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Original research

Organisational factors and under-reporting of occupational injuries in Sweden: a population-based study using capture–recapture methodology

Cecilia Orellana ¹, Bertina Kreshpaj,¹ Bo Burstrom,² Letitia Davis,³ Paolo Frumento,⁴ Tomas Hemmingsson,^{1,5} Gun Johansson,^{1,6} Katarina Kjellberg,^{1,6} David H Wegman,⁷ Theo Bodin^{1,6}

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¹Unit of Occupational Medicine, Institute of Environmental Medicine, Karolinska Institutet, Stockholm, Sweden

²Department of Global Public Health, Equity and Health Policy Research Group, Karolinska Institutet, Stockholm, Sweden

³Researcher, Cambridge, Massachusetts, USA

⁴Department of Political Sciences, Università di Pisa, Pisa, Italy

⁵Department of Public Health Sciences, Stockholm University, Stockholm, Stockholm, Sweden

⁶Center for Occupational and Environmental Medicine, Stockholm Region, Stockholm, Sweden

⁷University of Massachusetts Lowell, Lowell, Massachusetts, USA

Correspondence to

Dr Cecilia Orellana, Unit of Occupational Medicine, Institute of Environmental Medicine, Karolinska Institutet, Stockholm, Stockholm, Sweden; cecilia.orellana@ki.se

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ABSTRACT

Objective To estimate the magnitude of under-reporting of non-fatal occupational injuries (OIs) by different organisational factors in Sweden for the year 2013.

Methods Capture–recapture methods were applied using two data sources: (1) the national OI register and (2) records from a labour market insurance company. To assure comparability of data sources, the analysis was restricted to the public sector and private companies with at least 50 employees. OIs were matched using personal identification number and reported injury dates (± 7 days). Organisational factors were obtained from the national labour market register and injury severity (no healthcare/only outpatient/hospitalised) from the National Patient Register. Total number of OIs and ascertainment by data sources were estimated assuming data source independence.

Results There were an estimated 98 493 OIs in 2013. Completeness of reporting OIs to the national register and to the insurance company was estimated at 73% and 43%, respectively. No report to either source was estimated at 15 000 OIs (~15%). Under-reporting to the national register differed by selected organisational factors, being higher among organisations in the public sector, those with more females, with a younger workforce and with a higher proportion of immigrants. Overall under-reporting was more common in agriculture (19.7%), other services (19.3%), commerce and hospitality (19.1%), health (18.4%) and education (18.4%). Under-reporting decreased as injury severity increased, with little variations across sectors of economic activity.

Conclusions Results suggest considerable under-reporting of OIs in Sweden and differential under-reporting by organisational factors. Results are relevant for official estimates of burden and for setting priorities for workplace safety and prevention.

INTRODUCTION

Accurate recording of occupational injuries (OIs) serves several national objectives. Measuring the true burden of OIs provide appropriate estimates of the burden for workers and for the economy. Complete recording also appraises authorities of any hidden differential injury risks, providing

Key messages

What is already known about this subject?

► Studies conducted in other countries have shown substantial under-reporting of occupational injuries (OIs). The magnitude of under-reporting of OIs and factors associated with under-reporting in Sweden have not been systematically investigated.

What are the new findings?

- An estimated one in four OIs (27%) were not reported in official statistics in Sweden in 2013, despite reporting being legally mandated.
- The estimated magnitude of under-reporting was influenced by several factors at the organisational level, being highest among organisations with more female employment, with a younger workforce, with a high proportion of immigrants and among employers belonging to the public sector.
- Overall, sectors of economic activity with the highest estimated under-reporting were agriculture, other services, commerce and hospitality, health and education.
- Also, as OI severity increased under-reporting decreased, with little variations across economic sectors.

How might this impact on policy or clinical practice in the foreseeable future?

► Results suggest notable under-reporting of OIs in Sweden and differential under-reporting by factors at the organisational level. Results are relevant for official estimates of burden and for determining priorities for workplace safety and prevention efforts.

information essential to target properly limited inspectional resources as well as to guide effective implementation of prevention and educational programmes. Finally, this information allows individual employers to benchmark their OI experience within their industry sector, facilitating the identification and correction of injury prevention deficiencies. In the 1990s, actual OI reporting for Sweden was estimated to be approximately 50% of the true

level, for all branches of economic activity.¹ No investigation was prompted by this finding.

The number of OIs in Sweden that are officially reported to the Information System on Occupational Injuries (ISA), a national register held by the Swedish Work Environment Authority, has been in decline for decades. In the early 1990s, there was a sharp decline in serious OIs, especially among men, attributed to structural changes in the labour market. Employment opportunities moved from hazardous environments in large-scale manufacturing industries to service sector jobs in small and medium-sized enterprises.² During the following decade, OIs continued to decrease, although at a slower pace and not in all sectors of economic activity, such as the healthcare sector.³ Research outside Sweden suggests that under-reporting may contribute to the apparent decline in OIs.^{4,5} Studies conducted in neighbouring countries, Norway and Denmark, have shown substantial under-reporting.^{6–8}

Previous studies suggest that several organisational factors are associated with the under-reporting of OIs. However, apart from employer size,^{9–11} few factors have been investigated. A limited number of studies have suggested that ownership sector (private/public)^{11,12} and economic activity^{10–12} could be associated with under-reporting of OIs, although for the latter, results are not consistent across studies, possibly due to differences within the study populations. The reasons for under-reporting injuries are only partially known and could vary across countries, but perceptions with regard to eligibility for compensation,⁹ organisational safety climate¹³ and system barriers¹⁴ have been suggested to play a role.

Setting priorities for workplace safety, research and prevention of OIs depends on accurate and reliable data. One way to estimate under-reporting is by means of capture–recapture, a method used to estimate the size of an unknown population, using overlapping sets of data.¹⁵ Capture–recapture has been widely used in epidemiology and specifically to assess under-reporting of OI.^{6,10,12,16–19} To the best of our knowledge, no previous study has used this specific method to investigate under-reporting in Sweden. Furthermore, exploring differential under-reporting could result in new understanding of methods useful to guide OI research as well as prevention and public policy.

The aim of this study is to estimate the magnitude of under-reporting of OI in Sweden overall and by different factors at the organisational level, using the best available information from two separate national sources of OI data.

METHODS

Data sources

This study includes all reports of non-fatal OIs in Sweden during 2013, among residents aged 18–65 who had at least one registered employer during that year. We used information from two data sources: the ISA register and the AFA Insurance company (AFA, from the Swedish acronym ‘the labour market insurance company’).

Official ISA statistics are based on OI reports to the Social Insurance Agency, which covers all employees and self-employed persons in Sweden. The employee is responsible for notifying the employer of a work injury, who in turn is legally obligated to report it.

The second data source, AFA, is a mutual insurance company owned by employers’ organisations and trade unions. AFA primarily covers workplaces that have collective bargaining agreements—100% of public sector employees and 93%–95% of the total Swedish Labour market, with lower coverage among

smaller private sector companies.²⁰ Employees report directly to AFA through an online form. AFA provides a broader compensation than ISA including lost income, and sometimes compensation for pain and suffering. Additional details on the data sources can be found in our published study protocol.²¹

Both ISA and AFA use the Swedish legal definition of OI: ‘an occupational injury is an injury due to accident(s), which occurred at the workplace or other place where the injured person had been for work. For an event to be counted as an accident, it is required that the course was relatively short and arose in connection with a particular event.’³

We included reported OIs (not necessarily approved claims). We excluded OIs that occurred during transit to/from work because these are difficult to disentangle from regular traffic insurance. We excluded injuries due to accumulated exposure (many musculoskeletal disorders) and near injuries, as these are not included in the definition of OI required to be reported.

To characterise OI severity, we used data from the National Patient Register (NPR), which includes all visits to inpatient or specialised outpatient care (excluding primary care).²² We selected diagnoses included in chapter XIX of the International Statistical Classification of Diseases and Related Health Problems ICD-10: injury, poisoning and certain other consequences of external causes (S00–T99).

Information on organisational factors was available for all Swedish organisations in the Longitudinal Integration Database for Health Insurance and Labour Market Studies.²³ These included ownership sector (public/private), number of employees, sector of economic activity (full description in online supplemental table S1) and organisational level characteristics of the workforce: proportion of women, proportion of young employees (<30 years old), proportion of immigrants and proportion of highly educated workers.

Data management

ISA and AFA cover slightly different populations. To make our two sources comparable, we restricted the analysis to the public sector where all employers have collective agreements and therefore insurance,²⁴ and to private companies with ≥ 50 employees. This size restriction was based on the fact that nearly all (>98%) private employers with ≥ 50 employees pay occupational pensions, a proxy for also being covered by AFA insurance.²⁵

The Swedish unique personal identity number allowed information to be linked from all databases.²⁶ Statistics Sweden de-identified the original identification numbers ensuring confidentiality. We linked ISA and AFA based on a ± 7 days’ range, assuming that OIs reported within a week in either of them was considered the same injury. Then we added data from the NPR linking date of admission with injury date, on a ± 7 days’ range. Finally, we defined three levels of increasing OI severity: no healthcare (ie, no admission in NPR), outpatient care and hospitalisation.

Statistical analysis

We employed a two-source capture–recapture method, estimating the total number of OIs, including those not reported to either source, using the Lincoln-Peterson estimator¹⁵ that assumes source independence. Ascertainment for each data source was calculated as the actual number of OIs divided by the capture–recapture estimate. We computed estimates by OI severity and by all organisational factors, then stratified organisational factors by OI severity.

To adjust for predictors and make the independence assumption more plausible, we estimated log-linear regression models.²⁷ Covariate-adjusted models included proportion of women, proportion of young employees and proportion of migrants, at

the organisation level. We present crude results, as they were in close agreement with adjusted results and are more relevant for policy-makers.

Data management was conducted using the Statistical Analysis Software (SAS) V.9.4. Capture–recapture estimates were obtained in R (R Foundation for Statistical Computing), including bootstrap to obtain 95% CI.

RESULTS

The final sample for analysis included 71 921 and 42 278 OIs reported to ISA and AFA, respectively. Merging on ± 7 days, resulted in a dataset with 83 327 unique OIs. The distribution of OIs by demographic, organisational factors and severity is shown in [table 1](#).

This distribution was similar for the data sources, but the numbers from AFA are smaller. In general, OIs were higher in organisations

Table 1 Distribution of non-fatal occupational injuries by organisational factors and injury severity, sorted by data source, Sweden, 2013*

	ISA		AFA	
	N	(%)	N	(%)
Total	71 921	100	42 278	100
Proportion of women at the organisation				
Male-dominated (female<40%)	25 661	35.7	17 839	42.2
Gender-integrated (female \geq 40-<60%)	9 515	13.2	6 402	15.1
Female-dominated (female \geq 60%)	36 745	51.1	18 037	42.7
Proportion of young workers at the organisation (mean age <30years old)				
\leq 10%	8 393	11.7	4 880	11.5
>10 to <30%	54 303	75.5	30 945	73.2
\geq 30%	9 225	12.8	6 453	15.3
Proportion of immigrant workers at the organisation				
<10%	28 862	40.1	19 352	45.8
\geq 10 to \leq 20	26 948	37.5	14 433	34.1
>20%	16 111	22.4	8 493	20.1
Proportion with higher level education (>13 years) at the organisation				
<20%	14 871	20.7	11 005	26.0
\geq 20%–40%	18 858	26.2	11 703	27.7
\geq 40%–60%	25 741	35.8	13 548	32.1
\geq 60%	12 451	17.3	6 022	14.2
Ownership Sector				
Public †	40 309	56.0	21 270	50.3
Private	31 612	43.9	21 008	49.7
Employer size ‡				
Medium to small (50–99)	4 115	13.0	3 187	15.2
Medium to large (100–249)	5 523	17.5	4 014	19.1
Large (\geq 250)	14 324	69.5	13 807	65.7
Sector of Economic Activity§				
Agriculture	84	0.1	75	0.2
Industry	14 512	20.2	9 283	22.0
Construction	3 302	4.6	2 802	6.6
Commerce and hospitality	4 585	6.4	3 608	8.5
Transport	4 913	6.8	3 572	8.5
Financial services	949	1.3	720	1.7
Public administration	6 285	8.7	4 065	9.6
Education	7 198	10.0	4 634	11.0
Health	23 258	32.3	9 387	22.2
Other services	6 318	8.8	3 885	9.2
Missing	517	0.7	247	0.6
Injury Severity ¶				
No hospital contact	60 824	84.6	32 045	75.8
Only outpatient	9 967	13.9	9 069	21.4
Hospitalised	1 130	1.6	1 164	2.7

*Includes OIs among all public sector and medium and large companies in the private sector (\geq 50employees). Injuries missing information on sector were excluded (3,8% for the total OIs).

†Public sector is composed of municipal and government administration; municipal-owned and government-owned companies and organisations; and other public institutions.

‡Number of employees is available only for companies in the private sector.

§Sectors of Economic Activity according to the Sixth European working conditions survey. Industry is composed of Mining and quarrying; manufacturing; electricity, gas, steam and air conditioning supply; and, water supply, sewerage, waste management and remediation activities.

¶Severity of injuries using data from inpatient and specialised outpatient care, available from the National Patient Register.

AFA, AFA Insurance; ISA, the Information System on occupational injuries; OI, occupational injuries.

that tend to be gender-segregated, with more than 10% of workers being young (<30 years old), and with less than 10% being immigrant workers. The public sector was slightly overrepresented, as well as large companies in the private sector (≥ 250 employees). Most injuries did not require healthcare contact, and the highest numbers of OIs were observed in the health, industry and education sectors.

Capture–recapture estimates for this final sample, overall and by injury severity are presented in [table 2](#).

Overall, we estimated 98 493 OIs in 2013. Completeness of reporting OIs to ISA and to AFA was estimated at 73% and 43%, respectively, and 15 000 OIs (15.4%; 95% CI 15.1% to 15.7%) were estimated to be not reported to either data source. Under-reporting of OIs decreased as the injury severity increased, particularly for AFA. The capture proportions for hospitalised OIs were similar in ISA and AFA (~80%), while those associated to OIs with no healthcare contact were much smaller in AFA (38%) than ISA (72%).

Capture–recapture estimates by organisational factors are presented in [table 3](#).

Non-overlapping CIs were present for several factors in the different groupings calling attention to significant differences. Under-reporting was highest among female-dominated organisations (13.2%; 95% CI 12.8% to 13.5%), those with more than 10% immigrant workers (17.6%; 95% CI 17.1% to 18.1%), with a younger workforce (>30% of workers below 30 years old, 18.2%; 95% CI 17.4% to 18.9%) and those belonging to the public sector (14.4%; 95% CI 14.1% to 14.8%). Among private companies, under-reporting decreased as employer's size increased. However, with increasing size of the organisation, capture by ISA increased while capture by AFA decreased. Estimates for sector of economic activity ranged from 6.5% in public administration (95% CI 5.9% to 7.1%), to 19.7% in agriculture (95% CI 12.0% to 27.4%). Under-reporting was most notable among other services (19.3%; 95% CI 18.3% to 20.3%), commerce and hospitality (19.1%; 95% CI 18.0% to 20.1%), health (18.4%; 95% CI 17.8% to 18.9%) and education (18.4%; 95% CI 17.5% to 19.3%).

[Table 4](#) presents the magnitude of under-reporting for organisational factors stratified by OI severity.

In general, we observed a common gradient across organisational factors, with a decrease in the estimated under-reporting with increased injury severity. In those cases where the decrease in under-reporting was less evident across different organisational factors (eg, economic sector), small numbers may explain this difference. Complete count details for [tables 3 and 4](#) are presented as supplementary material (online supplemental tables S2 and S3).

Additional analysis showed that estimates for economic sectors by levels of severity remained even after adjustments for proportion of women, proportion of younger workers and proportion

of immigrants at the organisation level (online supplemental table S4). We also calculated the distribution of OIs and proportion of reported injuries by each source for the entire population, without the restriction of company size in the private sector and without capture–recapture estimates (online supplemental table S5). Findings from this side-by-side comparison of the two data sources including all employers were consistent with our main capture–recapture results.

DISCUSSION

In this study, we used capture–recapture methodology to estimate the extent of under-reporting of OIs in Sweden in 2013. While 85% of the estimated total number of injuries were reported in at least one of the two data sources, the estimated overall capture proportion in the official injury register (ISA) was only 73%. This estimation means that in the public sector and among medium and large private sector employers, one in four OIs—approximately 26 000 in 2013—were not in the official count of OI burden. The insurance company AFA only captured 43% of the total estimated OIs. Since these data sources are not routinely combined in practice, the under-reporting in ISA is most relevant to stakeholders who rely on official statistics to inform policy and to prevent OI in Sweden. Moreover, this national register forms the basis of the information reported at the European level.²⁸

In line with our findings, others have also found higher reporting of OIs to the national system among public employers^{11 12} and larger workplaces.^{10 11} Previous studies have investigated sectors of economic activity, either in stratified analysis^{10–12} or as part of a list of explanatory variables,^{17 29} with inconclusive results. The present study considers additional unexplored factors at the organisation level (eg, proportion of immigrants), includes data on both the public and private sectors, and adds a broader coverage of sectors of economic activity compared with previous studies.

Differential under-reporting across economic sectors could have several underlying explanations including reporting protocols, strong unions, workplace or industry awareness and professional cultures. Low under-reporting in the industrial production sector should not be surprising, as these are male-dominated sectors with high levels of unionisation.²⁰ The opposite situation could explain our results for agriculture, where less unionisation and less skilled workers may affect OI reporting.

Our results of decreased under-reporting with increasing injury severity are consistent with previous studies, which have identified lesser severity as a predictor of not reporting OIs, usually measured either as type of injury or part of the body^{8 29} or as time off from work.^{29 30} Severity, however, has not been

Table 2 Capture–recapture estimates of under-reporting non-fatal occupational injuries by injury severity in Sweden, 2013*

	Overlap	ISA only	AFA only	Total observed †	Total estimated‡ (95% CI)	% under-reported (95% CI)	% captured by ISA	% captured by AFA
Total	30 872	41 049	11 406	83 327	98 493 (98 115 to 98871)	15.4 (15.1 to 15.7)	73.0	42.9
No healthcare contact§	23 206	37 618	8839	69 663	83 991 (83 607 to 84376)	17.1 (16.7 to 17.4)	72.4	38.2
Only outpatient	6741	3226	2328	12 295	13 409 (13 344 to 13475)	8.3 (7.9 to 8.7)	74.3	67.6
Hospitalised	925	205	239	1369	1422 (1412 to 1432)	3.7 (3.0 to 4.4)	79.5	81.9

*Severity is defined using data from the National Patient Register (NPR), which includes all visits to inpatient or specialised outpatient care (ie, excluding primary care).

†Total observed corresponds to the sum of occupational injuries captured by ISA only, AFA only and the overlap. The final sample for analysis of 83 327 occupational injuries corresponds to 78 743 individuals.

‡Total estimated is the sum of the injuries observed plus those not captured by any of the sources.

§Without any date of admission in the NPR.

AFA, AFA Insurance; ISA, the Information System on occupational injuries.

Table 3 Capture–recapture estimates of under-reporting non-fatal occupational injuries by organisational factors in Sweden, 2013*

Variables	% Under-reported (95% CI)	%captured by ISA	%captured by AFA
Proportion of women at the organisation			
Male-dominated (female <40%)	13.2 (12.8 to 13.5)	73.2	50.9
Gender-integrated (female 40%–60%)	9.6 (9.1 to 10.1)	79.4	53.4
Female-dominated (female >60%)	19.2 (18.8 to 19.7)	70.6	34.6
Proportion of young workers at the organisation (<30 years old)			
≤10%	14.4 (13.7 to 15.2)	74.5	43.3
>10 to <30%	14.9 (14.6 to 15.2)	74.2	42.3
≥30%	18.2 (17.4 to 18.9)	66.2	46.3
Proportion of immigrant workers at the organisation			
<10%	12.5 (12.1 to 12.8)	75.0	50.3
10–20	17.6 (17.1 to 18.1)	71.5	38.3
>20%	18.0 (17.4 to 18.7)	71.1	37.5
Proportion of highly educated workers at the organisation (higher level education (>13 years)			
<20%	15.1 (14.5 to 15.6)	69.2	51.2
≥20%–40%	13.6 (13.1 to 14.1)	74.6	46.3
≥40%–60%	16.7 (16.2 to 17.2)	72.9	38.4
≥60%	14.2 (13.5 to 15.0)	77.3	37.4
Ownership sector			
Public	14.4 (14.1 to 14.8)	75.9	40.1
Private	16.0 (15.6 to 16.4)	70.1	46.6
Employer size †			
Medium to small (50–99)	18.0 (16.9 to 19.1)	64.2	49.7
Medium to large (100–249)	16.9 (15.9 to 17.8)	67.1	48.8
Large (≥250)	15.1 (14.6 to 15.6)	72.3	45.4
Sector of economic activity			
Agriculture	19.7 (12.0 to 27.4)	58.7	52.4
Other services	19.3 (18.3 to 20.3)	67.1	41.3
Commerce and hospitality	19.1 (18.0 to 20.1)	62.5	49.2
Education	18.4 (17.5 to 19.3)	67.4	43.3
Health	18.4 (17.8 to 18.9)	73.8	29.8
Construction	14.3 (13.3 to 15.3)	66.9	56.8
Financial services	13.1 (11.2 to 15.1)	71.4	54.2
Transport	12.3 (11.4 to 13.1)	73.6	53.5
Industry	11.1 (10.6 to 11.6)	77.9	49.8
Public administration	6.5 (5.9 to 7.0)	85.6	55.3
Missing	–	–	–

*Including working population in the entire public sector and medium and large companies in the private sector (≥50 employees).

†Employer size available only for private companies.

AFA, AFA Insurance; ISA, the Information System on occupational injuries.

investigated in combination with organisational factors as presented here. Our nuanced findings of under-reporting across economic sectors by levels of severity could be used to inform future research and provide better guidance for appropriate targeting of inspections and prevention programmes.

Our study also adds to understanding the importance of workforce gender structure and injury reporting by showing the lowest under-reporting among gender-integrated organisations and the highest among female-dominated organisations. This finding appears to align with the recent Swedish report on the overall importance of gender segregation across economic sectors.³¹ It also suggests that assumptions of male-dominated occupations being ‘high-risk’ occupations may actually be due in part to under-reporting of OIs in female-dominated occupations. Authorities should consider these findings when targeting injury prevention.

Finally, we found higher under-reporting among organisations with a high proportion of immigrants. Dong *et al* found that

under-reporting of OIs was higher among Hispanic workers compared with white workers in the USA.³² Their findings were limited to small establishments (1–10 employees) in the construction sector. While Hispanic workers are not all immigrants, this study finds specific evidence of under-reporting among organisations with a higher proportion of immigrants across all sectors of economic activity.

Studies conducted in neighbouring countries have shown that under-reporting of OIs may be higher than that reported for ISA in the present study. A Norwegian study using capture–recapture methods indicated an undercount of reported amputations, ranging from 16% to 58% during a 10-year study period.⁶ Capture–recapture methodology has been used in other jurisdictions, such as in the USA^{12 17–19} and The Netherlands,¹⁰ with a wide range of estimates for under-reporting of OIs. Other methods were used in Denmark, where only 24%–44% of the OIs in hospital records were found in the Danish equivalent of ISA⁷ and in Norway, where only 9%–13% of OIs registered by

Table 4 Capture–recapture estimates of under-reporting non-fatal occupational injuries in Sweden, stratified by severity levels, 2013*

	No healthcare contact % under-reported (95% CI)	Only outpatient % under-reported (95% CI)	Hospitalised % under-reported (95% CI)
Total	17.1 (16.7 to 17.4)	8.3 (7.9 to 8.7)	3.7 (3.0 to 4.4)
Proportion of women at the organisation			
Male-dominated (female <40%)	15.4 (15.0 to 15.9)	7.6 (7.1 to 8.1)	2.3 (1.9 to 3.3)
Gender-integrated (female 40%–60%)	10.3 (9.7 to 10.9)	6.0 (5.2 to 6.9)	6.5 (3.6 to 9.4)
Female-dominated (female >60%)	20.3 (19.8 to 20.8)	10.5 (9.8 to 11.3)	5.3 (3.7 to 6.9)
Proportion of young workers at the organisation (<30 years old)			
≤10%	16.2 (15.2 to 17.2)	7.9 (6.8 to 9.0)	3.7 (2.0 to 5.5)
>10 to <30%	16.4 (16.0 to 16.7)	7.8 (7.4 to 8.3)	3.1 (2.3 to 3.8)
≥30%	20.8 (19.8 to 21.7)	10.6 (9.5 to 11.7)	7.5 (4.6 to 10.4)
Proportion of immigrant workers at the organisation			
<10%	13.7 (13.2 to 14.1)	7.6 (7.0 to 8.1)	3.1 (2.3 to 4.0)
10–20	19.5 (18.9 to 20.1)	8.7 (8.0 to 9.5)	4.2 (2.9 to 5.5)
>20%	20.1 (19.3 to 20.9)	9.3 (8.4 to 10.2)	4.5 (2.8 to 6.2)
Proportion of highly educated workers at the organisation (higher level education >13 years)			
<20%	18.5 (17.8 to 19.2)	8.1 (7.4 to 8.8)	2.3 (1.5 to 3.1)
≥20%–40%	15.0 (14.5 to 15.6)	7.6 (6.8 to 8.3)	3.3 (2.1 to 4.5)
≥40%–60%	17.8 (17.3 to 18.4)	9.0 (8.2 to 9.8)	4.7 (3.2 to 6.1)
≥60%	15.1 (14.3 to 15.9)	8.4 (7.2 to 9.5)	10.1 (5.7 to 14.5)
Ownership sector			
Public	15.3 (14.9 to 15.8)	7.9 (7.3 to 8.6)	4.8 (3.5 to 6.0)
Private	18.8 (18.3 to 19.3)	8.5 (8.0 to 9.0)	3.1 (2.4 to 3.9)
Employer size †			
Medium to small (50–99)	23.2 (21.8 to 24.5)	9.5 (8.2 to 10.9)	4.8 (2.2 to 7.4)
Medium to large (100–249)	20.5 (19.3 to 21.7)	9.9 (8.6 to 11.2)	2.6 (1.3 to 4.0)
Large (≥250)	17.4 (16.8 to 18.0)	7.8 (7.2 to 8.4)	2.9 (2.0 to 3.8)
Economic activity			
Agriculture	22.1 (12.6 to 31.7)	NE	NE
Other services	22.6 (21.3 to 23.9)	10.0 (8.7 to 11.4)	5.7
Commerce and hospitality	21.6 (20.3 to 22.9)	12.3 (10.7 to 14.0)	7.1 (3.4 to 10.9)
Education	20.4 (19.3 to 21.4)	9.3 (7.9 to 10.8)	5.0 (2.4 to 7.7)
Health	18.9 (18.2 to 19.6)	10.8 (9.5 to 12.0)	6.0 (3.1 to 8.8)
Construction	18.7 (17.2 to 20.2)	8.4 (7.2 to 9.7)	2.5 (0.9 to 4.1)
Financial services	14.2 (11.8 to 16.6)	10.7 (7.2 to 14.1)	NE
Transport	13.5 (12.5 to 14.4)	8.1 (6.8 to 9.5)	4.3 (1.8 to 6.8)
Industry	13.0 (12.4 to 13.7)	5.5 (4.9 to 6.1)	1.2 (0.6 to 1.8)
Public administration	6.8 (6.1 to 7.5)	4.3 (3.3 to 5.2)	6.8 (3.3 to 10.4)
Missing	–	–	–

*Including working population in the entire public sector and medium and large companies in the private sector (≥50 employees).

†Employer size available only for private companies.

NE, no estimation due to low numbers.

one hospital were reported to their equivalent of ISA within 1 year.⁸ A 2015 Finnish report, including several countries in the Baltic region, concluded that for Sweden the reporting level was considered to be approximately 30%–50% of true levels,³³ slightly below the estimated 50% in the 1990s.¹ The more recent study, however, provided only rough estimates and was based on extrapolations from experience in ‘benchmark’ countries.

Based on this review, we conclude that our results suggest lower under-reporting to ISA than might be expected from the experience in other countries. The reasons for this are unclear, but differences in severity and nature of injuries covered in these studies, populations under study, healthcare and compensation systems, along with different methods used to estimate under-reporting, preclude precise comparisons across countries. The restriction to private companies having at least 50 employees could be another explanation. Larger workplaces are known to

have better reporting of OIs than smaller companies where there is widespread unawareness that reporting of OIs is mandatory.⁹ This is consistent with our analysis of capture rates by employer’s size presented in online supplemental table S5. Interestingly, ISA and AFA have the same percentage captured for microemployers, the group likely to be least well informed about official reporting requirements. Overall, we believe that our study presents a conservative estimate of total under-reporting.

The reasons for under-reporting are not well understood in the Swedish context, but factors such as precarious employment^{30 34} or disincentives to reporting that are enhanced in precarious work¹⁴ have been suggested to affect OI reports in other contexts. A Swedish report found that many employees consider it unnecessary to report injuries, as they may assume they are not eligible for financial compensation.⁹ Strategies that have been identified to encourage reporting in Sweden include

clear information and clear procedures at the workplace; the work environment management; knowledgeable and well-informed staff and management involvement.³⁵ The success of such strategies has not been assessed. In a study from the USA, under-reporting was higher in working environments with poorer organisational safety climate or where supervisor safety enforcement was inconsistent.¹³

Strengths and limitations

Strengths of this study include the use of nationwide register data with thorough coverage of the working population; the ability to link all registers thanks to the unique personal identity number; the existence of two separate reporting systems for OIs and the availability of covariates for adjusted models. Another strength is that ISA and AFA use the exact same case definition for OI, which made combination of data sources feasible.

However, some limitations should be mentioned. Our definition for the overlap of data sources on a ± 7 days' range might be considered arbitrary. Like previous reports,^{11 36} we chose to apply this range to avoid missing OIs due to administrative issues, or differences between date of report and actual date of the event. Even using this definition, OIs not having the exact same date in both sources was less than 5%. Also, reported injuries are not the same as injuries accepted for compensation. However, in our discussions with register holders, the issue of reporting injuries unrelated to work is perceived as negligible. Additionally, differential coverage of AFA insurance across economic sectors is known.³⁷ It is especially low in hotels and restaurants, which requires the results for economic sectors such as commerce and hospitality to be interpreted with caution. In the agricultural sector, we were unable to compute estimates for all severity levels due to small numbers. However, our overall estimate for this sector is in line with previous studies showing that the magnitude of under-reporting is of importance both in agricultural activities³⁸ as well as in forestry.³⁹

AFA does not include workers who are not covered by collective bargaining agreements, and workers covered by such agreements are more likely to report their injuries. To make sure that our two data sources were comparable (ie, individuals have the same likelihood to be 'captured'), we restricted the analyses to injuries within the public sector (with 100% coverage of collective bargaining), and private companies with ≥ 50 employees, which are highly likely to be covered by collective bargaining.^{20 37} This means that our analysis did not include self-employed workers.

Methodological issues from the capture–recapture methodology approach may arise from the lack of true independence between data sources.¹⁵ In case of a positive dependence (ie, if an OI is present in one data source it is more likely to be present in the other), then our results would be an underestimation of the true proportion of under-reporting. Source independency is a strong assumption, yet necessary for the employment of this method. Nonetheless, to make the assumption of independence more plausible, we took measures such as the restriction within the private companies as well as examining covariate-adjusted models which confirmed the unadjusted results.

We could not use clinical data as a third source of OI reports, because healthcare providers are not mandated to report known or suspected work-related injuries. We were able to use the NPR to characterise severity for injuries already reported to ISA/AFA.

Our results show the need for further quantitative studies exploring issues such as precarious employment conditions, business performance and sociodemographic characteristics of the workforce. Qualitative studies are also needed in order to

understand economic, social, and cultural barriers to reporting as has been done in other countries.^{14 40} Studies in areas of economic activity with low under-reporting (eg, industry) could inform interventions on how to improve reporting in those with high under-reporting such as healthcare where the downward trend of OIs in recent decades is less evident.³

CONCLUSIONS

To conclude, we observed differential under-reporting across several organisational factors, as well as by severity levels. It is important to explore these issues in further detail as they affect surveillance, inspection targeting and research of OIs, and at a minimum, may lead to biased official injury statistics.

Twitter Theo Bodin @theobodin

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Contributors CO was involved in conducting data analysis, interpreting results, writing the manuscript and addressing editorial changes. TB is the principal investigator of the project and was involved in all aspects, including the conception and design of the study. PF created the statistical model to obtain capture–recapture estimations. All authors were involved in planning the study, interpreting results and reviewing the manuscript. All authors gave final approval of the final version and agreed to be accountable for all aspects of published work.

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ORCID iD

Cecilia Orellana <http://orcid.org/0000-0002-5109-4698>

REFERENCES

- 1 EUROSTAT. *European statistics on accidents at work (ESAW) - Methodology*, 2001.
- 2 Swedish Work Environment Authority (Arbetsmiljöverket). *Nedåtgående trend av anmälda arbetsskador - Tillfälligt avbrott?* Stockholm: Arbetsmiljöverket, 2011.
- 3 Swedish Work Environment Authority (Arbetsmiljöverket). *Arbetssskador 2014, occupational accidents and work-related diseases*. Stockholm: Arbetsmiljöverket, 2015.
- 4 Leigh JP, Marcin JP, Miller TR. An estimate of the U.S. government's undercount of nonfatal occupational injuries. *J Occup Environ Med* 2004;46:10–18.

- 5 Friedman LS, Forst L. The impact of OSHA recordkeeping regulation changes on occupational injury and illness trends in the US: a time-series analysis. *Occup Environ Med* 2007;64:454–60.
- 6 Samant Y, Parker D, Wergeland E, et al. Estimating work-related amputations in the Norwegian manufacturing sector: a 10-year retrospective study based on two-source capture-recapture method. *Int J Occup Environ Health* 2012;18:292–8.
- 7 Lander F, Nielsen K, Rasmussen K, et al. *Underrapportering AF arbejdsulykker*. Øje på arbejdsmiljøet København: Landsorganisationen i Danmark, 2012.
- 8 Magne Gravseth H, Wergeland E, Lund J. Underrapportering AV arbeidsskader TIL Arbeidstilsynet. *Tidsskrift for den norske lægeforening* 2003;123:2057–9.
- 9 Swedish Work Environment Authority (Arbetsmiljöverket). *Hälsorelaterad arbetsmiljöövervakning*. Stockholm: Arbetsmiljöverket, 2014.
- 10 van Charante AW, Mulder PG. Reporting of industrial accidents in The Netherlands. *Am J Epidemiol* 1998;148:182–90.
- 11 Wuellner SE, Adams DA, Bonauro DK. Unreported workers' compensation claims to the BLS survey of occupational injuries and illnesses: establishment factors. *Am J Ind Med* 2016;59:274–89.
- 12 Rosenman KD, Kalush A, Reilly MJ, et al. How much work-related injury and illness is missed by the current national surveillance system? *J Occup Environ Med* 2006;48:357–65.
- 13 Probst TM, Estrada AX. Accident under-reporting among employees: testing the moderating influence of psychological safety climate and supervisor enforcement of safety practices. *Accid Anal Prev* 2010;42:1438–44.
- 14 Azaroff LS, Levenstein C, Wegman DH. Occupational injury and illness surveillance: conceptual filters explain underreporting. *Am J Public Health* 2002;92:1421–9.
- 15 Hook EB, Regal RR. Capture-Recapture methods in epidemiology: methods and limitations. *Epidemiol Rev* 1995;17:243–64.
- 16 Cormack RM, Chang YF, Smith GS. Estimating deaths from industrial injury by capture-recapture: a cautionary tale. *Int J Epidemiol* 2000;29:1053–9.
- 17 Boden LI, Ozonoff A. Capture-recapture estimates of nonfatal workplace injuries and illnesses. *Ann Epidemiol* 2008;18:500–6.
- 18 Tak S, Grattan K, Boden L, et al. Impact of differential injury reporting on the estimation of the total number of work-related amputations. *Am J Ind Med* 2014;57:1144–8.
- 19 Boden LI. Capture-recapture estimates of the undercount of workplace injuries and illnesses: sensitivity analysis. *Am J Ind Med* 2014;57:1090–9.
- 20 The Swedish social insurance inspectorate (Inspektionen för Socialförsäkringen). *Who receives provisions for occupational pension? An analysis of the coverage ratio of occupational pensions based on declaration information [Vem får avsättningar till tjänstepension? En analys av tjänstepensionernas täckningsgrad baserad på deklara-tionsuppgifter]*. Stockholm, 2018.
- 21 Orellana C, Kreshpaj B, Johansson G, et al. Precarious employment, business performance and occupational injuries: a study protocol of a register-based Swedish project. *BMJ Open* 2019;9:e026091.
- 22 National Board of Health and Welfare (Socialstyrelsen). The National patient register, 2019. Available: <https://www.socialstyrelsen.se/en/statistics-and-data/register/ register-information/the-national-patient-register/>
- 23 Statistics Sweden (SCB). Longitudinell integrationsdatabas för sjukförsäkrings- och arbetsmarknadsstudier (LISA) [Longitudinal integrated database for health insurance and labour market studies], 2017. Available: <https://www.scb.se/vara-tjanster/ bestalla-mikrodata/vilka-mikrodata-finns/longitudinella-register/longitudinell-integrationsdatabas-for-sjukforsakrings-och-arbetsmarknadsstudier-lisa/>
- 24 Kjellberg A, ed. *Organisationsgraden hos fack och arbetsgivare, kollektivavtalens täckningsgrad mm*. Seminarium Svenskt Näringsliv, 2017.
- 25 Inspektionen för socialförsäkringen. *Vem får avsättningar till tjänstepension? [Who gets provisions for occupational pensions?]* Stockholm: Inspektionen för socialförsäkringen, 2018.
- 26 Ludvigsson JF, Otterblad-Olausson P, Pettersson BU, et al. The Swedish personal identity number: possibilities and pitfalls in healthcare and medical research. *Eur J Epidemiol* 2009;24:659–67.
- 27 Tilling K, Sterne JA. Capture-recapture models including covariate effects. *Am J Epidemiol* 1999;149:392–400.
- 28 EUROSTAT. European Statistics on Accidents at Work (ESAW) - Summary methodology Luxembourg: Publications Office of the European Union, 2013. Available: <https://ec.europa.eu/eurostat/documents/3859598/5926181/KS-RA-12-102-EN.PDF/56cd35ba-1e8a-4af3-9f9a-b3c47611ff1c>
- 29 Boden L, Nestoriak N, Pierce B. *Using capture-recapture analysis to identify factors associated with differential reporting of workplace injuries and illnesses*. American statistical association, 2010.
- 30 Shannon HS, Lowe GS. How many injured workers do not file claims for workers' compensation benefits? *Am J Ind Med* 2002;42:467–73.
- 31 Swedish Work Environment Authority (Arbetsmiljöverket). *Work environment and ill health in a gender perspective - Commissioned research with relevance to the supervisory activities [Arbetsmiljö och ohälsa i ett genusperspektiv - Uppdragsforskning med relevans för tillsynsverksamheten]*. Stockholm: Arbetsmiljöverket, 2019.
- 32 Dong XS, Fujimoto A, Ringen K, et al. Injury underreporting among small establishments in the construction industry. *Am J Ind Med* 2011;54:339–49.
- 33 Kurppa K. *Severe under-reporting of work injuries in many countries of the Baltic sea region: an exploratory semi-quantitative study*. Helsinki: Finnish Institute of Occupational Health, 2015.
- 34 Quinlan M, Mayhew C. Precarious employment and workers' compensation. *Int J Law Psychiatry* 1999;22:491–520.
- 35 The Norwegian Labour Inspection Authority. Reliable occupational accident registration – indicator for prevention. The Realocc accidents project 2013-2015, 2015. Available: <http://www.balticseaoh.net/reliable-occupational-accident-registration-indicator-for-prevention/>
- 36 Koehoorn M, Tamburic L, Xu F, et al. Characteristics of work-related fatal and hospitalised injuries not captured in workers' compensation data. *Occup Environ Med* 2015;72:413–20.
- 37 Kjellberg A. *The coverage ratio of collective agreements and the degree of organization of employers' unions and trade unions [Kollektivavtalens täckningsgrad samt organisationsgraden hos arbetsgivarförbund och fackförbund]*. Lund, Sweden: Lund University, 2018.
- 38 Pinzke S, Lundqvist P. Occupational accidents in Swedish agriculture. *Agricultural Engineering Research* 2007;2007:159–65.
- 39 Hemmingsson P, Nielsen K, Blizzard E. *Tillsyn av skogsbranschen*. Arbetsmiljöverket, 2014.
- 40 Webb GR, Redman S, Wilkinson C, et al. Filtering effects in reporting work injuries. *Accid Anal Prev* 1989;21:115–23.