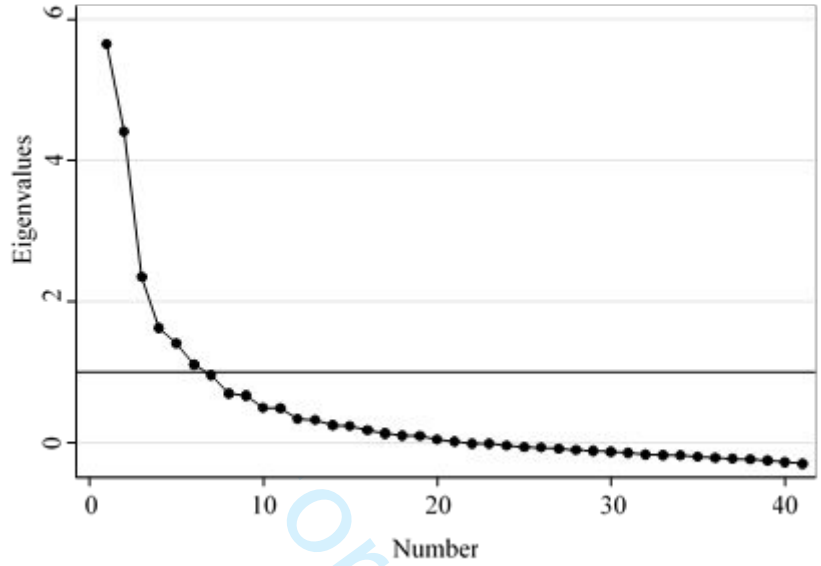


Figure 1 Scree plot of the eigenvalues as a rationale for the choice to use three factors in the analysis

Table 1. Characteristics of the mineworkers in the study

Variable	Respondents n=741
Sex	
Female	77 (10%)
Male	658 (89%)
Not reported	6 (1%)
Age (years)	Mean 40.4, SD 11.7
Work experience (years)	Mean 11.9, SD 10.9
Mineworker occupation*	
Miner-labourers	285 (39%)
Maintenance-technical staff	399 (54%)
Supervisors-managers	55 (7%)
Not reported	2 (0%)
Extra rescue guide/medical training and responsibility	
Yes	86 (12%)
No	595 (80%)
Not reported	60 (8%)

* Mineworkers consist of miner-labourers, maintenance-technical staff and supervisors-managers. Miner-labourers work with mineral processing. Maintenance-technical staff comprises, for example, electricians and machine operators. Supervisors-managers include all forms of supervisors and managers who work underground (c.f. Cole et al., 1998)

Table 2 Questions and responses (n=741)*

	Questions	Frequencies n(%)				
		a) Have you used self-protective and first aid equipment before?		b) Do you have access to self-protective and first aid equipment?		c) Do you consider yourself as being comfortable using self-protective and first aid equipment?
Q1		Yes		Yes		Yes
	Stretcher	177 (24%)		501 (68%)		406 (55%)
	Bandages	385 (52%)		670 (90%)		553 (75%)
	Splints	115 (16%)		233 (32%)		188 (25%)
	Eye-rinse	520 (70%)		705 (95%)		683 (92%)
	Defibrillator	328 (44%)		627 (85%)		443 (60%)
	Self-contained self-rescuer (SCSR)	371 (50%)		716 (97%)		624 (84%)
	Fire extinguisher	542 (73%)		724 (98%)		703 (95%)
		A very high extent	A high extent	Some extent	A low extent	A very low extent
Q2	To what extent do you consider there is a risk of being injured at your workplace?	55 (8%)	166 (22%)	378 (51%)	115 (16%)	25 (3%)
Q3	Imagine that your peer has sustained a moderate or more severe injury, e.g. crush injury, severe bleeding or has a fracture. To what extent do you consider yourself knowledgeable enough to help your peer?	43 (6%)	157 (21%)	448 (60%)	84 (11%)	4 (1%)
Q4	Imagine you are working as usual underground. Suddenly you witness the following situations at the incident site. To what extent would you know how to act?					
a)	If there is a rock-fall and my peers are trapped.	28 (4%)	170 (23%)	388 (52%)	126 (17%)	28 (4%)

	b)	If a vehicle crashes and the driver is moderately or more seriously injured.	36 (5%)	207 (28%)	420 (57%)	64 (9%)	12 (1%)
	c)	If smoke/gas develops in the vicinity of where I am working and my peer becomes unconscious.	45 (6%)	177 (24%)	412 (56%)	86 (12%)	18 (2%)
	d)	If my peer suffers a cardiac arrest.	61 (8%)	261 (35%)	351 (47%)	55 (8%)	12 (2%)
Q5		Imagine you witness a truck that is unable to brake and therefore crashes into the mine wall. The truck catches fire and it is impossible to get past it. The driver is alive, but trapped. A lot of smoke is emanating from the truck.					
	a)	To what extent would you be able to reach a safe location?	78 (11%)	291 (39%)	334 (45%)	17 (2%)	6 (1%)
	b)	Do you have the proper self-protective equipment?	65 (9%)	327 (44%)	319 (43%)	11 (1%)	5 (1%)
	c)	Have you been properly trained in self-protection?	74 (10%)	318 (43%)	291 (39%)	24 (4%)	17 (2%)
	d)	Would you know how to act?	40 (5%)	246 (33%)	412 (56%)	25 (3%)	7 (1%)
Q6		What is the probability of the following incidents occurring?					
	a)	A major vehicle incident.	16 (2%)	128 (17%)	369 (50%)	191 (26%)	30 (4%)
	b)	A major fire incident that requires the rescue services to be contacted.	26 (4%)	161 (22%)	400 (54%)	129 (17%)	16 (2%)
	c)	A major explosion, involving a risk of injury.	5 (1%)	21 (3%)	204 (27%)	401 (54%)	105 (14%)
	d)	A major rock-fall, involving a risk of being crushed.	20 (3%)	82 (11%)	375 (51%)	218 (29%)	40 (5%)
	e)	A combination of explosion, fire and rock-fall.	8 (1%)	25 (3%)	249 (34%)	273 (37%)	174 (23%)
Q7		To what extent do you think the following incidents could lead to moderate or more serious injury or death if they happened in your workplace?					
	a)	A severe vehicle incident.	54 (7%)	170 (23%)	292 (39%)	162 (22%)	58 (8%)
	b)	A severe fire that requires the rescue services to be contacted.	32 (4%)	157 (21%)	377 (51%)	145 (20%)	28 (4%)
	c)	A major rock-fall involving crushed personnel.	51 (7%)	107 (14%)	309 (42%)	219 (30%)	52 (7%)
	d)	A major explosion.	44 (6%)	76 (10%)	194 (26%)	310 (42%)	109 (15%)

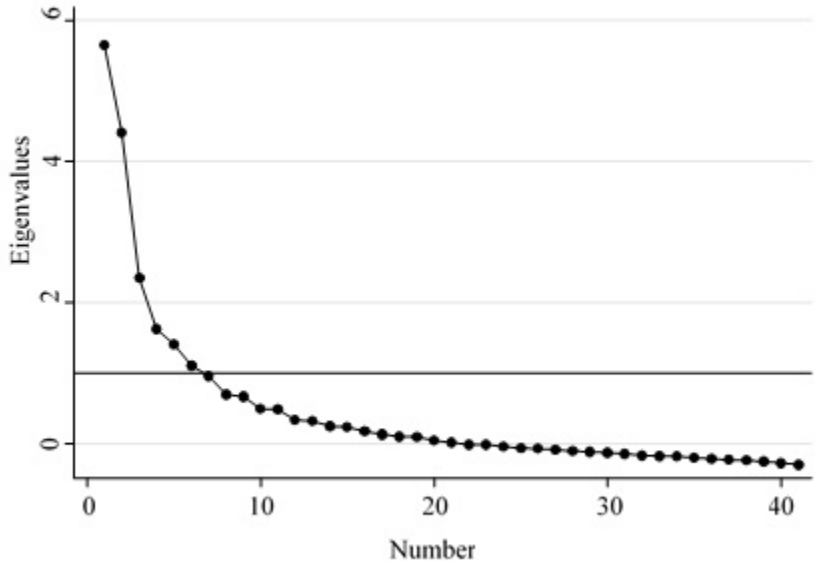
Q8	To what extent do you consider the mine you work in is prepared for an underground incident involving multiple injured parties?	42 (6%)	249 (33%)	347 (47%)	83 (11%)	12 (2%)

*Not reported 0-9% in all questions

Table 3: Loadings of the questions to the three factors and the unexplained variance

Variable	Factor 1	Factor 2	Factor 3	Uniqueness
Q 1a stretcher	0.08	0.00	**0.56**	0.65
Q 1b stretcher	0.19	-0.11	0.19	0.89
Q 1c stretcher	0.36	-0.11	0.19	0.77
Q 1a bandages	0.02	-0.00	**0.62**	0.61
Q 1b bandages	0.22	-0.12	0.15	0.89
Q 1c bandages	0.40	-0.08	0.11	0.78
Q 1a splints	0.10	-0.02	**0.57**	0.62
Q 1b splints	0.24	-0.09	0.20	0.86
Q 1c splints	0.38	-0.04	0.20	0.76
Q 1a eye rinse	-0.08	0.10	**0.54**	0.72
Q 1b eye rinse	0.12	-0.03	0.09	0.97
Q 1c eye rinse	0.26	-0.04	0.09	0.90
Q 1a defibrillator	-0.11	-0.01	**0.68**	0.57
Q 1b defibrillator	0.13	-0.03	0.15	0.95
Q 1c defibrillator	0.32	-0.07	0.19	0.81
Q 1a SCSR	-0.07	0.03	**0.65**	0.61
Q 1b SCSR	0.10	-0.13	0.02	0.97
Q 1c SCSR	0.32	-0.12	-0.00	0.87
Q 1a fire extinguisher	-0.16	0.06	**0.62**	0.64
Q 1b fire extinguisher	0.19	-0.12	0.01	0.94
Q 1c fire extinguisher	0.22	-0.09	0.02	0.93
Q 2	-0.00	**0.54**	-0.03	0.70
Q 3	**0.65**	0.07	0.09	0.54
Q 4a	**0.60**	0.10	0.03	0.64
Q 4b	**0.75**	0.11	0.04	0.44
Q 4c	**0.70**	0.12	-0.02	0.54
Q 4d	**0.62**	0.04	0.04	0.60
Q 5a	**0.60**	0.03	-0.20	0.69
Q 5b	**0.62**	-0.03	-0.24	0.65
Q 5c	**0.60**	-0.00	-0.13	0.67
Q 5d	**0.75**	0.04	-0.12	0.49
Q 6a	0.07	**0.61**	0.04	0.64
Q 6b	0.09	**0.71**	0.00	0.51
Q 6c	-0.03	**0.60**	0.13	0.61
Q 6d	-0.00	**0.71**	0.04	0.49
Q 6e	-0.00	**0.64**	0.12	0.57
Q 7a	0.11	**0.63**	0.01	0.62
Q 7b	0.07	**0.75**	-0.03	0.46
Q 7c	0.10	**0.75**	-0.08	0.46
Q 7d	0.08	**0.58**	-0.02	0.68
Q 8	0.32	-0.05	-0.11	0.90

Note: Loadings (>0.5) highlighted in bold indicate the factor on which the item was placed.



Scree plot of the eigenvalues as a rationale for the choice to use three factors in the analysis

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Preparedness for peer first response to mining emergencies resulting in injuries: a cross-sectional study

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Preparedness for peer first response to mining emergencies resulting in injuries: a cross-sectional study

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ABSTRACT

Objective: Identify factors of preparedness for peer first response to underground mining emergencies with injured victims.

Design: Cross-sectional questionnaire study of Swedish underground mineworkers.

Setting: Seven out of nine Swedish underground mines.

Participants: A total of 741 mineworkers out of 1022 (73%) participated in this study.

Interventions: None.

Outcome measures: Level of preparedness for emergencies with injuries in underground mines.

Results: Three factors influenced the preparedness of mineworkers for a peer first response: 1) familiarity with rescue procedures during emergencies with injuries; 2) risk perception of emergencies with injuries; and 3) experience of using self-protective and first aid equipment. Mineworkers who believed that they knew how to handle emergencies with injuries (odds ratio [OR] 1.30, 95% confidence interval [CI] 1.22–1.38) and those who were trained in the use of self-protective and first aid equipment (OR 1.19, 95% CI 1.07–1.32) considered themselves to be better prepared for a peer first response than those who were unfamiliar with the rescue procedures or who had not used self-protective and first aid equipment. However, mineworkers who rated the risk for emergencies with injuries as high considered themselves to be less prepared than those who rated the risk as low (OR 0.95, 95% CI 0.91–0.98).

Conclusion: This study identified three factors that were important for the peer-support preparedness of underground mineworkers. More research is needed to adapt and contextualise first aid courses to the needs of underground peer responders.

Strengths and limitations of this study

- The study had a high response rate (73%) and included participants from seven out of nine underground mines in Sweden.

- Exploratory factor analysis and multiple logistic regression analysis facilitated the identification of key factors associated with emergency medical preparedness.
- Post-estimation tests of the multiple logistic regression model indicated a goodness of fit.
- The questionnaire was evaluated with a face validity test among experienced mineworkers, whereas a comprehensive pilot study may have improved the questionnaire, as would a test/retest or random response test.
- This study is based on data from the mineworkers' self-assessed level of preparedness; other methods, including knowledge test or observation of full-scale practical exercises, could have generated more objective responses.

Keywords: Trauma management, Medical education & training, Accident & Emergency medicine, Occupational and Industrial medicine.

INTRODUCTION

Mining emergencies are infrequent occurrences but may result in severe consequences, such as the injury or death of mineworkers.[1, 2] Thus, mining emergencies require an efficient and timely response.[3] According to an international literature review [4], most of the literature relates to incidents in coal mines. The organic nature of coal has a different set of risks than metalliferous mines.[4] Thus, studying the Swedish setting, with its mineral and metalliferous underground mines, can contribute to the knowledge base of the scientific literature. The commonest emergencies in mineral and metalliferous underground mines are fires, vehicular incidents, and rock-falls.[4] A major underground fire, for example, can lead to partially or temporarily sealed off areas, which means that mineworkers might have to self-evacuate or be rescued.[5] Fires can influence the roof stability as well as generate toxic gases and create oxygen-depleted environments in large sections of the mine.[2] This makes both self-initiated escape and rescue operations difficult.[6] Mine rescue operations take time, regardless of whether the company's own mine rescue teams, as in most European countries, or the local rescue services and Emergency Medical Service (EMS), which is common in Sweden, undertake the rescue operations.[7, 8] Swedish mines are required to either train their own mine rescue service or have mine guides to assist the local rescue service during rescue operations.[9] Nonetheless, there is a delay as the rescue teams have to reach the remote mine [8], plan the rescue operation and navigate a complex environment to reach the incident site, which could be far underground.[10, 11]

Because time-consuming rescue operations can be fatal for severely injured victims[12], mineworkers in the vicinity of the injured need to act as immediate responders and care for their injured peers until professional help arrives.[13] Immediate responders must have essential knowledge, skills, and equipment [14] in order to care for their injured peers.

The combination of being a peer to the victim and being unskilled at handling injuries may lead to emotional distress that might impede their actions.[15]

To escape or be rescued during emergencies, the Mine Safety Technology and Training Commission[11] recommends that mineworkers should be trained in three key areas: (i) knowledge of escape/rescue technologies, (ii) mine-specific knowledge in order to find evacuation routes, and (iii) escape/rescue conceptual knowledge to facilitate difficult decision making in an emergency situation. A lack of knowledge of mineworkers in these areas may have fatal consequences. For example, in the Sago mine explosion in 2006,[16] 12 mineworkers died, and they lacked knowledge of how to use self-contained self-rescuers.[17]

Swedish mining companies aim to prevent and mitigate incidents by focussing on risk management, evacuation technology, and escape routes.[18] Moreover, the companies acknowledge the need for preparedness of their personnel for incidents and implement work-safety regulations, including those for first aid and psychological and social support after emergencies.[19] These regulations are defined based on the type and risks of the workplace, and a sufficient number of workers need to be prepared to provide first aid, with adequate knowledge of and access to the relevant equipment needed for first aid.[19] Thus, preparedness to respond to incidents is an essential element of any underground mine's strategic plan.[20] However, there are few studies in the literature on the medical aspects and peer first response in mining emergencies with injuries.[4] By studying the preparedness of Swedish mineworkers for emergencies with injuries, the complementing factors in the above-described three key areas can be identified.

Thus, this study aimed to identify factors of preparedness for peer first response to underground mining emergencies with injured victims. A secondary objective was to describe the preparedness of Swedish mineworkers, which is the data the factors are identified from.

METHODS

Design

This study was a national cross-sectional questionnaire survey.

Sample

Questionnaires (n=1,022) were distributed to seven participating mines between November 2016 and February 2017. The response rate was 73% (n=741) after excluding 29 individuals who were not working underground and 11 individuals with missing data for more than one fourth of the study variables. Table 1 presents the details of the participant characteristics.

Table 1. Characteristics of the mineworkers included in this study

Variables	Respondents n=741
Sex	
Female	77 (10%)
Male	658 (89%)
Not reported	6 (1%)
Age (years)	Mean 40.4, SD 11.7
Work experience (years)	Mean 11.9, SD 10.9
Mineworker occupation*	
Miner-labourers	285 (38%)
Maintenance-technical staff	399 (54%)
Supervisors-managers	55 (7%)
Not reported	2 (0%)
Extra rescue guide/medical training and responsibility	
Yes	86 (12%)
No	595 (80%)
Not reported	60 (8%)

* Mineworkers comprise miner-laborers, maintenance-technical staff, and supervisor-managers. Miner-laborers work with mineral processing. The maintenance-technical staff include electricians and machine operators. Supervisors–managers include all forms of supervisors and managers who work underground.[21] SD=standard deviation.

Questionnaire

The study-specific questionnaire in Swedish was specifically designed and constructed based on a review of preparedness literature and covered three areas: current mining preparedness

literature, likely scenarios in Swedish mines, and Swedish regulations. Preparedness for emergencies includes the inclusion of mineworkers with the relevant skills and ability to undertake the necessary actions.[11, 22] Relevant emergency scenarios in mineral and metalliferous mines include fires, vehicular incidents and rock-falls [4]; therefore, we focussed on these scenarios in the questionnaire. Swedish workplace regulations stipulate that the workplace risks determine the number of employees that should be educated in first aid and the availability of appropriate first aid equipment,[19] such as stretchers, bandages, and fire extinguishers.[9, 23]

The questionnaire was designed to capture data on the preparedness of the mineworkers as immediate responders of moderately or more severely injured peers (e.g., fractures, concussion or more severe injuries) until they were rescued during emergencies. Thus, the questions focussed on the mineworkers' self-perceived knowledge of injuries and first aid, their first aid training and equipment, and the presumed risks of mining incidents, particularly concerning fires, vehicular incidents and rock-falls. Answers to the questions were either yes/no responses or scores rated on a five-point Likert scale. Table 2 shows the frequencies of responses of 741 mineworkers to the questions in the questionnaire before an imputation of the dataset was performed. The face validity of the questionnaire was tested on three mineworkers. The relevance and validity of the items and the questionnaire were discussed during several seminars in an iterative process by the research group.

Table 2 Questions and responses before imputation for all mineworkers (n=741)

	Questions	Frequencies, n (%)								
Global variables	Do you consider yourself prepared to respond (before the EMS or rescue personnel arrive at the incident site) to emergencies, e.g. fire, explosions or rock-falls in the mine?							Yes	No	Not reported
								583 (79)	126 (17)	32 (4)
		a) Have you used self-protective and first aid equipment before?			b) Do you have access to self-protective and first aid equipment?			c) Do you consider yourself as being comfortable using self-protective and first aid equipment?		
Q1		Yes	No	Not reported	Yes	No	Not reported	Yes	No	Not reported
	Stretcher	177 (24)	557 (75)	7 (1)	501 (68)	204 (28)	36 (5)	406 (55)	302 (41)	33 (4)
	Bandages	385 (52)	339 (46)	17 (2)	670 (90)	45 (6)	26 (4)	553 (75)	154 (21)	34 (5)
	Splints	115 (16)	610 (82)	16 (2)	233 (31)	439 (59)	69 (9)	188 (25)	503 (68)	50 (7)
	Eye-rinse	520 (70)	212 (29)	9 (1)	705 (95)	12 (2)	24 (3)	683 (92)	29 (4)	29 (4)
	Defibrillator	328 (44)	403 (54)	10 (1)	627 (85)	89 (12)	25 (3)	443 (60)	265 (36)	33 (4)
	Self-contained self-rescuer (SCSR)	371 (50)	359 (48)	11 (1)	716 (97)	8 (1)	17 (2)	624 (84)	92 (12)	25 (3)
	Fire extinguisher	542 (73)	194 (26)	5 (1)	724 (98)	1 (0)	16 (2)	703 (95)	16 (2)	22 (3)
					A very high extent	A high extent	Some extent	A low extent	A very low extent	Not reported
Q2	To what extent do you consider that there is a risk of being injured at your workplace?				55 (7)	166 (22)	378 (51)	115 (16)	25 (3)	2 (0)
Q3	Imagine that your peer has sustained a moderate or more severe injury (e.g., crush injury, severe bleeding or has a fracture). To what extent do you consider yourself knowledgeable enough to help your peer?				43 (6)	157 (21)	448 (60)	84 (11)	4 (1)	5 (1)
Q4	Imagine you are working as usual underground. Suddenly, you witness the following situations at the incident site. To what extent would you know how to act?									

	a)	If there is a rock-fall and my peers are trapped.	28 (4)	170 (23)	388 (52)	126 (17)	28 (4)	1 (0)
	b)	If a vehicle crashes and the driver is moderately or more seriously injured.	36 (5)	207 (28)	420 (57)	64 (9)	12 (2)	2 (0)
	c)	If smoke/gas develops in the vicinity of where I am working, and my peer becomes unconscious.	45 (6)	177 (24)	412 (56)	86 (12)	18 (2)	3 (0)
	d)	If my peer suffers a cardiac arrest.	61 (8)	261 (35)	351 (47)	55 (7)	12 (2)	1 (0)
Q5		Imagine you witness a truck that is unable to brake and therefore crashes into the mine wall. The truck catches fire, and it is impossible to get past it. The driver is alive, but trapped. A lot of smoke is emanating from the truck.						
	a)	To what extent would you be able to reach a safe location?	78 (11)	291 (39)	334 (45)	17 (2)	6 (1)	15 (2)
	b)	Do you have the appropriate self-protective equipment?	65 (9)	327 (44)	319 (43)	11 (1)	5 (1)	14 (2)
	c)	Have you been properly trained in self-protection?	74 (10)	318 (43)	291 (39)	24 (3)	17 (2)	17 (2)
	d)	Would you know how to act?	40 (5)	246 (33)	412 (56)	25 (3)	7 (1)	11 (1)
Q6		What is the probability of the following incidents occurring?						
	a)	A major vehicular incident.	16 (2)	128 (17)	369 (50)	191 (26)	30 (4)	7 (1)
	b)	A major fire incident that requires rescue services to be contacted.	26 (4)	161 (22)	400 (54)	129 (17)	16 (2)	9 (1)
	c)	A major explosion involving a risk of injury.	5 (1)	21 (3)	204 (28)	401 (54)	105 (14)	5 (1)
	d)	A major rock-fall involving a risk of being crushed.	20 (3)	82 (11)	375 (51)	218 (29)	40 (5)	6 (1)
	e)	A combination of explosion, fire and rock-fall.	8 (1)	25 (3)	249 (34)	273 (37)	174 (23)	12 (2)
Q7		To what extent do you think the following incidents could lead to moderate or more serious injury or death if they occurred in your workplace?						
	a)	A severe vehicular incident.	54 (7)	170 (23)	292 (39)	162 (22)	58 (8)	5 (1)
	b)	A severe fire that requires rescue services to be contacted.	32 (4)	157 (21)	377 (51)	145 (20)	28 (4)	2 (0)
	c)	A major rock-fall involving crush injuries to personnel.	51 (7)	107 (14)	309 (42)	219 (30)	52 (7)	3 (0)
	d)	A major explosion.	44 (6)	76 (10)	194 (26)	310 (42)	109 (15)	8 (1)
Q8		To what extent do you consider that the mine you work in is prepared for an underground incident involving multiple injured parties?	42 (6)	249 (34)	347 (47)	83 (11)	12 (2)	8 (1)

EMS=Emergency Medical Services

Data collection

At the time of study data collection, Sweden had 14 mineral and metalliferous mines of which nine were underground mines. The research team contacted the mine managers of these nine underground mines. Written information about the study and the questionnaire was sent to the managers via email to obtain informed consent, and the main unions were notified about the study. Seven out of nine mine managers agreed to participate and were then sent paper questionnaires via regular post for all employed mineworkers who were working underground. The mine managers were responsible for the distribution and collection of the questionnaires. A letter was attached to each questionnaire to inform the mineworkers that their participation was voluntary and that, by completing the questionnaire, the respondents gave their informed consent for study participation.

At the time of this study, the seven mines employed between 18 and 290 mineworkers. These underground mineral and metalliferous mines were involved in mining zinc, lead, silver, copper, gold and tellurium through various methods, for example, with sub-level stoping at varying maximum depths of between 235 and 1,500 m.[24]

Analysis

Descriptive analysis and data management

First, a descriptive analysis of the data was performed, including frequencies, minimum and maximum, mean, standard deviation, skewness and kurtosis. The descriptive analysis indicated that all questions had less than 10% missing values. Imputation with an expectation-maximisation estimation was performed to impute the missing data of the variables included in the analysis.[25]

A significance level of 0.05 was used for all study analyses, and SPSS [26] was used to impute the data with an expectation maximisation estimation, and Stata [27] was used for all other analyses.

Exploratory factor analysis

Exploratory factor analysis was performed for data reduction purposes [28], to generate relevant analyses of the mineworkers' preparedness based on a rich material, wherein most of the mineworkers had chosen the middle alternative of the Likert Scale for the questions, which made it unclear how the data could fit into logistic regression models. Moreover, a decision to perform an exploratory factor analysis was made to identify latent factors that contribute to the covariance of the manifest variables.[28] Moreover, this made it possible to construct relevant complementing emergency medical factors to the key areas constructed by the Mine Safety Technology and Training Commission.[11] In the exploratory factor analysis, six factors had eigenvalues >1. However, when comparing the constructs and studying the resulting scree plot, a decision was made to retain three factors with an eigenvalue >2 due to the opportunity to form relevant and meaningful factors as well as the fact that the scree plot started to level out after three factors. The three retained factors were rotated using Promax, and a threshold of 0.5 was chosen for the factor loadings, where a value of 0.5 indicates a strong loading for the items.[28] Therefore, items with a minimum loading of 0.5 from the first, second, and third factors were added together. The three-factor solution is shown in Figure 1. Cronbach's alpha and average inter-item correlations were derived for factors 1, 2, and 3 as 0.86 and 0.41, 0.87 and 0.41, and 0.80 and 0.37, respectively.

The following three factors illustrate the mineworkers' medical peer response preparedness: 1) *Familiarity with rescue procedures during emergencies with injuries*, containing questions Q3, Q4a–Q4d and Q5a–Q5d; 2) *Risk perception of emergencies with injuries*, covering questions Q2, Q6a–Q6e and Q7a–Q7d and 3) *Experience of using self-protective and first aid equipment* containing questions covering Q1a stretcher, bandages, splints, eye rinse, defibrillators, self-contained self-rescuers and fire extinguishers.

Multiple logistic regression analysis

In the multiple logistic regression analysis, the three factors were used as independent variables and the question "Do you consider yourself prepared to respond (before the EMS or rescue personnel arrive at the incident site) to emergencies, e.g. fire, explosions or rock-falls in the mine?" was used as the global dependent variable. The post-estimation tests of the Pearson chi-square goodness-of-fit test as well as the Hosmer–Lemeshow test were performed and had insignificant results, indicating a goodness of fit for the model.[29]

Participant and public involvement statement

Neither patients nor the public was included in the design, conduct, reporting, or dissemination plans of the research. However, the questionnaire was tested for face validity from both, mining employer and employee, perspectives.

RESULTS

The three constructed factors illustrate the aspects of relevance for the mineworkers' medical peer first-response preparedness. *Familiarity with rescue procedures during emergencies with injuries* includes whether the mineworkers know how to act during stressful situations when there is an emergency, and a peer has been injured in the vicinity. *Risk perception of emergencies with injuries* includes how mineworkers interpret the perceived risk for emergencies with injuries at their workplace. *Experience of using self-protective and first aid equipment* includes aspects of whether the mineworkers have used/know how to use the equipment, such as a stretcher, bandages, splints, self-contained self-rescuers and fire extinguishers. There were significant associations between the three factors of preparedness and the global variable of self-reported preparedness. The associations between the factors and the global variable (Figure 2) are further presented along with relevant highlights of how the 741 mineworkers answered the questionnaire (Table 2).

Mineworkers familiar with rescue procedures during emergencies with injuries felt more prepared to respond before the rescue services and EMS arrived than those who were unfamiliar with the rescue procedures (OR 1.30, 95% CI 1.22–1.38). As many as 79% of the 741 mineworkers considered themselves prepared to respond in the event of an emergency. For example, the mineworkers considered that they, to a high or very high extent, would know how to act if the driver is moderately or more seriously injured when a vehicle crashes (33%), or when a vehicle catches fire (38%, and an additional 56% would to some extent, know what to do). Almost all (91%) respondents reported that they had received first aid training, and 22% had experience in helping an injured peer. However, if a peer was moderately or more severely injured, only 27% considered themselves, to a high or very high extent, of being able to help. Nearly two-thirds (60%) of the mineworkers thought that they, to some extent, knew how to provide a peer first aid response and help a moderately or more severely injured peer, whereas 43% of the mineworkers knew, to a very high or high extent, how to act if a peer would suffer a cardiac arrest.

Mineworkers who considered that there was a great risk of emergencies with injuries believed themselves to be less prepared to respond than those who considered that there was a low risk of incidents (OR 0.95, 95% CI 0.91–0.98). Overall, 80% of the mineworkers considered the risk of injuring themselves at their workplace to be moderate to severe. However, most mineworkers (87%) believed that their mine was prepared for an underground incident involving multiple injured mineworkers, with moderate to very high degree of injury severity. When asked what kind of major incident scenarios they thought were likely, 80% of the mineworkers considered that the risk of a major fire incident that would require the rescue service to be contacted was moderate to severe. One-fourth (25%) of the mineworkers believed that there was a high or very high risk for moderate or more serious injury during major fire incidents. Although major fires were considered probable, explosions

were not considered to be as likely; 68% of the mineworkers imputed a low or very low risk of major explosions involving injury, and 57% thought there was a low or very low risk of major explosions leading to moderate or more serious injury or death.

Mineworkers with experience using their self-protective and first aid equipment were more prone to respond than those without this experience (OR 1.19, 95% CI 1.07–1.32). In order to help injured peers, workers have to have knowledge in, access to and confidence in using several different kinds of self-protective and first aid equipment; to mention a few, 68% had access to a stretcher, about one fourth (24%) of the mineworkers had used one, and 55% considered themselves comfortable using stretchers. Seventy-five percent of the mineworkers considered themselves to be comfortable using bandages and 25% were comfortable using splints; 85% of the mineworkers had access to a defibrillator, 44% had used one, and 60% considered themselves comfortable using a defibrillator. Moreover, 73% of the mineworkers had used a fire extinguisher, and almost all (95%) felt comfortable using it.

DISCUSSION

This study resulted in the identification of three factors: (i) *Familiarity with rescue procedures during emergencies with injuries*, (ii) *risk perception of emergencies with injuries* and (iii) *experience of using self-protective and first aid equipment*, which were of importance for mineworkers' perceived level of preparedness for emergencies resulting in injuries. These three factors have an emergency medical dimension with regard to the scenarios, including preparedness for taking care of injured mineworkers. Thus, the three identified factors can be viewed as being complementary to the three factors identified by the Mine Safety Technology and Training Commission for mineworkers to be able to self-escape or be rescued during emergencies in underground mines.[11]

The first factor of this study indicated that mineworkers familiar with rescue procedures considered themselves to be more prepared to respond to incidents before the

rescue services and emergency medical service arrived than those who were unfamiliar with the rescue procedures. In this study, the mineworkers were asked if they knew how to act in several difficult situations involving an injured peer (Table 2). Although the mineworkers generally considered themselves prepared to respond (79%), their answers indicated that certain scenarios could prove difficult. For example, the mineworkers were somewhat confident in what they should do if the driver is moderately or more seriously injured when a vehicle crashes (57%), or when a vehicle catches fire (56%). Their ability to respond during such stressful situations included making sound decisions and judgements.[30] Prior training or experience of incidents have been shown to result in a better state of preparedness and to influence action during infrequent incidents that cause severe consequences.[3] For example, those with prior experience of escaping from a smoke-filled mine reported feeling less stress during an exercise under similar conditions, whereas mineworkers lacking this experience generally acted more on intuition than prior knowledge.[31] As in this study, training mineworkers in their emergency skills has been shown to increase their preparedness for handling emergencies.[30] However, the efficacy of self-escape training in communication, collaboration, leadership development, responsibility and accountability may be limited due to both structural and individual factors.[32] Another study[21] reported that mineworkers responding to dilemmas about critical self-rescue and escape skills did not always choose the safest option, though they understood the consequences of their choices. Two difficult dilemmas of that study included (i) leaving an injured mineworker behind and (ii) trying to rescue missing mineworkers during unsafe conditions.[21] Because mineworkers often respond to emergencies as a group,[11] they have to make optimal decisions for the whole group to escape. Training mineworkers to collaboratively make decisions and self-escape in simulated smoke may improve their ability to escape.[11] Thus, based on the results of this study, training the mineworkers in the appropriate responses may improve their preparedness

to act if their peers are injured. Their training may include table-top exercises, where the mineworkers can discuss different dilemmas and best practices when handling injuries, focussed training on how to perform a procedure and full-scale scenario training.

The second factor in this study indicated that mineworkers who considered that there was a significant risk of emergencies with injuries assessed themselves as being less prepared to act before the rescue and emergency medical services arrived than those who considered that there was a low risk. Thus, this is perhaps a contradiction to another study[33], which reported that people with more experience and education of disasters and emergencies perceive a higher risk of emergencies and, therefore, are more prepared for new emergencies. In this study, 29% and 51% of the mineworkers considered that there was a high or very high risk and moderate risk of sustaining workplace injuries, respectively. Furthermore, mineworkers considered that major fires were likely to occur, whereas uncontrolled explosions were not. The risk of the Swedish mineworkers sustaining a workplace injury has substantially decreased during the past 30 years, from 50.3 incidents per 1 million working hours to 7.1 in 2015, because of investments in both technological development and in organisational measures (e.g. the initiative of "Safety First").[34] The Swedish mining companies are required, according to the Civil Protection Act,[35] to be prepared for emergencies, which can occur even though relevant preventative measures have been implemented.[9] The Swedish mines, for example, utilise an emergency plan of action until the rescue service personnel arrive,[36] because, despite being uncommon, emergencies may include a risk to the life and health of the mineworkers.[1] Examples of major Swedish incidents include a major fire incident in 2013 [37], and rock-falls caused by seismic events in the mine in 2020.[38] The safety of mineworkers depends on their knowledge and ability to recognise and respond to hazards, and that might be influenced by training and experience.[39] The Swedish mineworkers consider emergencies to be wake-up calls, and

while the underlying problems are usually corrected, the mineworkers raise concerns about being trapped by a rock-fall or whether they could be rescued during major fires because of a complicated rescue operation.[35] Thus, though objective measures prove the decreased frequency of incidents, several mineworkers believe that there exists a risk of emergencies that can lead to injury or death. The findings of this study indicate which of the emergency scenarios the mineworkers think are most likely, and thus a combination of prevention and preparedness strategies can be implemented to improve the mineworker's perception of the associated risks.

The third factor indicates that mineworkers with experience in using self-protective and first aid equipment, such as self-contained self-rescuers (50%), bandages (52%) or defibrillators (44%), also considered themselves to be more prepared to respond during emergencies involving injuries. Hands-on training with first aid equipment improves layperson skills.[40] Other authors have recommended that mineworkers practise using self-contained self-rescuers because, on several occasions, mineworkers have claimed that their equipment did not work in a real emergency.[3] The equipment used during emergencies needs to be easy to use, even in highly stressful situations.[8] To increase the preparedness of Swedish mineworkers, the mandatory annual evacuation training[18] may preferably include the use of self-protective and first aid equipment. This supports the inclusion of practical training sessions in first aid courses, together with systematic training in the use of relevant self-protective and first aid equipment. Almost all of the mineworkers included in this study had been trained in first aid, as also reported from another Swedish study [35] which indicated that the mineworkers are trained to provide first aid and cardiopulmonary resuscitation and to use defibrillators. This means that the mineworkers have been educated in effective and safe techniques of first aid while using minimal or no equipment to provide initial care if a peer is injured or suffering from an acute illness.[41, 42] Furthermore, educating mineworkers in first

aid improves their confidence and likelihood of performing lifesaving first aid.[43] However, current first aid courses generally do not cover trauma or mass-casualty situations [44] or situations where professional help is far away.[41] The majority of the mineworkers (60%) believed that they, to some extent, would know how to help a severely injured peer. This might be due to the peers feeling of helplessness because they are unable to provide the appropriate level of care to the injured.[17] For example, though 60% of the mineworkers in this study felt comfortable using a defibrillator for cardiopulmonary resuscitation, they may feel exposed and powerless.[45] Other authors have shown that, in general, people tend to help injured people but may have low confidence in their first aid skills and training, with several other barriers for delivering first aid, for example, worry about making mistakes that could further harm the injured person.[46-48] In line with our findings, training responders in first aid, as recommended by other authors,[47, 48]could improve their self-confidence and willingness to respond. The first aid training might focus on typical injuries and illnesses relevant to the underground environment. Training has been shown to increase the likelihood of optimal behaviour and decrease the risk of injury,[49] but it needs to be context-sensitive and consider the specific conditions in different mines,[50] whereas providing each mineworker with sophisticated training in evacuation strategies.[17] Thus, mining companies may consider this aspect, particularly as the onsite mineworkers are not only immediate responders, but some of them also have duties as guides for rescue services.[35] Most of the mineworkers in this study attended regular first aid courses and, thus, the connection to the underground mining incident panorama might not have been evident. Moreover, in the first aid course, discussions of the psychological strain that emergencies with injuries could impose on the mineworkers could be included. These may be necessary for mineworkers to help a moderately or more severely injured peer in a rescue chamber for a long time before the arrival of rescue and emergency services. Therefore, modifying the first aid course to

become more relevant to the mining context, including with regard to the psychological aspects, needs to be further explored.

Limitations

The strengths of this study include the fact that seven out of nine mines chose to participate. The response rate was high (73%), which was adequate to assess the preparedness of the Swedish mineworkers. The decision to perform exploratory factor and multiple logistic regression analyses facilitated the analysis of a rich data material and the development of complementary factors associated with emergency medical preparedness to the key areas developed by the Mine Safety Technology and Training Commission. The multiple logistic regression analysis has insignificant post-estimation tests, indicating a suitable goodness of fit of the model.

Nonetheless, this study has some limitations. A drawback of the questionnaire was that most mineworkers chose the middle alternative of the Likert scale when answering the questions, which perhaps could have been counteracted by including another scale. The questionnaire itself was evaluated by the face validity of three mineworkers with vast experience of the mining environment in order to make the questions appropriate for the underground mine setting. Moreover, the questionnaire was discussed and improved iteratively by the research team before the questionnaires were sent out. However, a comprehensive pilot study might have improved the questionnaire further, as would a test/retest or random response test. Furthermore, this study analysed the self-assessed preparedness of mineworkers. More objective measures could have been obtained if a knowledge test or observations were performed on full-scale exercises. However, these were judged to be resource-intensive and beyond the scope of this study.

CONCLUSIONS

All mineworkers have to be readily prepared to act as immediate responders and care for their injured peers for a possibly extensive period until professional help arrives. We identified three factors important in the preparedness for peer support in underground mining environments. More research is needed to create evidence-based first aid courses that are adapted and contextualised to the needs of peer responders.

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Ethical considerations: The study was performed in accordance with the Declaration of Helsinki. The subject area and methods of this study were excluded from ethical whetting in accordance with the regulations of the Swedish Act concerning the Ethical Review of Research Involving Humans (SFS 2003:460); therefore, no ethical permission has been

sought. Measures were taken to protect the anonymity and free will of the participants. The participating mines were sent paper questionnaires and information letters. The information letters informed the participants about the study and that participation was completely voluntary. Furthermore, they were informed that the results were to be presented at the group level, and no one would be able to identify individual answers. Although the participants were encouraged to answer all questions, they were free to hand in a blank or partially answered questionnaire. No sensitive personal information was collected. The participants provided their informed consent by anonymously answering the questionnaires. The participants were completely anonymised to the researchers as the data collection method made it impossible to create code lists.

Data availability statement: All data relevant to the study are included in the article.

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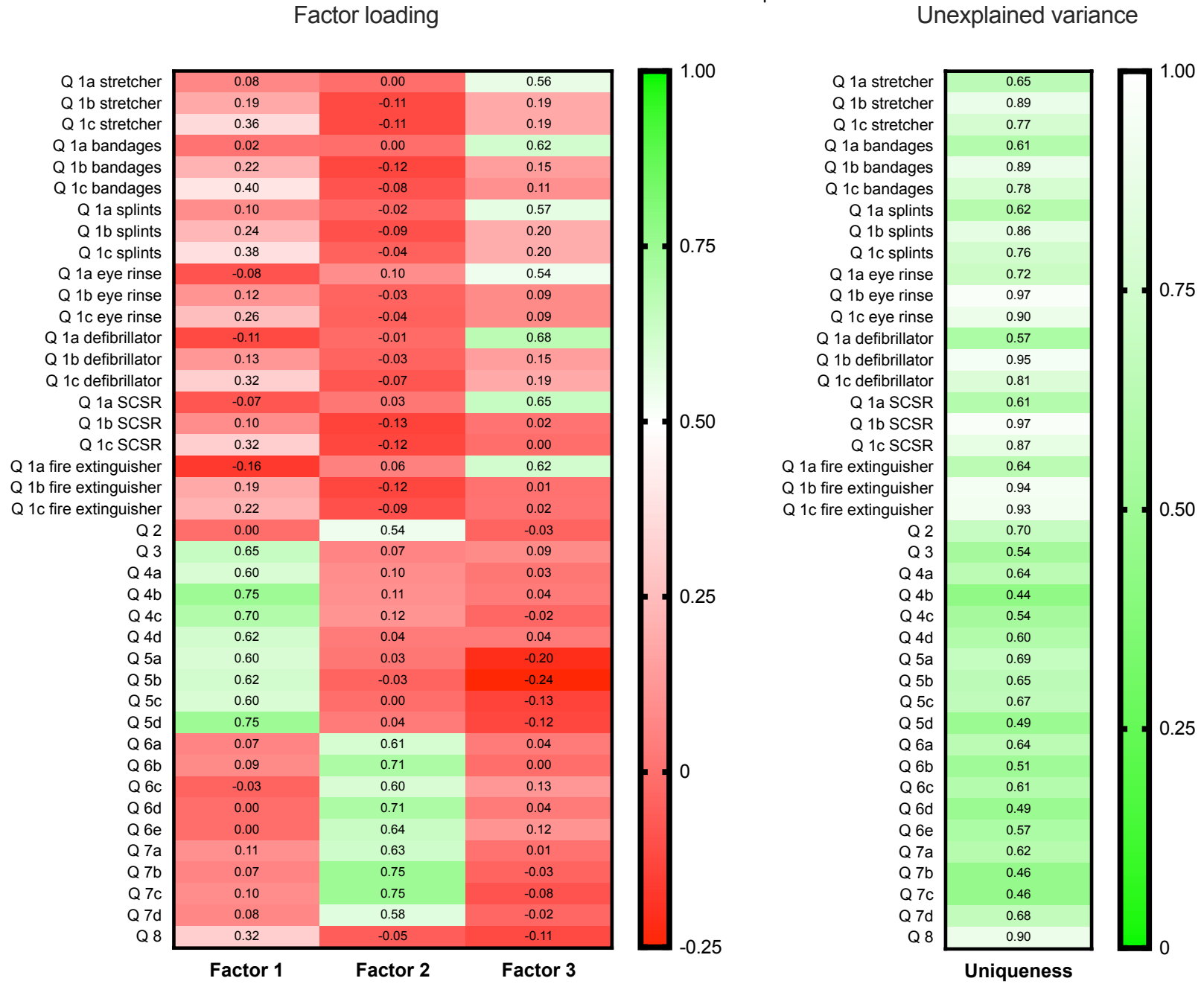
Figure Legends

Figure 1. a) Heatmap illustrating the loadings of the questions to the three factors, where 0.5 was the lower limit for being included in the respective factor and b) Heatmap illustrating the unexplained variance of the questions to the three factors.

Figure 2. Odds ratios and 95% confidence intervals showing the association between the three factors and the global variable of self-assessed preparedness to act before the rescue service and EMS arrive.


Factor loading
Unexplained variance
Q 1a stretcher 0.08 0.00 0.56 0.65
Q 1b stretcher 0.19 -0.11 0.19 0.89
Q 1c stretcher 0.36 -0.11 0.19 0.77
Q 1a bandages 0.02 0.00 0.62 0.61
Q 1b bandages 0.22 -0.12 0.15 0.89
Q 1c bandages 0.40 -0.08 0.11 0.78
Q 1a splints 0.10 -0.02 0.57 0.62
Q 1b splints 0.24 -0.09 0.20 0.86
Q 1c splints 0.38 -0.04 0.20 0.76
Q 1a eye rinse -0.08 0.10 0.54 0.72
Q 1b eye rinse 0.12 -0.03 0.09 0.97
Q 1c eye rinse 0.26 -0.04 0.09 0.90
Q 1a defibrillator -0.11 -0.01 0.68 0.57
Q 1b defibrillator 0.13 -0.03 0.15 0.95
Q 1c defibrillator 0.32 -0.07 0.19 0.81
Q 1a SCSR -0.07 0.03 0.65 0.61
Q 1b SCSR 0.10 -0.13 0.02 0.97
Q 1c SCSR 0.32 -0.12 0.00 0.87
Q 1a fire extinguisher -0.16 0.06 0.62 0.64
Q 1b fire extinguisher 0.19 -0.12 0.01 0.94
Q 1c fire extinguisher 0.22 -0.09 0.02 0.93
Q 2 0.00 0.54 -0.03 0.70
Q 3 0.65 0.07 0.09 0.54
Q 4a 0.60 0.10 0.03 0.64
Q 4b 0.75 0.11 0.04 0.44
Q 4c 0.70 0.12 -0.02 0.54
Q 4d 0.62 0.04 0.04 0.60
Q 5a 0.60 0.03 -0.20 0.69
Q 5b 0.62 -0.03 -0.24 0.65
Q 5c 0.60 0.00 -0.13 0.67
Q 5d 0.75 0.04 -0.12 0.49
Q 6a 0.07 0.61 0.04 0.64
Q 6b 0.09 0.71 0.00 0.51
Q 6c -0.03 0.60 0.13 0.61
Q 6d 0.00 0.71 0.04 0.49
Q 6e 0.00 0.64 0.12 0.57
Q 7a 0.11 0.63 0.01 0.62
Q 7b 0.07 0.75 -0.03 0.46
Q 7c 0.10 0.75 -0.08 0.46
Q 7d 0.08 0.58 -0.02 0.68
Q 8 0.32 -0.05 -0.11 0.90
1.00
0.75
0.50
0.25
0
-0.25
Factor 1
Factor 2
Factor 3
Uniqueness

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-7, 10
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6-7, 10
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7, 10
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-7, 10 Table 1 & 2
Bias	9	Describe any efforts to address potential sources of bias	6-12
Study size	10	Explain how the study size was arrived at	N/A, 6-7, 10
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-12 Table 2
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	10-12, Figure 1
		(*b*) Describe any methods used to examine subgroups and interactions	N/A
		(*c*) Explain how missing data were addressed	6, 10
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	N/A
		(*e*) Describe any sensitivity analyses	12
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	12
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1
		(b) Indicate number of participants with missing data for each variable of interest	Table 2
Outcome data	15*	Report numbers of outcome events or summary measures	12-14 Figure

			1 & 2
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	12-14
		(*b*) Report category boundaries when continuous variables were categorized	N/A
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10-14
Discussion			
Key results	18	Summarise key results with reference to study objectives	14, 20
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	19
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14-20
Generalisability	21	Discuss the generalisability (external validity) of the study results	19-20
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	20

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.