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Original article

The Characteristics of Accepted Work-related Injuries and Diseases Claims in the Australian Coal Mining Industry

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ABSTRACT

Background: Coal mining is a hazardous industry. The purpose of the study is to identify the nature of occupational injuries and diseases among coal miners and to determine the factors that affect the rate of injury and duration of time loss from work.

Methods: A retrospective cohort study was conducted using accepted workers' compensation claims data of 30,390 Australian coal miners between July 2003 and June 2017.

Results: Musculoskeletal and fracture conditions accounted for approximately 60% of claims in all occupational groups. Cox regression analysis showed that older age and female gender were significant predictors of longer time off work. Injury types and occupations were associated with work time loss: mental health conditions, and machine operators and drivers had significantly longer durations of time off work.

Conclusion: Future research can further address how these factors led to longer time off work so that coal industry regulators, employers, and healthcare providers can target interventions more effectively to these at-risk workers.

1. Introduction

Coal remains the most significant and widespread fuel source for electricity generation, accounting for 39.3% of all fuel sources [1]. Coal is extracted from coal seams by surface or underground mining, and both methods are fraught with a myriad of occupational hazards, not least coal being a combustible source of energy. Coal miners also contend with threats from the environment including weather, working underground, remoteness and the significant by-product of respirable coal dust released into the air by mining operations (e.g., drilling, blasting, shoveling, and tipping). Coal mine dust contains coal dust, inorganic minerals, and crystalline silica; excessive inhalation of these dust cause "coal worker's pneumoconiosis" and other pneumoconiosis forms include asbestosis and silicosis. Underground mine workers are exposed to heat and humidity, poor air quality, poor illumination, and slippery floors [2]. Not surprisingly, being hit by a moving object, falls, being trapped between objects, and being hit by falling objects are the leading causes of lost time injuries reported among underground coal miners [3]. Workers' stress and vocational aptitude may affect safety risk. Workers who are dissatisfied with their jobs experience more production pressure while high-risk-takers are more likely to be injured [4].

Consequences of injuries include time-off work, costs related to medical treatment, and disabilities. For the injured worker, negative consequences include loss of income, physical and mental suffering, relationship strain with the spouse who may be a de-facto carer, and activity limitations. Delayed return-to-work also disadvantages future employability and earnings [5]. The longer an injured person is absent from work, the more likely they will not return to work, thus worsening the social impacts of injury [6,7]. An extended time off work also incurs higher costs including lost-time income replacement, health care treatment, loss of productivity, training replacement workers, and administration. After a workplace injury, returning to work is a critical stage, and many factors influenced it. Early identification of predictors is crucial for early intervention and to minimize the consequences of injury. In Australia, large scale population-based studies are yet to be conducted among coal mining workers. Current literature involving coal mining workers' injury in Australia is limited to jurisdictional

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reports from the major coal-mining states, Queensland and New South Wales [3,8,9]. These safety reports are primarily focused on the number of incidents and fatalities. Injury types and the duration of time off work affecting the coal miners are not reported.

This study aims to investigate the characteristics and burden of work-related injuries among Australian coal miners. The type of injuries sustained by coal miners and time loss due to the injuries will be examined. Injury frequencies between different genders, age groups, and occupations within the coal mining industry will be compared. The study will also examine the workers, injury types, and claim factors associated with frequencies of injury and duration of time loss. Identifying the link between these predictors, frequency of injury and work absence can enable regulators, employers, workers, and healthcare providers to modify the associated risk factors to prevent injury and reduce the duration of time loss due to injury.

2. Methods

2.1. Setting

The majority of Australia's workers are covered by compulsory workers' compensation insurance regulated by state, territory, and Commonwealth government entities. Work-related injuries and diseases eligible for compensation include acute injuries, diseases resulting from exposure to biological or chemical hazards, or health conditions of gradual onset nature. Workers' compensation insurance systems also accept "psychological injury" claims when work is a significant contributor to a mental health condition. When a workplace injury or disease occurs, with a demonstrable link between the health condition and the workplace or duties, the workers'-compensation scheme may provide benefits including healthcare treatment expenses and/or income replacement payments for the time a worker is off work. Depending on the duration of the income replacement, income replacement payments are generally accorded at a percentage of the workers' pre-injury earnings. The compensation scheme may also cover expenses for vocational rehabilitation and retraining. Injured workers with a permanent injury or disability may receive lump-sum payments. The employer must inform the compensation scheme within a period of time when the claim is received, including a "claim form" to provide information about the worker's injury, and a medical certificate issued by the treating medical practitioner. Annually, all Australian workers' compensation authorities provide case-level claims data to Safe Work Australia, which compiles the National Data Set for Compensation-based Statistics (NDS). The data set is composed of information regarding each compensation claim lodged, including claimant age, gender, occupation, jurisdiction, income replacement payments, employer industry, type of injury, and time-off work. Current NDS data commences from 2003 to June 2017.

2.2. Participants

Workers of all occupations in the coal mining industry were the target population for this study. The cases were identified in the NDS through their unique Australian and New Zealand Standard Industrial Classification 2006 (ANZSIC) code for coal mining (code '06'). The data set available identified cases over fourteen years from July 2003 to June 2017. In cases when data was incomplete, it was excluded. Cases were also excluded if the worker was aged $<$ 15 years or $>$ 80 years. Cases with unlikely working hours worked ($<$ 1 or $>$ 100 h per week before injury) were excluded. The final number of cases available for analysis was 30,390.

Cases were then separated based on their four-digit Australian and New Zealand Standard Classification of Occupation (ANZSCO) codes as "drillers, miners, and shot firers" (code 7122), "machine operators and drivers" (rest of Major Group 7), "technicians and trade workers" (Major 6), "laborers" (Major Group 8) and "other occupations" (remaining groups within the coal mining industry). "drillers, miners, and shot firers" are normally classified under machine operators and drivers (Group 7) in the ANZSCO. In this study, they represented the largest number of workers in the coal industry. "drillers, miners, and shot firers" also have a different profile of occupational tasks compared to machine operators and drivers. Given these reasons, "drillers, miners, and shot firers" were separated from the rest of the machine operators and drivers during analysis as a unique occupational group. Similarly, "technicians and trade workers" and "laborers" are two larger occupational groups. Table 1 lists each type of occupational group based on the ANZSCO classification and their respective vocational tasks descriptions [10].

The type of condition coding was a modified version of the Type of Occurrence Classification System (TOOCS) version 3 [11] to account for differences in coding between jurisdictions and coding changes within jurisdictions over time (Table 2). The modification is based on a previously published condition classification system done by the same research team [12]. In this study, given the significant exposure to coal dust, respiratory conditions were separated.

2.3. Outcome variables

The primary outcome was the duration of time lost, measured as the cumulative number of weeks of paid compensation. Cumulative duration is considered an appropriate estimate measure of time off work when using administrative data [13]. The cumulative number of compensated weeks was calculated by dividing the number of hours compensated by the number of pre-injury work hours per week. Time loss was generated for each of the occupational groups. Claims were separated into medical claims only, where claims were accepted as a work-related injury or disease for treatment related cost, and claims included both medical claims and time loss due to work-related injury or disease.

Table 1
Occupational groups and task description

Occupational group	Vocational tasks
Drillers, miners, and shot firers	assemble, position and operate drilling rigs and mining plant, and detonate explosives to extract materials from the earth and demolish structures
Machine operators and drivers	operate machines, plant, vehicles, and other equipment to perform a range of agricultural, manufacturing and construction functions, move materials, and transport passengers and freight
Technicians and trade workers	perform various skilled tasks, applying broad or in-depth technical, trade or industry-specific knowledge, often supporting scientific, engineering, building and manufacturing activities
Laborers	perform a variety of routine and repetitive physical tasks using hand and power tools, and machines
Other occupations	includes managers, professionals who perform analytical, conceptual and creative tasks, community and personal service workers, clerical, and administrative workers and sales workers

Table 2
Newly defined condition code with corresponding major nature of injury/disease classification TOOCS groups

Condition	TOOCS nature of injury/disease classification major group
Fractures	Fractures
Musculoskeletal	Traumatic joint/ligament and muscle/tendon injury Musculoskeletal and connective tissue diseases
Neurological	Intracranial injuries Injury to nerves and spinal cord Nervous system and sense organ diseases
Respiratory	Respiratory diseases
Mental health conditions	Mental diseases
Other traumatic	Wounds, lacerations, amputations, and internal organ damage Burns Other injuries
Other diseases	Digestive system diseases Skin and sub-cutaneous tissue diseases Respiratory system diseases Circulatory system diseases Infectious and parasitic diseases Neoplasms (Cancer) Other diseases
Other claims	Other claims

Factors previously associated with the length of time off work from work-related injuries and diseases including the age at date of injury, gender, specific occupation (based on ANZSCO codes), injury types (using the standardized national TOOCS) were also derived from the NDS data set for inclusion in the analyses.

2.4. Data analysis

Descriptive statistics including gender, age groups, and injury types were used to characterize the claims across each occupational group. Predictor variables were tested for association with the outcome variable (duration of time loss) in a univariate Cox regression. Predictors significantly associated with duration of time loss were included in a multivariable stepwise Cox regression model. All predictor variables were entered into the model in the first step. Outcomes are reported as hazard ratio (HR), the likelihood of a worker being off work, and a 99% confidence interval (CI). Data manipulations and analyses were conducted using SPSS V.25, with p values of < 0.05 considered significant.

2.5. Ethics

This study received ethics approval from the Monash University Human Research Ethics Committee (MUHREC) on 8 October, 2014.

3. Results

3.1. Participant characteristics

Participant characteristics are presented in Tables 3 and 4. Table 3 shows that drillers, miners, and shot firers had the highest number of claims (40.6%), followed by technicians and trade workers (30.5%), machine operators and drivers (19.5%), laborers (4.9%), and other occupations (4.3%).

The frequency of all claims by the occupational group is detailed in Table 4 sorted by gender, age group, and injury types across between 2003 and 2017. Male workers constituted 95% or more of claims across most occupational groups, except in other occupations, where there was a lower proportion of males (86.3%).

Table 3
Occupational groups in the coal mining industry and the number of workers' compensation claims

	Number of claims	Column %
Drillers, miners, and shot firers	12324	40.6
Machine operators and drivers	5934	19.5
Technicians and trade workers	9312	30.6
Laborers	1503	5.0
Other occupations	1317	4.3
Total	30390	100

Technicians and trade workers, and laborers had a higher proportion of injured workers aged 16–24 years (7.5% and 6.7% respectively) compared to drillers, miners, and shot firers (2.6%). The older age injured workers group "55 years and over" were represented proportionally higher in "machine operators and drivers" (24.3%) and "other occupations" (25.5%) compared to "drillers, miners, and shot firers" (17.1%). Musculoskeletal and fracture conditions accounted for approximately 60% of claims in all occupational groups.

Drillers, miners, and shot firers had the highest number and proportion of respiratory condition claims amongst all conditions while other occupations had a higher proportion of mental health condition claims. Machine operators, drivers, and laborers had a higher proportion of claims due to neurological conditions than other occupational groups.

3.2. Duration of compensated time loss

The frequency of claims and median weeks' time loss for each occupational group are listed in Table 5. Median time loss across the entire sample was 4.2 weeks (IQR: 1.2–14.0). Machine operators and drivers (6.4 weeks) had the most prolonged median durations while other occupations (3.4 weeks) had the shortest. Differences were also reflected in the proportion of all claims that had compensated time loss. Laborers (55.7%) had the highest proportions of their group resulting in time-loss injury while "other occupations" (33.6%) had the lowest proportion of their claims that received compensated time loss. For claims with time loss of at least 52 weeks, "machine operators and drivers" (5.4%) had the highest proportions of their group while "technicians and trade workers" and "other occupations" (2.8%) had the lowest proportions of their respective occupations with at least 52 weeks' time loss.

3.3. Cox regression analysis

In the multivariate model, Cox regression models included 12,295 cases. Results of the final Cox proportional hazards model are reported in Table 6. Female workers had longer time off work than male workers (HR: 0.89; CI (99%) 0.79 to 1.00) ($p < 0.05$). Compared to workers aged 16–24, the older age groups showed significantly longer compensated time loss: age group 25–34 years (HR: 0.74; CI (99%) 0.64 to 0.84), 35–44 years (HR: 0.70; CI (99%) 0.61 to 0.80), 45–54 years (HR: 0.66; CI (99%) 0.58 to 0.75) and 55 years over (HR: 0.54; CI (99%) 0.47 to 0.62). The age of the workers displayed a graded relationship with the length of time loss increasing as the groups' age increased.

In compensated time loss for health conditions, there were also significant differences in the duration of time loss. Compared to "fractures" as the reference group, mental health conditions had significantly longer duration time loss (HR: 0.64; CI (99%) 0.53 to 0.78). In contrast, musculoskeletal conditions 1(HR: 1.19; CI (99%) 1.09 to 1.29), other traumatic conditions (HR: 1.84; CI (99%) 1.67 to

Table 4
Characteristics of compensation claims for various occupational groups in the coal mining industry in Australia

	Drillers, miners, and shot firers		Machine operators and drivers		Technicians and trade workers		Laborers		Other occupations	
	Number	%	Number	%	Number	%	Number	%	Number	%
Gender										
Male	12139	98.5	5620	94.7	9273	99.6	1440	95.8	1136	86.3
Female	185	1.5	314	5.3	39	0.4%	63	4.2	181	13.7
Age group										
16 to 24 years	326	2.6	147	2.5	700	7.5	101	6.7	51	3.9
25 to 34 years	2597	21.1	1230	20.7	1868	20.1	295	19.6	213	16.2
35 to 44 years	3291	26.7	1504	25.3	2333	25.1	335	22.3	299	22.7
45 to 54 years	4000	32.5	1612	27.2	2726	29.3	461	30.7	418	31.7
55 years and over	2109	17.2	1441	24.3	1685	18.1	311	20.7	336	25.5
Condition type										
Fractures	608	4.9	292	4.9	501	5.4	86	5.7	75	5.7
Musculoskeletal	6975	56.6	3524	59.4	4983	53.5	842	56.0	768	58.3
Neurological	1214	9.9	816	13.8	662	7.1	211	14.0	156	11.8
Respiratory	33	0.3	12	0.2	18	0.2	2	0.1	3	0.2
Mental health conditions	88	0.7	68	1.1	63	0.7	29	1.9	34	2.6
Other traumatic	3186	25.9	1131	19.1	2927	31.4	289	19.2	249	18.9
Other diseases	197	1.6	79	1.3	145	1.6	43	2.9	32	2.4
Other claims	15	0.1	12	0.2	12	0.1	1	0.1	0	0
Type of claims										
Medical only claims	7138	57.9	3424	57.7	5986	64.3	666	44.3	874	66.4
Medical and time loss claims	5186	42.1	2510	42.3	3326	35.7	837	55.7	443	33.6

Table 5
The number of claims and median weeks' time loss for each occupational group in Australia

Occupational g roups	No. of time loss claims	%	No. of claims with at least 52 weeks' time loss	%	Median (IQR) weeks loss
Drillers, miners, and shot firers	5186	42.1	453	3.7	4.0 (1.2, 13.4)
Machine operators and drivers	2510	42.3	320	5.4	6.4 (1.6, 20.8)
Technicians and trade workers	3326	35.7	259	2.8	3.6 (1.1, 11.9)
Laborers	837	55.7	51	3.4	4.2 (1.2, 12.8)
Other occupations	443	33.6	37	2.8	3.4 (1.1, 11.5)
All occupations combined	12302	40.5	1120	3.7	4.2 (1.2, 14.0)

2.04) and other diseases (HR: 1.45; CI (99%) 1.23 to 1.72) had shorter duration time loss compared to fractures ($p < 0.001$).

Amongst occupational groups, when compared to "drillers, miners and shot firers", "machine operators and drivers" had significantly longer durations time loss (HR: 0.85; CI (99%) 0.80 to 0.90) while "other occupations" had shorter time off work (HR: 1.13 CI (99%) 0.99 to 1.29). The remaining occupational groups including "technicians and trade workers" and "labourers" have no significant difference in weeks' time loss compared to "drillers, miners, and shot firers". Since "machine operators and drivers" had the longest median weeks' time loss amongst the occupational groups, the individual occupations and their respectively median weeks' time loss are listed in Table 7. "Other stationary plant operators" was a large group and had the second-longest duration at 9.3 weeks while each of the individual sub-groups had longer median durations than the drillers, miners, and shot firers, except for store-persons.

Table 6
Factors associated with duration of time loss (weeks), Cox regression with multiple imputations for gender, age, conditions, and occupational groups

Variables in equation	HR	(99% CI)	p-value
Gender (reference: male)			
Female	0.89	(0.79 to 1.00)	0.014
Age (reference: 16 to 24 years)			
25 to 34 years	0.74	(0.64 to 0.84)	<0.001
35 to 44 years	0.70	(0.61 to 0.80)	<0.001
45 to 54 years	0.66	(0.58 to 0.75)	<0.001
55 years and over	0.54	(0.47 to 0.62)	<0.001
Conditions (reference: fractures)			
Musculoskeletal	1.19	(1.09 to 1.29)	<0.001
Neurological	1.10	(0.91 to 1.34)	0.195
Respiratory	0.87	(0.49 to 1.56)	0.541
Mental health conditions	0.64	(0.53 to 0.78)	<0.001
Other traumatic	1.84	(1.67 to 2.04)	<0.001
Other diseases	1.45	(1.23 to 1.72)	<0.001
Other claims	0.88	(0.39 to 2.00)	0.694
Occupational groups (reference: drillers, miners, and shot firers)			
Machine operators and drivers	0.85	(0.80 to 0.90)	<0.001
Technicians and trade workers	1.01	(0.96 to 1.07)	0.527
Laborers	1.05	(0.96 to 1.16)	0.176
Other occupations	1.13	(0.99 to 1.29)	0.015

4. Discussion

This study is the first to examine the duration of time loss among injured and ill workers in the coal mining industry in Australia. The study identified significant differences in the duration of time loss for workers of different genders, age, occupation, and injury types. The study demonstrated that older workers had significantly longer time off work than younger workers in the coal industry. Female workers and the occupation "machine operators

Table 7
The number of claims and median weeks' time loss injury burden for operators and drivers in Australia

Occupation	Number	Median week time lost	IQR
Drillers, miners, shot firers	5186	4.0	(1.2, 13.4)
Other mobile plant operators	765	5.8	(1.5, 19.8)
Other stationary plant operators	684	9.3	(1.9, 31.2)
Earthmoving plant operators	415	5.8	(1.5, 18.7)
Other machine operators	243	5.6	(2.0, 16.2)
Truck drivers	222	5.6	(1.2, 20.1)
Industrial spray painter	53	8.7	(2.1, 18.0)
Engineering production system workers	37	7.9	(1.5, 18.6)
Agricultural plant operators	30	4.4	(0.7, 14.7)
Crane hoist lift operator	28	12.5	(2.0, 37.2)
Store-persons	18	2.0	(1.4, 6.8)

and drivers" also recorded significantly longer durations of time loss from work-related injuries and diseases in the study. This study further demonstrated that mental health conditions had a significantly longer duration of time loss when compared to fractures while musculoskeletal conditions had significantly shorter durations.

The coal mining industry is a male-dominated industry (88% male for all occupations) [14]. For most occupations, almost 95% of the injuries occurred in men, except in "other occupations" where 86.3% of claims made by men. The "other occupations" group consists of managers, professionals, community and personal service workers, clerical and administrative workers, and sales workers (Table 1) [10]. 2.6% of all injury claims were female workers even though they made up 12% of the workforce. In coal mining, most injuries were traumatic, and the most common mechanisms of injury were being hit by a moving object, muscular stress, and falls [3]. While the actual gender distribution of these occupations in the coal industry is not available in the literature, it is anticipated that these occupational groups are more male dominated, and relatively more female workers are employed in the less manual "other occupations" category to correlate with some of the results. It may also be partly explained by the fact that risk-taking behavior, which is positively related to injury, is associated with the male gender [15]. This was also supported by a meta-analysis of 150 studies [16]. A Safe Work Australia survey also found that female workers are less likely to report minor injuries. Even though female workers are less frequently represented in the claims [17], this study found that female workers in the coal industry have longer durations of time off work. This finding was consistent with previous studies in other occupational cohorts, although no explanation was hypothesized for this finding [18–20]. The reasons underlying the gender disparity in time off-work due to work injury may be due to biological or sociodemographic features, availability of support, or behavioral characteristics. It will be important that future research examine these reasons to address this gender disparity.

Findings of this study showed that more injured workers in the younger age group "16 to 24" occurred amongst technicians, trade workers, and laborer than other occupational groups. Younger workers recorded more claims arising from work-related injury and diseases can be explained by vocational inexperience, more deficient safety awareness and increased likelihood to engage in risky behavior while participating in physically laborious duties required in those roles, consistent in previous studies [21,22]. A study by Weston et al. [23] in the United States found that musculoskeletal injuries were most common in mining workers with both less than five years' experience and more than 20 years of experience in mining. The overall injury frequency amongst the youngest workers in our study is low (<10%). In the older age groups, "machine operators and drivers" and workers of "other occupations" over 55 years have more injury claims than other groups. This study further demonstrated that older workers in the coal industry had significantly longer time loss due to injuries and diseases when compared to the youngest age group, adding to the current evidence base including the study by Weston et al. [19,20,23,24].

Musculoskeletal injuries were the most common of all injury types in the coal industry, accounting for 60% of all claims. The leading causes of these musculoskeletal injuries were overexertion, falls, and being struck by an object both amongst coal miners in Queensland [3] and the US mining sector [23]. At the other end of the spectrum, mental health conditions made up only 0.9% of all claims. Nonetheless, our findings indicated that having a mental health condition is a strong predictor of increased time loss from work compared with other injury types amongst coal miners. Working conditions relating to the mining industry may affect a workers mental health and include long hours, shift work, physically demanding and repetitive tasks, working far from home, and displacement from social support networks. Additionally, higher rates of depression in male-dominated industries compared to other industries or the general population have been reported [25]. Some of the challenges that may delay return-to-work are stigma and discrimination [26], and the reluctance to seek help amongst Australian miners [27].

Coal mining machine operators and drivers have been identified as more likely to spend longer time off work due to work-related injuries and diseases than other occupational groups in this study. For the type of injury in this group, the dataset showed that machine operator and drivers had a higher proportion of musculoskeletal and neurological disorders. Mechanical hazards from machinery include moving parts, ejecting objects, sharp edges, electrical cable or hose connections, predisposing its operator to traumatic injuries. Further research can clarify the nature of injuries explicitly sustained in this occupational group to determine how factors including the mechanism of injury (e.g. faulty machine, slips, or chronic overuse injuries) and psychosocial elements delay return-to-work.

There is an obvious need to develop comprehensive early return-to-work and injury prevention interventions for those at-risk. This study identified that these risk factors include female workers, older age workers, mental health conditions and machine operators and drivers. A systematic review completed by Cancelliere et al. [18] reported that factors that accelerate early return-to-work include optimistic expectations, return-to-work coordination, and multidisciplinary interventions that include the workplace and stakeholders. Most recently, in New South Wales coal mines, injury prevention studies in 2018 included peer-support and supervisor training to reduce mental health stigma and encourage help-seeking [28]; and task rotation has been trialed to decrease over exposure to tasks and reduce the risk of musculoskeletal injuries in an underground coal mine [29].

4.1. Strengths and limitations

One strength of using a pre-existing national compensation data set was it encompassed work injury occurrences and the injury information from all Australian jurisdictions. The initial dataset was compiled for administrative purposes and not for research. It has been shown that compensated time loss administrative datasets can underestimate the time lost to injury [30]. Other advantages of using the NDS are standardized industry, occupation, and injury coding schemas to identify the specific sub-groups of interest. The time series of fourteen years provided substantial data for analysis,

but one limitation of this study is that the claims over time have not been examined. That would be an opportunity for future research. While the information will capture most coal miners and the related work injuries, not all information relating is there for further secondary analysis of the dataset, for example, illness severity, education and socioeconomic status, perceived level of support received, and presence of other comorbidities. The dataset presented in this study included only accepted claims. Injured workers who did not report their injuries and diseases, had claims rejected and self-employed workers (around 10% of all Australian workers) are not included in workers' compensation statistics. The risk of acquiring an injury or disease in each of the occupational groups also cannot be compared as the size of the various occupational sub-groups within the coal mining industry is not available from the Australian Bureau of Statistics' published data. Diseases that result from long-term exposure to occupational hazards or have long latency periods are generally underrepresented in the workers' compensation system as the association between the disease and the workplace has historically been challenging to establish.

Disclaimer

Nil known.

Conflicts of interest

The authors declare no conflict of interest.

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