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Article

Mental Health, Cardiovascular Disease and Declining Economies in British Columbia Mining Communities

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Abstract: The purpose of this study was to investigate the relationship between community-level exposure to changes in economic conditions and the incidence and prevalence of mental disorders and cardiovascular disease in 29 resource-based communities (with a focus on mining communities) in British Columbia (BC) during a period of time marked by an economic downturn (1991–2002) The investigation relied on Labour Force Survey (LFS) and Statistics Canada Census data, and health records from the British Columbia Ministry of Health (MoH). Age and sex adjusted prevalence and incidence rates were calculated for each community from 1991 to 2002 and the development of an economic change indicator defined using Census data and industry/government documents allowed for yearly assessment of community-level exposure to economic conditions. The relationship between exposure to economic change and rates of acute and chronic cardiovascular disease and mental disorders across the 29 study communities was investigated using a generalized linear model (stratified by type of community, and

adjusted for the effect of the community). Findings indicate an impact on the prevalence rates for acute cardiovascular disease (CVD) during periods of economic decline (rate increased by 13.1 cases per 1,000 population, $p < 0.0001$ as compared with stable periods) and bust conditions (rate increased by 30.1 cases per 1,000 population, $p < 0.0001$ as compared with stable conditions) and mental disorders (rate increased by 13.2 cases per 1,000 population, $p = 0.0001$) in mining communities during declining economic conditions as compared to steady periods of mining employment. This is not observed in other resource-based communities. The paper concludes by highlighting implications for the mining industry to consider as they begin to recognize and commit to mining community health.

Keywords: mining; community health; sustainable development; mental illness; cardiovascular disease

1. Introduction

Natural resource development has played an integral role in determining the social, economic and political landscape in Canada, and has played an integral role in shaping the rural Canadian economy. As an example, it is estimated that over 25 percent of employment in rural communities is dependent on resource industries, including mining [1]. In parallel, social, health and economic challenges faced by rural Canadian communities are increasingly being recognized [2] as higher mortality and morbidity rates (for most but not all health outcomes) have been observed in residents of these communities in comparison to Canadians living in urban centers [3,4].

In the western Canadian province of British Columbia (BC), many rural and remote communities have been founded and are economically dependent on mining [3,5,6], a continued key economic driver for the province. Recent research has brought attention to BC mining communities, identifying them as vulnerable to mining boom-bust cycles. Specifically, BC mining communities have been identified to be highly economically dependent on the mining sector (in some cases mining has represented 80% of total community-level employment), and have over the course of the most recent economic downturn (1991–2001) these communities faced reduced employment with the mining sector coincided with losses (in some cases over 50%) in community populations and increases in unemployment rates [7-10]. These conditions continue to characterize and define economic dynamics in northern BC today with high community-level economic and employment dependency on mining as this leading BC industry is, at present, booming [11-13]. In partial recognition of the impacts (both positive and negative) resource sectors can have on rural and northern communities, large federally funded research initiatives have been recently launched with aims to build research capacity to enhance understanding of the social dimensions of rural and northern health in order to improve the health of residents living in these regions of the province (such as The New Emerging Team for Health in Rural and Northern BC, funded by the Canadian Institutes of Health Research; [14]).

Traditionally, epidemiology studies have focused on the identification of individual-level risk factors for disease. However, given the importance of broader determinants of health that may arise

from social structures, physical or cultural environments, and the context within which individuals live their lives, epidemiology is increasingly focusing on investigations of the impact of the broader social determinants on health. The different contexts have been described as "macro-pathways" that mediate or modify individual health in populations [15]. Several macro-pathway models have been proposed to explain how various determinants associated with economic, social, physical, cultural, and other environments, including at the community-level, produce different population health outcomes [16-18]. The existence of the macro-pathways in these models is supported by research on the relationships between economic change and the distribution of morbidity and mortality in populations; in particular, studies have demonstrated an association with cardiovascular and mental health outcomes [19].

Investigations into the relationship between economic change and health outcomes are limited and have focused on the effects of unemployment, job insecurity and economic instability amongst individuals (workers) and neighborhood's (*versus* at the community-level). For instance, a literature review of the impact of unemployment on health strongly supported the linkage between unemployment and greater risk of morbidity and mortality [20]. Rapidly increasing unemployment has also been associated with increased all-cause mortality rates among workers [21], and high neighbourhood unemployment rates in London (UK) have been associated with poor self-rated health [22]. A study in the British Columbia (BC) sawmill industry [23] found that workers who remained employed in sawmills during extensive restructuring were approximately 50% more likely to report poor health than those who were re-employed elsewhere. In other words, health status was better for workers who, under pressure of massive industry downsizing and change, left the sawmill industry and obtained re-employment elsewhere.

Studies on employees (including blue collar and white collar industries) have established that psychological stress induced by industry instability has a negative effect on mental health [19,24-27]. Job insecurity has also been shown to act as a chronic stressor whose effects intensify with increasing exposure over time [28]. A 1994 study of mental health outcomes among miners in the United Kingdom found higher rates of psychological distress and morbidity in miners two years after a mine closure compared to working miners and to workers in other professions [29].

Several recent articles have also pointed to the effect of socioeconomic context on heart disease mortality after adjusting for individual-level indicators. Literature reviews found consistent relationships between socioeconomic measures of education, income, occupation, employment status, and living conditions and cardiovascular disease [30-32]. Neighborhood economic context has also been shown to influence heart disease mortality and risk factors [33-36]. For, example, living in economically disadvantaged neighborhoods increased the risk of cardiovascular death by 50% after adjustment for individual risk factors in a population-based study of elderly men in the US [33]. Although it is evident that economic changes affect local economies (and in particular, workers), many cross-sectional studies have focused on worker health. In addition, studies have generally investigated community-level characteristics measured at a single point in time in relation to changes in health. Overall, there is a lack of research relating changes in community-level economic indicators to population health in communities reliant on natural resource development over time. This is especially the case for those dependent on mining.

The purpose of this paper is to report on the relationship between community-level exposure to declining economic conditions and community-level health outcomes (prevalence and incidence rates

of heart disease and mental disorders) among residents of BC resource-based communities with a focus on mining communities. The study is retrospective, mainly covering the decade of the 1990s that marked a major recent economic downturn impacting BC resource sectors (mining and forestry). It is hypothesized that individuals living in BC mining communities during periods of economic decline will have an increase in community-level rates of heart disease and mental disorders as compared to stable economic periods and that the effect might be greater in mining communities compared to other resource-based communities. The rationale for this hypothesis stems from associated research findings that identified these study mining communities as highly dependent on mining, lacking in economic diversity, and vulnerable to severe population fluctuations over the same study period [7-10].

2. Methodology

2.1. Data Sources

Data for this retrospective study for 29 resource-based communities in British Columbia (University of British Columbia Ethical Review Certificate # B05-0942) was drawn from administrative data from Statistics Canada, BC Ministry of Health data and the BC Vital Statistics Agency. Ministry of Health and Vital Statistics data were accessed via PopulationDataBC (www.popdata.bc.ca), one of the richest data sources available for health services and health research with population-based data (from 1991 onwards) for virtually all BC residents [37]. Specifically, this investigation relied on existing data from (a) Statistics Canada Labour Force Survey (LFS) Census data to identify mining and other resource-based communities in BC; (b) LFS data to identify community level economic and employment conditions; and (c) health contact data (physician visits, hospitalizations, deaths) accessed via PopulationDataBC to construct yearly, community-level rates of cardiovascular disease and mental disorders. The follow-up period was defined as 1991 to 2002 based on the availability of health outcome records at the time of the study.

2.2. Study Sample

This was a community-level analysis of rates of disease so the study sample consisted of 29 resource-based communities in the province of BC. Fifteen of the study (mining) communities relied mainly on mining and the fourteen (other resource-based) communities consisted of similar communities but based on other types of resource extraction and processing (mainly forest products). For the purposes of this study, Census Subdivisions (CSDs) were used to geographically define study communities that were further classified as mining or other resource-based. Mining communities (n = 15) were identified using the following criteria: (1) Mining was the most common economic activity at one Census point in time during the study period (highest percentage employment income across all possible economic activities) based on Statistics Canada's Labour Force Survey data; and (2) there was an active mine/mine processing plant within the CSD region at one point in time during the study period that provided employment to these communities based on government and industry documents. Other resource-based communities were identified using the following criteria: (1) A resource activity (aside from mining) was the most common economic activity in the community (e.g., n = 12 forestry, n = 1 oil and gas, n = 1 agriculture) at one point in time during the study period

using the LFS data; and (2) At least one other resource-based community was chosen within the same census division as a mining community to ensure a matched comparison (two mining communities and one other resource-based community were in the same Census Division resulting in a 15 to 14 ratio of communities).

2.3. Outcome Measures

Rates of Cardiovascular and Mental Disorders

Yearly, community-level health rates were constructed as the number of residents with cardiovascular disease or mental health within each follow-up year, divided by the total number of residents in each community for that year. Total number of residents in each of the study communities was available from the Ministry of Health Registry file by using postal code of the resident mapped to the community CSDs. The Registry file is a yearly registration of individuals eligible for health benefits in the provincial health care system. As a universal health care system, the registry is considered comprehensive at the population level for BC residents. Health data available via PopulationDataBC included the provincial Medical Services File (physician and specialist billings), the Hospital Discharge File and the Vital Statistics Mortality File. These records were linked across databases at the individual-level by PopulationDataBC in order to identify unique cases of cardiovascular disease or mental disorders. Personal information was removed from the merged file and a research data file was released to the researchers with an anonymous study identifier.

The health data files included up to a 5-digit International Classification of Disease, 9th edition (ICD-9) diagnostic codes in the hospitalization and vital statistics records and a 3-digit ICD-9 codes in the medical services records until 31 March 2002 [38]. Diagnostic codes were selected over procedure codes, as they offer more specific and sensitive coding for identifying disease. Two broad categories of cardiovascular disease were used for this study [39,40]: acute coronary syndrome which includes acute myocardial infarction, unstable angina or other acute forms of ischemic heart disease (ICD9 410 or 411) and chronic coronary syndrome which includes stable angina pectoris, other chronic forms of ischemic heart disease, or arteriosclerotic cardiovascular disease (ICD9 413, 414, 429.2). These particular health outcomes were selected as they have been demonstrated to be influenced by environmental, cultural, economic conditions through stress mechanisms. Individuals under the age of 15 were excluded from the cardiovascular outcome definitions. Mental disorders were defined as depression (ICD9 296.0–296.9, 300.4–300.49, 311.0–311.99), anxiety disorders (ICD9 300.0–300.9), acute/chronic stress reactions (308.0–309.99), or suicide (ICD9 E950–E959). These non-organic/non-congenital mental disorders were also selected as they are impacted by stress (including economic stressors).

By combining health data files, all cases of cardiovascular disease or mental disorders were captured on a yearly basis by the presence of (1) a hospitalization with the aforementioned diagnostic codes as the ‘primary diagnosis’ or ‘most responsible diagnosis’ with a separation date in that year; or (2) at least two physician or specialist visits within a 12 month period with the study diagnostic codes [41] and the first of the two visits occurring in that year; or (3) a vital statistics death record with a study diagnostic code and a death date in that year.

Age and sex standardized annual incidence (number of new cases divided by the population at risk) and prevalence rates (number of existing cases) for the study outcomes were calculated per 1,000 populations by study community. We were interested if the effect of economic cycles on individuals living in mining communities, through physiological stress-related reactions, may trigger the onset of underlying disease (incidence) or may aggravate existing disease (prevalence). Rates were constructed for the three broad categories: Acute CVD, Chronic CVD and Mental Disorders.

Economic Change Indicator

In order to assess exposure to economic conditions, a community-level economic indicator was constructed by the research team for each study community for each year during the study period. This indicator was based on the number of people employed within the dominant industry (mining or other resource-based) using Labour Force Survey (LFS) data and government/industry documents in each community. In Canada, detailed LFS data provides estimates of employment (and unemployment) (www.statcan.gc.ca) at the CSD level. LFS data describing employment conditions for each community was extracted for the 29 study communities for the 1991, 1996 and 2001 Census time periods. Study years were identified as being "stable", "in decline", or in a "bust" cycle. A community was identified as: "stable" if the level of industry-specific employment remained the same or increased from one Census window to the next (In this study only three communities exhibited "stable" conditions and all were other resource-based, as identified in section 3.2 Economic Conditions in Mining and Comparison Communities. Of these communities, only one exhibited an actual increase in employment, and provided the rationale for aggregating stable and increased employment into one category). A community was identified as "in decline" if employment decreased between Census time periods, or "bust" if there was a decline in industry employment between Census windows in conjunction with a cessation of industry operations such as plant suspension or mine closure as identified through the evaluation of industry specific data gained from BC government/industry annual reports.

2.4. Data Analysis

Data was entered into SAS v. 9.1 (SAS Institute, Cary, NC, USA) for storage, management and analysis. Rates were normally distributed across communities over the entire study period. A generalized linear model [42] was used to investigate the relationship between community-level exposure to economic change and community level rates of cardiovascular disease and mental disorders across the 29 study communities, stratified by resource community type (mining *versus* other resource-based). This procedure is used to analyze data within the framework of general linear regression models (continuous measure of cases or rates) using the method of least squares, adjusting for covariates [42]. The analyses were conducted for incidence and prevalence cases separately. The GLM models were adjusted for the effect of community and corrected for the correlation of rates within communities (*i.e.*, repeated measures over time).

3. Results

3.1. Study Sample

Among the 29 study communities, the number of residents per community ranged from 487 to 14,420 over the study period. Table 1 summarizes demographic characteristics for mining and other resource-based communities. On average, the percentage of males and females and the distribution by age was similar between the mining and other resource-based communities. A more detailed description of community-level demographic and economic characteristics for this study period can be found in [7].

Table 1. Study community characteristics.

	Mining Communities (n = 15)		**Other Resource-based Communities (n = 14)**	
	1991 Census Year	2001 Census Year	1991 Census Year	2001 Census Year
Total Population	59,975	50,675	64,950	68,970
Distributions	(%)	(%)	(%)	(%)
Male (overall)	51	50	50	50
0–14 years	12	11	12	11
15–64 years	34	34	33	33
65+ years	5	6	5	6
Female (overall)	49	50	50	50
0–14 years	12	9	11	10
15–64 years	32	33	32	33
65+ years	6	8	6	8

3.2. Economic Conditions in Mining and Comparison Communities

Over the study period three communities experienced stable economic conditions for the entire study period (all were other resource-based); 19 communities (15 were mining communities, four were other resource-based) transitioned from a stable period at the beginning of the study period, to a period of economic decline; two communities transitioned from declining conditions in the beginning of the study period to a stable period (both were other resource-based); five communities experienced economic decline for the entire duration of the study period (all were other resource-based); and four mining communities in addition to periods of economic decline, were also exposed to bust conditions (due to mine closures).

3.3. Cardiovascular Disease and Mental Disorder Rates in Study Communities

A total of 319 yearly health rates were calculated for each of the three study outcomes of acute and chronic cardiovascular disease and for mental disorders (29 communities by 11 years of follow-up for each community). The mean rates were compared descriptively for mining and other resource based communities by the economic periods defined as stable, decline or bust. Prevalence rates are summarized in Table 2, and incidence rates are summarized in Table 3. As seen in Table 2, the mean

yearly prevalence rate of acute cardiovascular disease was similar between mining and other resource-based communities, but other resource-based communities had slightly higher mean yearly prevalence rates of chronic cardiovascular disease and mental disorders.

Table 2. Comparison of age- and sex-adjusted cardiovascular and mental disorder prevalence rates across stable, in decline, and communities in a bust cycle (n = 29 communities).

Health Indicator	**MINING COMMUNITIES (n = 15) Mean Yearly Rate per 1,000 (sd)**			
	Study Period	Stable Periods	Decline Periods	Bust Periods
Prevalence				
Acute Cardiovascular Disease	61.7 (26.3)	51.6 (21.2)	65.7 (27.1)	62.6 (29.3)
Chronic Cardiovascular Disease	12.2 (4.9)	13.1 (5.5)	11.9 (4.6)	11.9 (5.1)
Mental Disorders	46.3 (19.6)	37.1 (17.0)	50.7 (19.3)	43.5(19.3)
Health Indicator	**OTHER RESOURCE-BASED COMMUNITIES (n = 14) Mean Yearly Rate per 1,000 (sd)**			
	Study Period	Stable Periods	Decline Periods	Bust Periods
Prevalence				
Acute Cardiovascular Disease	61.3 (21.9)	59.7 (14.4)	62.3 (25.7)	*
Chronic Cardiovascular Disease	15.8 (7.1)	13.9 (3.9)	17.1 (8.4)	*
Mental Disorders	52.1 (21.1)	53.3 (19.2)	51.3 (22.3)	*

* Other resource-based communities did not experience plant closure during the study period.

Table 3. Comparison of age- and sex-adjusted cardiovascular and mental disorder incidence rates across stable, in decline, and communities in a bust cycle (n = 29 communities).

Health Indicator	**MINING COMMUNITIES (n = 15) Mean Yearly Rate per 1,000 (sd)**			
	Study Period	Stable Periods	Decline Periods	Bust Periods
Incidence				
Acute Cardiovascular Disease	15.0 (6.0)	15.3 (6.8)	14.2 (4.8)	17.9 (8.2)
Chronic Cardiovascular Disease	5.8 (2.9)	7.3 (3.6)	5.1 (2.0)	6.2 (3.5)
Mental Disorders	18.5 (7.3)	20.3 (7.9)	18.1 (6.6)	16.6 (8.3)
Health Indicator	**OTHER RESOURCE-BASED COMMUNITIES (n = 14) Mean Yearly Rate per 1,000 (sd)**			
	Study Period	Stable Periods	Decline Periods	Bust Periods
Incidence				
Acute Cardiovascular Disease	14.8 (4.7)	15.0 (4.3)	14.7 (4.9)	*
Chronic Cardiovascular Disease	7.1 (3.8)	5.9 (2.1)	7.8 (4.4)	*
Mental Disorders	20.6 (8.8)	22.2 (9.8)	19.5 (7.9)	*

* Other resource-based communities did not experience plant closure during the study period.

In mining communities, we observed that the mean yearly prevalence rate for acute cardiovascular disease and mental disorders were higher during decline and bust periods as compared with stable periods; whereas the rate for chronic cardiovascular disease was lower. In other resource-based communities, the yearly prevalence rate for acute and chronic cardiovascular disease was higher during periods of decline *versus* stable periods, and the rate for mental disorders was lower for decline periods as compared to stable periods. Changes in incidence rates (Table 3) across stable, decline, and bust periods were less pronounced than changes in prevalence rates for all health indicators (acute and chronic cardiovascular diseases and for mental disorders).

3.4. Relationship between Economic Conditions and Health Outcomes

Results from the GLM models adjusted for community, to investigate the relationship between community-level exposure to economic change (periods of boom, bust or stable) and community level rates of cardiovascular disease and mental disorders across the 29 study communities, stratified by community type (mining *versus* other), are summarized in Table 4.

Table 4. Relationship between community-level exposure to economic change and community-level rates of cardiovascular disease and mental disorders *.

		Mining Communities (n = 15)		**Other Resource Communities (n = 14)**	
	Economic Conditions	Change in Rate	p-values	Change in Rate	p-values
Health Indicator					
Prevalence					
Acute CVD	Decline *vs.* Stable	**13.0**	**<0.0001**	4.5	0.28
	Bust *vs.* Stable	**30.1**	**<0.0001**	NA	NA
Chronic CVD	Decline *vs.* Stable	−1.1	0.39	1.3	0.13
	Bust *vs.* Stable	−1.2	0.06	NA	NA
Mental Disorders	Decline *vs.* Stable	**13.2**	**<0.0001**	**−9.4**	**0.004**
	Bust *vs.* Stable	5.0	0.20	NA	NA
Incidence					
Acute CVD	Decline *vs.* Stable	−1.2	0.18	−1.2	0.26
	Bust *vs.* Stable	1.6	0.38	NA	NA
Chronic CVD	Decline *vs.* Stable	**−2.2**	**<0.0001**	0.1	0.88
	Bust *vs.* Stable	**−1.9**	**0.04**	NA	NA
Mental Disorders	Decline *vs.* Stable	**−2.4**	**0.02**	**−8.7**	**<0.0001**
	Bust *vs.* Stable	**−4.5**	**0.03**	NA	NA

* Bold p-values represent a significant difference between economic periods at the 0.05 level. Models adjusted for community and for repeated measures within community.

Prevalence

Acute Cardiovascular Disease: In mining communities, a statistically significant increase in the yearly community-level prevalence rate by 13.0 cases per 1,000 population for acute cardiovascular disease was observed during periods of economic decline compared to stable periods. A statistically significant increase in the prevalence rate by 30.1 cases per 1,000 was also seen during bust periods (marked by mine closure). In other resource-based communities, a smaller increase in the acute cardiovascular disease rate was observed (4.5 cases per 1,000) during decline periods, compared to stable economic periods. This difference was not statistically significant.

Chronic Cardiovascular Disease: In mining communities, there was no significant change in the rate of chronic cardiovascular disease across economic comparison periods (decrease of 1 case per 1,000 residents for bust and decline compared to stable periods). Other resource-based communities demonstrated a slight increase in the prevalence of chronic cardiovascular disease conditions by 1.2 cases per 1,000 during decline compared to stable periods.

Mental Disorders: The prevalence rate of mental disorders in mining communities increased by a statistically significant amount during decline economic periods by 13.2 cases per 1,000 compared to stable periods. Rates also increased during bust periods by 5 cases per 1,000, although this increase was not statistically significant. In contrast, the rate in other resource-based communities decreased by 9.4 cases per 1000 during decline compared to steady periods; the decline was statistically significant.

Incidence

Acute Cardiovascular Disease: We observed slight, statistically non-significant decreases in the incidence rate of acute cardiovascular disease during decline periods as compared with stable periods for both mining and other resource-based communities (decrease by 1.2 cases per 1,000). A small statistically non-significant increase in the incidence rate of acute cardiovascular disease by 1.6 cases per 1,000 was observed for bust periods, as compared to stable periods in mining communities.

Chronic Cardiovascular Disease: Statistically significant changes were observed for the incidence of chronic cardiovascular disease in mining communities during decline *versus* stable periods of mining employment (2.2 fewer cases per 1,000) and during decline *versus* bust periods (1.9 fewer cases per 1,000). In other resource-based communities no change was observed.

Mental Disorders: Statistically significant decreases in the incidence of mental disorders was observed for decline periods *versus* stable periods in mining (decrease by 2.4 cases per 1,000) and in other resource-based communities (decrease by 8.7 cases per 1,000). A decrease in the incidence of mental disorders by 4.5 cases per 1,000 was also observed in mining communities for bust periods as compared to stable periods, and this decrease was also statistically significant.

4. Discussion

In the period under study (1991 to 2002), we observed that deteriorating economic conditions characterized by a decrease in community-level industry-specific employment had a negative impact on the prevalence of acute cardiovascular disease and mental disorders in mining communities. This was not observed in other resource based communities (forestry).

While there are few multi-community studies that have investigated the relationship between economic conditions in mining communities and health outcomes over time, results from this exploratory study are consistent with findings from other studies on the impact of the economic environment on the health of residents of British Columbian communities that are primarily based on resource extraction and processing. For example, in studies conducted in Northern BC, the influx of transient resource-based workers, with high disposable incomes, has had a demonstrated negative impact on the health, especially of already vulnerable residents, in two northern BC communities [11,43,44]. In a study in a northern BC community experiencing an oil and gas boom Goldenberg *et al*. [43-46] also identified an acute lack of important basic health services. Shandro *et al*. also documented the overextension and heavy burden placed on existing health services by the needs of an ever-expanding mining workforce [11], and the contraction of health services in BC mining communities post-closure [12]. As well, in a research program devoted specifically to understanding the relationship between adverse social and economic conditions and the health of rural and northern British Columbians, Ostry and the New Emerging Team for Health in Rural and Northern British Columbia (NETHRN-BC) have demonstrated the links between adverse economic conditions in some of these communities and adverse health outcomes among residents [47-51].

In addition to supporting evidence, the 1990s decade witnessed a major economic collapse for mining in BC. While the same decade was difficult for forestry communities, economic and socio-demographic data indicate this period of time was less difficult than it was for mining communities [7,9]. A detailed review of the study period, and additional contextual information, helps to explain the differences in health outcomes between mining and other resource-based communities and the differences in prevalence and incidence rates.

For the mining sector, the first three years of the study period (1991 to 1993) were marked by a decrease in exploration expenditures, mining revenues, and employment [52,53]. Low metal markets, increased regulation, increased global competition and a lack of risk financing were all contributing factors to this decline [54]. In 1995, the industry experienced a brief revitalization, spurred generally by higher metal and coal prices, a weaker Canadian dollar, the introduction of a BC government industry tax cut, and the launching of Explore BC (the BC Government provided approximately $3.5 million in exploration grants) [55]. The BC government underwent some significant transformations during this period by temporarily integrating the Ministry of Energy, Mines and Petroleum Resources with the Ministry of Employment and Investment [56]. In 1997, exploration activities declined by 25%, and by 1998 sharper decreases were felt through exploration expenditures, and mineral production (for instances exploration expenditures declined by 66% between 1997 and 1998). Globally, the mining and mineral exploration industries faced restrained activities as low metal and coal prices were coupled with an economic crisis in Asia. This precipitated 8 mine closures, 9 mine suspensions, and was paralleled by renegotiation of contracts between the BC coal mining sector and Japanese steelmaking industries that resulted in the supply of 1.35 million less tonnes per annum of metallurgical coal at significantly lower prices than past contracts had realized [57]. The 1990s ended with a continued difficult period of time for the mining industry; existing metal mines for the most part continued production, however, Highland Valley Copper mine, BC's largest metal mine suffered a five month shutdown. Low prices for coal and most metals continued into 2000, and resulted in the premature closure of the Quintette Coal Mine in Tumbler Ridge, BC. In 2001 after

over a century of production, the Sullivan mine in Kimberly, BC was permanently closed due to ore exhaustion.

The majority of other resource-based communities were dependent on forestry activities (n = 12), although one study community relied on oil and gas (n = 1) and another on agriculture (n = 1). Over the study period oil and gas development steadily increased in the northeastern region of BC, and agriculture remained a consistent economic opportunity in the south-central region. On the other hand, the forest sector has undergone enormous transformations over the past few decades in BC. Prior to the study period, the forest sector experienced a major economic depression, in which more than 23,000 people lost their jobs. This downturn continued during the study period with the permanent loss of approximately 6,000 additional BC forest sector jobs [58]. Rural and northern BC communities were strongly impacted during the 1990s as many small sawmills located in these regions disappeared with the consolidation and centralization of the forest industry [59]. The BC forest sector continued to undergo significant changes as the American soft-wood lumber tariff placed a considerable amount of strain on the industry [60]. In addition, the study period was marked by the introduction of a variety of new Forest Practice Codes aimed at improving the BC sector [60]. However, these policy changes limited the access and control rural and northern communities had previously had over their local forest resources [1,61]. Community-level impacts (stress) resultant from long-term transformations within the BC forest sector that reach beyond declining economic and employment conditions could explain why higher overall study period prevalence rates for chronic cardiovascular disease and mental disorders are presented in these study communities.

While forest-based industries have undergone significant changes, these resource-based communities experienced more gradual declining employment conditions in comparison to mining communities. Other resource-based communities in our study also demonstrated more stability within their populations, and in many cases, experienced population growth [7]. In addition, over the study period the ratio of people employed in resource industry to community residents was greater in mining communities than in other resource-based communities; BC mining communities were observed to be economically more dependent on mining than other resource-based communities were on comparison sectors; mining communities had lower community economic diversity and were found to be more vulnerable to economic downturns than other resource-based communities [7,8,10]. It is hypothesized these mining community-level economic traits are driven by the general demand for a large number of workers that will be compensated with higher than average wages during mine operation. In a recently published study, stress and mental disorders were community health impacts reported by health care providers in a Northern BC mining community as being prominent during declining economic conditions (marked by employment and inevitably income loss) that preempted mine closure [11].

Economic conditions as captured by industry employment in this study also identify that the nature of mineral development projects have been starkly different than other sectors over the study period. Mine suspensions and closures occurred rapidly, and closures coincided with dramatic community-level changes within short time frames [7]. To exemplify this point, many study mining communities experienced population loss and in some cases drastic reductions in populations (over 50% population loss) were observed post mine closure [7,10,12]. In contrast, other resource-based communities observed no periods of plant closure. Also the combination of the economic decline observed in most mining communities and the low availability of alternative economic options present

in study mining communities [7,11] mean that residents of mining communities are likely acutely aware that declining conditions threaten livelihoods. These key characteristics lead to the expectation that mining communities could be experiencing increased stress, and thus have a higher prevalence of mental health and acute cardiovascular disease compared to other resource-based communities.

In contrast to prevalence rates, incidence rates were not adversely affected by economic conditions in the study communities. It is possible that during periods of economic decline individuals who are at risk for new cases of disease (generally the younger population demographic) relocated elsewhere to find work resulting in the observed decrease in the rates, albeit small decreases that were not statistically significant. Therefore, these potential new cases were not captured. It is also possible that there was insufficient follow-up time or latency period to capture the effects of the economic cycles on the onset of new disease such as cardiovascular outcomes, the effect of which may not been seen until decades after living through economic cycles in mining communities. Finally, it is also possible that the impact of economic change within a community is felt more by those who already have underlying conditions, symptoms, and prior health history, and thus declining conditions may aggravate existing, prevalent cases of illness and disease.

While the vast majority of the study communities could be considered rural as they were not located in close proximity to a major urban centre, it is noteworthy to address the challenges of defining study communities through Census Subdivision Boundaries. During this study period, many BC communities underwent significant transformations to their census boundaries in the middle of the study period (1996), thus limiting the number of potential study communities to the presented study sample. Our original data set included over 50 BC resource communities. In many northern and rural regions in BC, it is also common to have a proportion of individuals residing outside municipal boundaries. These individuals and their health outcomes were not captured in community-level rates.

As the focus of the research study was on mining communities, it is important to highlight the implications of these findings for the mining sector. Internationally, in Canada, and in British Columbia, the mining industry has committed to the well-being of associated communities. As examples, the International Council on Mining and Metals (ICMM), a representation of 19 mining companies and 30 national and regional mining associations aims to "*Implement good practice and innovate to improve social, environmental and economic performance while enhancing shareholder value*" [62] and "*Enhance social and economic development by seeking opportunities to address poverty; Report on our economic, social and environmental performance and contribution to sustainable development*" [63]. The Mining Association of Canada in their Towards Sustainable Mining initiative (of which was recently adopted by the Mining Association of British Columbia [64] has expressed the need to "*provide lasting benefits to local communities through self-sustaining programs to enhance the economic, environmental, social, educational and health care standards they enjoy*" [65]. In addition, the British Columbia Ministry of Energy, Mines and Petroleum Resources has pledged to "*support: strong, enduring relationships between the mining industry, communities and First Nations; the development and implementation of a made-in-British Columbia approach to sustainable exploration, mining and communities*" in their BC Mining Plan [66]. However, determinants of health outside the realm of the physical environment have only been recently highlighted as important considerations during the assessment of potential health impacts associated with mineral development [67]. It is therefore the hope that this study strengthens the importance of

health determinants within the economic and social dimension; highlights the need for recognizing, planning for, and mitigating potential impacts mining operations can have on communities, especially in rural and remote locations where economic dependency on mineral development is generally high; and brings forth a research priority focused on the well-being and resilience of rural resource-based locales.

Finally, this exploratory study points to the impact that mining has on health through stress-mediated pathways. Future research should focus on investigating the health of mine workers and their families in comparison to the community at large. In addition, as differences between mining and other resource-based communities were noted for the period under investigation, it is important to note that this study focused on a period of time where an economic downturn gradually impacted forest sectors and more severely impacted mining sectors. Future studies should also focus on how these communities have fared into the millennium, where the BC mining industry boomed, and the pine beetle epidemic along with the BC softwood lumber crisis continued to negatively impact forest sectors; and how the latest global economic recession has severely impacted all BC resource sectors.

5. Conclusions

We observed that declining economic conditions had a negative impact on the age-sex adjusted prevalence rates of acute cardiovascular disease and mental disorders in mining communities, many of which were located in rural and Northern BC. Specifically, acute cardiovascular disease and mental health prevalence results were worse for mining *versus* other resource-based communities and these outcomes illuminate how deteriorating economic environments can impact health through stress pathways. Our findings suggest that these health outcomes require attention by industry and government in their planning and mitigation for potential health impacts as a result of industrial development, especially given the current global economy. The recent recognition of the importance of community health by mining sector leaders [67] may help to reduce the burden of mental disorders and cardiovascular disease within mining communities.

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