PSYCHOSOCIAL JOB STRAIN AND CORONARY HEART DISEASE IN A COHORT OF BLUE COLLAR WORKERS

by

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ABSTRACT

This dissertation investigated the impact of cumulative and time-weighted average exposure to psychosocial stressors and moderators in a cohort of blue-collar workers in 14 sawmills located in the province of British Columbia (B.C.). The cohort, originally gathered to investigate the effects of chlorophenol anti-sapstain chemicals on sawmill workers' health, contains complete occupational histories for over 26,000 workers who worked for at least one year in a study mill between 1950 and 1985 and complete mortality outcomes. The analysis was focused on mortality from atherosclerosis but also investigated mortality from all-causes, cerebrovascular accidents, and suicides and accidents.

This dissertation was a retrospective study in which exposure for five psychosocial work-condition variables was added to an existing cohort. There were several unique features to this investigation. First, this is the first cohort study of psychosocial work conditions and CHD outcomes which used multiple job history information to calculate exposures. Second, this is the first cohort study to model these exposures using duration of exposure as well as an intensity measure. Third, this is the first cohort study to use expert job evaluators to estimate psychosocial work conditions retrospectively.

The main positive findings of this dissertation were that time-weighted average exposure to physically sedentary and noisy jobs was associated with increased risk of mortality from atherosclerotic heart disease. The main negative findings were that time-weighted average exposures for control, psychological demand and social support were not associated with atherosclerosis mortality. Although cumulative exposures to psychosocial variables were modeled definitive results were not found because of collinearity both among psychosocial variables.

Secondary findings included an inverse association between time-weighted average physical demand for all-cause mortality and an inverse association between time-weighted average psychological demand and suicide mortality. Also, a weak direct association between psychological demand and cerebrovascular accidents was found which disappeared after controlling for employment duration. As well, the expert rater method used in this investigation was able to reliably and with validity estimate exposures to four psychosocial work conditions: control, physical demand, co-worker social support, and noise. Psychological demand was estimated with less reliability than these four variables and was not shown to be valid using tests for concurrent and predictive validity.

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ACKNOWLEDGMENT

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CHAPTER ONE

1.0 Introduction

This dissertation investigates cumulative and time-weighted average (TWA) exposure to psychosocial stressors and moderators in a cohort of blue-collar workers in 14 sawmills located in the province of British Columbia (B.C.). The cohort, originally gathered to investigate the effects of chlorophenol anti-sapstain chemicals on sawmill workers' health, contains complete occupational histories for over 26,000 workers who worked for at least one year in a study mill between 1950 and 1985 (Hertzman and others 1996). Mortality outcomes were obtained by probabilistic linkage with the Canadian Mortality Data Base (CMDB). The analysis was focused on mortality from atherosclerosis because it accounted for 81.1 percent of all CHD deaths in the cohort and, because atherosclerosis has been the main CHD mortality outcome investigated in relation to psychosocial job strain (Johnson and others 1996).

Although atherosclerosis was the main focus of this investigation, four other mortality outcomes were also studied. Two of these, all-cause mortality and deaths from cerebrovascular accidents (CVA), were chosen because they are the non-CHD mortality outcomes which have been most investigated in relation to psychosocial job strain (Astrand and others 1989; Falk and others 1992). The two remaining outcomes, suicide and accidental deaths, have been little studied with respect to workplace psychosocial characteristics but because they may plausibly be related to job strain these were also investigated. Investigation of mortality outcomes other than atherosclerosis was also useful as a validity check for the expert-rater method used to assess psychosocial work conditions in this dissertation.

Independent variables were the psychosocial "stressors" (psychological demand, physical demand, and noise) and the "moderators" (control and co-worker social support). All five variables were estimated retrospectively for 86 job titles in the B.C. sawmill industry by three industry and one union job evaluator using a modified version of Karasek's demand/control/support model (Johnson and Hall 1988; Karasek and others 1985). Intensity scores for psychological demand, physical demand, control, noise, and co-worker social support were applied to all job titles in the cohort. Cumulative and TWA exposures for the five variables were calculated for each worker and Standardised Mortality Ratios (SMRs) obtained for major causes of death. Cumulative exposures were modeled for the five mortality outcomes using Poisson regression and TWA exposures were modeled with logistic regression.

Until the 1980s, research on psychosocial job strain and CHD mortality and morbidity was dominated by cross-sectional studies, so that "with few exceptions (Frese and Zapf 1988; House and others 1986; Johnson 1989; Johnson and others 1990) the idea of exposure as a time-dependent process exerting an incremental effect on the risk of disease has not been thoroughly conceptualised or investigated in the occupational stress field" (Johnson and Stewart 1993, 21). Over the past decade, researchers have called for methodological improvements, especially longitudinal studies, to allow better exploration of causality and the temporal nature of job strain exposure (Carayon 1995; Frese and Zapf 1988; House and others 1986; Johnson and Stewart 1993; Johnson and others 1996; Kasl 1987; Marmot and Madge 1987).

A few longitudinal studies of psychosocial job strain and CHD have been conducted over the past decade but, most of these did not measure duration of exposure, which makes the temporal dimension of job strain exposure difficult to investigate. Almost all models of job strain assume that stressors exert their effects through chronic exposure; therefore, a measure of job strain duration is essential to model chronic exposure.

The Whitehall II study (a prospective-cohort investigation), measured the intensity of job control two years apart. For each individual, scores for control were summed for the two points in time to estimate cumulative job control. This score was divided into tertiles. Subjects in the lowest tertile of job control had an odds ratio for "any" subsequent coronary event of 1.93 compared with subjects in the highest tertile (Bosma and others 1997). Although this study did not model duration explicitly, this estimate for cumulative control was strongly predictive of CHD morbidity.[1]

Only one study has measured the duration and intensity of exposure to psychosocial stressors and moderators (Johnson and others 1996) and modeled these as cumulative scores with a CHD outcome. [2] This nested-case control study obtained intensity scores from a psychosocial job-strain exposure matrix developed for Swedish occupational codes (Johnson and Stewart 1993). These scores were multiplied by duration to produce cumulative scores for job control, psychological and physical demand, and co-worker social support. This was a retrospective investigation and demonstrated that workers with a combination of low cumulative control and low cumulative co-worker social support had a relative risk of 2.62 for CHD mortality compared with workers with a combination of high cumulative control and high social support (Johnson and others 1996).

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[1] Seven studies using this method (measurement of either job status or job strain intensity at two or more points in time) have been conducted using non-CHD outcomes (Carayon 1995; Heaney and others 1994; House and others 1986; Johnson and Stewart 1993; Mare 1990; Moore and Hayward 1990; Pavalko and others 1993). All these studies indicated positive associations between exposure intensity measured at two or more times and the outcomes of interest.

[2] No study has investigated the impact of time-weighted average exposure to psychosocial variables on either CHD risk factors or CHD morbidity or mortality.

This dissertation is a retrospective study in which exposure for five variables was added to an existing cohort. The cohort database already had sawmill job history data for the years 1950 to 1985 and mortality outcomes from 1950 to 1990. This is the first cohort study of psychosocial work conditions and CHD outcomes which both uses multiple job history information for a group of workers and models exposure based on these with duration as well as intensity. All other studies with CHD outcomes (except Johnson's nested case-control study and the cohort study by Bosma) used psychosocial exposures based on a single usual or current job to determine exposure. And, all other studies (except Johnson's) modeled exposure only in terms of the intensity of psychosocial work condition variables.

Ideally, to carry out an investigation of cumulative and TWA job strain and CHD within a single industry, exposure assessment should be based on job titles within the industry. Once job strain scores are obtained, they can be applied to a data set with job history information within the same industry, and exposure scores calculated. The requirement for such an investigation is an exposure assessment that is job-title based, and a database with occupational histories based on the same job titles and linked to CHD outcomes.

While the sawmill cohort satisfies these requirements in terms of job history information and CHD outcomes it has some limitations. In particular, information on several potential confounders was unavailable. No person-specific information on biomedical or behavioural risk factors was available. Nor was data available for unemployment and shift work which have both been associated with CHD and could potentially confound any association between psychosocial work condition variables and the outcomes in this dissertation. These latter limitations are outlined in Chapters 3 and 4 and the possibility of confounding due to biomedical and behavioural risk factors is discussed in Chapter 9.

There are potential theoretical as well as data limitations which must be discussed in this dissertation also. In particular, the choice of the demand/control/support model must be explained, justified, and located within job strain theory. There are several possible models for conceptualising job strain besides Karasek's. The choice of this model implies a set of assumptions, limitations, strengths, and implications for policy, which must be taken into consideration when judging the outcome of this research.

Even if one is convinced that the conceptualisation and operationalisation of psychosocial work condition variables is sound in this investigation, other questions remain. Psychosocial stressors and their moderators, unlike many physical and chemical exposures, are found outside the workplace. Even if variables measured narrowly at the task-level capture psychosocial job strain completely, stressors and moderators experienced outside the workplace may confound the association (Pearlin and Turner 1987). Furthermore, it is not clear whether a focus on task-level psychosocial work condition variables will capture the major sources of psychosocial job strain in the work environment as factors operating at the organisational or interpersonal level may generate psychosocial job strain (Michela and others 1995). Finally, there may be interactions between psychosocial, physical, chemical, and other stressors and moderators arising from other dimensions of the work environment.

As well, special conditions may arise because this is an investigation of blue-collar workers. A number of studies show blue-collar workers are at greater risk for CHD than white-collar workers (Kawakami and others 1989; Marmot 1993; Marmot and Mustard 1992; Marmot and Theorell 1988; Mathews and others 1987; Rose and Marmot 1981; Siegrist and Matschinger 1989; Siegrist and others 1990). They may be exposed to physical and chemical hazards that white-collar workers do not encounter. And, interactions between the effects of psychosocial stressors and noxious physical and chemical substances may be particularly relevant for blue-collar workers (House and others 1979).

Some consideration must also be given to adapting the model to the unique conditions of work in sawmills. For example, studies of sawmill workers show machine-pacing is a major task-level stressor (Baneryd 1974; Johannson and others 1978; Punnett 1994; Seppala 1979; Seppala and Nieminen 1980). While the demand/control/support model may measure this particular aspect of sawmill work quite well, modifications may be needed to incorporate other sawmill stressors and/or moderators. For example, noise has a direct effect on blood pressure (Talbott and others 1985) and may also act indirectly as a stressor to raise blood pressure (Kristensen 1989b). The high level of noise in sawmills necessitates its addition to the model.

The relationship between independent and dependent variables must be reviewed too. Extensive research has been conducted on stressful life events and personality factors (Rahe 1972), which has produced the concept of Type-A personalities which may predispose to risk for CHD (Friedman and Rosenman 1974). There is also a research tradition, originating in Scandinavia and largely ignored until the 1980s in North America, that has focused on the "objective" work environment rather than life-event or personality factors as a source of job strain (Gardell 1982; Johnson 1989; Karasek and Theorell 1990). This literature must be evaluated to rationalise using the demand/control/support model in this investigation.

Finally, the use of expert raters must be justified. Direct self-reports or pooled within-occupation self-reports are the usual methods used to assess psychosocial conditions of work. While experts, using the demand/control/support model, assessed psychosocial exposures in the Whitehall study of civil servants this method has not been used widely in psychosocial job strain research (Bosma and others 1997; North and others 1996; Stansfeld and others 1993, 1997). The expert method used in this dissertation is unique as it is based on job evaluators (rather than managers as in the Whitehall studies) and both the rationale for using expert raters in general and the particular method used in this investigation are outlined.

This thesis is organised into nine chapters, with the theoretical and empirical foundations in Chapters 2, through 6. Chapter 2 begins with a brief overview of stress theory in order to frame the concept of psychosocial job strain. The purpose of this chapter is to justify an exclusively work-based approach to modeling psychosocial job strain and to provide an empirical and theoretical rationale for choosing the demand/control/support model from among other work-based models. Chapter 3 describes the two versions of Karasek's model that are used in CHD epidemiology and discusses major criticisms of the models.

Chapter 4 describes the socio-economic conditions which have shaped the development of the sawmill industry and psychosocial conditions of work in the industry. The purpose of this discussion is to better understand the historical conditions which have affected job design and therefore work conditions during the study period and provide an appropriate framework for the empirical investigation of psychosocial work conditions undertaken in this investigation. As well, the 14-study sawmills are described, mainly in terms of their technological/industrial history and labour demography, to evaluate the extent to which unemployment might confound the analyses.

Chapter 5 is a review of the literature linking job stressors in general and, the stressors and moderators measured in the demand/control/support model in particular, with CHD outcomes. The model is usually operationalised using worker self-reports; however, the exposure assessment method in this investigation is unusual as it relies on expert raters.

Chapter 6 is a review of the evidence for using experts to estimate psychosocial work conditions.

The methods section is in Chapter 7 which is organised into four sub-sections; first, study design and data-gathering methods for building the cohort for the original study are described; second, the ways in which this original data set was modified for the present investigation are outlined; third, exposure assessment methods are explained as well as supplementary analyses to measure their validity. The final section presents the analytic methods.

Chapter 8 contains results, which are presented in six sub-sections. Vital status ascertainment is presented in the first section. The second section describes the 14-study sawmills and presents descriptive statistics for the cohort members. The exposure assessment results are presented in the third section and results of supplementary validity analyses presented in the fourth. The Standardised Mortality Ratio analyses are shown in section five and results for the regression analyses are presented in section six.

Chapter 9 is an interpretation of these results contextualised within the literature and discussed in relation to confounding, bias, and misclassification. The final sub-section in Chapter 9 discusses the implications of study findings.

CHAPTER TWO

2.0 Conceptualising Job Strain

2.1 Workplace Psychosocial Strain

Hans Seyle developed one of the earliest theories of stress (Seyle 1936). His General Adaptive System Theory postulated that in response to physical, chemical, or emotional stimuli, the body has a predictable non-specific biochemical response which primes it for "fight" or "flight" (Seyle 1946). If biochemical arousal is maintained, either because the stressor is not removed or because fight or flight is blocked, physiological damage occurs. Although the non-specific nature of the biochemical response to external threats as postulated by Seyle is in some doubt, his basic conceptual framework underpins most models of job strain (Seyle 1983).

Seyle's is a response-based model in which stress is the dependent variable measured by physiological and biochemical changes in the organism. According to Seyles, the nature of the stressor was irrelevant. All stressors produced a characteristic biochemical response so that what mattered to him was the nature of the response rather than the characteristics of the stressors. Occupational stress research is concerned with the nature of the stressors as these may be potentially modifiable conditions of work. Thus, while most occupational stress research is framed by Seyle's model, the occupational stressor is the independent variable causing biochemical and physiological arousal, termed stress. Once aroused, if constraint is placed on the ability to fight or flee, job strain may occur and, if sustained, may cause measurable symptoms and eventually, disease. Thus, in a response-based model, stress is a normal biophysical reaction to stressors, whereas in a stimulus-based model "strain is an overload condition experienced by an organism's control system when it attempts to maintain integrated functioning in the face of too many environmental challenges" (Karasek and Theorell 1990, 87).

Before proceeding with this discussion, the terminology used in this investigation requires definition. The term psychosocial job strain (used inter-changeably with job strain) means the strain caused by psychosocial conditions in the work environment. The psychosocial conditions of work arise from stressors and moderators located in the work environment. (It is also possible that stressors and moderators at home effect psychosocial job strain. This will be discussed later.) In any case, for this investigation, the stressors psychological demand, physical demand, and noise, and the moderators co-worker social support and control are of main interest. [3]

2.2 The Relative Importance of Stressors and Moderators Arising from Work and Non-Work Environments

Rationalising the use of a job-based model requires assessment of the relative contribution of work compared to home-based stressors and moderators to the development of psychosocial job strain. In recognition of the importance of this question Kasl called for "more studies which are specifically concerned with inter-relationships among life roles, or which study effects of events and changes which cross several life roles" (Kasl 1978). Since then, only a few studies of this type have been performed. A decade after this call for "more research", in a review of work and non-work stressors and their effects, Cooper was only able to suggest a "feed-back" loop with stressors at work affecting family life and stressors in the family arena affecting work (Cooper 1987).

In a study of 8,700 male and female white-collar workers, representing one-quarter of occupations in Sweden, "adding job factors to explanations of health and behaviour

[3] The reasons for choosing these particular stressors and moderators are explained in detail in the remainder of this chapter and in Chapter 3.

increases the explained variance by roughly 60 percent versus the 20 percent increase that comes from adding family stressors" (Karasek and others 1987, 203). In this study, for both men and women, job stressors and moderators were stronger than family stressors and moderators in predicting physical illness symptoms and health-related behaviour. In another study of 1,010 men and women in 20 different occupations, the effect on job strain was assessed for psychological demand and control on-the-job versus family conflict. Psychological demand and control accounted for 17.6 and 18.6 percent, respectively, of the variance in job strain, while family conflict explained 5.8 percent of this variance (Radmacher and Sheridan 1995).

These findings could be attributed to many factors. Work, in most Western societies, is central to people's self-esteem—it marks social position, and affects income and life quality. Several researchers have shown that work shapes the behaviour of workers in ways that affect their actions outside of work. For example, Kahn postulated that at work, individuals develop a set of roles, experiences, and behaviours that carry over into non-work life (Kahn 1981). Others have shown that the socialisation effects of work are very powerful in providing workers with coping styles and a world view that are carried over into the non-work world (Kohn and Schooler 1969, 1973, 1979).

Several studies have attempted to measure the behavioural "spill over" of work on non-work life. Gardell found that those who worked with complex technology were the least alienated and the most likely group to participate in union and community affairs (Gardell 1982). Karasek found that workers with greater task-level control were more socially active during their leisure time and, similarly Aronnson showed that workers in low-control jobs participated less in activities at work that promoted collective change in the workplace (Aronnson 1985; Karasek 1978). Elden and Karasek have shown that high task-level control was associated with political participation outside work even after controlling for social class (Elden 1981; Karasek 1981). Finally, several studies have shown that for workers in repetitive or machine-paced jobs and those who work excessive overtime, the time taken to "unwind" after work is extended, indicating physiological "carry-over" of work pressure into non-work life (Frankenhaeuser 1989; Frankenhaeuser and Johansson 1986; Rissler 1979).

The influence of work on health becomes clearer when one considers the mortality patterns of wives in relation to their husband's occupations. In an investigation of the deaths of 324,822 working aged men and 35,915 women in Britain for the years 1979-80 and 1982-83, across a broad range of diseases and occupations, specific occupational mortality of husbands was predictive of the cause of death of women married to men in those occupations. According to Fletcher, there is "a synergy between occupation and marriage, because it implies that the wife of a man in any given occupation is more likely to die of the same disease as her husband compared to a single woman employed in the same occupation as her male counterpart" (Fletcher 1991, 176). Shared social class, the effect of spousal bereavement, physical transmission of occupational risk factors, and personality factors were, according to Fletcher, not the reason for the associations. He concluded that "the whole ecology of the husband's occupation and other shared environments, affects the psychological framework of both partners" (Fletcher 1991, 182).

More support for the strong influence of the psychosocial conditions of work on health comes from the Whitehall civil service studies (Bosma and others 1997; Marmot and others 1978). In these studies, position in an occupational hierarchy was a strong and independent risk factor predicting CHD even after controlling for conventional CHD risk factors and the effects of social class. Marmot demonstrated that work-based psychosocial conditions varied according to position in the occupational hierarchy. He postulated that different psychosocial environments at work which are associated with each position in the hierarchy may be the way in which these health effects are mediated (Marmot and others 1978; Marmot and Madge 1987).

Most of these studies were focused on stressors and ignored the effect of moderators on the generation of psychosocial job strain. In the past 15 years researchers have recognised the importance, in particular, of social support at work as a moderator. According to Johnson:

> if one considers the increasing fragmentation of older forms of social cohesion, such as the village, neighbourhood, or church, it seems possible that the interactions in the workplace are one of the few remaining sources of stable, on-going personal contact (outside the family). For many people work relationships may be one of the major sources of human companionship in the modern era (Johnson 1989, 470).

The empirical evidence for the impact of social support obtained at work is fairly consistent and strong. But, it is unclear whether social support obtained in non-work dimensions of life effects job strain (House 1981). There is some evidence that social support and social networks outside of work reduces job strain, at least for older men (Falk and others 1992). On the other hand, House showed that co-worker and supervisor support may be twice as important as support from home and family in reducing job strain (House 1981). In addition, LaRocco found co-worker support more effective in lowering the mental and physical effect of job strain than support at home (LaRocco and others 1980). And, finally, in the Whitehall study of sickness absence among civil servants "the protective effect of work support on short spells of absence is much stronger than non-work support" (Stansfeld and others 1997, 45).

This review indicates that the "psychosocial situation at work appears to have a greater influence on psychological well-being than do family situations," and supports the use of a model that only measures stressors and moderators arising within the work environment (Karasek and Theorell 1990, 76). In the next section solely work-based models of job strain are compared in order to elucidate both the mechanisms by which stressors and moderators at work might produce psychosocial job strain, and to rationalise the selection of the demand/control/support model for use in this dissertation.

2.3 Models of Psychosocial Job Strain

Many researchers "assume that the stress state is linked to the subjective perception (interpretation, appraisal) of the environmental exposure, not its objective characteristics" (Kasl 1987, 311). Thus, people may differ in their stress responses depending on personality, perceptions of stressors, and differential coping ability given the same level of objective resources (Lazarus and others 1985). From this theoretical stance, the assessment of objective work conditions is much less relevant than measurement of subjective perception and response to these. Several interactive models of occupational stress have been developed based on this foundation (Caplan and others 1975; Fletcher 1991; French and others 1974; Lazarus and others 1985; Payne 1988; Van Harrison and others 1987).

The best known of these is the Person-Environment Fit (P-E Fit) model developed by Caplan (Caplan and others 1975; French and others 1974; Van Harrison and others 1987). The model distinguishes between the objective and subjective person, and the objective and subjective environment, and postulates that job strain depends on the "fit" between the subjective person and the subjective environment (French and others 1974). Psychosocial conditions are interpreted by the individual, so that job strain is a consequence of individual perceptions and is best operationalised by measuring subjective perceptions of psychosocial work conditions and perceptions of the ability to meet and cope with these. When using the P-E Fit model, objective work conditions are not usually measured.

A major strength of the model is that it deals with the complexities of the cognitive appraisal of stressors, which are fundamental to most theoretical formulations of psychosocial job strain (Fletcher 1988; Lazarus and others 1985). The model, however, requires measuring perceived work demands (subjective environment) and perceived capability to meet these demands (subjective person), which may derive from the same psychological framing of self. It is not clear how much contamination occurs between measures of a person's perception of work demands and measures of the perception of their own ability to cope with them. The issue is more problematic when one considers using the model with "soft" dependent variables such as job satisfaction, which may also derive from the same conception of self as the independent variables. In this case, there is a problem of methods' variance in which the independent and dependent variables are hardly distinguishable (Kasl 1978, 1987).

These measurement problems have made it difficult to use such models in epidemiological studies. Perhaps, in the case of the P-E Fit model, this is why little empirical evidence has been gathered to demonstrate its validity. According to Edwards, "most empirical evidence regarding the P-E Fit approach to stress is extremely limited in scope or, in some cases, largely inconclusive" (Edwards 1990). Besides measurement and empirical problems, for the present investigation, the use of the P-E Fit model and others which rely on subjective perception of the work environment was not possible because such data were not collected for the original cohort and would be impossible to gather retrospectively.

Another approach to job strain research, largely developed in Europe, focuses on the objective conditions of work rather than worker's perception of these. Because different workers will perceive, process, and cope with the same objective work conditions differently, these may *potentially,* but not necessarily, lead to strain (Frese and Zapf 1988). It is necessary to measure core objective conditions even if perceptual differences of these may lead to different job strain outcomes in individuals. This is required due to the methodological problems in measuring worker perceptions of job conditions and operationalising them in epidemiological studies, and because of the need to direct remedial policy to changing objectively measurable work conditions.

The largely subjective North American research tradition has created a tendency to disengage or disregard the relationship of objective conditions to perceptions. As early as 1978, Kasl stated that "it is a good indication of how far we have gone in ignoring the objective work environment when such an excellent and rich report as *Job Demands and Worker Health* (Caplan and others 1975) provides us with no information about the work setting other than the briefest of occupational titles" (Kasl 1978, 36). [4]

Several models including Karasek's demand/control/support, Fletcher's demands/supports/constraints, and Warr's vitamin model have been developed to measure "objective" psychosocial stressors and moderators at work (Fletcher 1988). The best known and most widely used of these is the demand/control model developed by Karasek (1979) and expanded into the demand/control/support model (Johnson and others 1989; Karasek and others 1982). The original version of the demand/control model has been the most widely used and validated in epidemiological studies with CHD outcomes.

Another approach, the effort/reward imbalance model, merges aspects of both traditions. Using German steel workers, Siegrist developed a job strain model for predicting CHD which measures the objective work environment and workers' perceptions of both this and themselves (Siegrist and Matschinger 1989). Workers who are exposed to a high workload, low status control (meaning control over earning long-term rewards), and with a high "need-for-control" are hypothesised to have an elevated risk for CHD. Siegrist measures work load and status control with a mixture of self-report variables some of which measure the objective work environment and others which measure the worker's

[4] Caplan's report describes the early operationalisation of the P-E Fit model.

perception of this objective environment. The “need-for-control” variable measures attitude and personality characteristics thereby bringing the “subjective” worker into the model (Siegrist and others 1990). Given that this model has been validated for blue-collar workers, it might be the “best” to use in this investigation. This is impossible, however, because there is no subjective data available for this cohort

In summary, an argument has been advanced to justify the use of a solely work-based model for psychosocial job strain. A second discussion outlined the possible choices of a work-based model. Because of measurement and validity limitations with the PE-Fit model and the impossibility of using the effort-reward imbalance model with this database these two models were rejected. Because of its widespread use and validation with CHD outcomes, the demand/control/support model was selected and is further described in the next chapter.

CHAPTER THREE

3.0 The Demand/Control Models

3.1 Original and Expanded Models

The demand/control model was developed empirically using factor analysis with data from three American labour surveys carried out in the late 1960s and 1970s. [5] In its original form, the model was based on a 27-question instrument measuring task-level psychological demand and control. By the 1980s the core model was expanded to include social support. Since then, the questionnaire has been expanded and revised several times, in particular to include stressors located in other work dimensions and various psychosocial job strain outcomes. For this investigation, newer versions of the demand/control instrument were disregarded because most epidemiological studies with CHD outcomes have been conducted with the original demand/control or demand/control/support models and associated questionnaires. A shortened instrument based on the demand/control/support model, adapted to the special psychosocial work conditions of sawmills, was used in this dissertation.

In the original model, Karasek postulated that the stressor, demand, is moderated by control (Karasek 1979). Demand is usually operationalised as psychological demand measured by estimating the extent to which work is conflicting, excessive, hard, fast, and whether or not there is enough time to complete a job. Physical demand (based on a single question) is considered less important in this model and in some investigations has been

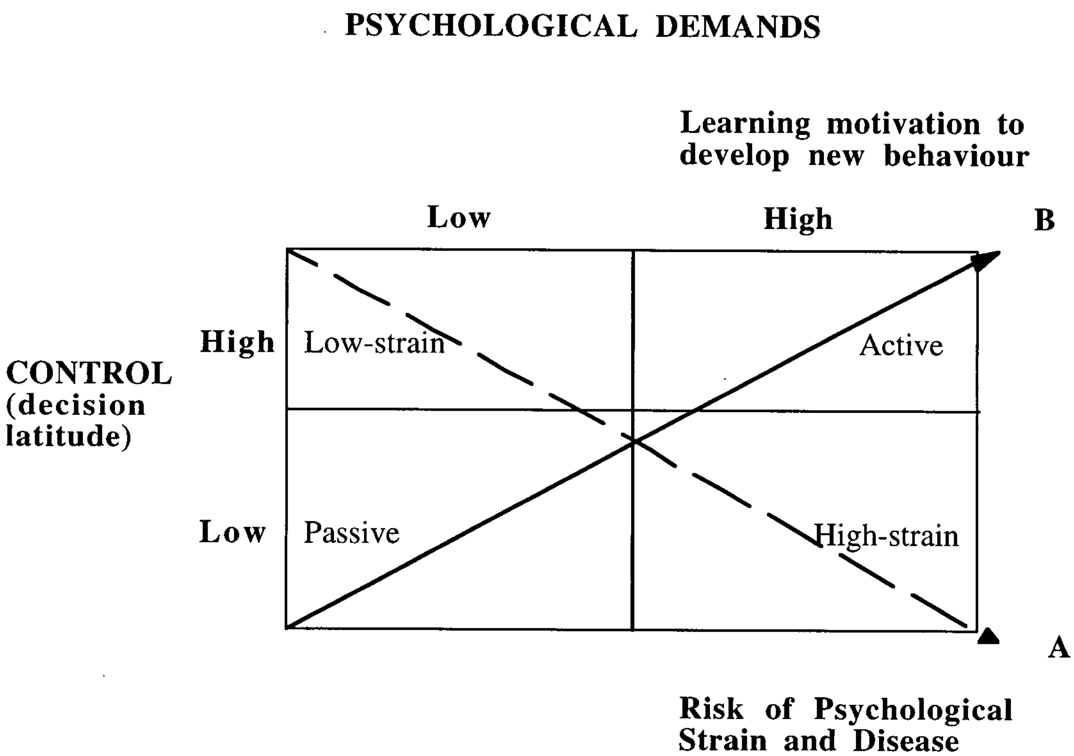
[5] Using similar labour force surveys in Sweden in the 1970s and 1980s a Swedish version of the demand/control model was also developed.

combined with psychological demand into a single "demand" variable (Astrand and others 1989; Haan 1988).

Job control, termed decision latitude, is "the worker's ability to control his or her own activities and skill usage" and is subdivided into skill discretion and decision authority (Karasek and Theorell 1990, 60). Skill discretion is the ability to develop skills on the job, to learn new things, and to perform varied work. Decision authority is a measure largely of job responsibility and independent decision making.

This is a two-dimensional model (figure 1) which postulates that psychosocial job strain is the result of a multiplicative interaction between psychological demand and control. A job with high demand and low control is high-strain. In contrast, a job with high control and low demand is low-strain. Jobs that are both high-control and high-demand are termed active, while those with low control and low demand are termed passive. The model hypothesises that active and passive jobs both lead to levels of strain which are intermediate between high- and low-strain jobs.

Karasek theorises that chronic adaptation to passive jobs may result in reduced ability to solve problems, tackle challenges, and can lead to depression, resulting in "learned helplessness" (Karasek and Theorell 1990). Conversely, if high job demands are matched with greater authority and skill use, "active learning" and greater internal locus of control occur, which broadens the range of a worker's coping strategies. The interaction between demand and control is thus related to physiological and health outcomes as well as to behavioural outcomes, which may feedback to promote or decrease control.



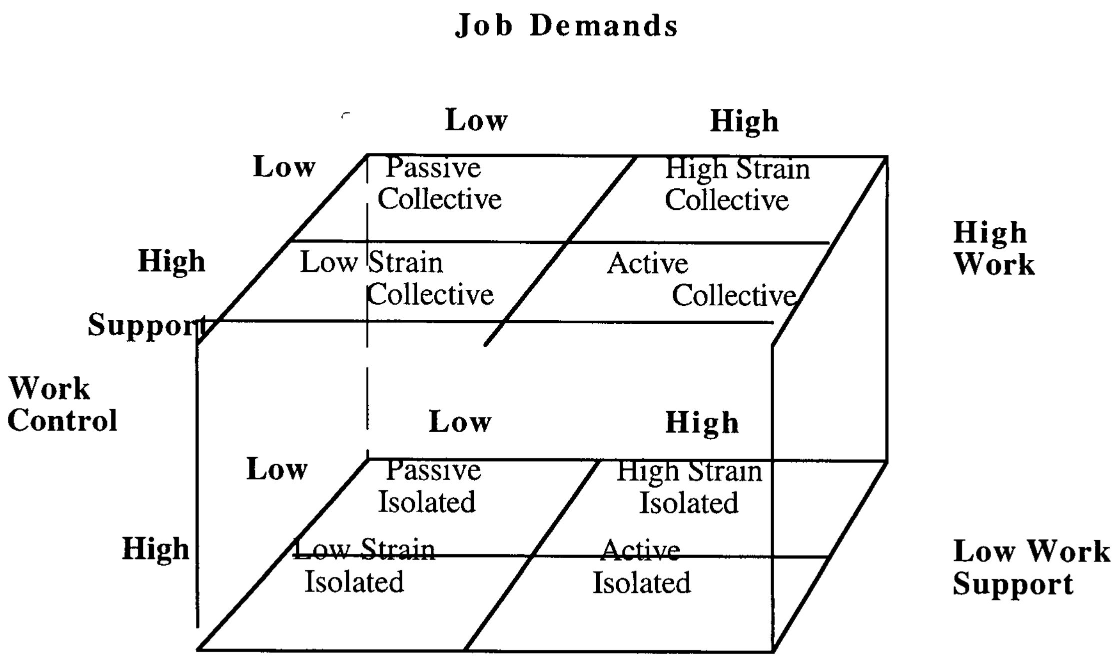
Source: Karasek, R., Theorell, T. Healthy Work, p. 32.

Figure 1. Demand/Control Model

One of the major criticisms of this model is its simplicity. With the increasingly voluminous literature relating social support (obtained from co-workers and supervisors) to job strain this construct was included in the expanded demand/control/support model (Johnson and others 1989; Karasek and Theorell 1990; Karasek and others 1982) (figure 2). Social support is thought to act (like control) as a moderator of psychological demand by facilitating coping patterns such as active learning.

In most studies, social support is measured as individually based, emotional transactions. It can also be viewed as a structural resource. Thus, organisational features of work, such as spatial proximity of workers to each other, predicated on the architectural layout of the work process, the extent to which problems are experienced and solved collectively at work, and the level of equality in the work hierarchy, are measurable features which promote or detract from the workplace's ability to provide social support (Johnson 1989).

Supervisor support is not measured in this investigation. Social support as operationalised in this dissertation consists entirely of co-worker social support. The assessment of co-worker social support is based on the location of the job title in the sawmill in terms of its proximity to co-workers both spatially and in terms of a workers ability to leave his job station to interact with co-workers. A similar construct, using co-worker social support by itself, has been used by Johnson in three studies with CHD outcomes (Johnson 1988,1989,1996).



Source: Johnson, J. V., Hall, E. M. Job Strain, Work Place Social Support, and Cardiovascular Disease: A Cross-Sectional Study of a Random Sample of the Swedish Working Population. *American Journal of Public Health.* 78 (10) p.1336.

Figure 2. Demand/Control/Support Model

3.2 Strengths and Weaknesses of the Models

The demand/control model has been widely tested for reliability and validity across a range of health outcomes (Karasek and Theorell 1990). The model has also been extensively tested with CHD morbidity, mortality, and risk factors (see tables 2 and 3 in Chapter 5) and in male blue-collar workforces (Albright and others 1992; Alterman and others 1994; Carrere and others 1991; Green and Johnson 1990; Haan 1988; Harenstam and Theorell 1988; Kawakami and others 1989; Mathews and others 1987; Netterstrom and Suadicani 1993). Although the demand/control/support model has been less widely tested than the parent model, it also has been used in investigations with CHD outcomes (Astrand and others 1989; Bosma and others 1997; Falk and others 1992; Johnson and Hall 1988; Johnson and others 1989, 1996; Landsbergis and others 1994).

The original demand/control model has been criticised for four main reasons (Fletcher and Jones 1993):

i) Demand and control may not interact as postulated by Karasek.

ii) Focus on task-level control and psychological demand alone is inadequate as they do not explain enough variance in job strain.

iii) The model fails to consider social support at work.

iv) Most of the studies are across heterogeneous occupations and therefore vulnerable to confounding by socio-economic status.

Some of these objections have been addressed. A key component in Karasek's model is his multiplicative interaction thesis. In seven studies of CHD, a multiplicative interaction term, partialled for main effects, was used (Chapman and others 1990; Haratani and others 1992; Johnson and Hall 1988; Johnson and others 1996; Landsbergis and others 1994; Pieper and others 1989; Reed and others 1989). The interaction term significantly improved the variance explained by the main effects of psychological demand and control on CHD prevalence (Haratani and others 1992; Johnson and Hall 1988), hypertension (Landsbergis and others 1994), and CHD mortality (Johnson and others 1996) in 4 of these 7 studies.

Interaction effects have also been tested for non-CHD outcomes. Karasek, assessing dependent variables such as depression, exhaustion, job dissatisfaction, tranquilliser/sleeping pill consumption, and sickness absence from work found evidence for interaction (Karasek 1979). Dwyer also found that an interactive term for demand and control predicted absenteeism and job satisfaction and Perrewe found limited support for an interaction effect (Dwyer and Ganster 1991; Perrewe and Ganster 1989); however, eight other studies with non-CHD outcomes found no interaction effect (Fletcher and Jones 1993; Ganster 1989; Landsbergis 1988; McLaney and Hurrell 1988; Payne and Fletcher 1983; Spector 1987; Stansfeld and others 1995; Warr 1991). These included a re-analysis of Karasek (1979) by Fletcher and Jones (1993) which was unable to replicate the interaction effect for any outcomes. In most of these studies, direct effects (usually statistically significant) were found for control and, less often for psychological demand.

The second major criticism, is that the model is too simple and does not explain enough of the variance in job strain. The model, as usually used with CHD outcomes, measures stressors and moderators only as the task-level. According to Cooper, occupational stressors are generated and operate at different levels within the work environment (Cooper 1987). Workplace stressors can arise from the chemical and physical work environment, job-task content, and from organisational and extra-organisational factors (Baker 1985). Adding to this complexity is the possibility for interactions by stressors and moderators across work dimensions. For example, the physical work environment may produce heat, noise, and chemicals which act directly as physiological stressors or indirectly via psychological mechanisms such as discomfort and lack of control (Kristensen 1989b). [6] In

[6] Usually task-level demand and control are measured using self-reports. It is difficult to see how these

this investigation noise was measured adding complexity to the original model and moderating this second criticism to some extent.

The third criticism, that the model fails to include social support, has been addressed by the development of the demand/control/support model. Seven studies with CHD outcomes have been undertaken using this model (Astrand and others 1989; Bosma and others 1997; Falk and others 1992; Johnson and Hall 1988; Johnson and others 1989, 1996; Landsbergis and others 1994). In three of these studies, evidence was obtained that work-place social support interacted with psychological demand to reduce job strain (Astrand and others 1989; Falk and others 1992; Johnson and Hall 1988). One study showed that workplace social support had main effects on job strain in the predicted direction but no interaction effects were observed (Johnson and others 1996). In two studies, which did not try to disentangle main from interaction effects of social support, workers in jobs with a combination of high psychological demand, low control, and low social support had increased risk for CHD morbidity and mortality (Johnson and others 1989), and increased ambulatory blood pressure (Landsbergis and others 1994). And, in one study no effect for social support was found (Bosma and others 1997). Finally, two studies with non-CHD outcomes and the demand/control/support model found main effects but no interaction effects for social support (Lerner 1994; Stansfeld and others 1997).

Three studies with non-CHD outcomes have been conducted with homogeneous occupational groups using the demand/control or demand/control/support model. Payne found the demand/control model was unpredictive in a group of school teachers (Payne and Fletcher 1983). Spector also found the model was not predictive with 136 female university

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would not incorporate the impact of organisational-level stressors and moderators. Thus, it may be that task-level variables are contaminated by organisational factors. If this were true, studies with the demand/control model might be less "simple" than its critics claim as some organisational factors would be included in the task-level estimates. However, it should be noted that in this investigation, with expert raters, there is little chance that organisational factors operating at the mill level were incorporated in expert task-level measures.

clerical workers (Spector 1987). Both studies used self-assessed measures of satisfaction and health as outcomes. Using similar outcomes in a study of 76, mostly female clerical workers, Carayon obtained positive results when modeling cumulative social support, psychological demand, and control. She found that lack of control and social support from supervisors may act as a chronic stressor and that these effects were due, not only to the strength of stressors, but also to the duration of exposure (Carayon 1995).

Seven studies with homogeneous occupational groups have been conducted using the demand/control model with CHD risk factors as outcomes. Three studies conducted with a total of 3,400 male bus drivers found no significant effects of high-strain jobs on blood pressure (Albright and others 1992; Carrere and others 1991; Netterstrom and Suadicani 1993); however, in one of these studies, high strain was significantly associated with elevated catecholamines (Carrere and others 1991). Harenstam, in a study of 66 male prison guards, found no effect on ambulatory blood pressure, while Theorell, in a study with 56 female nurses, found a significant association between strain and systolic and diastolic blood pressure (Harenstam and Theorell 1988; Theorell 1993). These blood pressure studies may be methodologically suspect because self-reports of demand and control may be systematically under-reported by hypertensives and because causal rather than ambulatory blood pressure was measured. [7]

Two more studies with CHD risk factor outcomes other than blood pressure have been conducted for homogeneous groups of women workers. Doncevic, in a study of 63 female nurses found that low intellectual discretion (a measure of control) was associated significantly with elevated cholesterol levels (Doncevic and others 1992). And, in a study of 519 female clerical workers, Haynes demonstrated lower prevalence of self-reported angina in workers with high control (Haynes and others 1987).

[7] Causal blood pressure measures are subject to observer bias and are therefore not as reliable as studies based on ambulatory blood pressure.

As well as these investigations four cohort studies using homogenous cohorts of blue collar workers have been conducted with CHD mortality or morbidity outcomes. Three of these (Haan and others 1988; Siegrist and others 1990; Theorell and Floderum-Myrhed 1977), showed positive results and one (Netterstrom and Suadicani 1993), produced negative findings. Thus, 3 of 4 cohort studies which were homogeneous in terms of class produced positive findings.

As well, three other cohort studies with CHD morbidity or mortality outcomes have been conducted across heterogeneous occupational groups and adjusted for social class. The best designed was the Whitehall Civil Service study because it was large, conducted with both men and women, and used several measures of CHD incidence. This study adjusted for both bio-medical and behavioural risk factors, and negative affectivity, and used both indirect and direct exposure assessment measures. The study demonstrated a strong protective effect for control in relation to CHD morbidity for both men and women, after all these adjustments and with both indirect and direct exposure estimates (Bosma and others 1997).

Two more cohort studies with CHD outcomes also adjusted for social class (Alterman and others 1994; Johnson and others 1989). Johnson's study produced positive results and although Alterman's results were negative a non-significant trend of decreased CHD mortality with increased control was demonstrated for white collar workers. (*No such trend was found for blue-collar workers in this study*).

In summary, results are mixed from studies with non-CHD outcomes and for studies with CHD risk factors (particularly blood pressure) as outcomes. However, it is important that the only study (with a non-CHD outcome) that modeled cumulative exposure to psychosocial work conditions (Carayon's) found that for both duration and intensity, low control and low social support from supervisors at work produced job strain within a homogeneous occupational group.

Results for studies with CHD morbidity and mortality outcomes were less mixed. Of 7 cohort studies with these outcomes, which either adjusted for class or were conducted with homogenous groups, 6 showed positive results. Thus, it appears that with "hard" outcomes (CHD morbidity or mortality) and "strong" study designs, associations between psychosocial conditions of work remain in most studies even after controlling for social class.

A description of the models and a review of their major criticisms was necessary to rationalise the use of the demand/control/support model in this dissertation. A further discussion is needed to determine whether it should be modified for use in the unique situation of sawmills particularly as the model was originally designed to measure psychosocial work conditions across heterogeneous occupations. While occupations are not homogeneous in sawmills, they are limited to a few blue-collar occupations and many of these involve exposure to unique physical and chemical hazards. Some discussion is therefore needed to determine how the demand/control/support model was adapted for use in sawmills.

3.3 Adapting the Model for Use in Sawmills

Adverse environmental conditions are an integral feature of sawmill work. Work in a sawmill has many of the most unpleasant features of traditional male blue-collar occupations—many jobs are unskilled and on an assembly-line, with exposure to high levels of noise and dust. Some jobs are inside, others are outside, so that exposure to heat and cold varies across job titles. In the B.C. sawmill industry, chlorophenols were widely used from 1945 until the late 1980s as an anti-fungicide; as a result, many workers were exposed to this dioxin-contaminated chemical (Teschke and others 1994). Other chemical exposures are also possible in sawmills, particularly from asbestos, diesel fuel, welding fumes, and chlorinated solvents.

In a series of reviews of chemical exposures in relation to CHD, Kristensen found that organic solvents and chlorinated organics like chlorophenols were not likely risk factors (Kristensen 1989a). In a further comprehensive review of chronic non-chemical exposures and CHD, Kristensen ruled out heat and cold but estimated that the most serious risk factors were (in descending order) psychosocial job strain, physical inactivity at work, shift work, and noise, which are all present in sawmill work (Kristensen 1989b). For this investigation, person-specific information on shift work was unavailable, but noise and physical demand were estimated by the expert raters.

Another potential confounder not considered in Kristensen's review is unemployment. The sawmill industry is subject to cyclical employment because of fluctuating prices for lumber. In a unionised environment, those with the lowest seniority are most prone to layoffs. The bigger the recession the further up the seniority ladder the layoffs reach. Unemployment has been linked to increased rates for CHD mortality and morbidity (Jin and others 1995). There may also be an association between task-level job strain and unemployment because, in sawmills, low-seniority jobs tend to have the highest psychosocial job strain so that there is the potential for confounding with unemployment. The potential for confounding by unemployment is discussed more fully in the next chapter.

If person-specific information on shift work were available in the database the model could be operationalised as usual and shift work controlled for in the analysis. Unlike unemployment and job insecurity, shift work in the study sawmills is not as closely tied to seniority as both low- and high-seniority employees are involved in shift work. This means that psychosocial conditions of work are likely less associated with shift work and, although shift work is associated with CHD, the potential for confounding by this variable may not be as high as it is for unemployment. Ideally, in a study with CHD outcomes and a blue collar work force, it would be best to control for shift work but, given the unavailability of this information, it was not possible in this investigation. [8]

3.4 Summary

In this chapter, the two versions of Karasek's model usually used with CHD outcomes were described and major criticisms of the models reviewed. Control and psychological demand exert main effects for a range of psychosocial and physiological outcomes but, it is not clear whether psychological demand and control interact multiplicatively. Nor is it clear whether, for the expanded model, work-place social support interacts with psychological demand as postulated. With CHD outcomes the evidence for multiplicative interaction is stronger than for non-CHD outcomes, but is not conclusive. Even if the model does not work exactly as Karasek and others have claimed, because control, (and to a lesser extent) psychological demand, and social support exert main effects on CHD in most studies, the use of the model is justified for this investigation.

The second criticism, that the model is too simple, has been partly handled by the addition of social support to the model. But, the focus on task-level measures of psychosocial work conditions means that the model may still be too narrow in its focus as it omits stressors and moderators which arise within the work place but are located or generated at the organisational or supra-organisational level. The third, criticism that social support should be added to the original model has been partly met. However, for this investigation supervisor support could not be assessed and it is unclear if the variable as operationalised

[8] No studies with CHD outcomes and the demand/control model have measured and controlled for the effect of shift-work.

in this investigation with only co-worker social support has construct validity as a measure of social support in the workplace. [9]

The final criticism that positive results with the model are largely due to confounding by socio-economic status may be incorrect. Using the best designed studies with the most valid and reliable outcomes, positive associations have been consistently shown with the demand/control and demand/control/support models after controlling for social class or conducting investigations within homogenous (in terms of class) cohorts. This is relevant to the present dissertation because most members of the sawmill cohort are blue-collar workers.

The way in which the model was adapted for this sawmill investigation was outlined. The major adaptation was the addition of a question to measure the intensity of noise because this is a common exposure in sawmills and has been associated with morbidity and mortality from CHD. Three other potential confounders arising from sawmill work were identified. The first of these, physical demand, is measured in this investigation. The second, shift work was not measured but may have low potential to confound the analysis and has not been controlled for in other investigations with the demand/control model and blue-collar cohorts. The third potential confounder, unemployment, may be the most serious one in the sawmill work environment and is discussed in more detail in the next chapter.

In the next chapter socio-economic conditions which have shaped the development of the sawmill industry and driven job design are outlined. The purpose of this description is to better understand historical conditions which may have influenced job design and therefore

[9] In three Swedish investigations with CHD outcomes social support was also operationalised only in terms of co-worker social support. All three studies showed positive associations between co-worker social support and CHD outcomes (Johnson and others 1988,1988,1996).

work conditions (including psychosocial work conditions) during the study period both generally and specifically for the B.C. sawmill industry. This is particularly important because the method of exposure assessment used in this dissertation is cross-sectional and, to be valid, psychosocial work conditions must have remained relatively stable during the study period. Although the changes in psychosocial work conditions during the study period were determined empirically in this dissertation (see Section 8.4.2), the broader discussion provides context for this analysis.

Second, the history of technological change and labour demography for the 14-study sawmills is outlined and linked to the theoretical discussion just outlined. The purpose of this description is to estimate the extent to which post-war industrial change in work organisation and psychosocial conditions of work may have effected the specific mills used in this study. Also, mainly using the labour demography information from the study sawmills, mill-level labour turnover and unemployment data is used to determine the extent to which unemployment might confound the analyses.

CHAPTER FOUR

4.0 The Industrial Geography of B.C.'s Post-war Sawmill Industry

Change in the ways in which mass production manufacturing is organised is likely to find its way down to the task-level as jobs are redefined and redesigned to fit with new managerial and organisational methods. These will be felt in terms of changed conditions of work including the psychosocial work environment. Studies of task-level work conditions can therefore benefit from a more contextualised understanding of these broader industrial changes.

Also, because the organisational principles of mass manufacturing began to change for many industries beginning in the 1970s it is necessary to determine the extent to which these changes may have affected the B.C. sawmill industry in general, and the cohort mills in particular. If there were large-scale changes in the organisation of work in B.C.'s sawmills in the 1970s and 1980s these could have affected psychosocial work conditions. Investigation of the nature and extent of these changes is therefore necessary to provide a framework for both the empirical determination of the validity of the cross-sectional job strain measures proposed in this investigation and the impact of unemployment during the study period.

This discussion is developed in three parts. First, Fordist production methods and the flexible methods of production that began to replace these in many industries are described. Second, the relationship between these two systems of production and psychosocial conditions of work are outlined. Finally, in order to understand the Canadian context, Harold Innis's staples theory is briefly discussed as well as Barnes and Hayter's view of the changing industrial geography of B.C.'s sawmill industry.

4.1 Fordism and Flexible Production

There are a number of ways in which historians, sociologists, and geographers have conceptualised the unfolding of economic history in capitalist countries. Generally economic historians (particularly of the "regulationist" school) attempt to "identify relatively distinct periods of capitalist development in terms of dominant technological-institutional systems as they are embodied in ensembles of leading industries and complemented by different political and quasi-political arrangements which steer and coordinate the economy." (Scott and Storper 1992, 6).

For most of the 19th century manufacturing work was organised as craft production with skilled artisans planning, directing, and organising production from start to finish. This mode of production was based on integration of the manufacturing process within the artisans workshop. Automation, assembly-line technology, and the development of mass markets increasingly displaced craft methods of production towards the end of the 19th and beginning of the 20th century. These methods of mass production resulted in the fragmentation of tasks within the manufacturing process. The mass production methods, called Fordism, were well entrenched in the major capitalist economies by the inter-war years. But, by the 1970s, Fordism was increasingly replaced by "flexible production" methods in many industrialised countries.

For most of the industrialized world during the 20th century (at least until the 1970s) methods of industrial production, technology, work organisation, associated infrastructure and markets were dominated by "Fordism". This refers to a particular configuration of the technical and social division of labour involved in making long runs of standardised goods. Fordist "mass production" is "typically based on a technical division of labour which is organised along Taylorist lines, subject in its immediate production phase to mechanical pacing by moving assembly line techniques, and organised overall on the supply-driven principle that production must be unbroken and in long runs to secure economies of scale" (Jessop 1992, 46).

The particular configuration of the technical and social division of labour under Fordism is based in large part on the management principles espoused by Frederick Taylor and put into practice early in the 20th century by Henry Ford in his automobile factories. Taylor's methods of work organisation involved strict separation between management and the execution of standardised and formally prescribed tasks on the shopfloor. These management principles also affected work conditions including psychosocial conditions of work (see section 4.2).

Fordism was underpinned by large and highly capitalized units of production consisting either of continuous flow or assembly line processes. Production was geared to continual search for internal economies of scale by routinization of technology and process and rigid dedication of capital equipment. In institutional terms, these economic features of Fordism were matched by emergence of oligopolistic corporations and large industry-wide labour unions. In terms of agreements over work organization, " blue-collar workers secured contractual codification of job categories, seniority rules, and productivity-based wage-setting practices. The rigidities brought into being by these contractual arrangements were then typically matched by countervailing lay-off and recall processes as the mechanism by which producers attempted to adjust their demand for labour to changes in the economic cycle" (Storper and Scott 1989, 23).

According to Harvey, in the 1970s Fordism began to break down as a new type of industrial organisation with associated institutional, cultural, and regulatory infrastructure began to emerge (Harvey 1985). Flexible production is characterised by an ability to shift quickly from one product configuration to another and also to adjust volume of output without negative implications for the efficiency of production. In flexible production, "craft work takes place in networks of interconnected, independent, specialised, and flexible firms, which are in a position to react quickly to changes in fashions on the world market and to implement efficiently new technologies" (Leborgne and Lipietz 1992, 333). This kind of flexibility is achieved by the use of non-dedicated capital equipment (usually rendered flexible because it is programmable). Also, "there is a tendency within the flexible firm for job descriptions to break down into a restricted number of broadly-ranging categories, and for concomitant extensions to occur in the redeployability of labour on the shop floor" (Storper and Scott 1989, 27).

Fordist production requires a workforce of homogenized semiskilled "mass" labour whereas flexible production is based on a small number of permanently employed highly skilled "core" workers capable of performing multiple tasks and a secondary category of part-time "peripheral" workers who move in and out of the production process depending on levels of market demand. Also, "industrial relations strategies focus on integrating core workers into the enterprise and on mobilizing the production intelligence of workers by dissolving the Taylorist distinction between conception and execution. There may also be more intensification, marginalization, and insecurity for peripheral workers. They will often be poorly paid, unorganised, and recruited from politically marginalized social groups" (Jessop 1992, 63). Such firms will also be less bureaucratic relying on outside subcontractors rather than internal staff for many management functions.

The ways in which re-organisation of production embodied in a move from Fordism to flexible production might influence task-level psychosocial work conditions is further discussed in the next section.

4.2 Taylorism, Flexible Production, and the Psychosocial Conditions of Work

Taylor's theories of enhanced managerial efficiency were based on the understanding that "job design and technology could be used as instruments of social power by management to desocialise workers, through social isolation and the disintegration of informal work groups" (Braverman 1974). Thus, Taylor's principles were explicitly directed at altering the psychosocial conditions of work (Montgomery 1979; Noble 1984; Thompson 1983; Zimabalist 1979).

This has long been recognized by epidemiologists working in the field of psychosocial job strain research. For example, according to Karasek:

> it is noteworthy that a "stressful" job could be an embarrassingly direct result of the specific job design recommendations of Frederick Taylor's Principles of Scientific Management which were nominally intended to increase productivity. Under scientific management the worker was left with little time for psychological relaxation. Increased productivity was to come from an increase in work pace from elimination of "wasted motions" in craftworker's jobs. Many of these apparently "wasted" motions were actually the workers only "rhythmic respites" from psychological pressures of production. Also, the worker was restricted from making decisions about how to perform a job. This reduction in decision latitude was seen as a loss of control, not as a desirable "lifted burden" by workers. The transformation was so thorough as to deprive workers of possibilities for self-pacing , and self-initiated improvements to the work process. To craftsmen the ultimate loss was the loss of mastery of a "trade" capable of rendering a complete service to a customer. The "divide and conquer" aspects of job fragmentation placed workers at the mercy of the new market middle men and of engineers' and managers' planning requirements (Karasek 1991, 167).

A move from Fordism to flexible production is likely to influence psychosocial conditions of work differently for the core compared to peripheral workers. It is possible that, relative to peripheral workers and workers in Fordist industries, core workers in flexible production units will have greater job security, more control at the task-level because of greater responsibility and decision making in planning work and in quality control. It's also possible that quality circles, the need to integrate management and execution functions on the shop floor, and the concomitant breakdown of traditional rigid job descriptions, will act to decrease the social isolation of workers imposed by Taylor's principles. While these may be the ways in which control and social support are affected, it is not clear how a move towards flexible production might affect psychological demand.

The particular principles of work organisation and management adopted during the 20th century were therefore central to the way in which psychosocial job conditions at the task-level have evolved in manufacturing industries. Any change in these organisational and managerial methods can be expected to exert effects on psychosocial job strain at the task-level. While this discussion may help elucidate the general mechanisms driving industrial change and work organisation in the post-war era it is necessary to focus on the nature of these in Canadian industry in general and the B.C. sawmill industry in particular to determine whether such changes occurred during the study period, and if so, how they might have effected psychosocial work conditions and unemployment in the cohort.

4.3 The Canadian Industrial Context

According to Harold Innis, Canada is unique among western industrialized countries in having its economy particularly dependent on the direct exploitation of nature. This is part of Canada's historical and economic legacy. Much of Canada's economic history has been based on the discovery of natural resources, consequent industry and community formation to facilitate their extraction, resource depletion, and finally disappearance of both industry and community (Hayter and Barnes, 1990). This Innesian "cycle of destruction" which began with Canada's fur trade economy may be less salient today but still describes the underlying dynamic of many staples industries in Canada such as sawmilling.

Staples production is different from other manufacturing processes because it is based ultimately on natural capital, and, as has been shown repeatedly in Canadian economic history, this can either run out or be replaced by synthetics or cheaper sources located elsewhere. Therefore, the pressures on a given regime of staples production will be heightened during an era of either natural capital substitution or shift to newer and cheaper sources of natural capital.

Also, many staples firms require enormous capital investments in machinery for resource extraction or refinement so that large oligopolistic firms tend to dominate. Tying up large amounts of capital in the creation of the industrial landscape means that staples industries are highly vulnerable to market changes. And, staples firms produce fairly simple products which are not usually amenable to changes in market again making staples manufacturing uniquely vulnerable to market shifts. The large amounts of capital invested and the rigid market conditions which define staples manufacturing mean (particularly during an era of natural capital depletion) both that resistance to change will be high and the ability of such firms to adapt to new production methods (such as flexible production) will be constrained.

In the next section, the extent to which flexible production methods had emerged in the 14-study sawmills will be assessed That such changes have occurred recently in the sawmill industry in B.C. are indisputable (Barnes and Hayter 1992; Hayter and Barnes 1992). However, it is not clear whether these changes occurred before of after the end of the study period and also to what extent they were linked to unemployment in the cohort.

4.4 Changes in Psychosocial Conditions of Work in Study Sawmills During the Study Period

Before beginning this discussion the names, location, and a brief description of technological change in study sawmills are undertaken. Table 1 shows the name and location of each sawmill, the earliest date for which job history data were available, and the final number of workers recruited into the cohort by mill.

Table 1: Description of Cohort Sawmills

Sawmill Name	Location	Number of Workers	Date of Cohort Entry
Eburne	Vancouver	2,232	1950
Canadian White Pine	Vancouver	2,467	1950
Fraser Mills	Vancouver	2,441	1950
Somass	Vancouver Island	2,681	1950
Alberni Pacific	Vancouver Island	2,126	1950
Tahsis	Vancouver Island	2,402	1950
Youbou	Vancouver Island	1,991	1950
Harmac	Vancouver Island	1,507	1950
Chemainus	Vancouver Island	2,247	1950
Powell River	Coast Garibaldi	2,797	1950
Squamish	Coast Garibaldi	674	1963
Finlay Forest	Interior (McKenzie)	766	1966
Fletcher Challenge	Interior (McKenzie)	1,402	1966
Crown	Interior (Kelowna)	490	1950

The 14-study mills were unionised. The Pulp and Paper Workers of Canada (PPWC) represented workers at Powell River, Harmac, and Fletcher Challenge in McKenzie. All other mills were served by the International Woodworkers of America (IWA). Eleven sawmills were built before World War II. Three study mills, Squamish and the two McKenzie mills were built in the 1960s and workers from these mills entered the cohort during this decade. The smallest mill, with 490 members, was in Kelowna and the largest, with 2,797 members, was Powell River. The relatively small number of cohort members from the two McKenzie and the Squamish mills was due to their 1960s construction dates and consequent late cohort entry for workers.

Three of the mills were located in Vancouver. One was in the city of Kelowna, 400 kilometres east of Vancouver. The six Vancouver Island mills were located in established mill towns that were economically dependent on the forest industry. Tahsis and Youbou differed from the rest of the Vancouver Island mill towns in that they were true single-industry towns with the sawmill providing the only real source of employment. Also, Chemainus was unique as it was entirely closed down in 1982 and re-built and re-opened in 1984. For this reason, workers at Chemainus contributed exposure information to the cohort only until 1982. The town of McKenzie, located 750 kilometres north-east of Vancouver, was created in 1965 specifically for forest resource processing and is a "new mill town."

Canadian White Pine, Chemainus, Port Alberni, Somass, Tahsis, and Squamish sawmills were "stand-alone" mills for most of the study period. Eburne had a shingle mill on site, Youbou a green-veneer plant, and Kelowna a plywood plant. The rest of the sawmills shared their site with a pulp mill. Fraser Mills was a complex site with a sawmill, plywood mill, and door factory for most of the study period.

A key issue for this investigation is the timing of the shift away from Fordism towards flexible production as such a shift was very likely accompanied by changed psychosocial work conditions. Specifically it is important to ascertain if and when such a shift occurred in the 14-study sawmills during the study period. Such a shift may currently be underway in B.C.'s forest industry in part because fiber is being grown increasingly in warmer climates with quicker more efficient growth times increasing the pressure on B.C. companies to reduce costs or relocate (Marchak 1995). But, it is unclear whether the move away from Fordist modes of production in the 14-study sawmills occurred after 1985 or not.

According to Barnes and Hayter "there are clear signs that the British Columbian economy during the course of the 1980s took on some of the general characteristics of flexible production" (Hayter and Barnes 1992, 340). And, "it is also the wood industry that experienced the greatest shift within the manufacturing sector towards flexible production methods and away from traditional Fordist techniques" (Hayter and Barnes 1992, 344).

These statements indicate that flexible production methods had arrived in the B.C. forest products industry (but not necessarily the sawmill industry) by the early 1980s and that the introduction of these new methods was probably given a new urgency and impetus by the severity of the 1981 recession in the forest industry. This means in effect that Fordist production was found throughout the wood products industry at least between 1950 and 1980 and, if methods of flexible production were introduced into the industry in a major way, this did not likely happen until after 1981.

The question remains whether flexible production methods were introduced into the 14-study sawmills during the study period. The most technologically advanced of the study sawmills was the Chemainus mill located on Vancouver Island. This mill was torn down in 1982. Approximately 650 workers were laid off and a modern mill re-opened on the site in 1984. When the mill re-opened in 1984 it was operated on the principles of flexible production. Job titles were re-designed and workers placed in rotating jobs with more flexible job descriptions than is usual in the sawmill industry. While these new job titles likely also had very different psychosocial conditions of work associated with them, this is irrelevant to this dissertation as work exposure in this mill was only measured in the old sawmill at Chemainus up to 1982.

Of the 14-study sawmills Chemainus underwent the most extreme technological change. However, considerable addition to, expansion of, and retooling of other mills occurred throughout the study period. In several mills, large sections were torn down and rebuilt. In a few mills there was almost no expansion or technological upgrading. The Canadian White Pine mill, for example, is almost exactly the same in 1997 as it was in 1950.

In general, two waves of technological change occurred during the study period. The first wave occurred in the mid-1960s and often involved tearing down older, pre-war plants or sections of plants and adding new buildings, saws, trimming machines, planers, or dry kilns. Three of the cohort mills, Squamish and the two McKenzie mills, were built during this time. The changes in the 1960s were primarily an expansion of size and capacity undertaken in response to the economic boom of the 1960s, and did not involve the kind of fundamental change in technology, organisation, or management techniques witnessed in the Chemainus sawmill.

The second wave of technological change began in some mills in the early 1980s and in others during the late 1980s. The major changes instituted were the automation of the "tail-end" of the sawmill and planer mill assembly lines, known as green chains, although this did not occur in all study mills.[10] Automation of the tail-end of sawmill and planer mill assembly lines did not involve wholesale redesign of jobs in these mills or a move away from Taylor's management principles so that the effect on psychosocial work conditions of this technological change would not have been profound. The major effect, in terms of psychosocial job strain, of these limited technological changes would likely have been felt through threatened and actual job loss as green chain jobs disappeared increasingly by the 1990s.

[10] Green chains are the last several dozen feet of the assembly line in a sawmill or planer mill. Workers stand beside a conveyor belt and manually remove lumber for sorting, packaging, and shipping. In many mills these were replaced by automated sorting machines.

While this discussion indicates that technological change may not have altered the psychosocial conditions of work much through the study period, limited automation of assembly lines combined with the recession of 1981-1985 may have elevated unemployment rates at study mills increasing the potential for confounding by this variable. While person-specific information on unemployment was not available, termination rates were calculated for cohort members so that aggregate changes in employment patterns could be investigated for the study period.

Figure 3 shows the number of workers employed in the cohort at the mid-point of each year. Employment levels were fairly steady at approximately 6,500 workers from 1951 to 1962. Thereafter, employment increased to a high of just over 9,500 workers in 1973. Between 1973 and 1979, employment fluctuated but remained at a plateau of over 9,000 workers. However, after 1980, employment was reduced by approximately one-third.

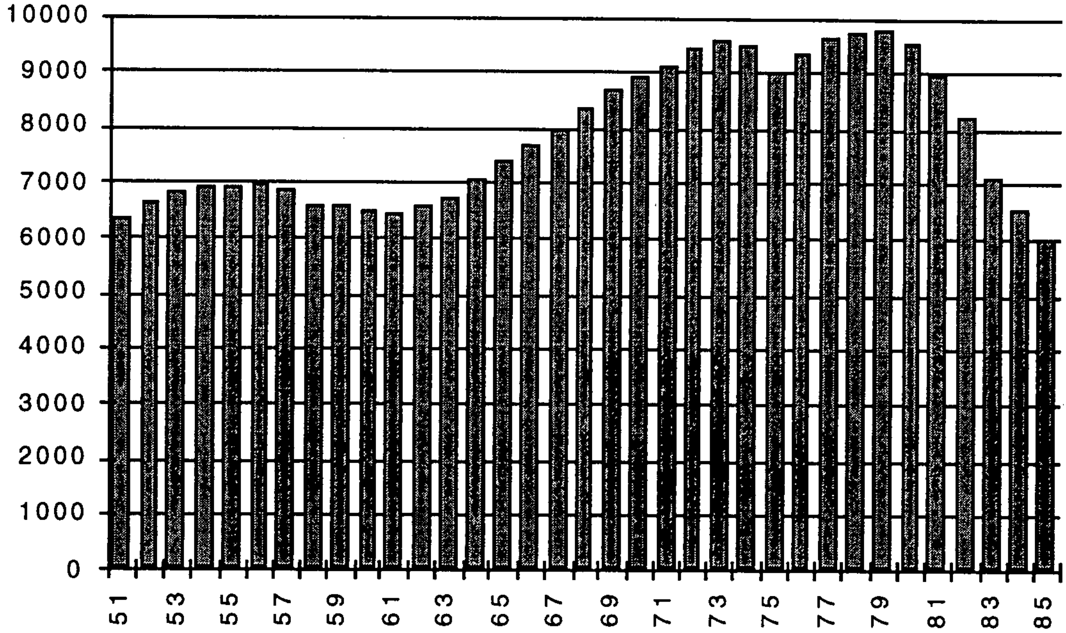

Figure 3. Number of Workers in the Cohort by Year

What was the potential for confounding by unemployment given the broad changes in labour demography over the study period? One can begin to understand these by analysing the general pattern of labour turnover in the cohort mills. Figure 4 indicates that turnover rates (rate of mill entry + rate of mill departure/number of workers employed at mid-year) averaged 13.1 percent over the study period, ranging from a high of 18.5 percent in 1973 to a low of 3.7 percent in 1985. To ascertain the possible impact of these changes on job security, what is needed is a more exact measure that separates 1) hiring from terminations and 2) worker exits due to retirement and sickness from terminations.[11] Terminations were both voluntary and involuntary and exclude exits from the workforce due to sickness and retirement.

[11] This was done by calculating net termination rates. Net termination rate = (terminations-hirings)/number of workers employed at mid-year.

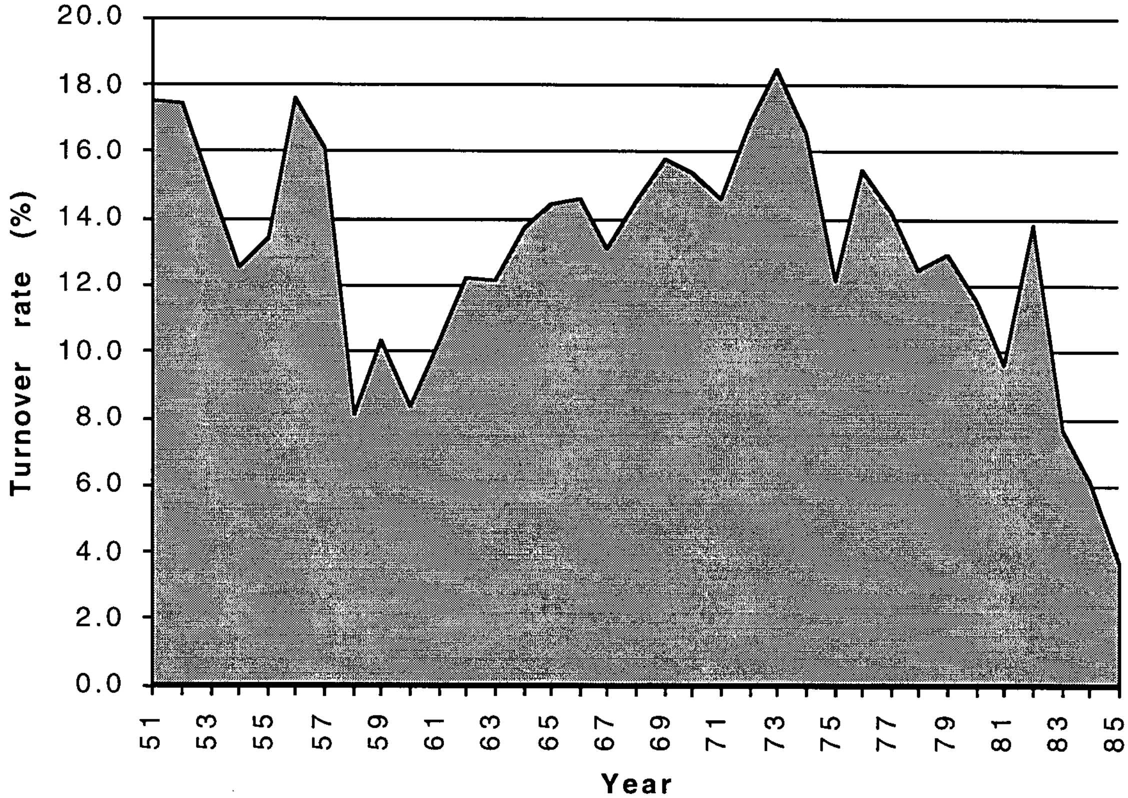

Figure 4. Labour Turnover in the Cohort by Year

Figure 5 shows that net termination rates prior to 1980 were mostly negative. Given that turnover rates averaged more than 13 percent, this means that most of this was due to hiring. Net termination rates were particularly low from 1965 to 1967 as two new sawmills in McKenzie commenced operation and began hiring hundreds of workers. If these two mills are factored out, net termination rates for the time period 1950-1980 fluctuated between zero and -10.[12]

[12] The interpretation of these data is limited because terminations cannot be broken down into voluntary and involuntary or lay-offs. A better measure would highlight involuntary terminations. In spite of this, the fact that terminations were less than hirings on a year-by-year basis indicates a stable employment environment across the cohort mills before the 1981 recession.

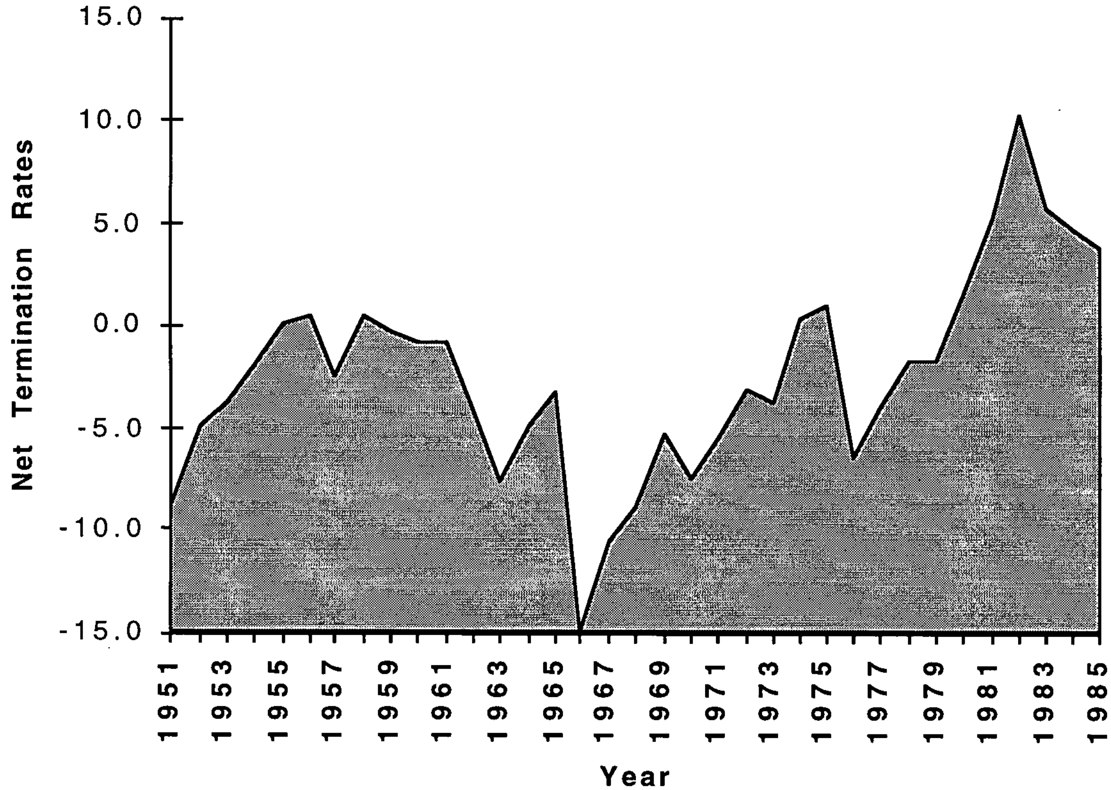

Figure 5. Net Termination Rates for the Cohort by Year

In contrast, from 1981 to 1985, net termination rates were positive, with a maximum value of 10.3 percent in 1982. These analyses point out the uniqueness, in terms of labour demography, of this five-year period. While the period 1950 to 1980 was characterised by relatively low termination rates, clearly the last five years of the study period, 1980-85 witnessed high termination rates. This must be taken account of in the analysis.

4.5 Summary

As noted by Karasek, Taylor's management principles, which underpin Fordist production, have direct implications for psychosocial job strain. The question addressed in the first part of this chapter was to ascertain the extent to which Fordism was replaced by the new flexible production methods in the study sawmills. This discussion indicates that changes of this type likely did not occur until after the study period. This provides evidence that psychosocial work conditions likely remained stable through the study period and provides the context for examining this empirically (see Section 8.4.2).

Shifts away from Fordism and Taylor's management principles came relatively late to the B.C. sawmill industry. Although one sawmill was redesigned entirely according to principles of flexible production and although the psychosocial job conditions at this mill were likely quite different than at other study sawmills this re-design was unusual and occurred after 1982. For this particular mill, exposure measurement was discontinued after 1982. And, even though computerized green chains were common in study mills by the end of the 1980s, these technological changes were not likely accompanied by job redesign. The main psychosocial influence of these changes was likely felt through job insecurity and unemployment.

In this regard, while the sawmill industry is exposed to fluctuating employment mainly in response to cyclic changes in the price of lumber, employment and labour turnover data indicate that from 1950 to 1981 the hiring rate was usually greater than the termination rate in study sawmills indicating either expansion or steady employment for most cohort members during these years. However, the last five years of the study period were characterized by major employment losses in the industry so that the potential for confounding due to unemployment may be greater for these years. In order to deal with this potential, all regression analyses were run with exposure measured to 1980. By excluding the last 5 years of exposure, the effect of the employment upheavals of the early 1980s and the potential for confounding by unemployment will be minimized in the analysis.

CHAPTER FIVE

5.0 Psychosocial Job Strain and Coronary Heart Disease

5.1 Strain at Work and Coronary Heart Disease

During the 1960s and 70s, a number of researchers showed that myocardial infarction (MI) in middle-aged males was correlated with working long hours, or with an unusual accumulation of "stressful" events at work in the period preceding an MI (Blohmke and others 1969; Buell and Breslow 1960; Theorell and Rahe 1971). Reviewers of these works concluded that working excessive hours and/or holding down more than one full-time job was associated with increased CHD morbidity and mortality (House 1974; Jenkins 1971; Zohman 1973).

Using a range of epidemiological methods, job dissatisfaction was also linked to CHD and CHD risk factors (Groen and Drory 1967; House 1972, 1974; Jenkins 1971; Medalie and others 1973; Sales and House 1971; Theorell and Rahe 1972; Wolf 1969) however, these were balanced by several studies that found no association between job dissatisfaction and CHD or CHD risk factors (Caplan 1971; Caplan and others 1975; Mueller 1965; Schar and others 1973; Wardwell and Bahnson 1973). These studies indicate that the association between job dissatisfaction and CHD may hold only for special subgroups and not for others (House 1972, 1974; Medalie and others 1973; Wardwell and Bahnson 1973).

The 1960s and 70s also witnessed the birth of studies that measured CHD morbidity by occupation. A study involving medicine, dentistry, and law reported that those specialities rated by experts as stressful had higher CHD morbidity rates (Russek 1962). A study of lawyers also found that, although morbidity gradients did not exist across a range of stress-rated legal subspecialties, the least stressful speciality had the lowest CHD rates (Friedman and Hellerstein 1968). Studies of CHD prevalence comparing Trappist with Benedictine monks (Trappist monks are postulated to have much less stressful work lives than Benedictine monks) by three groups of researchers produced two positive and one negative result (Barrow and others 1961; Caffrey 1969; Groen and others 1962). In addition, an aerospace industry study found that CHD prevalence in a group of managers who experienced higher levels of role conflict, higher responsibility, and work overload, was greater than among scientists and engineers (French and Caplan 1970).

The relationship between various risk factors and CHD were also investigated by occupation during this time. In a study of tax accountants, cholesterol levels increased as the tax deadline approached and took approximately two months to return to baseline levels (Friedman and others 1958). Similarly, air traffic controllers were found to have higher blood pressure than workers classified as having less stressful jobs (second class airmen). In this study, blood pressure was also elevated for workers monitoring high- versus low-density air traffic (Cobb and Rose 1973).

As in the studies of job dissatisfaction and CHD, results were not uniform. For example, Caplan found that blood pressure among air traffic controllers was no higher than among many other occupational groups, and that controllers at small airports had no blood pressure differences compared with controllers at large airports (Caplan and others 1975). Similarly, aerospace employees under severe deadline pressure showed no differences in cholesterol, blood pressure, and EKG abnormalities compared with non-deadline control groups (Reynolds 1974).

By the mid-1970s, a number of psychosocial stressors, such as job pressure, excessive hours, and role conflict at work had been linked to higher rates of CHD morbidity and mortality and, less frequently, to the presence of risk factors for CHD. During the late

1970s and the 1980s, studies became more sophisticated in terms of design (more prospective and cohort designs), better measurement of outcome variables (particularly blood pressure), and, perhaps most importantly, they employed more rigorous models to conceptualise and operationalise stressors and moderators.

A number of prospective studies were conducted in the late 1970s. In a study of Swedish construction workers, reports of "any job difficulty and important job change within one year" predicted excess risk of an MI (Theorell and Floderum-Myrhed 1977). In a cohort study of American telephone workers, attending college at night in combination with full-time work was associated with excess cardiac mortality (Hinkle 1974). In another prospective study comparing the psychosocial work conditions in two Belgian banks, the one with a hectic work environment and low employment security had a higher incidence of MI compared with the control bank with a less hectic work pace and more employment security (Kornitzer and others 1982). Similarly, in an American study of middle-aged men, self-reported job pressure predicted excess risk of MI after controlling for traditional risk factors (Shekelle and others 1979).

Some of these studies with more sophisticated designs, however, produced inconsistent or negative results. In the Framingham study, Haynes found that, among males, clerical and sales workers had the lowest incidence of heart disease, professionals and managers the highest incidence, and blue-collar workers were somewhere between the two (Haynes and others 1980). In the Tecumseh study, a prospective cohort of 1,215 blue-collar men and 1,318 women, House reported no occupational differences in CHD incidence for men, although female clerical and sales workers had twice the prevalence of CHD compared to other women in the cohort (House and others 1986).

Studies with more sophisticated designs had produced, by the early 1980s, fairly consistent associations with many stressors and across various CHD outcomes. These studies, limited by a relatively atheoretical approach, were usually of single stressors. The next level of complexity, introduced in the early 1980s, were models, firmly connected to stress theory, with one or more stressors and moderators. Over the past 15 years, the demand/control and demand/control/support models have been the most widely used and validated in epidemiological studies, particularly with CHD outcomes (Kasl 1987; Kristensen 1989b). Studies using this or similar models with CHD outcomes are reviewed in the next section.

5.2 The Demand/Control Model and Coronary Heart Disease

Fifty-six studies, most of them using either rigorous definitions of psychosocial job strain or the demand/control model, have been undertaken on the relationship between stressors and moderators and CHD morbidity and mortality (table 2), and CHD risk factors (table 3). While some of these studies are of women, most focus on blue- and white-collar Caucasian American or Swedish working-age males.

Twenty-four studies were found with CHD mortality or morbidity outcomes. Fourteen were cohort studies, 6 were case control, and 4 cross sectional. Twenty of these 24 studies showed positive associations between job strain and CHD mortality or morbidity. Of the 32 studies on job strain and CHD risk factors, 19 were cross sectional, 11 cohort, and only 2 were case control. Seventeen of the 32 studies showed positive associations between job strain and CHD risk factors.

In the 56 studies, positive associations were found among cross-sectional, case-control and cohort studies. For the strongest design (cohort studies), significant associations between job strain and CHD mortality or morbidity were found for 10 of 14 studies with follow-up varying between 1 year and 25 years. Two cohort studies showed no association with

CHD outcomes (Suadicani and others 1993; Hlatky and others 1995) and a third study (Reed and others 1989) demonstrated a non-significant association between psychosocial job strain and CHD mortality in the opposite than predicted direction. And, in 1 of the 4 non-significant cohort studies, with 18 and 25 years of follow-up, CHD mortality showed a non-significant trend in the expected direction with control (Alterman and others 1994). For the 10 statistically significant cohort studies, relative risks ranged from 1.6 for all-cause mortality in 477 retired Swedish men followed for 6 years (Falk and others 1992), and 1.9 for CHD mortality among a random sample of 7,219 Swedish white- and blue-collar working men followed for 9 years (Johnson and others 1989), to 6.2 for 79 Swedish men followed for 6 to 8 years after a first MI (Theorell and others 1991). The 5 cross-sectional and 5 case-control studies (matched) showed significant associations between a measure of job strain and CHD mortality or morbidity.

Table 2: Job Strain and Mortality/Morbidity Outcomes

1. Cross-Sectional Studies

Reference	Study Description	Outcome	Results
House, 1979	1,809 male US blue collars	Angina (self-report) Hypertension	Angina=NS. Hypertension low vs high job satisfaction (3.5-16%). Occupational self esteem low vs high (6.7-13%). Intrinsic reward low vs high (2.6-16.9%). Extrinsic reward (2.1-19.1)
LaCroix, 1987	North Carolina, 519 female office workers	Angina (self-report)	Lower prevalence of angina for workers with high control non-VDT work
Johnson, 1988	13,799 employed Swedish men & women	CHD morbidity	•PR=2.2 for high demand, low support, low control vs low demand, high support, high control. PR=7.22 for blue collar
Karasek, 1988	1960-62. 2,409 employed US men	MI	•SOR=1.5 for high strain vs other •SOR=1.6

2. Case Control Studies

Reference	Study Description	Outcome	Results
Karasek, 1981	22 cases & 66 matched controls Swedish men. f.u. 9 years.	CHD mortality	•OR=4.0 for personal schedule freedom+high demands. For workers with low education •••OR=14.3 (unmatched analysis).
Alfreddson, 1982	334 employed male cases & 882 controls	MI	Hectic job+no private visit: •OR=1.3 Hectic job+no influence: •OR=1.4 Hectic job+few possibility to learn: •OR=1.5
Theorell, 1987	72 male MI survivors <45	MI (survivors)	••Low demand divided by low monotony and •low demand divided by personal schedule freedom sig. greater for cases
Hammar, 1994	9,295 employed men and women & 26,101 matched controls in Sweden	First MI	High strain vs. low strain for men and women •RR=1.1-1.4
Wellin, 1995	288 male and 55 female cases 283 male and 129 female controls	Non-fatal 1st MI	Job strain associated with >MI
Johnson, 1996	Nested case-	CHD	•RR=2.6 low vs. high control + high

	control with 521 cases and 2,422 matched controls. f.u.14 years	mortality	support Adjusted for class, education, smoking, exercise, age.

3. Cohort Studies

Reference	Study Description	Outcome	Results
LaCroix, 1984	Framingham study. 548 men, 328 women. 10 years f.u.	CHD self report	All women: •RR=2.9 Clerical women ••RR=5.2
Alfreddson, 1985	958,096 Stockholm residents 1 year f.u.	Hospitalised for MI	Hectic job & low influence=NS Hectic job & monotony: Women •SMR=164 Men •SMR=118 Men (20-54) •SMR=153 Hectic job and few possibilities to learn: Women =NS Men •SMR=128. Men (20-54) •SMR=157
Haan, 1988	603 men, 299 female Finnish factory workers. 10 years f.u.	Incidence of fatal & non-fatal IHD	•OR=5.0 low control, low variety, high physical strain vs other. Adjusted for conventional risk factors
Johnson, 1989	7219 employed Swedish men 9 years f.u.	CVD morbidity & mortality	Top quintile high iso strain (high demand, low control, low support) vs bottom quintile: Morbidity: Men •PR=1.8 Blue collar ••PR=2. Mortality: Men •RR=1.9 Blue collar •RR=2.6
Reed, 1989	4,737 Hawaiian men 18 years f.u.	CHD incidence	NS trend for lower strain men to have >CHD
Astrand, 1989	391 male Swedish pulp and paper workers 22years f.u.	All-cause mortality	High control+high support=•32% mortality v other combinations =•42%, •46%, •44%. Iso-strain NS psychological and physical demand NS
Theorell, 1991	79 male employed Swedish MI survivors. 6-8 years f.u.	Mortality from MI	•RR=6.2
Siegrist, 1990,92	416 German blue collar men 6.5 years. f.u.	IHD incidence Fatal and nonfatal MI & stroke	IHD incidence Status inconsistency OR=4.4 Job insecurity OR=3.4Work pressure OR=3.4 Fatal and non-fatal MI &stroke Status inconsistency OR=2.86. Immersion OR=3.57.
Falk, 1992	477 retired Swedish men 6 years. f.u.	All-cause mortality	Adjusted •RR=1.6 high demand, low personal schedule freedom If low social support adjusted RR=2.1-4.6
Netterstrom, 1993	2,045 male Danish bus drivers.10 years f.u.	IHD mortality	RR=1.6 for bus drivers in high traffic intensity No association with psychosocial factors except > job

			satisfaction associated with >IHD.
Alterman, 1994	1,683 male employees of Chicago telephone factory	CHD incidence& mortality	25 year. CHD mortality NS but elevated for demand, 25 year CHD mortality control RR>1 and job strain NS
Suadicani, 1994	1,638 old employed Danish males 4 years. f.u.	IHD incidence	Psychosocial work factors NS.
Hlatky, 1995	1,489 mainly white, white collar & male Ave. age 52. 4 years. f.u.	Coronary artery disease	NS for Karasek model
Bosma, 1997	7,373 male and female civil servants. 5.3 yrs. f.u.	Angina, severe chest pain, IHD incidence	Low control at baseline and 3 years later OR=1.9 vs workers with high control at both times. Psycho demands and social support NS.

• Abbreviations: Immersion, "need for control"; VDT, video display terminals; MI, myocardial infarction; CVD, cardiovascular disease; CHD, coronary heart disease; IHD, ischaemic heart disease; NS= Non-significant at $p<0.05$; RR, risk ratio; SMR, standardised mortality ratio; SOR, standardised odds ratio; OR, odds ratio; PR, prevalence ratio. •$p<0.05$;••$p<0.01$;•••$p<0.001$.

Table 3: Job Strain, Coronary Heart Disease Symptoms and Risk Factors

1. Cross Sectional Studies

Reference	Study Description	Outcome	Results
Johansson, 1978	14 high strain&10 low strain Swedish sawmill workers	Catechol-amines	Monotony, physical constraint, lack of control over machine paced work, noise, and piece rate related to increased catecholamines
Karasek, 1987	5,000 male and 3,700 female	CHD symptoms	Men: Workload •SOR=1.2: Control •SOR=0.92 Women: Workload •SOR=1.1. Control •SOR=0.82
Matthews, 1987	288 male workers blue collar	Casual DBP	Participation:•r=-0.15. Promotion: •r=-0.13
Mensch, 1988	5,335 male and 4,874 female employed youth	Smoking	•Highest rates in high strain jobs
Harenstam, 1988	66 male Swedish prison guards	Ambulatory BP	Demand and control NS
Peiper, 1989	12,555 men Meta analysis	BP, smoking CL hypertension	Job strain NS. Control associated with lower smoking and lower SBP.
Karasek, 1990	Swedish white collars and job tech change	CHD symptoms	Less symptoms if workers participated in changes at work resulting in greater control.
Green, 1990	389 male US blue collar older	Smoking	Smoking cessation NS.Smoking amount •SOR=1.7> smoking ••SOR=3.7
Theorell, 1991	161 Swedish males with borderline hypertension	Ambulatory BP	••Sig. assoc with work, home, sleep & DBP. SBP was NS
Netterstrom, 1991	1,209 employed male and female Copenhagen residents	Casual BP, smoking, CL etc.	Most risk factors NS. Some evidence of higher fibrinogen
Carrere,1991	60 male US bus drivers	BP & catecholamin	BP on the job NS. High strain vs low strain > catecholamines.
Van Egeren, 1992	20 female and 17 male workers	Ambulatory BP	For men and women both. •••SBP. Work=+12mm Hg;•Home=+7mm Hg Sleep=+7mm. •DBP Work=+4mm Hg;
Albright, 1992	1,296 male bus drivers San Fran.	Hypertension	NS
Haratani, 1992	2,672 male Jap. blue collars	Casual BP, smoking, CL	••SBP and ••DBP Sig. Smoking and CL NS
Light, 1992	65 employed men	Ambulatory	•Men Work SBP=+6mm. •Work

	& 64 women	BP	DBP=+4mm Women Work SBP & DBP NS
Georges, 1992	1,377 Mexican American men	Central Body Fat distn.	NS
Fletcher, 1993	985 women and 1289 male volunteers for BP study in UK.	Causal BP	SBP Sig. in wrong direction. BP NS
Theorell, 1993	56 Female Swedish nurse aides	Ambulatory BP	Sig assoc. with work SBP, DBP. SBP on waking Leisure SBP, DBP, DBP on waking NS.
Greenlund, 1995	2,665 US young workers. Male, female, black, white	Ambulatory BP smoking, CL alcohol use	Mainly null results. For white women more alcohol use assoc. with high control and low job strain.

2. Case Control Studies

Reference	Study Description	Outcome	Results
Schnall, 1990,92	88 cases. 176 controls New York employed males	Hypertension	••SBP Work=+6.8. ••Home=+6.5 ••Sleep=+6.2 •DBP Work=+2.8 •Home=+2.4 Sleep=+1.7 Hypertension: •OR-2.7. •LVMI=9.7g/m2 higher
Landbergis, 1994	272 NY City men	Ambulatory BP	High job strain hypertension •OR=2.9.

3. Cohort Studies

Reference	Study Description	Outcome	Results
Karasek, 1981	1,461 Swedish men 6 years f.u.	CHD symptoms	High strain jobs = > prevalence of CHD symptoms.
Theorell, 1985	71 Stockholm men 10 years f.u.	Ambulatory BP	NS. but sig. interaction for hypertensives with higher SBP rise at work if in high strain job
Theorell, 1988	51 men, 22 women in 6 jobs in Stockholm 1 year f.u.	Ambulatory BP	Work •SBP higher by 4mm during hi vs low job strain periods in 1 year. Work DBP NS
Chapman, 1990	2,100 male and 534 female Australian govt. workers 5 years f.u.	Casual BP	Women: ••demands, •••low work support, ••job insecurity assoc. with DBP. Men NS SBP NS
Schnall, 1992	197 NY City men 3 years f.u.	Ambulatory BP	High strain jobs over 3 years vs low strain jobs Work •SBP =+6mm. Work

			•DBP=+4.3mm.
Knox, 1985	88 Stockholm 18 year olds 10 years f.u.	Amb.BP, CL, Adrenaline	CL was NS. Sig association of high strain jobs with BP in 18 year old hypertensives
Kawakami, 1989	373 male Jap blue collars 1 year f.u.	Ambulatory BP	Job stress due to complex machine operation may >DBP
Doncevic, 1992	63 female Stockholm nurses 1 year f.u.	CL	High CL associated with low intellectual discretion
Landsbergis, 1995	717 Working pregnant women.	Pregnancy induced hypertension	Low control SOR=2.4; For high status women, job strain SOR=3.6.
Siegrist, 1991	310 German blue collar men 6.5 years. f.u.	CHR status Smoking	Smoking OR=2.19. Low promotion prospects OR=2.71 Job instability NS
Everson, 1997	1,038 Finnish men. 4.2 yrs f.u.	Progression of carotid arterosclerosis.	Increase demands interacted with predisposition to stress to produce increases in thickness of carotid arteries. (p<0.04)

• Abbreviations: CL, cholesterol; SBP, systolic blood pressure; DBP, diastolic blood pressure; CHD, coronary heart disease; LVMI, left ventricular mass index; NS= Non-significant at p<0.05; RR, risk ratio; SMR, standardised mortality ratio; SOR, standardised odds ratio; OR, odds ratio; PR, prevalence ratio. •p<0.05;••p<0.01;•••p<0.001.

The main CHD risk factors investigated were smoking, cholesterol, CHD symptoms (chest pain, et cetera), and blood pressure. Three of six cross-sectional studies of smoking and the only cohort study reported positive associations. One of six studies showed a significant positive association between cholesterol and job strain. This cohort study (prospective with one-year follow-up) of 63 Stockholm nurses showed that high cholesterol was associated with low intellectual discretion at work.

Twenty-two of 32 CHD risk factor studies involved blood pressure outcomes. Those using ambulatory blood pressure monitors were the most useful, as they eliminate observer and "white coat" bias. Of 13 job strain studies using ambulatory blood pressure, 7 yielded significant positive results while the remaining 6 gave a mixture of non-significant, positive, negative, and null results. Using a range of study designs, the outcomes all-cause mortality, CHD mortality, CHD morbidity, and ambulatory blood pressure, have shown fairly consistent positive association with job strain variables.

5.3 Summary

This review indicates that psychosocial job strain operationalised in both the demand/control and the demand/control/support models and related models has had a consistent association with CHD outcomes. With better characterisation and location of strain within stress theory and development of more sophisticated study designs, this association has become stronger. The generalizability of these results may be limited because study populations were usually American or Swedish Caucasian males. This is, however, a good reason for selecting the demand/control/support model for this investigation as it is also male, mainly Caucasian and blue-collar.

In the first five chapters, arguments for the use of the demand/control model and its adaptation for this sawmill investigation were presented. Further explanation is necessary to justify using expert estimators to measure job strain. The purpose of the next chapter is to outline the various ways in which stressors and moderators are usually measured when using this model. This chapter will compare and contrast these with expert exposure assessment methods in general and the specific expert method used in this investigation.

CHAPTER SIX

6.0 Exposure Assessment

6.1 Exposure Assessment Methods Used with the Demand/Control Model

There are two elements in the exposure assessment methodology for this investigation that were unusual compared to other studies of psychosocial job strain 1) the exposure assessment was retrospective, and 2) it was based on expert ratings.

In most studies of CHD using Karasek's model, two methods for measuring psychosocial conditions at work are used: direct self-reports (Haan 1988; Johnson and Hall 1988; Johnson and others 1989; Karasek and others 1981; Schnall and others 1990) and pooled within-occupation self-reports (Alfredsson and others 1982, 1985; Karasek and others 1988; Pieper and others 1989; Theorell and others 1991). Recently, a third method using job strain exposure matrices, based on pooled self-reports, has been developed in Sweden and the USA (Johnson and Stewart 1993; Schwartz and others 1988).

Five investigations with non- CHD outcomes (Baneryd 1974; Frankenhaeuser and Gardell 1976; Johannson and others 1978; North and others 1996; Stansfeld and others 1993, 1997) and one with CHD outcomes (Bosma and others 1997), have used expert raters Two of these, using a single expert, were of sawmill workers in Sweden (Baneryd 1974; Frankenhaeuser and Gardell 1976; Johannson and others 1978). Many experts (supervisors and personnel managers) were used in the Whitehall study of sickness absence (North and others 1996), psychiatric disorder (Stansfeld and others 1995, 1997), and CHD (Bosma and others 1997). In these studies, 140 personnel managers in 18 different departments estimated stressors and moderators (using the demand/control/support model) for approximately 10,000 civil servants.

No studies with the demand/control model have used retrospective measures. In occupational epidemiology retrospective exposure assessment is common using both experts (usually industrial hygienists) and self-reports. Teschke has shown that with expert worker raters, the reliability of estimates drops the further back in time retrospective assessments are made. Yet, experts assessments for exposures which occurred 30 year's previously are not uncommon (Teschke and others 1996). Thus, while unused in job strain epidemiology, there is a strong tradition of using expert retrospective exposure assessment in occupational epidemiology which provides a rationale for its use in this investigation.

While retrospective methods have yet to be used in job strain epidemiology, as illustrated above, experts are beginning to be utilised to estimate current exposure to psychosocial stressors and moderators. In the next section, a rationale is presented for using expert estimators in job strain epidemiology in general and for this investigation in particular.

6.2 The Meaning of Subjective and Objective Psychosocial Work Conditions

The demand/control/support instrument purports to measure *objective* psychosocial work conditions. But, the questionnaire is usually operationalised as a direct self-report. When a person reports their eye colour or how many board feet of lumber they processed in a day, one assumes that, although subjectively reported, the answers reflect objective reality. But, if that same person reports that his job has conflicting demands then cognitive processing involving perception, personality, appraisal, and coping (all interacting in complex ways) may be involved. Thus, questions in a self-report instrument "can be placed somewhere on a dimension from low to high depending on cognitive and emotional processing" (Frese and Zapf 1988, 379). This means that the extent to which a question answered as a direct self-report measures objective reality likely depends on whether it is structured and worded in such a way that emotional/cognitive processing is minimised.[13]

Early use of the demand/control model was criticised on grounds that its direct self-report methodology was too vulnerable to confounding with personality factors. In response, users of the model pooled self-reports within job titles or occupations. The explicit purpose of averaging exposures in this way was to deal with the confounding critique and to produce more objective measures of psychosocial job strain. Averaging direct reports (within occupations) for questions which are low in cognitive/emotional processing may produce more objective measures. But, for questions high on this continuum, it is not clear whether pooling self-reports will increase "objectivity" or simply increase misclassification of exposure.

In a study estimating psychosocial work characteristics using several panels of experts in a single workplace inter-rater agreement was higher for moderators compared to stressors (Frese and Zapf 1988). According to these authors "the resources (moderators like control) can be well observed and without much interference from cognitive and emotional processing; in contrast, the judgement of stressors is more private and therefore more strongly related to cognitive and emotional processing. Therefore, the average interrater agreements are lower for the stressors" (Frese and Zapf 1988, 382). Karasek's own analysis using the three American labour force surveys from which the demand/control

[13] This is not to imply that where a question lies on the emotional/cognitive continuum is simply a matter of question construction and wording. Even if much attention is paid to re-conceptualising and re-wording questions some concepts will require more emotional/cognitive processing than others. The point is, that construction and wording of questions to measure psychosocial work conditions have not been considered in relation to this continuum and in relation to making the instruments more amenable for expert estimation.

instrument was originally developed also showed reliability for direct self-reports was much lower for psychological demand compared to control (Karasek and Theorell 1990).

These limited data may indicate that in adapting or using an existing psychosocial instrument with expert raters, questions which are low in emotional and cognitive processing may be most reliably and validly estimated. And, according to these limited data, development of questions measuring stressors may require the most effort for adaptation as they likely require more emotional/cognitive processing than moderators.

As stated earlier in Chapter 2, objective conditions may potentially, but not necessarily, lead to strain (Frese and Zapf 1988). If researchers believe it is necessary to measure these core objective conditions, then more objective measurement methods must be developed. In this regard more effort is needed to develop questions which are amenable to expert rating. As well, efforts must be made to identify the best kinds of "experts" and the best ways to use these experts for conducting expert estimations of exposure to psychosocial work conditions. Both these are attempted in the next two sub-sections of this chapter.

6.3 Expert Raters and Expert Rating Methods

Very little discussion has been published about the best way to conduct expert ratings (Frese and Zapf 1988). Expert raters can use direct observation or experiential estimation by experts in which they utilise their knowledge of jobs and work conditions in a reflective tapping of their expertise. Problems with direct observation include the expense of rating large numbers of jobs or occupations. There is also difficulty with observation periods, as they are usually limited and discrete; because work pacing and control may vary over time, the method is subject to observation bias.

Even less discussion has occurred about possible types of experts who might be best suited to conduct these estimations. Experts could be persons who have a broad and detailed knowledge of the jobs or occupations to be investigated. For example, personnel managers, plant managers, job designers, job evaluators, job efficiency experts, may be very knowledgeable about a range of jobs based on years of observation and experience. This type of expert was used in the Whitehall Studies in combination with an "experiential" method as supervisors were asked to rate the job titles under their supervision, not by direct observation, but based on their knowledge and experience gained mainly by supervising workers in these jobs (North and others 1996; Stansfeld and others 1995; Bosma and others 1997).

The use of experiential expert job raters could have problems because supervisors and personnel managers may be biased because of their involvement in supervising the workers whose jobs they are rating (Spector and others 1988). It is also possible that they might not be able to separate the person from the job and, therefore, may contaminate the job rating with attitudes about the workers in these jobs.

Because experiential ratings have not been used extensively in this field (the Whitehall studies provide the best example), there are no published discussions about the "best" possible expert raters or the best way to conduct such a rating; however, many industries employ experts whose work is job evaluation. The purpose of job evaluations vary, but generally they are used to assess, as objectively as possible, job function, demand, pacing, effort, concentration, responsibility, exposure to hazards, et cetera, in order to more fairly assess pay rates for groups of jobs within an industry.

Where they exist, there are a number of advantages in using job evaluators as expert raters for psychosocial strain. First, they are likely to know enough about the objective work environment from years of direct observation, to effectively rate demand, control, and social support across an entire industry or segment of an industry. Second, unlike personnel managers and supervisors, they are not direct supervisors and are more likely to rate the job than the person or persons who fill these jobs. Third, because some industries have joint union/management teams conducting these job evaluations, there is the potential to reduce management or union bias in scores. Fourth, there is the potential to blind expert raters to the purpose of the ratings. Fifth, development of expert rating methods means that retrospective assessments for psychosocial work conditions can be conducted.

For this investigation, expert raters, using an experiential method were used for the following reasons:

i) A unique group of experienced job evaluators was available for the industry.

ii) There were no self-reports available in this database.

iii) Use of direct observation was impossible both because this investigation was retrospective and because of the large number of sawmill job titles involved.

While little investigation has been undertaken in this field, a number of studies have been conducted in which estimation using direct self-reports have been compared with expert assessments. These empirical studies are reviewed in the final sub-section in this chapter.

6.4 Empirical Reasons for Using Expert Raters

Pooled self-reports are a "defacto" gold standard as they have been most widely used; therefore, one way to evaluate expert ratings is to compare them with this gold standard. There are pitfalls in this approach because for questions high in emotional/cognitive content it is likely that there will be little correlation between the two. For questions lower in this continuum correlations will likely be higher. Comparing the associations between expert and pooled ratings with various outcomes will also be useful as better designed questions will tend to be more predictive of outcomes.

Frese (1985) investigated two groups of German blue-collar automobile and steel workers and found correlations averaging 0.35 between self-reports and direct observers for a number of job characteristics. He found associations between self-reports and psychosomatic complaints of between 0.31 and 0.40. Correlations between direct observers and psychosomatic outcomes were about half those for self-reports. In another study using direct observers, Jenkins found correlations with self-reports of 0.43, 0.48, 0.35, 0.30, 0.16, respectively, for the job characteristics skills, autonomy, worker-pace, control, and co-operation (Jenkins and others 1975). These correlations were similar to the those obtained by Frese.

Comparisons of experiential ratings using different kinds of expert raters with self-reports have been performed in three studies. Algera (1983) asked three workers and three experts (supervisors) to rate 61 blue-collar jobs in the Dutch steel industry for 24 characteristics. Each job had a different group of six judges for a total of 183 workers and 183 expert raters. Correlations between pooled self-reports and experiential rating ranged from a low of 0.21 to a high of 0.77 across the 24 job characteristics. It is quite possible that the large range may be a function of where each question lies on the cognitive/emotional continuum.

In this study, correlations between self-reports of job characteristics and health symptoms such as anxiety, depression, coronary ailments, stress, and irritability ranged from 0.27 to 0.36. Correlations between experiential ratings and these outcomes were similar. Correlations of self-reports with psychosomatic complaints were similar in this and in Frese's study. In comparing correlations between experts and psychosocial outcomes between the two studies, for Algera's study, using experiential methods, correlations were approximately double those obtained in Frese's study with direct expert observation.

Spector obtained self-reports of job characteristics (including autonomy and skill variety, both measured in the Karasek questionnaire) from 232 university employees working at 129 different jobs (Spector 1991, 347). Each written job title description was reviewed by four raters (university researchers) to obtain job characteristic scores. This study was, therefore, a comparison of self-reports and experiential ratings. (It should be pointed out that the method of experiential rating used in this study was completely different from that used by Algera.) Convergence between self-reports of job autonomy, complexity, and variety with experiential ratings was respectively 0.19, 0.28, and 0.23. Correlations between self-reports and psychosomatic symptoms, such as frustration and anxiety, were statistically significant but less than in Algera and Frese's studies. There were no significant correlations between expert ratings and psychosomatic complaints and affective reactions such as job satisfaction; however, experiential ratings showed significant correlation with doctor's appointments, the only objective indicator of health outcomes.

These four reviewed studies used different kinds of experts and varied methods for conducting the expert ratings, and measured job characteristics using varying methods. While the variation between studies precludes exact comparisons, the consistency of association between expert ratings (both direct and experiential) and psychosocial outcomes (or doctor's visits in the case of Spector's study) given the methodological variability, lends strength to the associations. In these studies, some of the job characteristics measured were similar, but not exactly the same as Karasek's constructs of psychological demand, control, and social support.

In the Whitehall study of civil servants, with sickness absence, psychiatric disorder, and CHD as outcomes, the demand/control/support model was operationalised using both worker self-reports and expert ratings (Bosma and others 1997; North and others 1996; Stansfeld 1995, 1997). Correlations of self-reports with experiential ratings were 0.20 for men and 0.19 in women for psychological demands, and 0.33 in men and 0.32 in women for job control. In the case of sickness absence "externally assessed work demands and level of control predicted rates of both short and long spells of sickness absence to a greater extent than the self-reports" (North and others 1996, 337). In the case of CHD, significant associations were also found although self-reports were more predictive than expert estimates (Bosma and others 1997). However, for psychiatric disorders, self-reports for psychological demand were predictive, whereas experiential ratings were not.

In all these studies, correlations between self-reports and expert ratings for various psychosocial job characteristics ranged from 0.20 to 0.77. Correlations between expert ratings and psychological and physical outcome measures were generally lower than for self-reports, except in Algera's study and the Whitehall study of sickness absence. Experiential ratings were shown to correlate with "hard" outcomes, such as an appointment with a doctor, and sickness absence and the incidence of CHD. Also, correlations for moderators appear higher than for stressors indicating that the latter may be more difficult to measure with experts. Thus, there is some evidence that expert ratings of variables similar to those used in the demand/control model can be used to predict psychological outcomes. The evidence is limited, however, to a few studies and only two (the Whitehall study and Spector 1988) in which expert raters used the demand/control/support model.

6.5 Summary

Despite more than 20 years of calls for the development of objective procedures for measuring stressors and moderators, little headway has been made. The use of pooled self-reports, as in the usual operationalisation of the demand/control model, is a move towards more objective measures; however, further development of expert rating methods is in its infancy. The few expert ratings that have been conducted have been relatively unsophisticated, with almost no thought given to the types of experts that might be best suited to the estimation of psychosocial job strain. With the exception of a few studies outlined in this chapter, very little work has been carried out to compare methods of expert and self-report ratings.

Also the issue of low compared to high cognitive/emotional processing required for adapting questions for use by expert estimators has yet to be addressed. As Frese and Zapf have noted and as shown in the reviewed studies, moderators like control may be easier to measure than stressors such as psychological demand. Control as measured in the demand/control instrument may be low enough on the cognitive/emotional continuum that it can be measured well both as direct self reports and using expert estimations. Psychological demand may not be as amenable to expert assessment at least as currently conceptualised and worded in the demand/control instrument.

In spite of these potential pitfalls for using the demand/control/support model with expert raters, the Whitehall studies indicate that this model can be used successfully by experts. And although job evaluators have never been used to estimate psychosocial work conditions a rationale has been outlined for using a panel of these experts to assess psychosocial work conditions using the demand/control/support model in this investigation.

CHAPTER SEVEN

7.0 Methods

This chapter is divided into three sections. The first describes methods used to build the original cohort. The second section, consisting of four sub-sections, explains the exposure assessment. And, the third section outlines the methods for the SMR and regression analyses.

In the first section the selection criteria for the 14-study sawmills and the cohort members are outlined. Then, methods to gather the job histories of cohort members are explained. Finally, methods used to link cohort members to mortality outcomes are described.

The exposure assessment is outlined in the second section which is divided into four sub-sections. The first sub-section discusses development of the job title list which was the basis for exposure estimation by the expert raters. It was necessary to produce a list of manageable size for interviews from the thousands of unique job titles in the cohort job history database. Once developed, all unique job titles in this database were recoded to a title on this list so that exposures obtained from the interviews could be attributed to these. This job title list was the key linking exposure assessment to job titles in the data base.

In the second sub-section, the procedures for carrying out the exposure assessment are explained. The selection criteria for the expert raters are outlined and the interview process described both for retrospective estimation (1965) and for estimation of current exposure (1997). Expert raters conducted two exposure ratings. The 1997 exposure estimate was conducted to provide evidence for the validity of the exposure assessment methods. Also, the methods used to assess the intra- and inter-rater reliability for expert raters are explained.

In the third sub-section, shortening and validation of the demand/control/support instrument for use in this study is explained. Even with development of a smaller job title list, many jobs were estimated so it was necessary to reduce the number of items in the instrument to keep interviews to a reasonable length. The rationale for eliminating these questions is outlined and the methods used to validate the shortened instrument shown.

The fourth sub-section outlines supplementary studies which provide evidence for the validity of the exposure assessment methods. Threats to the validity of the exposure assessment arise in three ways. First, expert raters estimated exposure near the mid-point of the study period (1965) and these were applied to job titles throughout the study period. A study is described which determines the construct validity of this method of attributing exposure over time. Because there were more management than union expert raters, a second supplementary study explores the possibility of management bias in the exposure assessment. And finally, the concurrent and predictive validity of the exposure assessment method was determined in a third supplementary study.

In the third section of the chapter, methods for the SMR and regression analyses are described. Because of difficulty ascertaining vital status for the cohort, some discussion is required to determine the appropriate length of follow-up for the SMR regression analyses. And, because job history information was not available for the entire working lives of most cohort members, restriction on the length of follow-up was also necessary in the regression analyses to reduce the potential for misclassification.

7.1 Building the Original Cohort

A retrospective cohort study was initiated in the Department of Health Care and Epidemiology at the University of British Columbia in January 1988, and was completed in 1996 (Hertzman and others 1996). This study was designed to determine whether sawmill workers exposed to chlorophenol wood preservatives were at increased risk of mortality or incidence of soft tissue sarcoma and non-Hodgkins lymphoma.

In order to build the cohort, a population of chlorophenol-exposed workers and a comparison population of unexposed workers from medium or large sawmills had to be found. Eleven mills on British Columbia's South Western Coast and on Vancouver Island that had used chlorophenols (mostly since the early 1950s) and three mills in the interior of the province where chlorophenols were not used were chosen, since they had intact personnel files, and agreed to participate in the study (see section 4.4 and Table 1).

A total of 26,487 workers were enrolled in the cohort. To be eligible, a worker had to be employed at a study mill for at least one year between January 1, 1950 and December 31, 1985. The year 1950 was chosen as the cohort inception date because it was the earliest year for which computerised provincial death records were available, and it was the beginning of the era when chlorophenol use became widespread in the industry. A worker could accrue the qualifying year by working part-time or for intermittent periods over several years. For all workers, 260 working days constituted a qualifying year; this entry criterion excluded highly transient workers. Only those workers paid on an hourly basis were eligible for cohort membership, so that workers who started at a mill on salary (some foremen and other management staff) could not enter the cohort. However, hourly workers who subsequently became salaried were included.

The 14 sawmills were distributed among several large forestry companies and had different personnel record systems, which, in many mills, changed during the study period. Four qualified medical records technicians were hired for the study. Prior to entering each sawmill, the technicians were trained using a sample of the mill's personnel records. Technicians abstracted personal identifying and job history information from records onto portable computers (Appendix A). Supervision of the record-abstraction process was performed with error-checking programs and random 10 percent recoding of personnel files throughout this phase.

The method used for assessing exposure to chlorophenols required detailed knowledge of changes in chlorophenol application technology over the study period so that complete industrial histories were obtained for each mill (Teschke and others 1994). Historical information on technological change was gathered from administrative records, blueprints, maps, and other pertinent documents and, by conducting dozens of interviews with older retired or currently working employees.

To obtain mortality outcomes, the cohort was linked probabilistically to the B.C. Division of Vital Statistics (BCDVS) mortality file (under the auspices of the Cancer Agency of British Columbia) for the years 1950 through 1989.[14] In order to obtain one more year of deaths (for 1990) and to ascertain out-of-province deaths for the entire period 1950-1990, a second linkage was made to the Canadian Mortality Data Base (CMDB). This linkage was also probabilistic and used one more field (sawmill location) than was used for the BCDVS linkage. The final CMDB linkage mortality results were used in this investigation.

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[14]The cohort was also linked to B.C. cancer incidence files from 1969—the year they were first computerized—to 1990. Subsequent analyses showed a weakly positive association between increasing chlorophenol exposure and the incidence of non-Hodgkin's lymphoma, but no associations were found for any causes of death (Hertzman and others 1996).

After both death registry linkages and follow-up with pension records and motor vehicle records, 39 percent of the original cohort members still had unknown vital status. In order to reduce this number a direct (non-probabilistic) linkage was performed by Statistics Canada to the income tax file.

7.2 The Exposure Assessment

7.2.1 Modifying Job Titles for Use in this Investigation

Approximately 4,500 unique job titles were identified in the job history database. In the original chlorophenol study these were grouped together producing a final list of approximately 800 job titles upon which the chlorophenol analysis was based. For the current investigation, a smaller list of job titles was necessary for two reasons. First, it was impractical for expert raters to estimate exposure for either the 4,500 unique jobs or the 800 job titles used in the chlorophenol analysis. And, second, in the original investigation, jobs were grouped together depending on their proximity to sources of chlorophenol exposure. This meant, for example, that two jobs which could be different in terms of task, function, and psychosocial conditions of work might be amalgamated into a single job category if they were located next to each other and were roughly equidistant from a chlorophenol source. For these reasons, a new list of job titles was developed for the current investigation based on the 4,500 unique titles in the job history data base.

In the original data gathering phase, technicians abstracted job titles exactly as written in personnel records so that many apparently unique job titles were unique only because of trivial spelling or syntax differences. These trivial differences were resolved leaving a list of approximately 1,200 job titles. Because of different job-title naming conventions in personnel offices in sawmills, common, easily recognisable job titles which differed in name only were grouped to produce a list of approximately 500 job titles. For example, a common job in sawmills (offbearer) involves pulling lumber from a conveyer belt called a green chain and stacking it. Approximately 30 discrete names were found in the job history database for this job. All were resolved to the name "offbearer". These resolutions were performed by the investigator and a research assistant who had extensive experience with the original sawmill study.

These job titles represented the greatest resolution from the original list of 4,500 that could be achieved by a process of correcting syntax and spelling and standardising common and easily recognised job titles. At this point, expert help was necessary because some of the remaining 500 job titles were unknown to the investigator. As well, for some of the jobs which were known, there was limited understanding about their function and place in the sawmill process and in some cases, little knowledge about the tasks performed by workers with these jobs. Detailed information about the operation of sawmills and the changing nature of jobs was required particularly for the 1950s and 1960s because most of the gaps in the investigator's knowledge of job titles involved those found early in the study period.

Accordingly, management and the union were asked to recommend six knowledgeable retired sawmill workers willing to participate in the study. Six were recommended and an expert panel formed consisting of two retired foremen, a former head sawyer, a production control manager, a millwright, and a lumber grader. All had wide experience over the past 40 years in sawmills throughout the province, including the 14-study mills. The panel met together several times with the investigator who organised the discussion.

The panel was given the list of 500 job titles, developed as outlined above, and asked to identify and describe job titles unknown to the investigator and to explain their function and associated tasks. The investigator also asked the group to explain the function and associated tasks for job titles which he knew little about. At the end of this process approximately 15 job titles remained unidentified on the list. Because these were likely gross spelling and syntax errors rather than real job titles which the experts had failed to recognise, and because they would therefore appear only rarely in the job history data base, these were grouped into the job title, "labourer."

Next, the expert panel was given two criteria for further reducing the size of the job title list. First, job titles which occurred rarely in the sawmill industry were identified within the list. Rare job titles usually arose because they were associated with use of an unusual technology by a few of the cohort sawmills and/or they were attached to an unusual process or technology introduced (often as an unsuccessful trial) for a short time. Each rare job title was then grouped with its closest job title (determined by consensus with the panel), in terms of task and function reducing the list to approximately 350 job titles.

Once rare job titles had been grouped in this way, the second grouping criterion was employed by the expert panel. Functionally similar job titles were grouped together and within these categories job titles were grouped on the basis of similarity in performed tasks. For example, within the list of 350 job titles there were 25 different job titles for performing the function of "sawyer". [15] These were resolved into 8 sawyer job titles based on discussion about the tasks performed by the 25 different sawyers. By the end of this process, the list of 350 job titles was reduced to 86 (Appendix B). All original job titles on the occupational history database were recoded to one of these 86 standardised job titles. This list was estimated for psychosocial conditions of work by the 4 expert job evaluators and was the key linking exposure estimates to cohort-member work histories.

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[15]This is because there are numerous types of saws in sawmills located at different points on the assembly line.

7.2.2 Selecting Expert Raters

Through a series of union/management agreements, a system of "wage-rate evaluation" has been in place in the sawmill industry for approximately 25 years. Workers in any sawmill can request an evaluation of their job if they feel it has changed and deserves greater remuneration. On receiving a request, a union and management evaluator travel to the sawmill and observe workers in the job title under evaluation. Job evaluators use a 14-item instrument and independently rate the job title. The instrument includes a scale assessing the level of skill and training required, amount of independent decision making and responsibility, level of concentration required, physical demand, and social contact on the job. Thus, the job evaluators have been measuring psychosocial conditions of work for over 25 years with an instrument that is similar to the demand/control/support instrument.

Six job evaluators with over 20 years of experience in sawmill job evaluation in B.C. were identified as potential interviewees. Three were currently employed by the industry, one was currently employed by the union, and two were recently retired from the union. All three industry raters agreed to participate, as did the currently employed union rater. One of the retired union raters was too ill to participate and the other refused without giving a reason.

7.2.3 Exposure Assessment Interviews

The four expert raters each performed two estimations of exposure. The first, conducted in November 1996 by the investigator, estimated exposure retrospectively in the year 1965. The results from these estimates were attached to the job titles in the job history data base and are the main focus of this investigation. A version of the demand/control/support instrument, shortened to 13 items was used for this estimation (Appendix C). (The rationale for reducing the size of the instrument is explained fully in section 7.3).

In February 1997, the expert raters performed a second estimation for current exposures to validate the shortened 13-item instrument and, to help determine the validity of the exposure assessment method. To validate the shortened 13-item instrument an already validated 18-item version of the instrument was used for these 1997 interviews (Appendix D). (see Section 7.3).

In the next several paragraphs, the methods used to obtain the retrospective, 1965, estimations are described. This is followed by a description of the methods used to obtain the 1997, exposures.

The 1965 estimations were obtained from two separate interviews, carried out by the investigator, with each of the four expert raters. Each rater was asked to rate job titles as they remembered them in a "typical" coastal sawmill in 1965. The year 1965 was chosen as it was the earliest time that all four raters had direct experience with job evaluation in the industry and was near the mid-point of the study period. In the first interview, half the job titles were rated. This interview took two and a half hours. In the second interview (conducted the next day), which also took two and a half hours, the remaining job titles were rated. To determine intra-rater reliability, 10 percent of jobs (9 of the 86 "core" job titles) were randomly selected from the job title list and presented to the raters in the second interview. For 1965 estimations, each rater estimated a total of 103 job titles. These consisted of the 86 "core" job titles, 9 randomly selected job titles to test for intra-rater reliability, 5 job titles to estimate exposure for job titles with the modifier "chargehand", and finally, 3 job titles with the modifier apprentice. (The estimation procedure for the modifiers "chargehand" and "apprentice" is explained in the next few paragraphs.)

For two job categories, chargehands and apprentices, a special estimation procedure was developed. Chargehands perform a supervisory function on the shop floor, and while they do not have the authority to hire or fire they do fill important "line" supervisory functions. They are paid marginally more, and are usually more senior than their co-workers.

Chargehands are found in all the mills throughout the study period. The word "chargehand" appears as a modifier which can be applied to many different job titles. Because there might be implications for control, demand, and social support due to the quasi-supervisory nature of the chargehand function, and because of the unfeasibility of asking expert raters to rate every job title to which chargehand might apply, a more generic method was used.

There were 35 job titles (out of the 86) to which the modifier "chargehand" was sometimes applied. Five of these were randomly selected for each of the expert raters. The difference in rater evaluation between the five selected job titles and the same job title with the chargehand modifier added was averaged across the raters. In this way, the four experts produced an adjustment factor for any job title modified by the word chargehand.

As in the case of chargehand, only a limited number of apprentice job titles could be estimated by the expert raters, so a similar technique was employed for apprentices. All maintenance jobs have an apprenticeship phase that could receive different psychosocial job strain scores compared to fully qualified tradesmen. There were 12 maintenance job titles in the final job title list of 86. Three were randomly selected for each of the expert raters. The difference between the maintenance job title and the same job title with modifier apprentice was determined for the three jobs and averaged. Using this method a score for chargehand

and apprentice was determined for the five psychosocial variables. The exposure score for any job title was adjusted if the job title was modified by either of these two descriptors.

The 1997 estimations were carried out differently than the 1965 ratings. First, they were performed by a different interviewer. Another interviewer was used as the 1997 estimations were part of a separate study for which a paid interviewer was available. Second, as previously mentioned, an 18-item version of the instrument was used (Appendix D). And, third, 54 instead of 86 job titles were rated. Because expert raters were very busy they would agree to the 1997 estimations only if interviews were kept short. To accomplish this goal, the number of job titles was reduced to 54 (Appendix E).

The six-expert panel involved in the development of the core job title list was consulted to reduce its length. The core list of 86 job titles represented jobs present in the industry for the time period 1950 to 1985. To develop this list for use in estimating current exposure, jobs which had become obsolete or were found only rarely by 1997 were identified and eliminated. Accordingly, the panel identified 2 job titles which were entirely obsolete and 18 job titles which were only found rarely in the industry by 1997 (Appendix F). These 20 job titles were removed from the core list reducing it to 66 job titles. This was further reduced to 54 by amalgamating job titles which were similar in task and function using the second of the two major criteria employed in developing the core list of 86 (see section 7.2.1). The reduced job title list enabled the 1997 estimations to be conducted in one two-hour interview. For the 1997 estimations, 54 core job titles were assessed, plus 5 job titles randomly selected from the 54 core jobs to measure intra-rater reliability so that total of 59 job titles formed the final job list.

7.2.4 Exposure Assessment Reliability Analyses

To estimate the reliability with which expert raters estimated control, psychological and physical demand, noise, and social support, intra-rater reliability scores were calculated for both the 1965 and 1997 estimations using intra-class correlation coefficients (ICCs). Inter-rater reliability was calculated using individual ICCs, which describe the level of agreement between individual raters, and group ICCs which describe the reliability of the mean ratings of the group of four expert raters (Armitage and Berry 1994, 273). As well as ICCs, the proportion of variance distributed between raters, job titles, and the residual was calculated (Hertzman and others 1988).

7.3 Modifying and Validating the Demand/Control/Support Instrument

For the 18-item version of the demand/control/support model, five dimensions are measured: skill discretion (six items), decision authority (three items), psychological demand (five items), physical demand (one item), and co-worker social support (two items). As outlined previously, a question on noise exposure was added so that one item measuring noise exposure makes up the sixth dimension of this instrument. This item was adapted from several validated questionnaires commonly used to measure noise exposure. (This question was developed in consultation with occupational epidemiologists in the sawmill cohort study group at the University of British Columbia).

Because 103 job titles were estimated by expert raters in the retrospective exposure assessment interviews, at least 1,854 statements (18 items X 103 job titles) would have been estimated by each rater requiring approximately 8 hours of total interview time. Accordingly, five questions were eliminated to produce a 13-item instrument (Appendix C). Advice on shortening the questionnaire was obtained from an expert to ensure that core questions for psychological demand and control were retained (Landsbergis personal communication 1996). In the only other modification, the 13 items were changed to the past tense, since raters were estimating historical job titles.

In developing the 13-item instrument two items measuring psychological demand ("work is very fast" and, "work is very hard") were excluded based both on expert advice and criticism in the literature that the items "hard" and "fast", particularly when measured in a blue-collar context, are as likely to assess physical as psychological demand (Frese and Zapf 1988; Kristensen 1995). Exclusion of these two items ensured that the psychological demand construct was not contaminated with physical demand.

Two items, whether the job "required creativity" and, whether "the job allows opportunity for the worker to develop his own special abilities", were dropped from the skill discretion dimension. According to expert advice, creativity is implicit in the four remaining questions involving skill discretion (i.e. "new things", "repetition", "skill", and "variety) (Landsbergis personal communication 1996). If a worker is learning new things, if his job is not repetitious, if he can use his skills effectively, and if he has a variety of tasks to perform then his job is likely creative.

The item on "special abilities" was dropped because the investigator judged this as unmeasureable by experts raters. Experts might be able to judge (based on a job title) whether the job requires creativity. However, whether a job allows a worker to develop his own "special abilities" is partly dependent on that worker's special abilities of which the four experts could have no knowledge and were therefore not in a position to evaluate.

Finally, decision authority was reduced from three to two questions. The eliminated question, "the job allows the worker make alot of decisions on his own" largely repeats the remaining two questions. If the worker "has alot to say on the job", and if he "has alot of freedom about how to perform his tasks", then it is likely that the worker is making decisions on his own (Landsbergis personal communication 1996).

Because, as outlined above, the 13-item instrument is a sub-set of the 18-item version, psychological demand and control scores could be calculated using both versions of the instrument. For the 13-item instrument, the score for psychological demand was based on 3 items, and the score for control on 6 items. For the 18-item version, the score for psychological demand was based on 5 items and for control on 9 items.

The sensitivity and specificity of the 13-item instrument was determined in relation to the 18- item instrument for control and psychological demand as these were the two dimension altered in reducing the size of the validated instrument. The median scores for psychological demand and control were determined for each instrument. Job titles above the median for psychological demand and below the median for control were classified as "high strain". Job titles below the median for psychological demand and above the median for control were classified as "low strain" (Karasek and Theorell 1990). [16] The sensitivity and specificity of the 13-item instrument was then assessed in comparison to the "gold standard" 18-item instrument in terms of its ability to identify low and high strain jobs.

[16]This is the usual way in which the demand/control model is used to calculate job strain (see Figure 1).

7.4 Determining the Validity of the Exposure Assessment Method

Three questions of validity were addressed to test the soundness of the exposure assessment method. First, the construct validity of using retrospectively obtained estimates from near the mid-point of the study period (1965) to represent psychosocial conditions of work for the entire study was ascertained. Second, because three of the job evaluators were employed by industry and one by the union, it is possible to argue that a systematic bias might occur because of the preponderance of "management" evaluators. The potential for this bias was assessed. Finally, in a supplementary study, the concurrent and predictive validity for using expert raters was investigated by comparison with the more usual method for measuring psychosocial conditions at work, self-reports.

7.4.1 The Validity of Using 1965 Estimations to Represent Psychosocial Conditions of Work for the Entire Study Period

The construct validity of attributing control and psychological demand scores measured at one point in time to the same job titles at different points of time, although used widely in job-strain epidemiology, has not been tested. For example, a basic assumption behind the use of a job-strain exposure matrix for Swedish occupations is that scores for control and psychological demand developed for the matrix may be applied to occupations at times either earlier or later than when originally measured (Johnson and others 1990; Johnson and Stewart 1993). And, this assumption is implicit in the many analyses with the demand/control model in which scores for control and psychological demand are obtained for job titles at one point in time and applied to similar job titles at a different time (often decades apart). [17]

[17] The qualitative framing of this empirical analyis was undertaken in Chapter 4.

For the retrospective exposure assessment undertaken in this dissertation, this assumption was empirically tested by comparing the psychosocial conditions of work in 1965 and 1997. This comparison was based on the 54 job titles estimated in 1997 because this group of job titles represents jobs which remained in the industry over this time. Within-job title change in psychosocial work conditions were calculated for the period 1965 to 1997. Absolute differences and 95 percent confidence intervals in scores for control, psychological and physical demand, co-worker social support, and noise were calculated and paired t-tests conducted to determine whether differences were statistically significant.

As well, mean scores for psychosocial conditions of work for the 20 jobs eliminated or occurring only rarely by 1997 were compared with the scores for jobs which remained in the industry. While this comparison does not show within-job title change in these conditions, and while it does not speak directly to the validity issue under investigation, it broadens understanding of the relationship between technological change and shifting psychological conditions of work in the study mills and contributes indirectly to this validity assessment.

It should be noted that this supplementary validation study measures change in work conditions for the latter half of the study period. Because no estimates of exposure were made between 1950 and 1965, it is unknown whether psychosocial work conditions shifted within job titles during this time. However, because this validation study included the portion of the study period when technological change was most rapid, (1965-1985) results of the validation should be applicable to the entire study period. Also, because the pace of technological change was even more rapid between the end of the study period and 1997, the 1965-1997 comparison will likely produce an over-estimation of change in work conditions compared to the period 1965 to 1985. Therefore, no change or little change in psychosocial work conditions would be strong evidence that these conditions did not change within job titles during the entire study period.

7.4.2 The Potential for Management Bias in Exposure Assessment

In Chapter Six some discussion about the "ideal" type of expert rater was undertaken and it was shown that little research has been conducted to determine this. It was also pointed out that supervisors have been used as expert raters although it is not clear to what extent they might have a "management" bias when rating jobs. Because three of the four expert raters were from industry there could have been an imbalance between a "worker" compared to a "management" view of psychosocial work conditions.

To estimate the potential for "management bias", scores for psychosocial work conditions obtained by the three industry raters were averaged and compared to those obtained from the single union evaluator. Absolute differences and 95 percent confidence intervals in control, psychological and physical demand, co-worker social support, and noise were calculated between the union rater and the averaged industry raters and paired t-tests conducted to determine whether differences were statistically significant.

7.4.3 Concurrent and Predictive Validity of the Expert Rater Method

Self-reports are the current "gold standard" when operationalising the demand/control/support model. Therefore, an ideal way to determine the validity of using expert rater might be to obtain worker self-reports of psychosocial conditions for the 86 core job titles in all the sawmills in the coastal industry, or a representative sample of these for 1965. Once obtained in this manner, control and psychological demand could be calculated for each self-reporting worker. Each of the 86 job titles would then have a self-report for control and psychological demand as well as scores for these two variables obtained from the 4 expert raters. The validity of the self-reports and the expert ratings could then be determined.

This ideal approach cannot be taken as self-reports from workers in 1965 are not available. However, a study currently underway was used to provide self-reports for comparison with expert estimates for 1997 obtained in this investigation. This study, an investigation of the impact of unemployment on the health status of sawmill workers, is based on a sub-cohort of the cohort used in this investigation. This sub-cohort consists of approximately 11,000 workers who were employed during 1979. Presently (June 1998) interviewers are in the process of contacting these workers to determine their job history, unemployment history, and also, to administer the 13-item demand/control/support instrument to obtain direct self-reports of psychosocial work conditions in previous and current jobs. As well, self-reported health status scores on a five-point scale (excellent, good, fair, poor, bad) are being obtained from these workers.

This study is in progress so that self-reports for current jobs are available for many of the job titles estimated by the four expert raters. These self-reports (either direct or pooled) can be compared with expert rater scores obtained for 1997 estimations in the current investigation in two ways. First, as a test of the concurrent validity of the 1997 expert estimations and second as a test of the predictive validity of these expert estimations using self-reported health status as an outcome.

Although this study is in progress, it was possible to obtain and use some of the preliminary data obtained from workers resident in the City of Vancouver. Seven hundred and thirty three members of the sub-cohort resided in the city of Vancouver in 1997. A letter was sent to these workers asking them to participate in the unemployment study. The letter was followed-up with a telephone call from an interviewer a week later. Of the 733 people sent introductory letters, 612 individuals were telephoned by an interviewer. From these 612 individuals, 324 complete interviews were obtained (53 percent), 22 were hard refusals (4 percent), 53 soft refusals (11 percent), and 195 (32 percent) who were "hard to contact". That is, their telephone was out of service, they didn't answer, or they were away on holiday.

Therefore, the demand/control/support instrument was administered to 324 individuals. They were selected from a cohort of men who were working in the industry in 1979. Of the 324 individuals who were interviewed, 120 were still working in the sawmill industry so self-reports for psychosocial conditions of work for current jobs were obtained from these 120 experienced sawmill workers.

The 120 self-reports were obtained from workers at 6 of the 14-study sawmills. Among the 120 workers with current self-reports for a sawmill job title there were 30 unique job titles. One worker from a group of workers with the same job title was randomly selected to obtain 30 workers each with a unique job title. Each worker was assigned his self-report scores for control, psychological and physical demand, co-worker social support, and noise. As well, a pooled self-report score was calculated for each worker by averaging scores for psychosocial conditions of work across workers with the same job title. (The randomly selected worker was excluded so that pooled self-reports attributed to the worker do not include that worker's direct self-report.)

In this manner, 30 workers with unique job titles supplied direct and pooled self-reports for psychosocial work conditions for sawmill jobs estimated in the autumn of 1997. Estimations for control, psychological and physical demand, co-worker social support, and noise made by the 4 expert workers in the spring of 1997 for these same 30 job titles were also attributed to these 30 workers. The 30 job titles estimated were a sub-set of the 54 job titles assessed by the expert raters in this dissertation and represent 56 percent of the job titles used in the 1997 estimation. While this validity test does not involve all the job titles used in the present investigation it does use 56 percent of job titles used for 1997 estimations (Appendix G).

The concurrent validity of the expert rater method was determined by calculating Pearson correlation coefficients for control, psychological and physical demand, co-worker social support, and noise for direct self-reports, pooled self-reports, and the 4 expert raters. Because the direct and pooled self-reports represent "de-facto" gold standards, correlations of expert scores with both or either of these are a measure of the concurrent validity of the expert rater method.

The predictive validity of the expert rater method was determined by linear regression using scores for control, psychological and physical demand, co-worker social support, and noise for the 30 workers with self-reported health status as the outcome variable. Univariate analyses were undertaken by forcing entry of each variable into the model. Any variables which were statistically significant were offered in a multivariate model using stepwise entry with an entry criterion of $p<0.05$.

7.5 Standardised Mortality Ratio Analyses

The cohort was processed using the Occupational Cohort Mortality Analysis Program (OCMAP plus) in conjunction with British Columbia Division of Vital Statistics (BCDVS) cause-specific mortality rates to compute person-years, observed deaths, expected deaths, and standardised mortality ratios (SMRs). Mortality rates were calculated on the basis of five-year age and calendar categories.

CHD causes of death were divided into four categories as follows (the codes are ICD9s): hypertension, 4010–4059; atherosclerotic disease, 4100–4149; diseases of the heart, 4150, 4152–4179, 4200–4239, 4250–4252, 4254–4289, 4292–4299, and diseases of the circulatory system, 4151, 4400–4440, 4460–4480, 4510–4519, 4530–4599, 427, 430–436, 440–445. All four categories of heart disease were analysed in the SMR analysis even though the main outcome of interest was atherosclerotic disease.

A major drawback should be noted with the heart disease categories available for this analysis. Myocardial infarction deaths were not available as a separate cause of death. The CHD deaths were grouped in this fashion by the BCDVS. Other ways of grouping CHD death codes were unavailable for historical populations in British Columbia.

Other causes of death that were of interest because of their possible relationship to job strain were also analysed. These causes of death included cerebrovascular accidents (CVA), 4300–4389; suicide, accidental deaths, (all E codes), and all-cause mortality.

7.5.1 Determining the Appropriate Length of Follow-up for the SMR Analysis

A major analytical challenge in this investigation arises in determining the appropriate length of follow-up for the standardised mortality ratio analysis. Two mortality linkages were performed so that death ascertainment was particularly thorough. In spite of this, 39 percent of the cohort had unknown vital status in 1990. Direct linkage to Statistics Canada tax files, using social insurance number was undertaken to determine which workers were alive in 1990. This linkage reduced those with unknown vital status in the cohort to 14.3 percent (These results are fully presented in section 8.1.1). However, for confidentiality reasons, Statistics Canada would not release the results of their tax linkage so it was not possible to re-label individuals in the cohort data base who were among the 39 percent with unknown vital status and identified as alive in this linkage. These persons had to remain labelled as "unknown" in spite of the fact that most were alive in 1990.

According to Checkoway, "one can count person-years of observation for unknowns up until the dates of last contact, typically the dates of termination from the industry, and make no assumptions regarding their vital status thereafter" (Checkoway and others 1989, 115). Given that most of these unknowns were alive in 1990, such an approach will reduce the size of the denominator leading to inflated SMRs. On the other hand, because 14.3 percent of the cohort had unknown status in 1990, it may not be safe to assume that these workers were alive in 1990 as this would deflate the SMRs. Therefore, SMRs were calculated with both assumptions and are presented in section 8.5.

7.6 Regression Analyses

7.6.1 Determining the Appropriate Length of Follow-up for the Regression Analyses

In most occupational studies the exposure of interest occurs only at the work site under investigation. But, for ubiquitous exposures, such as psychosocial work conditions, this approach may result in under-ascertainment of exposure introducing systematic bias. For example, in this investigation, if a worker leaves a study sawmill at age 40 after 20 years of work, he is likely to work elsewhere until he is 65 years old. Because job history and therefore exposure data is only available for 20 of his 45 years at work, less than half his exposure for psychosocial work conditions will be captured.

This will not be a problem for workers who die at relatively young ages while employed at a cohort mill. But, for short-term workers who terminated early in the study period and were known to be under 65 and alive in 1990, a significant proportion of their work lives will be spent working outside a study sawmill. Because such a small portion of their working life is spent at a study sawmill, the exposures calculated for these workers will be under ascertained resulting in misclassification.

Several approaches to address this problem were considered. First, follow-up of such workers could occur under the assumption that no further exposure occurs after they leave a cohort sawmill. Second, one could assume that these workers upon leaving a study sawmill find a similar job, with similar psychosocial conditions, at another (non-study) sawmill and attribute exposure accordingly. Third, the average sawmill exposures for these workers could be calculated and applied to the remaining non-study portion of their work life. Fourth, a fixed cohort could be generated consisting mainly of workers who had spent all or almost all of their work life in a study sawmill. Finally, follow-up of all the workers in the cohort could be shortened as a way of reducing the impact of misclassification.

The first approach involves an unrealistic assumption. The second and third analytic strategies involve a number of assumptions both about job duration and exposure that might not be valid. Developing a fixed cohort within this dynamic one would produce a cohort of less than 2,500 workers resulting in a loss of power, waste of exposure information, and considerably restricted generalizability for the investigation.

The last strategy, restricting the length of follow-up for all workers, is adopted in this study for three reasons. It does not involve any assumptions about the occupational history of cohort members after they leave a study sawmill. It preserves all the occupational exposure information gathered and uses all cohort members in the analysis. While restricted follow-up will reduce both the number of observations and person-years in the analysis, given the size of the cohort there will still be adequate power for the analysis.

Reduction of person-years in this manner will act to reduce, but not eliminate, misclassification. By measuring the person-years contributed by workers between their termination date at a study sawmill and the time they turned 65, an *estimate* of the person-years contributed at work outside study mills can be obtained (table 4).[18]

[18] In performing this calculation, if a worker died before age 65 his person-year contribution would be equal to the time between termination and death rather than between termination and age 65. This is just an estimate as it does not attempt to measure person-years accrued in non-study workplaces prior to the study sawmill hire date. However, this contribution will be relatively minor because most cohort members were hired very early in their work lives (less than age 25).

Table 4: Estimation of Person-Years Worked Outside Study Sawmills by Duration of Follow-up*

Follow-up	Person-Years	Person-Years Outside a Study Mill	Percentage
To 1990	608,593	290,361	47.7
10 years	440,208	147,485	33.5
5 years	355,273	82,181	23.1

*In this estimation it is assumed that a worker terminated from a study sawmill under the age of 65 will have found work elsewhere. And, his person-year contribution was calculated by assuming he found work between his study termination date and age 65. This may lead to an over-estimate as it does not consider the worker might retire before age 65 or that he might be unemployed for periods after terminating at a study mill.

Restricting follow-up to 10 years after termination in a study sawmill will result in a cohort with 33.5 percent of person-years spent in jobs outside study sawmills compared to 47.7 percent in such jobs with follow-up to 1990. Further reduction to 23.1 percent of person-years spent in non-study sawmill jobs will occur by reducing the length of follow-up to 5 years.

Restricting follow-up to 5 or 10 years will eliminate CHD mortality outcomes that occur long after a worker terminated at a study sawmill. For example, in the case of a worker who dies of CHD in 1990 at age 75 and who worked at a study sawmill from 1954 to 1957, the likelihood of a link between exposure to psychosocial work conditions during this 3 year experience at the study sawmill and his death is remote. Restricting follow-up will therefore act to eliminate death events that occur a long time after exposure in a study sawmill and should increase the precision of the analysis.

A potential danger of restricting the length of follow-up in this way could arise if there was a long period between exposure and manifestation of disease symptoms and death. If, for example, CHD mortality tended to occur 15 or 20 years after exposure to "high" levels of job strain, then restricting follow-up could miss any association between exposure and outcome. At this point, there is no evidence for a long latency period between exposure to psychosocial work conditions and the development of CHD so that restriction of follow-up will not likely "miss" such an association.

An alternative strategy in the analysis would have been to conduct regression analysis with no follow-up after termination at a study sawmill. This would have eliminated misclassification of exposure due to work in non-study sawmills but it would also have limited the investigation to acute deaths (mainly acute myocardial infarctions) occurring only at work. Because non-acute CHD mortality will likely occur after a period of morbidity, and because such periods of morbidity may lead to termination of employment, an analytical strategy with no follow-up after termination of employment will result in under-ascertainment of work-related CHD deaths. The 5 and 10 year periods of follow-up chosen for these analyses therefore represent a "trade off" which balances the impact of exposure misclassification and CHD mortality ascertainment.

7.6.2 Methods Used for Poisson Regression Analysis

According to Checkoway, "Poisson regression may be an efficient method for time-related analyses of occupational cohort data when mathematical modeling is required" (Checkoway and others 1989, 259). Cox regression is also a method that could be used for handling time-related analyses in this investigation. Again, according to Checkoway, "the proportional hazards model is rarely used in occupational cohort studies because of its computational complexity. Computer time is no longer of major importance with the advent of high speed microcomputers, but the practical complexities of running the proportional hazards model with time-related factors are still of concern" (Checkoway and others 1989, 259).

Another important advantage of Poisson compared to Cox regression is that the former yields coefficients which measure absolute risk whereas the latter produces coefficients which measure risk relative to baseline only. Given the large cohort size, Poisson regression is the best possible analytic approach as it can utilise the entire data base with least computational burden and produce the most useful estimates of risk. Finally, Poisson analysis was chosen because of the availability of a "state of the art" person-years program (OCMAP Plus) capable of modeling time-varying co-variates.

Exposure response relations were examined by means of internal rate comparisons with Poisson regression modeling (Breslow and Day 1987). Files for analysis were generated using OCMAP Plus. This program is able to handle up to seven exposures as well as duration of exposure, age, and calendar year. Using OCMAP Plus, cumulative exposure scores were generated for each of the five psychosocial variables. Five mortality outcomes were analysed; atherosclerosis, CVA, suicide, accidents, and all-cause mortality.

The study period was divided into eight five-year calendar periods starting at 1950 and workers' ages were divided into 16 five-year age periods starting at age 15. Separately, for each of the following exposure variables (duration of exposure, and cumulative scores for control, psychological demand, physical demand, co-worker social support, and noise), cut-off points were determined that divided person-years into quartiles. OCMAP Plus was run with all eight variables so that person-years were distributed into appropriate cells according to quartiles for exposure variables, according to eight calendar periods, and according to 16 age periods. Output files were exported directly from OCMAP Plus to STATA and Poisson regression analysis performed on a personal computer (StataCorp 1997).

The analytic strategy had three components. First, univariate analyses were run for each of the five mortality outcomes using all eight independent variables. Variables were forced into the model in order to determine the strength of association for all independent variables before multivariate modeling. Next a multivariate model was run (Model 1) by first forcing age and calendar period into the model and then offering, in a forward stepwise regression (with $p<0.05$ as the entry criterion) variables which were statistically significant in the univariate analysis. Model 1 was run for all five outcomes.

A final multivariate model (Model 2) was run by first forcing age, calendar period, and duration of exposure into the model and then offering, as in Model 1, the variables which were significant in univariate analysis. Model 2 was run for all five outcomes. And because, according to the demand/control/support model, control interacts multiplicatively with psychological demand a multiplicative interaction term (Interact 1) was run for all univariate and multivariate analyses. And, similarly because social support is postulated to moderate psychological demands a multiplicative interaction term (Interact 2) with these two variables was also run.

To explore the possibility of a latent effect for cumulative exposure, lagged analyses were run with 5, 10, 15 and 20 year intervals for atherosclerosis with both 5- and 10-years of follow-up. These 5-year periods were arbitrarily selected as there is little data in the job strain literature upon which to base selection of appropriate lagging intervals. Lagging with these intervals was performed only for analysis with atherosclerosis as this was the main outcome of interest in the investigation.

Using all five outcomes final analyses were run measuring exposure only up to December 31st 1980. The results for these anlayses were compared with the results obtained in the Poisson models with exposure to December 31st 1985 to ascertain whether including exposure during an era of unusually high unemployment may have confounded results.

7.6.3 Methods Used for the Logistic Regression Analysis

Logistic regresson was undertaken on a personal computer using STATA (StataCorp 1997). Models were analagous to those run in the Poisson regression except that lagged analyses were not performed with logistic regression and atherosclerosis. The major difference between these two analytic approaches was that the Poisson regression with cumulative exposure modeled time-varying co-variates whereas logistic regression with time-weighted average exposure was a fixed-effects model. Modeling TWA with time-varying Poisson regression was not possible because TWA exposures could not be calculated with OCMAP Plus.

As well, for the logistic regression, the unit of analysis was the person rather than the person-year. Separate analyses were done for each of the five outcomes atherosclerosis, all cause mortality, cerebrovascular accidents, suicide and accident deaths. In each analysis the outcome for each person was death from the specified cause; yes or no. The exposures were the time-weighted averages (TWAs) over the whole available working history of each individual for each of the job strain indicators: control, psychological demand, physical demand, social support and noise. In addition, age at first hire, year of first hire, and duration of employment in the study sawmills were modelled as covariates. The relation between exposures and outcomes, after adjustment for covariates, was assessed in a series of logistic regression models.

As for the Poisson regressions the analytic strategy for logistic regression had three components. First, univariate analyses were run for each of the five mortality outcomes using all eight independent variables. Variables were forced into the model in order to determine the strength of association for all independent variables before multivariate modeling. Next a multivariate model was run (Model 1) by first forcing age at hire and year of hire into the model and then offering, in a forward stepwise regression (with $p<0.05$ as the entry criterion) variables which were statistically significant in the univariate analysis. Model 1 was run for all five outcomes.

A final multivariate model (Model 2) was run by first forcing age at hire, year of hire, and duration of exposure into the model and then offering, as in Model 1, the variables which were significant in univariate analysis. Model 2 was run for all five outcomes. And because, according to the demand/control/support model, control interacts multiplicatively with psychological demand a multiplicative interaction term (Interact 1) was run for all univariate and multivariate analyses. And, similarly because social support is postulated to moderate psychological demands a multiplicative interaction term (Interact 2) with these two variables was also run.

Using all five outcomes final analyses were run measuring exposure only up to December 31st 1980. The results for these anlayses were compared with the results obtained in the logistic regression models with exposure to December 31st 1985 in order to ascertain whether including exposure during an era of unusually high unemployment may have confounded results.

CHAPTER EIGHT

8.0 Results

The results chapter is organised in six sections. Vital status ascertainment is presented in the first section. The second section describes the 14-study sawmills and presents descriptive statistics for the cohort members. The exposure assessment results are presented in the third section and results of supplementary validity analyses presented in the fourth. The Standardised Mortality Ratio analyses are shown in section five and results for the regression analyses are presented in section six.

8.1 Vital Status Ascertainment

8.1.1 Vital Status Ascertainment for the Original Cohort

The original cohort was linked to two mortality data bases. The first linkage was to the B.C. Division of Vital Status mortality files for deaths occurring between 1950 and the end of 1989. Table 5 presents the results of this linkage. To ensure that death ascertainment in B.C. was as complete as possible, and to obtain any deaths which may have occurred out-of-province, a second linkage was made to the Canadian Mortality Data Base (CMDB). This linkage used an extra field (mill location) not available for the linkage to the B.C. death registry and produced 278 more within-B.C. deaths between 1950 and the end of 1989. The CMDB linkage also produced 196 out-of-province deaths during this time period.

Table 5: Deaths by Registry for the Original Cohort to the End of 1989

Death Status	Number	Percent
Dead to end of 1989 (BCDVS)	3,948	89.3
Extra within B.C. (CMBD)	278	6.3
Extra outside B.C. (CMDB)	196	4.4
Total*	**4,422**	**100**

* The CMDB linkage also obtained 288 deaths among cohort members for the year 1990 so that the final total of deaths for cohort members was 4710.

With these two mortality linkages complete, vital status for the original cohort to the end of 1990 is shown in table 6.

Table 6: Vital Status for the Original Cohort to the End of 1990

Vital Status	Number	Percent
Alive	11,434	43.2
Dead	4,710	17.8
Unknown with SIN	7,447	28.1
Unknown with no SIN	2,896	10.9
Total	**26,487**	**100**

After both death registry linkages and follow-up with pension records and motor vehicle records, 39 percent of the original cohort members still had unknown vital status. In order to reduce this number a direct (non-probabilistic) linkage was performed by Statistics Canada to the income tax file. This linkage was only possible for workers who had a social insurance number. The results are shown in table 7.

Table 7: Vital Status for the Original Cohort to the End of 1990 After Tax File Linkage

Vital Status	Number Post-Tax File Linkage	Percent
Alive	17,986	67.9
Dead	4,710	17.8
Unknown with SIN	895	3.4
Unknown with no SIN	2,896	10.9
Total	**26,487**	**100.0**

After the tax file linkage 3,791 workers (14.3 percent) still had unknown vital status producing a vital status ascertainment rate for the original cohort of 85.7 percent. Given that mortality ascertainment with the CMDB is estimated at 97.6 percent for deaths in Canada (Schnatter and others 1990) and, because linkages were made to two mortality databases, it is highly unlikely that the 14.3 percent of workers with unknown vital status died between 1950 and 1990 and were somehow missed in the mortality linkages. It is likely that most of the 3,791 workers with unknown vital status either did not file a tax return and were still alive or that a proportion of the workers had inaccurate or missing personal identifier data which precluded linkage. Many people, particularly the very old and infirm with no dependants, stop filing tax returns so that it is not unreasonable to assume that most of those with unknown vital status were alive as of 1990.

8.1.2 Vital Status Ascertainment for the Current Cohort

The current cohort differs from the original because 264 workers from the original cohort were excluded. In the original chlorophenol analysis, the Person-Year program was used to edit the cohort data and process it into person-years (Coleman and others 1989). The superior error checking capabilities of OCMAP Plus resulted in the exclusion of these workers. This change did not affect the vital status ascertainment already outlined in a major way, but deletions from the original cohort are shown in table 8 and the final vital status ascertainment in table 9.

Table 8: Deletions from the Original Cohort

Vital Status	Number	Percent
Alive	94	35.6
Dead	70	26.5
Unknown	100	37.9
Total	**264**	**100.0**

Table 9: Vital Status Ascertainment for the Current Cohort

Vital Status	Number	Percent
Alive	11340	43.2
Dead	4640	17.7
Unknown	10243	39.1
Total	**26223**	**100**

8.2 Descriptive Statistics for the Cohort

The distributions of age at first employment, year of first employment, duration of employment, and duration of follow-up are shown in tables 10 to 12. These results are typical of manufacturing industries. Approximately 70 percent of workers were hired before age 30, with the mean age at first employment of 27.2 years. Approximately 60 percent of workers were employed for 9 or less years. Forty percent of workers had more than 10 years of employment and 21.2 percent worked for 20 or more years. Mean duration of follow-up was 23.2 years (assuming follow-up to 1990 for those with unknown vital status).

Table 10: Age at First Employment

Age	Number	Percent
<20	8,489	32.4
20-29	9,561	36.5
30-39	4,675	17.8
40-49	2,452	9.4
>50	1,046	4.0
Mean	**27.2**	

Table 11: Duration of Employment

Duration	Number	Percent
0-4	10,399	39.7
5-9	4,980	18.9
10-19	5,310	20.2
20-29	2,975	11.4
>30	2,559	9.8
Mean	**11.72 yrs**	

Table 12: Duration of Follow-up

Duration	Number	Percent
0-4	378	1.4
5-9	2,082	7.9
10-19	9,693	36.9
20-29	6,586	25.1
>30	7,484	28.5
Mean	**23.2 yrs**	

Table 13 shows that 26,223 workers in the cohort contributed 492,710 person-years assuming follow-up to the last known year. As outlined in the section on vital status ascertainment, it is likely that most of those with unknown vital status were alive until 1990. With this assumption the distribution of person-years by employment duration is as shown in table 14.

Table 13: Person-years at Risk by Duration of Employment to Last Known Year

Duration of Employment	Person-years	Percent
1-9	226,900	46.1
10-19	98,199	19.9
20-29	78,995	16.0
>30	88,616	18.0
Total	**492,710**	**100.0**

Table 14: Person-years at Risk by Duration of Employment with Follow-up to 1990

Duration of Employment	Person-years	Percent
1-9	323,003	53.1
10-19	111,818	18.4
20-29	83,135	13.6
>30	90,614	14.9
Total	**608,593**	**100.0**

Table 15 shows that a total of 115,860 (19 percent) of person-years were contributed by 10,243 workers lost to follow-up but likely alive in 1990.

Table 15: Contribution of "Extra" Person-years at Risk by Duration of Employment for 10,243 Workers with Unknown Vital Status

Duration of Employment	Number of Workers	Person-years (Number)	Person-years (Percentage)
1-9	8,877	96,103	82.9
10-19	1,025	13,619	11.8
20-29	213	4,140	3.6
>30	128	1,998	1.7
Total	**10,243**	**115,860**	**100.0**

Table 16: Duration of Employment by Duration of Follow-up (Assuming Follow-up to 1990 for Workers with Unknown Vital Status)

Duration of Employment	Duration of Follow-up				
	1-9	**10-19**	**20-29**	**>30**	**TOTAL**
1-9	2,223 (8.5)	6,218 (23.7)	3,630 (13.8)	3,313 (12.6)	15,384 (58.7)
10-19	177 (0.7)*	3,123 (11.9)	1,005 (3.8)	993 (3.8)	5,298 (20.2)
20-29	38 (0.2)*	283 (1.1)*	1,639 (6.3)	998 (3.8)	2,959 (11.3)
>30	24 (0.1)*	69 (0.2)*	315 (1.2)*	2,174 (8.3)	2,582 (9.8)
TOTAL	**2,462 (9.5)**	**9,693(36.9)**	**6,589(25.1)**	**7,478(28.5)**	**26,223**

Percentage of the Total in brackets
* Started employment prior to 1950

Table 17 shows the distribution of person-years by duration of employment and duration of follow-up assuming follow up to 1990 for all persons with unknown vital status. Approximately 72 percent of person year of follow-up occurred 20 or more years after first follow up. The person-years totalled 34.4 percent for workers employed for more than 9 years who were followed for 20 or more years.

Table 17: Person-years at Risk by Duration of Employment and Duration of Follow-up (Assuming Follow-up to 1990 for Workers with Unknown Vital Status)

Duration of Employment	Duration of Follow-up				
	1-9	**10-19**	**20-29**	**>30**	**TOTAL**
1-9	17,714 (2.9)	96,243 (15.8)	88,682 (14.6)	120,364 (19.8)	323,003 (53.1)
10-19	1,495 (0.3)*	48,592 (8.0)	25,180 (4.1)	36,522 (6.0)	111,818 (18.3)
20-29	220 (.04)*	5,109 (0.8)*	40,515 (6.7)	37,330 (6.1)	83,135 (13.7)
>30	1,168 (0.2)*	1,150 (0.2)*	8,170 (1.3)*	81,126 (13.3)	90,614 (14.9)
TOTAL	**19,626(3.2)**	**151,055(24.8)**	**162,570(26.7)**	**275,342(45.2)**	**608,593**

Percentage of the Total in brackets
* Started employment prior to 1950

8.3 Exposure Assessment Results

8.3.1 Retrospective Estimations

Table 18 presents expert rating scores for 1965 estimates. Raters 1, 2, and 3 were industry raters and Rater 4 was a union rater. In all cases where jobs were not rated, the reason cited was lack of familiarity with the job title in question.

Table 18: Descriptive Statistics for 1965 Estimations for Four Raters

Rater 1

N=84	Con	Ps	Ph	Social	Noise
Mean	19.2	6.9	2.6	5.5	2.7
Median	18.0	7.0	3.0	6.0	3.0
Minimum	12.0	4.0	1.0	3.0	1.0
Maximum	30.0	9.0	3.5	8.0	4.0
Stand. Dev.	3.91	0.96	0.54	1.28	0.84

Rater 2

N=81	Control	Ps	Ph	Social	Noise
Mean	20.3	7.3	2.5	5.2	2.5
Median	20.0	7.0	2.0	6.0	2.0
Minimum	12.0	6.0	1.4	3.0	1.0
Maximum	29.0	10.0	4.0	8.0	4.0
Stand. Dev.	3.60	1.09	0.60	1.03	0.76

Rater 3					
N=82	**Control**	**Ps**	**Ph**	**Social**	**Noise**
Mean	20.3	7.0	2.7	5.6	2.6
Median	19.0	7.0	3.0	6.0	3.0
Minimum	14.0	4.0	1.0	4.0	1.0
Maximum	31.0	10.0	4.0	8.0	4.0
Stand. Dev.	4.53	1.22	0.85	1.18	1.02

Rater 4					
N=85	**Control**	**Ps**	**Ph**	**Social**	**Noise**
Mean	18.9	6.4	2.7	5.7	2.6
Median	18.0	6.0	3.0	6.0	3.0
Minimum	16.0	6.0	2.0	4.0	2.0
Maximum	24.0	9.0	4.0	6.0	4.0
Stand. Dev.	2.77	0.76	0.49	0.72	0.61

Average					
N=86	**Control**	**Ps**	**Ph**	**Social**	**Noise**
Mean	19.7	6.9	2.6	5.5	2.6
Median	19.0	6.8	2.6	5.5	2.5
Minimum	12.7	5.5	1.4	3.9	1.3
Maximum	28.3	8.9	3.9	7.3	4.0
Stand. Dev.	3.30	0.67	0.51	0.84	0.67

Ps = Psychological demand; Ph = Physical demand; Social = Co-worker social support. Possible range in score for control (8-32); for Ps (3-12); for Ph and Noise (1-4); for Social (2-8). For all scores, increasing values indicate greater exposure.

Table 19 summarises and presents the mean scores for each rater.

Table 19: Mean Scores for 1965 Estimates by Rater

Rater	Control	Ps	Ph	Social	Noise
Rater 1	19.2	6.9	2.6	5.5	2.7
Rater 2	20.3	7.3	2.5	5.2	2.5
Rater 3	20.3	7.0	2.7	5.6	2.6
Rater 4	18.9	6.4	2.7	5.7	2.6

Ps = Psychological demand; Ph = Physical demand; Social = Co-worker social support.

Table 20 presents intra-rater reliability (based on the 10 percent expert rating of repeat job titles) using the intra-class correlation coefficients (ICCs) for the 1965 estimates.

Table 20: Intra-Rater Reliability for 1965 Estimates

	Control	Ps	Ph	Social	Noise
Rater 1	0.91	-0.27	0.67	0.76	0.87
Rater 2	0.78	0.64	0.70	0.80	0.72
Rater 3	0.87	0.24	0.74	0.55	0.63
Rater 4	0.91	0.09	1.00	0.66	0.75
Average	**0.87**	**0.18**	**0.78**	**0.69**	**0.73**

Ps = Psychological demand; Ph = Physical demand; Social = Co-worker social support.

Mean intra-rater reliabilities were "excellent" for control and physical demand and "good" for social support and noise. Intra -rater reliability for psychological demand was "poor" for all raters except Rater 2.[19]

Table 21 describes inter-rater reliability in terms of the "proportion of the variance" explained between job titles (expressed as a percentage of total variance), between raters and residual and, also in terms of Individual and Group ICCs.

Table 21: Inter-Rater Reliability for 1965 Estimates

Source of Variance	Control	Ps	Ph	Social	Noise
Between Job Titles	79.0	38.0	62.0	59.0	65.0
Between Raters	2.0	9.0	2.0	3.0	1.0
Residual	19.0	53.0	36.0	38.0	34.0
Individual ICC	0.72	0.20	0.50	0.46	0.54
Group ICC	0.92	0.53	0.81	0.78	0.82

Ps = Psychological Demand; Ph = Physical Demand; Social = Co-worker social support.

Individual ICCs estimate between-rater agreement which was "good" for all variables except psychological demand which was "poor". Group ICCs estimate the reliability of the mean of the four raters which, for variables except psychological demand, was "excellent". For psychological demand "good" reliability was obtained. Although as a group, the expert raters assessed psychological demand with "good" reliability, "poor" reliability was obtained for this variable at the individual level and for intra-rater reliability. These results indicate that psychosocial demand may be less amenable to expert rating

19 The intraclass correlation coefficient can be given the same numerical interpretation as its analog used for categorical data, the Kappa statistic. The levels of agreement for Kappa have been graded as excellent

than the other four variables. In spite of this, and the low intra-rater and individual inter-rater reliability, a Group ICC of 0.53 for psychological demand means that this construct was estimated reliably enough by the group of four experts to justify its use in the SMR and regression analyses.

To determine whether there were differences between scores for a given job title and its chargehand or apprentice designation, pair-wise t-tests were performed. Tables 22 and 23 show the results of the t-tests.

Table 22: Pair-wise t-Test for "Chargehand" Compared to the Same Job Title without Chargehand Designation

N=14[1]	t-score	P-value	Mean Difference[2]	Proportional Difference
Control	2.25	0.040	1.30	5.4%
Psychological Demand	0.14	0.880	0.03	0.3%
Physical Demand	-1.00	0.336	-0.14	-4.7%
Co-worker Social Support	0.51	0.620	0.11	1.8%
Noise	0.23	0.818	0.03	1%

[1] Although 20 jobs were selected, one rater or another was unable to rate 6 of these so the final number of job title comparisons was 14.
[2] Mean and proportionate difference calculated by (chargehand + job title)- (job title).

There was no significant difference between job titles alone and job titles bearing the chargehand designation for the dimensions psychological and physical demand, social support, and noise. Control scores for chargehand were significantly greater than for the job title alone. In absolute terms, chargehand control scores were 5.4 percent greater than for the same job title without the status of chargehand. While differences between chargehand and job title for physical demand were not statistically significant, physical

(.75 or more), good (.40 to .75), and poor (less than .40) (Fleiss 1975; Landis and Koch 1977).

demand was 4.6 percent less for chargehands. Because this difference was, on a scale from 1 to 4, practically unmeasureable, it was ignored. However, the absolute difference in control scores was 1.3 units in a scale of 24 units and therefore observable by a rater. Accordingly, all job titles with the adjective chargehand had their control scores increased by 1.3 units.

Table 23: Pair-wise t-Test for "Apprentice" Compared to the Same Job Title without the Apprentice Designation

N=9[1]	t-score	P-value	Mean Difference[2]	Proportional Difference
Control	-5.57	0.001	-4.60	-19.2%
Psychological Demand	-2.53	0.035	-0.89	-9.9%
Physical Demand	-2.00	0.081	-0.33	-11.0%
Co-worker Social Support	0.00	1.000	0.00	0.0%
Noise	-1.00	0.347	-0.22	-7.3%

[1] Although 12 job titles were selected for rating, one rater or another was unable to rate 3 of them.

[2] Mean and proportionate difference calculated by (apprentice + job title)- (job title).

There was no significant difference between job titles alone and job titles with apprentice designation for physical demand, social support, and noise. Control scores for apprentices were significantly less than for job title alone. In absolute terms, apprentices had control scores 19.2 percent less than for fully qualified maintenance job titles. Psychological demand scores were also significantly less for apprentices, averaging a 9.9 percent reduction. Differences in control and psychological demand were both significant and practically measurable on the instrument, allowing scores for apprentice tradesman to be calculated by decreasing the control and psychological demand scores of qualified trades job titles by 4.6 and 0.89 units, respectively.

8.3.2 Current Estimations

Table 24 shows descriptive results for 1997 estimations. Although 1997 estimations were conducted using the 18-item instrument, scores presented in tables 24 though 27 were calculated with 13-items to facilitate comparison with 1965 estimations.

Table 24: Descriptive Statistics for 1997 Estimations for Four Raters

Rater 1					
N=54	**Control**	**Ps**	**Ph**	**Social**	**Noise**
Mean	20.7	6.6	2.3	5.5	2.9
Median	20.5	6.0	2.0	6.0	3.0
Minimum	12.0	6.0	1.0	3.0	1.0
Maximum	31.0	9.0	4.0	8.0	4.0
Stand. Dev.	5.17	0.75	0.88	1.65	0.98

Rater 2					
N=54	**Control**	**Ps**	**Ph**	**Social**	**Noise**
Mean	21.1	7.1	2.5	5.2	2.6
Median	21.0	6.0	2.0	6.0	3.0
Minimum	12.0	6.0	1.0	2.0	1.0
Maximum	28.5	10.0	4.0	8.0	4.0
Stand. Dev.	4.20	0.97	0.57	1.50	0.70

Rater 3

N=54	Control	Ps	Ph	Social	Noise
Mean	20.7	6.4	2.2	5.7	2.3
Median	20.5	6.0	2.0	6.0	2.0
Minimum	9.0	5.0	1.0	3.0	1.0
Maximum	30.0	9.0	4.0	8.0	4.0
Stand. Dev.	4.40	0.71	1.00	1.10	1.00

Rater 4

N=54	Control	Ps	Ph	Social	Noise
Mean	20.0	6.3	2.6	5.4	2.6
Median	19.0	6.0	3.0	6.0	3.0
Minimum	14.0	6.0	2.0	4.0	2.0
Maximum	30.0	9.5	3.0	8.0	4.0
Stand. Dev.	3.60	0.66	0.51	1.20	0.53

Average

N=54	Control	Ps	Ph	Social	Noise
Mean	20.6	6.6	2.4	5.5	2.6
Median	20.0	6.5	2.3	5.5	2.6
Minimum	13.4	5.8	1.3	3.0	1.0
Maximum	28.3	8.4	3.8	8.0	4.0
Stand. Dev.	3.90	0.54	0.62	1.20	0.67

Ps = Psychological demand; Ph = Physical demand; Social = Co-worker social support. Possible range in score for control (8-32); for Ps (3-12); for Ph and Noise (1-4); for Social (2-8). For all scores, increasing values indicate greater exposure.

Table 25 summarises and presents the mean scores for each rater.

Table 25: Mean Scores for 1997 Estimates by Rater

Rater	Control	Ps	Ph	Social	Noise
Rater 1	20.7	6.6	2.3	5.5	2.9
Rater 2	21.1	7.1	2.5	5.2	2.6
Rater 3	20.7	6.4	2.2	5.7	2.3
Rater 4	20.0	6.3	2.6	5.4	2.6

Ps = Psychological demand; Ph = Physical demand; Social = Co-worker social support.

Intra-rater reliabilities for 1997 estimates are shown in table 26. Intra-rater reliability was "good" for physical demand, co-worker social support, and noise and "poor" for psychological demand. Intra-rater reliability was "excellent" for control. Intra-rater reliability was lower for 1997 compared to 1965 estimations for all variables except psychological demand.

Table 26: Intra-Rater Reliability for 1997 Estimates

N=5	Control	Ps	Ph	Social	Noise
Rater 1	0.66	0.07	1.00	0.24	0.00
Rater 2	0.69	0.68	0.50	0.00	0.64
Rater 3	0.70	-0.50	0.43	1.00	0.79
Rater 4	0.96	0.66	1.00	0.93	0.60
Average	0.75	0.23	0.73	0.54	0.54

Ps = Psychological demand; Ph = Physical demand; Social = Co-worker social support.

Table 27 describes inter-rater reliability in terms of the proportion of the variance explained between job titles, raters, and residual, (expressed as a percentage of total variance) and in terms of Individual and Group ICCs.

Table 27: Inter-Rater Reliability for 1997 Estimates

Source of Variance	Control	Ps	Ph	Social	Noise
Between job titles	80.0	42.0	63.0	70.0	54.0
Between raters	1.0	11.0	3.0	2.0	7.0
Residual	19.0	47.0	34.0	28.0	39.0
Individual ICC	0.73	0.26	0.52	0.60	0.41
Group ICC	0.92	0.63	0.82	0.86	0.76

Ps = Psychological demand; Ph = Physical demand; Social = Co-worker social support.

Inter-rater reliability for 1997 estimates were slightly higher than for 1965. Reliability for psychological demand was 10 percent higher for 1997 estimates. For both 1965 and 1997 estimates Group ICCs were "excellent" for all variables except psychological demand for which Group ICCs were "good". This pattern of reliability scores is similar to the 1965 estimations. The lower reliability of psychological demand relative to the other four variables for both estimations indicates that this construct (at least as measured in this investigation) may not be as reliably measured using expert rating methods.

8.4 Supplementary Validity Analyses

8.4.1 Sensitivity and Specificity of the 13-item Instrument

Using 1997 estimations the sensitivity and specificity of the shortened 13-item instrument was calculated as shown in table 28.

Table 28: Sensitivity and Specificity of the 13-item Instrument

13-item	18-item	
	Low Strain*	High Strain
Low Strain	23	4
High Strain	3	24
Total	26	28

* Job strain is calculated by dividing psychological demand by control.
** Sensitivity=23/26; Specificity=24/28.

Sensitivity of the 13-item instrument was 88.5 percent and the specificity 85.7 percent, indicating that it is a valid instrument for use in this investigation. To determine if the reliability with which the four expert raters estimated psychosocial conditions of work differed depending on whether they used the 13 or the 18-item instrument, inter-rater reliability for control and psychological demand was compared for the two instruments (table 29).

Table 29: Comparison of Inter-rater Reliability for 1997 Estimations Using the 13- and 18-item Instruments

	Control		Psychological Demand	
	18-item	13-item	18-item	13-item
Individual ICC	0.76	0.73	0.41	0.26
Group ICC	0.93	0.92	0.74	0.63

When measuring control, the reliability for the group of four expert raters was relatively unchanged and over .90 with both instruments. Elimination of three items from the control dimension had little effect on the reliability with which control was estimated at the individual and group level by the expert raters. However, for psychological demand, the 13-item instrument was approximately 15 percent less reliable than the 18-item version. Eliminating the two items "hard" and "fast" from the psychological demand dimension may be responsible for lower reliability with the 13-item instrument. The reliability of the group of four experts for psychological demand was still "good" for the 13-item instrument. And, in spite of this reduction in reliability, as shown in table 28, the sensitivity and specificity of the 13-item instrument using both the control and psychological demand constructs was nearly 90 percent.

It should be noted that the sensitivity and specificity test as well as the reliability comparison for the 13 and 18-item instruments were carried out for 1997 estimations. For 1965 estimations, with the 13-item instrument, group reliability for control was similar to 1997 estimations but was 16 percent less (0.53 versus 0.63) for psychological demand. Therefore, although the sensitivity and specificity for 1965 estimations with the 13-item instrument will likely be less than for the 1997 estimations because of the lower reliability with which psychological demand was estimated, it will likely be adequate for this investigation.

8.4.2 Validity of the Expert Rating Method

The main purpose of conducting estimates at two time periods was to determine the extent of change, if any, in psychosocial working conditions over time. As outlined in the methods, a two-step process was used to describe differences in job strain between the two time periods. Table 30 shows the 1965 job strain scores for the 20 eliminated or rare jobs compared to the 66 un-eliminated jobs.

Table 30: Mean 1965 Psychosocial Work Condition Scores for Eliminated or Rare Jobs Compared to those Remaining in the Industry

Variable	20 Eliminated or Rare Jobs	66 Un-eliminated Jobs
Control	16.8	20.2
Psychological demand	6.8	7.0
Physical demand	2.8	2.5
Co-worker social support	5.2	5.5
Noise	2.7	2.5

In 1965, jobs that were later eliminated or became rare had control, psychological demand, and social support scores that were, respectively, 15, 3, and 6 percent less than for job titles retained in the industry. In contrast, scores for physical demand and noise were seven percent greater in eliminated or rare jobs. In other words, except for psychological demand, jobs which were eliminated in the industry with technological change had worse psychological conditions of work , on average, than those jobs which were not eliminated.

In the second step, the within-job title change in psychosocial working conditions was determined for the job title list of 54 and tested for statistical significance using paired t-tests (table 31).

Table 31: Comparison of Mean 1965 and 1997 Job Strain Scores Using a Paired t-Test

Variable	t-Test	P-value	Mean Difference[1]	Absolute
Control	-2.58	0.013	0.56	3.0%
Psychological demand	5.44	0.000	-0.40	-5.6%
Physical demand	3.55	0.001	-0.16	-6.4%
Co-worker social support	0.18	0.860	0.00	0.0
Noise	-1.33	0.189	0.07	3.0%

[1] Mean and absolute difference calculated by (1997 score - 1965 score).

While scores for control and physical and psychological demand were significantly different for the two time periods, absolute differences were small. On a scale 24 units in length, control was 0.5 units greater in 1997 than in 1965. The absolute decrease in physical demand from 1965 to 1997 was 0.2 on a 4-point scale, and the absolute decrease in psychological demand was approximately 0.4 on scale 9-point scale. These small absolute differences indicate that for job titles common through most of the study period, there was, on average, very little change in the rating of psychosocial conditions of work between 1965 and 1997 providing evidence to support the method of attributing scores estimated for 1965 to job titles throughout the study time period. These empirical results are congruent with the qualitative results obtained in Chapter 4.

8.4.3 Potential for Management Bias

For both 1965 and 1997 estimations for all variables, paired t-tests revealed no significant differences in job strain among the three industry raters. To determine if there were systematic differences between the industry and union raters, the scores for 5 psychosocial variables were averaged for the 3 industry raters and compared to the union rater's scores using paired t-tests. The results of this analysis are shown in table 32.

Table 32: Comparison of Psychosocial Work Conditions between Three Industry Raters and a Single Union Rater Using Paired t-Tests

	Year of Estimate					
Variable	**1965**			**1997**		
	Union	**Industry**	**p-value**	**Union**	**Industry**	**p-value**
Control	19.0	20.0	0.000	20.0	20.9	0.016
Psychological Demand	6.5	7.0	0.000	6.3	6.7	0.000
Physical Demand	2.7	2. 6	0.020	2.5	2.3	0.013
Co-worker social support	5.7	5.5	0.005	5.4	5.5	0.800
Noise	2.6	2.7	0.780	2.6	2.7	0.450

Statistically, there were differences between the union rater and the three industry raters for all variables except noise for both time periods and co-worker social support for 1997 estimates. The magnitude and direction of the differences were similar in both time periods. For both time periods, the union rater gave control and psychological demand lower scores and physical demand higher scores than did industry raters.

Differences in score between the three industry raters and the single union rater were more marked for the 1965 estimations. In terms of absolute differences for 1965 estimations, the union rater scored control and psychological demand 5.2 and 8.4 percent lower than the industry raters, respectively. The union rater also scored physical demand and co-worker social support, 5.5 and 6 percent higher than the industry raters, respectively.

Although scores for the union rater were different from the three industry raters these were not predictable on the basis of the vested interest of the raters. In other words, the union rater estimated control lower than industry raters and physical demand higher perhaps indicating a more negative view of these two psychosocial work conditions than the industry experts. But, at the same time he rated psychological demand lower and co-worker social support higher providing a more positive view of these two work conditions. Differences were small in absolute terms and not systematically skewed in an expected or vested direction and therefore could have been due as much to the different personality of the union rater as to any bias.

8.4.4 Concurrent and Predictive Validity of Expert Estimates

As outlined in section 7.4.3, a supplementary analysis was undertaken to determine concurrent and predictive validity for the expert rater method using direct and pooled self-reports from 30 sawmill workers obtained in a study of unemployment. Concurrent validity was measured by comparing 1997 expert rater scores with 1997 direct and pooled self-reports using Pearson correlation (table 33).

Table 33. Pair-wise Pearson Correlation Coefficients for Three Methods for Estimating Psychosocial Conditions of Work

	4 Experts	Pooled	Direct
Control			
4 Experts	1	0.56**	0.52**
Pooled		1	0.60**
Psychological Demand			
4 Experts	1	0.22	0.05
Pooled		1	0.44*
Physical Demand			
4 Experts	1	0.61**	0.24
Pooled		1	0.44**
Co-worker Social Support			
4 Experts	1	0.79**	0.66**
Pooled		1	0.51**
Noise			
4 Experts	1	0.55**	0.59**
Pooled		1	0.71**

Pooled=Pooled self-reports and Direct=Direct self-reports; **P<0.01

Correlations for the expert raters with pooled self-reports were statistically significant at p<0.01 for all variables except psychological demand . And, correlations for the expert raters with direct self-reports were statistically significant at p<0.01 for all variables except psychological and physical demand.

Using direct and pooled self-reports as the "gold standard", these results indicate that for control, co-worker social support, and noise, the expert rating method demonstrates concurrent validity. Concurrent validity for physical demand was demonstrated for pooled self-reports only as the correlation between direct self-reports of physical demand and expert estimates of this were not statistically significant. Concurrent validity was not demonstrated for psychological demand.

The predictive validity of the expert rating method was assessed with self-reported health status as the outcome variable (table 34). (Self-reported health status was measured on a 5-point scale: 1=excellent; 2=very good; 3=good; 4=poor; 5=bad).

Table 34: Regression of Direct Self-reports for Psychosocial Work Conditions with Self-reported Health Status

	Univariate Analyses			
	R	**Adj. R^2**	**Beta**	**P-value**
Control	0.33	0.07	-0.33	0.13
Ps	0.50	0.21	0.50	0.016
Ph	0.60	0.32	0.59	0.003
Social	0.43	0.14	-0.43	0.04
Noise	0.41	0.13	0.41	0.051
	Multivariate Analyses			
	R	**Adj. R^2**	**Beta**	**P-value**
Ph	0.60	0.32	0.59	0.003

Adj. R^2= Adjusted R^2; Ps = Psychological demand; Ph = Physical demand; Social = Co-worker social support.

The univariate analyses indicates that psychological and physical demand and co-worker social support measured as a direct self-report predicted self-reported health status. The Beta values for psychological and physical demand were positive and for co-worker social support negative. Increased psychosocial and physical demand were associated with lower health status and increased co-worker social support was associated with higher health status. When these three statistically significant variables competed for entry in a multivariate model, self-reported physical demand was the best predictor of health status.

Table 35 shows the regressions for pooled self-reports with psychosocial variables.

Table 35: Regression of Pooled Self-reports for Psychosocial Work Conditions with Self-reported Health Status

	Univariate Analyses			
	R	**Adj. R^2**	**Beta**	**P-value**
Control	0.36	0.090	-0.36	0.088
Ps	0.01	-0.050	0.01	0.960
Ph	0.28	0.040	0.28	0.190
Social	0.14	-0.030	-0.14	0.516
Noise	0.33	0.070	0.33	0.130

Adj. R^2= Adjusted R^2; Ps = Psychological demand; Ph = Physical demand; Social = Co-worker social support.

No multivariate analysis was conducted as univariate analyses showed that none of the psychosocial work condition variables measured as a pooled self-report predicted health status.

Table 36: Regression of Four Expert Rater Reports for Psychosocial Work Conditions with Self-reported Health Status

Univariate Analyses				
	R	**Adj. R^2**	**Beta**	**P-value**
Control	0.44	0.16	-0.44	0.035
Ps	0.14	-0.03	-0.14	0.521
Ph	0.38	0.11	0.38	0.073
Social	0.22	0.01	-0.22	0.314
Noise	0.24	0.01	0.24	0.279
Multivariate Analyses				
	R	**Adj. R^2**	**Beta**	**P-value**
Control	0.44	0.16	-0.44	0.035

Adj. R^2= Adjusted R^2; Ps = Psychological demand; Ph = Physical demand; Social = Co-worker social support.

Table 36 indicates that control estimated by the expert raters predicted self-reported health status. Beta was negative indicating that increasing control was associated with better health status.

These results demonstrate the concurrent validity of the expert rater method used in this dissertation for all psychosocial work conditions assessed except psychological demand. In terms of predictive validity, control measured by the expert raters predicted self-reported health status in the 30 workers. Workers with high control jobs had better self-reported health than workers with low control jobs.

These validity tests were conducted with 1997 estimations so that extrapolation of results to the validity of the retrospective estimations must be performed cautiously. Clearly, control, physical demand, co-worker social support and noise demonstrated reliability and concurrent validity for 1997 estimations. As well, control demonstrated predictive validity. The similarity in reliability results for these four variables for 1965 and 1997 estimations (and the fact that all were estimated with "excellent" reliability), increases the probability that they will also demonstrate concurrent validity for the 1965 estimations.

In contrast, lack of concurrent validity for psychological demand for 1997 estimations in conjunction with lower reliability for this dimension for 1965 compared to 1997 estimations demonstrate that concurrent validity of this dimension for 1965 estimations is unlikely. However, this must be qualified because the concurrent and predictive validity tests involved 30 of 86 job titles; not a comprehensive validity check. This uncertainty and the "good" reliability results for psychological demand with the four expert raters as a group provides a rationale for using this variable in the subsequent analyses.

8.5 Standardised Mortality Raio Analysis

Including person-years to 1990 may cause underestimation of standardised mortality ratios (SMRs), while including only person-years to last known year alive will tend to inflate them. Accordingly, SMR analyses for major causes of mortality in the cohort were performed using both assumptions (table 37).

Table 37: Standardised Mortality Ratios and 95 Percent Confidence Intervals for Major Causes of Mortality in the Sawmill Cohort

	To Last Known Year				To 1990	
Cause of Death	**Obs**	**Exp**	**SMR**	**CI**	**SMR**	**CI**
All causes	4,640	4,508.2	102.9	(100.0-105.9)	81.4**	(79.0-83.7)
Atherosclerosis	1,395	1,348.0	103.5	(98.1-109.1)	82.5**	(78.3-87.0)
Cerebrovascular accid.	292	279.8	104.3	(92.7-117.0)	79.8**	(70.9-89.5)
Disease of Circulation	133	125.9	105.7	(88.5-125.2)	80.4**	(67.3-95.3)
Hypertension	35	41.0	85.4	(59.5-118.7)	70.5**	(49.1-98.0)
Other disease of heart	119	80.1	148.5**	(123.0-177.7)	107.5	(89.1-128.7)
All accidents	435	512.4	84.9**	(77.1-93.3)	70.0**	(63.5-76.8)
Suicides	145	149.17	97.2	(82.0-114.4)	79.2**	(66.8-93.1)
Cirrhosis of liver	77	107.4	71.7**	(56.6-89.6)	58.1**	(45.8-72.6)
Diabetes	46	52.1	88.3	(64.6-117.8)	68.0**	(50.1-90.1)
All cancers	1,172	1,036.7	113.1**	(106.7-119.7)	89.2**	(84.2-94.5)
Lung cancer	372	325.1	114.1*	(103.1-126.7	91.1	(82.0-100.8)
Cancer: Bladder	33	28.7	115.1	(79.2-161.6)	88.9	(61.2-124.8)
Cancer: Pancreas	63	61.2	103.0	(79.1-131.8)	82.3	(63.2-105.2)
Pneumonia	68	97.9	69.5**	(54.0-88.1)	51.1**	(39.7-64.7)
Bronchitis & Emphysema	86	100.1	85.9	(68.7-106.1)	68.5**	(54.8-84.6)

Cancer: Stomach	79	77.4	102.1	(80.9-127.3)	83.4	(66.0-103.9)
Cancer: Colon	96	79.5	120.8	(97.8-147.5)	95.3	(77.2-116.4)
Cancer: Prostate	113	86.8	130.2	(107.3-156.5)	96.7	(79.7-116.3)

Obs= Number of observed deaths; Exp= Number of expected deaths; SMR=Standardised Mortality Ratio standardised using 5 year age and calendar periods and BCDVS cause-specific mortality rates for the B.C. general population. CI= 95 percent confidence intervals. P<0.05; ** P<0.01.

For the analysis to last known year alive, SMRs for 12 out of 19 major causes of death were greater than 100. For most industrial cohorts, SMRs are in the range of .70 to .90. due to the healthy worker effect. As outlined in section 6.5.2, although 39 percent of the cohort have unknown vital status, most of these were likely alive in 1990. This fact and the inflated SMRs for most causes of death in the analysis with follow up to last known year indicates that follow up to 1990, although a more conservative approach, is appropriate for this investigation .

When person-years to 1990 are included in the analysis, SMRs for major causes of death lie between 51.1 for pneumonia and 107.5 for other diseases of the heart. In terms of CHD, atherosclerosis, hypertension, and disease of circulation, SMRs were between 70.5 and 82.5. The SMR for other diseases of the heart was 107.5 but this was not statistically significant. The SMRs for all CHD except other diseases of the heart were statistically significant.

With follow-up to 1990, for all causes, CVA, accidental deaths, and suicidal deaths, SMRs were 81.4, 79.8, 70.0, 79.2, respectively. For these causes of death confidence intervals did not include one.

While most SMRs with follow-up to 1990 were low there were some that were greater than 100 (see table 38).

Table 38: Standardised Mortality Ratios and 95 Percent Confidence Intervals for Causes of Mortality with SMRs > 100 (to 1990)

Cause of Death	Obs	Exp	SMR	95% CI
Cancer: Lip	1	0.95	105.3	(2.6-586.6)
Cancer: Pharynx Unspecified	5	4.48	111.5	(36.2-260.3)
Cancer: Bone	5	4.06	123.2	(40.0-287.4)
Cancer: Soft Tissue	6	5.37	111.7	(41.0-243.2)
Cancer: Melanoma	17	15.65	108.6	(63.3-173.9)
Cancer: Kidney	40	34.57	115.7	(82.7-157.6)
Cancer: Eye	3	1.49	201.0	(41.5-587.5)
Cancer: Other Endocrine	4	2.21	181.1	(49.3-463.6)
Cancer: Lymphosarcoma	22	18.44	119.3	(74.8-180.6)
Acute upper respiratory infection	10	3.10	322.8**	(154.8-593.6)
Other Infectious respiratory disease	3	0.82	364.7	(75.2-1065.6)
Pleurisy	1	0.79	126.1	(3.2-702.4)
Hypostasis of the lung	2	1.93	103.4	(12.5-373.7)

Obs= Number of observed deaths; Exp= Number of expected deaths; SMR=Standardised Mortality Ratio standardised using 5 year age and calendar periods and BCDVS cause-specific mortality rates for the B.C. general population. CI= 95 percent confidence intervals. P<0.05; ** P<0.01.

Raised SMRs for cancer of the lip and the pharynx (unspecified), acute respiratory infections, other infectious respiratory disease, pleurisy, and hypostasis of the lung might point to the impact of smoking in this cohort. This is unlikely for two reasons. First, SMRs for these causes of death are based on very small numbers, and second, SMRs for lung cancer and heart disease (causes of death which are both smoking-related and have an adequate number of deaths) were not elevated.

It is not clear why the other causes of death are elevated in this table. One might expect elevated levels of melanoma in a cohort of workers like this where a large proportion work outside. In the chlorophenol analysis, higher incidence of lymphosarcoma and soft tissue cancer were not related to chlorophenol exposure (Hertzman and others 1996) and so remain unexplained. Interestingly, in terms of high rates of eye cancer, a study of the effects of chlorophenols on the offspring of fathers in the original cohort found elevated rates of congenital ocular abnormalities in the children of fathers with high chlorophenol exposure (Dimich-Ward and others 1997).

The SMR analyses indicate that among the outcomes of interest (atherosclerosis, CVA, all cause mortality, accidental and suicidal mortality) SMRs remain within the usual range found for blue-collar industrial workers. In order to explore any relationships between exposure to psychosocial work conditions and these outcomes Poisson and logistic regression analyses were undertaken. As outlined in section 7.6., regression analyses were conducted with follow up to 5 and 10 years post-employment at a study sawmill. Before moving to these analyses table 39 compares SMRs for follow up to 1990, and 5- and 10-years post-employment to determine whether restriction of follow-up affected SMRs.

Table 39: SMRs for Job-Strain Related Causes of Death by Follow-up Period

Follow-up	To 1990			10-Year			5-Year		
Cause of Death	Obs	SMR	(95% CI)	Obs	SMR	(95% CI)	Obs	SMR	(95% CI
Atherosclerosis	1,395	82.5**	(78.3-87.0)	719	83.0**	(77.0-89.3)	479	81.2**	(74.1-88.9)
CVA	292	79.8**	(70.9-89.5)	117	74.5**	(61.6-89.3)	69	70.7**	(55.0-89.5)
Suicide	145	79.2**	(66.8-93.1)	99	76.3**	(62.0-92.9)	76	78.5*	(61.9-98.3)
Accidents	435	70.0**	(63.5-76.8)	303	66.4**	(59.1-74.3)	248	71.5**	(62.9-81.0)
All cause	4,640	81.4**	(79.0-83.7)	2,373	78.9**	(75.8-82.2)	1,613	77.7**	(73.9-81.5)

Obs= Number of observed deaths; Exp= Number of expected deaths; SMR=Standardised Mortality Ratio standardised using 5 year age and calendar periods and BCDVS cause-specific mortality rates for the B.C. general population. CI= 95 percent confidence intervals. P<0.05; ** P<0.01.

SMRs tend to drop with less follow-up, probably because of the healthy worker selection effect (Checkoway 1989). In the case of CVA the relatively large decrease in SMRs for 5 and 10 year follow-up probably occur because such a restriction excludes CVA deaths among the very old so that SMRs with less follow-up represent mortality among younger workers. Except for CVA, restriction of follow-up exerts very little effect on SMRs.

8.6 Poisson Regression Analyses

As outlined in the methods section, using Poisson regression, univariate analyses were first run for each of the five mortality outcomes using all eight independent variables. The five psychosocial work condition variables were controlled for age and calendar period and for age, calendar period, and duration of employment in univariate models. Next a multivariate model was run (Model 1) by first forcing age and calendar period into the model and then offering, in a forward stepwise regression (with $p<0.05$ as the entry criterion) variables which were statistically significant in the univariate analysis. Model 1 was run for all five outcomes.

A final multivariate model (Model 2) was run by first forcing age, calendar period, and duration of exposure into the model and then offering, as in Model 1, the variables which were significant in univariate analysis. Model 2 was run for all five outcomes. To explore the possibility of a latent effect for cumulative exposure to psychosocial work condition variables, lagged analyses were run with 5, 10, 15 and 20 year intervals for atherosclerosis with both 5- and 10-years of follow-up. And because, according to the demand/control model, control interacts multiplicatively with psychological demand a multiplicative interaction terms (Interact 1) was run for all univariate and multivariate analyses. And, similarly because social support is postulated to moderate psychological demands a multiplicative interaction term (Interact 2) with these two variables was also run.

Table 40 presents Poisson regression results for univariate and multivariate models with atherosclerosis for 5-year follow-up and latency intervals of 0, 5, and 10 years. (Models for 15- and 20-year latency intervals were also run but the results are not shown because they do not differ from the 10-year latency results.)

Table 40: Univariate Analysis Using Poisson Regression for Atherosclerosis by Latency Period (Five-Year Follow-up).

LATENCY PERIOD	0-Years		5-Years		10-Years	
Variable	**IRR**	**CI**	**IRR**	**CI**	**IRR**	**CI**
Duration	2.44	2.19-2.72	2.42	2.12-2.76	2.42	1.95-3.00
Calendar	0.99	0.95-1.03	0.96	0.93-1.01	0.95	0.90-0.99
Age	1.85	1.77-1.94	1.82	1.73-1.91	1.79	1.69-1.90
Control a*	1.06	0.94-1.18	0.99	0.87-1.13	0.96	0.81-1.15
Control b**	0.96	0.79-1.18	0.96	0.79-1.18	0.96	0.76-1.21
Ps a	1.07	0.95-1.20	1.00	0.88-1.14	1.01	0.85-1.21
Ps b	1.00	0.81-1.23	0.98	0.80-1.21	1.05	0.82-1.33
Physical a	1.09	0.97-1.22	1.03	0.90-1.17	1.07	0.89-1.30
Physical b	1.06	0.87-1.29	1.04	0.86-1.27	1.13	0.90-1.43
Social a	1.06	0.95-1.19	0.99	0.87-1.13	0.99	0.83-1.19
Social b	0.98	0.80-1.20	0.96	0.79-1.18	1.01	0.80-1.28
Noise a	1.03	0.93-1.15	0.96	0.85-1.09	0.96	0.81-1.14
Noise b	0.92	0.77-1.10	0.90	0.75-1.08	0.96	0.78-1.18
Int1 a	1.01	0.99-1.03	1.00	0.98-1.02	1.00	0.97-1.03
Int1 b	0.99	0.95-1.02	0.99	0.95-1.03	1.00	0.96-1.04
Int2 a	1.01	0.99-1.03	1.00	0.98-1.02	0.99	0.96-1.02
Int2 b	0.99	0.96-1.03	0.99	0.97-1.02	0.99	0.96-1.02

* a= Variable controlled for age and calendar period; **b=variable controlled for age, calendar period, and duration of employment.

Physical=Physical demand; Ps=Psychological demand; Social=Co-worker social support; IRR= Incidence Rate Ratio; CI= 95 percent Confidence Interval. Int1=control*ps; Int2=control*social.

Table 41: Multivariate Analysis Using Poisson Regression for Atherosclerosis by Latency Period (Five-Year Follow-up).

		Model 1		Model 2	
Latency	**Variable**	**IRR**	**CI**	**IRR**	**CI**
0 years	Calendar	0.96	0.92-1.01	0.96	0.91-0.99
	Age	1.86	1.77-1.94	1.83	1.74-1.93
	Duration			1.08	0.96-1.22
5 years	Calendar	0.96	0.91-1.00	0.95	0.91-1.00
	Age	1.82	1.73-1.92	1.82	1.72-1.92
	Duration			1.01	0.87-1.17
10 years	Calendar	0.94	0.90-0.98	0.94	0.90-0.99
	Age	1.79	1.69-1.90	1.80	1.69-1.91
	Duration			0.97	0.77-1.22

Table 42 repeats the analysis with 10 years of follow-up.

Table 42: Univariate Analysis using Poisson Regression for Atherosclerosis by Latency Period (Ten-Year Follow-up)

LATENCY PERIOD	0-Years		5-Years		10-Years	
Variable	**IRR**	**CI**	**IRR**	**CI**	**IRR**	**CI**
Duration	2.74	2.49-3.02	2.76	2.46-3.09	3.41	2.81-4.14
Calendar	1.01	0.98-1.05	0.98	0.95-1.01	0.96	0.93-0.99
Age	1.78	1.72-1.84	1.75	1.70-1.82	1.72	1.65-1.79
Control a*	1.07	0.97-1.18	1.02	0.92-1.13	0.98	0.86-1.11
Control b**	1.02	0.87-1.17	1.00	0.87-1.15	0.99	0.85-1.17
Ps a	1.04	0.95-1.14	0.99	0.90-1.09	0.96	0.85-1.08
Ps b	0.96	0.83-1.10	0.95	0.83-1.09	0.95	0.82-1.11
Physical a	1.03	0.94-1.13	0.99	0.81-1.09	0.97	0.85-1.09
Physical b	0.94	0.82-1.07	0.95	0.83-1.08	0.97	0.83-1.13
Social a	1.04	0.95-1.14	0.99	0.89-1.09	0.95	0.84-1.08
Social b	0.95	0.83-1.09	0.95	0.83-1.08	0.95	0.82-1.12
Noise a	1.02	0.93-1.11	0.97	0.88-1.07		0.84-1.07
Noise b	0.92	0.81-1.04	0.92	0.81-1.05	0.95	0.82-1.10
Intl a	1.01	0.99-1.03	0.99	0.97-1.02	0.99	0.97-1.02
Intl b	0.99	0.97-1.02	0.99	0.97-1.02	0.99	0.97-1.02
Int2 a	1.01	0.99-1.02	1.00	0.98-1.02	0.99	0.97-1.02
Int2 b	0.99	0.96-1.01	0.99	0.97-1.02	0.99	0.97-1.02

* a= Variable controlled for age and calendar period; b=variable controlled for age, calendar period, and duration of employment.

Physical=Physical demand; Ps=Psychological demand; Social=Co-worker social support; IRR= Incidence Rate Ratio; CI= 95 percent Confidence Interval. Int1=control*ps; Int2=control*social.

Table 43: Multivariate Analysis Using Poisson Regression for Atherosclerosis by Latency Period (Ten-Year Follow-up).

		Model 1		Model 2	
Latency	**Variable**	**IRR**	**CI**	**IRR**	**CI**
0 years	Calendar	0.96	0.92-0.99	0.94	0.92-0.99
	Age	1.73	1.73-1.85	1.76	1.70-.1.83
	Duration			1.09	0.99-1.21
5 years	Calendar	0.95	0.92-0.99	0.95	0.91-0.98
	Age	1.76	1.70-1.83	1.76	1.69-1.82
	Duration			1.03	0.91-1.16
10 years	Calendar	0.94	0.90-0.98	0.94	0.90-0.97
	Age	1.73	1.66-1.80	1.73	1.66-1.81
	Duration			0.95	0.77-1.18

Univariate analysis with both five and ten years of follow-up and with latency periods of 0, 5, 10, 15, and 20 years showed no statistically significant associations between psychosocial work condition variables and atherosclerosis. Comparison of the results of univariate analysis for 5 and 10 years follow-up shows that the strength of association between psychosocial variables and atherosclerosis was similar but that confidence intervals for the 10 year follow-up were marginally narrower than for the 5 year follow-up.

While the 10 year follow-up was more precise, absolute differences both in the size of incidence rate ratios (IRRs) and the width of confidence intervals were minimal compared to analyses with 5 years follow-up. Also, in this analysis, 10 compared to 5 years of follow-up likely results in more misclassification so that the slightly increased precision with 10 years of follow-up was likely obtained at the cost of increased misclassification.

Univariate analyses for both five and ten years of follow-up with latency intervals of 0, 5, 10, 15, and 20 years showed statistically significant associations for both age and duration of employment with death from atherosclerosis. These associations were positive indicating that the incidence rate ratio for mortality from atherosclerosis increased with increasing age and duration of employment. For calendar period statistically significant results were obtained only with latency intervals of 10, 15, and 20 years for both 5 and 10 years follow-up. The effect of calendar period was negative indicating increasing calendar period was associated with a decrease in mortality from atherosclerosis. As in the case of psychosocial variables, differences in the size of incidence rate ratios and the width of confidence intervals were minimal for age, calendar period, and duration of employment across all combinations of latency intervals and follow-up periods in the univariate analyses.

The multivariate models with both 5 and 10 years of follow-up and with latency intervals of 0, 5, 10, 15, and 20 years showed IRRs for age ranging from 1.73 to 1.86 and in all cases with confidence intervals which did not include one. Confidence intervals for duration of employment included one in all multivariate models. For multivariate models, IRRs for calendar period ranged from 0.94 to 0.96. The variable calendar period was statistically significant for all multivariate models except for the model with 5 years latency period and 5 years of follow-up.

With follow-up of 5- and 10-years, and no lagging the only variables with statistically significant multivariate association with atherosclerosis were age and calendar period. The largest effect size was produced by age. Incidence rate ratios of 1.83 and 1.76 respectively for 5-year and 10- year follow-up indicate that each 5-year increase in age produced an approximately 80 percent increase in the rate of mortality from atherosclerosis. Similarly incidence rate ratios of 0.96 and 0.94 respectively for 5-year and 10-year follow-up indicate that each 5-year increase in calendar period (between the 1950 and 1990) was associated with a 4 to 6 percent decrease in the rate of mortality from atherosclerosis.

Incidence rate ratios and confidence intervals for psychosocial variables were of similar size and direction in all analyses indicating the possibility that these variables may be highly correlated. Table 44 presents Pearson correlation coefficients for these variables as well as age, calendar period, and duration of employment.

Table 44: Pearson Correlations for Cumulative Psychosocial Variables

	Control	Ps	Ph	Social	Noise	Age	Dur	Calendar
Control	1.00							
Ps	0.97	1.00						
Physical	0.93	0.95	1.00					
Social	0.97	0.97	0.94	1.00				
Noise	0.93	0.95	0.96	0.94	1.00			
Age	.63	.63	.61	.63	.61	1.00		
Duration	.75	.76	.74	.76	.75	.63	1.00	
Calendar	0.07*	0.07*	0.06*	0.06*	0.06*	0.01*	0.20	1.00

Ps = Psychological demand; Dur= Duration of employment; Social = Co-worker social support.* Non-significant. Remaining correlations were statistically significant at the 0.01 level (2-tailed).

The five psychosocial variables are highly correlated with each other and with duration and age. According to (Armitage and Berry 1994, 323) problems of collinearity may be resolved in two ways. First, if the problems are computational, collinear variables can be re-scaled to reduce their correlation. Second, if correlations cannot be reduced in this way, principle components factor analysis with rotation may be undertaken to generate uncorrelated "principle components" which can then be used in the analysis (Selvin 1995).

Using the first approach, psychosocial variables were re-scaled by subtracting the minimum value of each variable from the score thereby "zeroing" each scale. These zeroed scores were cumulated and Pearson correlation coefficients calculated. After re-scaling, correlations were similar to those obtained in table 44. Because duration is a major component of the cumulative scores for each variable re-scaling does not appreciably reduce correlations between variables. Therefore the problem of collinearity was not resolved by this computational manipulation.

Using the second approach, factor analysis, with varimax rotation was conducted with the cumulated scores for the five psychosocial variables using STATA on a personal computer. Only one factor was extracted accounting for 97.2 percent of variance indicating that the five psychosocial variables did not resolve into principle components. Both approaches, re-scaling and factor analysis, were unsuccessful in reducing the correlations among variables.

Further Poisson models were run with outcomes all-cause mortality, accident and suicide mortality and CVA mortality. However, because of the correlations between duration of employment and all psychosocial variables when psychosocial variables enter models, results were uninterpretable. Univariate results for accidental mortality with 10 years of follow-up are presented in table 45 and multivariate results in table 46 to illustrate this problem of model uninterpretability.

Table 45: Poisson Regression for Accidental Mortality: Univariate Analysis with 5- and 10-Years Follow-up

Variable	5-year IRR	5-year CIs	10-year IRR	10-year CIs
Duration	0.73	0.65-0.82	0.78	0.71-0.86
Calendar	1.01	0.95-1.07	1.00	0.95-1.06
Age	0.90	0.86-0.94	0.92	0.88-0.96
Control a*	0.68	0.58-0.79	0.76	0.67-0.86
Control b**	0.67	0.54-0.84	0.80	0.68-0.93
Ps a	0.67	0.58-0.78	0.78	0.69-0.88
Ps b	0.65	0.53-0.81	0.83	0.71-0.96
Physical a	0.69	0.59-0.79	0.79	0.69-0.90
Physical b	0.68	0.55-0.83	0.84	0.72-0.98
Social a	0.70	0.60-0.81	0.79	0.69-0.89
Social b	0.70	0.56-0.88	0.84	0.72-0.98
Noise a	0.68	0.59-0.79	0.81	0.71-0.92
Noise b	0.67	0.54-0.83	0.87	0.74-1.01
Int1 a	0.92	0.89-0.95	0.94	0.92-0.97
Int1 b	0.91	0.87-0.96	0.95	0.92-0.98
Int2 a	0.92	0.89-0.95	0.94	0.92-0.97
Int2 b	0.92	0.88-0.97	0.95	0.92-0.98

* a= Variable controlled for age and calendar period; **b=variable controlled for age, calendar period, and duration of employment.
Physical=Physical demand; Ps=Psychological demand; Social=Co-worker social support; IRR= Incidence Rate Ratio; CI= 95 percent Confidence Interval. Int1=control*ps; Int2=control*social.

These univariate results show that incidence rate ratios and confidence intervals for the 5 psychosocial variables were virtually the same. In the multivariate analyses, when these 5 psychosocial variables were offered in a step wise fashion, control was selected. However, when control was held back from the selection process then psychological demand entered the model. When, in turn, psychological demand was held back from the selection process, then physical demand entered the model and so on. The high correlation between variables makes the results of this multivariate modeling meaningless.

In the multivariate model shown below (Table 46) it is also clear that duration of employment and cumulative control are highly correlated (0.75) as these variables were virtually interchangeable. In Model 1a duration was forced into the model along with calendar period and age. In Model 1b control was forced in with the two latter variables. And, in Model 1c, all four variables were forced into the model. Without control in the model, duration was almost as protective for accidental mortality. And, in Model 1c when both control and duration were forced into the model, the effect size for both was reduced and confidence interval for duration of employment included one. These results indicate that the effects of cumulative control in these models is mainly an effect of exposure duration.

Table 46: Poisson Regression for Accident Mortality: Multivariate Analysis with 10- Years of Follow-up

	Model 1a		**Model 1b**		**Model 1c**	
Variable	**IRR**	**CIs**	**IRR**	**CIs**	**IRR**	**CIs**
Calendar	1.03	0.97-1.09	1.01	0.96-1.07	1.03	0.97-1.08
Age	0.97	0.92-1.03	0.98	0.93-1.04	0.99	0.94-1.05
Duration	0.80	0.70-0.92			0.91	0.78-1.06
Control			0.76	0.67-0.86	0.79	0.68-0.93

Because of collinearity between variables Poisson regression modeling with cumulative psychosocial variables for outcomes other than CHD was discontinued. In the next section logistic regression with time-weighted average psychosocial exposures are modeled.

8.7 Logistic Regression Analyses

Correlations between variables used in the logistic regression models were first performed in order to determine whether these average exposure variables were also collinear (Table 47)

Table 47: Pearson Correlations for Time-weighted Average Psychosocial Variables

	Con	Ps	Ph	Social	Noise	Age	Year	Dur
Control	1.00							
Ps	0.15	1.00						
Physical	-0.66	0.11	1.00					
Social	0.45	-0.05	-0.35	1.00				
Noise	-0.49	0.19	0.54	-0.20	1.00			
Age hired	0.20	-0.08	-0.15	0.08	-0.17	1.00		
Year hired	-0.10	0.03	0.13	-0.01*	0.06	-0.23	1.00	
Duration	0.20	0.05	-0.22	-0.05	-0.10	0.09	-0.55	1.00

Ps = Psychological demand; Dur= Duration of employment; Social = Co-worker social support.* Non-significant. Remaining correlations were statistically significant at the 0.01 level (2-tailed).

The largest correlation was -0.66 between physical demand and control. Although all but one correlation was statistically significant, correlations among averaged psychosocial exposure variables were very low compared with those for cumulative variables ensuring that problems of collinearity among variables did not occur for logistic regression models.

The distribution of TWA score for the five psychosocial variables is shown in table 48. In order to compare these distributions with each other, scores for all variables were converted to a scale from 0 to 100.

Table 48: Distribution of Psychosocial Variables Using a Scale of 100 Units

	Quartile					
Variable	**25th**	**50th**	**75th**	**I-Q range**	**Mean**	**Median**
Control	27.4	34.9	66.8	39.4	40.8	34.9
Ps	54.8	58.4	62.8	8.0	58.8	58.4
Ph	41.7	52.9	62.3	20.6	50.5	52.8
Social	46.8	58.4	66.7	19.9	47.3	47.2
Noise	38.0	47.3	59.4	21.4	56.6	58.4

Ps = Psychological demand; Ph= Physical demand; Social = Co-worker social support; I-Q= Inter-quartile range.

Control exhibited the largest inter-quartile range and psychological demand the least. Comparison of means and medians shows that the distribution for control was skewed away from zero indicating that most sawmill jobs have low control scores. Scores for psychological demand were narrowly distributed around the mean. Distributions for co-worker social support, physical demand, and noise were broader (and similar to each other) compared to control and psychological demand.

Table 49 presents results of logistic regression using TWA exposures and with 5 and 10 years follow-up.

Table 49: Logistic Regression for Atherosclerosis: Univariate Analysis with 5- and 10- Years of Follow-up

Variable	5-year OR	5-year CIs	10-year OR	10-year CIs
Duration	1.06	1.05-1.07	1.06	1.05-1.07
Year hired	0.93	0.92-0.94	0.92	0.91-0.93
Age hired	1.06	1.06-1.07	1.08	1.07-1.09
Control a*	1.03	0.99-1.06	1.03	1.01-1.06
Control b**	1.01	0.98-1.04	1.01	0.99-1.04
Ps a	1.09	0.91-1.30	1.16	0.99-1.35
Ps b	1.03	0.87-1.23	1.10	0.95-1.28
Physical a	0.72	0.60-0.87	0.73	0.62-0.85
Physical b	0.83	0.68-1.01	0.83	0.70-0.98
Social a	0.95	0.81-1.11	0.98	0.86-1.11
Social b	0.97	0.83-1.12	0.99	0.87-1.13
Noise a	1.02	0.85-1.22	0.99	0.85-1.15
Noise b	1.07	0.89-1.29	1.04	0.90-1.22
Int1 a	1.00	1.00-1.00	1.01	1.00-1.01
Int1 b	1.00	0.99-1.01	1.01	1.00-1.01
Int2 a	1.00	0.99-1.00	1.01	1.00-1.01
Int2 b	1.00	0.99-1.01	1.01	1.00-1.01

* a= Model 1 (controlled for age hired and year hired); b**=Model 2 (controlled age hired, year hired, and duration of employment). Physical=Physical demand; Ps=Psychological demand; Social=Co-worker social support; OR= Odds Ratio; CI= 95 percent Confidence Interval. Int1=control*ps; Int2=control*social.

Table 50 presents results of multivariate analysis for atherosclerosis.

Table 50: Logistic Regression for Atherosclerosis: Multivariate Analysis with 5- and 10- Years of Follow-up

		Model 1		Model 2	
Follow-up	**Variable**	**OR**	**CIs**	**OR**	**CIs**
5 year	Year hire	0.93	0.92-0.94	0.96	0.95-0.97
	Age hire	1.07	1.06-1.08	1.09	1.08-1.10
	Duration			1.06	1.04-1.07
	Physical	0.62	0.49-0.78	0.72	0.57-0.92
	Noise	1.29	1.05-1.60	1.26	1.01-1.55
10 year	Year hire	0.93	0.92-0.94	0.95	0.94-0.96
	Age hire	1.08	1.07-1.09	1.10	1.09-1.11
	Duration			1.06	1.05-1.07
	Physical	0.73	0.62-0.85	0.74	0.61-0.90
	Noise	1.24	1.04-1.49	1.21	1.01-1.44

* All possible interactions between noise and physical demand and other psychosocial variables were offered in Models 1 and 2 after controlling for the main effects of noise and physical demand but none were statistically significant.

Statistically significant associations between physical demand and atherosclerosis were demonstrated in univariate analysis with ten years of follow-up. Odds ratios for physical demand were less than one indicating an inverse association with atherosclerosis. In the univariate model with five years of follow-up controlling for age hired and year hired, a statistically significant association between physical demand and atherosclerosis was demonstrated. But, with duration of employment also in the model the confidence interval for physical demand included one.

No other psychosocial variables showed statistically significant associations with atherosclerosis in univariate models. As in the case of the Poisson regression results, the strength of association between psychosocial variables and atherosclerosis was similar for 5 and 10 years follow-up but confidence intervals were marginally narrower for models with 10 years follow-up .

Univariate analyses for both five and ten years of follow-up showed statistically significant associations between age of hire, year of hire, and duration of employment and mortality from atherosclerosis. Odds ratios were greater than one for duration of employment and age of hire and less than one for year hired. As in the case of psychosocial variables, differences in the size of odds ratios and the width of confidence intervals were minimal for age hired, year hired, and duration of employment in models with 5 compared to 10 years follow-up.

The multivariate models with both 5 and 10 years of follow-up showed statistically significant associations for physical demand and noise with mortality from atherosclerosis. With 5 years of follow-up, controlling for age and year hired, the odds ratio for physical demand was 0.62 with confidence interval 0.49-0.78 and the odds ratio for noise was 1.29 with confidence interval 1.01-1.55. Adding duration of employment to the model decreased the strength of association for physical demand (OR=0.72) and noise (OR=1.26) and increased (marginally) the width of confidence intervals. For both models with 10 years of follow-up statistically significant associations with physical demand and noise were also observed.

For the models with 5 years follow-up the odds ratios indicate that, after controlling for age of hire, year of hire, and duration of employment, for every unit decrease in average physical demand the odds of death from atherosclerosis increases by 28 percent and with every unit increase in average noise exposure the odds increase by 26 percent.

The odds ratios for age hired ranged from 1.07 to 1.10 (depending on length of follow-up and controlled variables) indicating that each one year increase in this variable was associated with a 7 to 9 percent increase in CHD mortality. As well, odds ratios for duration of employment were 1.06 in all models indicating a 6 percent increase in CHD mortality for each year of employment. Finally, odds ratios for year hired ranged from 0.93 to 0.96 (depending on length of follow-up and controlled variables) indicating that CHD mortality decreased by 4 to 7 percent with each increase in year hired.

Comparison of age, calendar period, and duration of employment results obtained from Poisson and logistic regression, is difficult both because compared variables were not the same and because they were modeled in different ways. However, it is important to note that the direction of effect for year hired in the logistic regression and calendar period in the Poisson regression were similar. As well, the direction and magnitude of the effect of age hired and duration of employment in the logistic regression was similar to those obtained for age and duration of employment in the Poisson analysis.

In the multivariate logistic models, the R^2 value for average physical demand was approximately 0.001 indicating that physical demand accounted for approximately 0.1 percent of the variance in the model. The R^2 value for average noise exposure was approximately 0.004 indicating that noise exposure accounted for approximately 0.04 percent of total variance. In contrast, 7, 1.7, and 1.7 percent of total variance, respectively, was accounted for by age of hire, year of hire, and duration of employment.

Table 51 presents results of univariate modeling of average psychosocial job condition variables with cerebrovascular accidents.

Table 51: Logistic Regression for Cerebrovascular Accidents: Univariate Analysis with 5- and 10- Years of Follow-up

Variable	5-year OR	5-year CIs	10-year OR	10-year CIs
Duration	1.07	1.05-1.08	1.06	1.05-1.08
Year hired	0.93	0.91-0.94	0.92	0.91-0.93
Age hired	1.08	1.06-1.10	1.09	1.08-1.10
Control a*	1.04	0.96-1.14	1.04	0.99-1.10
Control b**	1.02	0.94-1.09	1.03	0.96-1.07
Ps a	1.20	0.76-1.90	1.42	1.02-2.00
Ps b	1.14	0.73-1.78	1.34	0.97-1.87
Physical a	1.20	0.72-2.02	1.09	0.74-1.58
Physical b	1.41	0.83-2.40	1.24	0.85-1.83
Social a	1.01	0.68-1.51	0.85	0.63-1.14
Social b	1.03	0.70-1.51	0.86	0.65-1.15
Noise a	1.30	0.82-2.08	1.09	0.77-1.53
Noise b	1.38	0.86-2.20	1.14	0.81-1.60
Int1 a	1.00	0.99-1.01	1.01	1.00-1.03
Int1 b	1.00	0.99-1.01	1.01	1.00-1.01
Int2 a	1.00	0.99-1.01	1.01	1.00-1.03
Int2 b	1.00	0.99-1.01	1.01	1.00-1.01

* a= Model 1 controlled for age hired and year hired;
**b=Model 2 controlled age hired, year hired, and duration of employment.
Physical=Physical demand; Ps=Psychological demand; Social=Co-worker social support; OR= Odds Ratio; CI= 95 percent Confidence Interval. Int1=control*ps; Int2=control*social.

Table 52 presents results for multivariate modeling with cerebrovascular accidents.

Table 52: Logistic Regression for Cerebrovascular Accident Mortality: Multivariate Analysis with 5 and 10 Years of Follow-up

		Model 1		Model 2	
Follow -up	**Variable**	**OR**	**CI**	**OR**	**CI**
5 year	Year hired	0.93	0.91-0.95	0.96	0.94-0.98
	Age hired	1.07	1.05-1.09	1.10	1.07-1.13
	Duration			1.06	1.03-1.09
10 year	Year hired	0.92	0.91-0.94	0.95	0.94-0.97
	Age hired	1.09	1.07-1.10	1.12	1.10-1.14
	Duration			1.07	1.04-1.10
	Ps	1.42	1.01-2.00		

Ps=Psychological demand.

Univariate results for cerebrovascular accidents were similar to those obtained with CHD for age hired, year hired, duration of employment, and control. For the remaining psychosocial variables odds ratios were larger than those obtained with CHD and all were greater than one. One univariate and one multivariate model with 10 years of follow-up demonstrated a statistically significant association between psychological demand and CVA controlling for age and year hire. In this model the odds ration was 1.42 indicating a 42 percent increase in CVA mortality for every unit increase in average psychological demand. On adding employment duration to this model, this statistically significant association disappeared in both the univariate and multivariate models.

Table 53 presents univariate results for all-cause mortality and table 54 presents multivariate results.

Table 53: Logistic Regression for All-Cause Mortality: Univariate Analysis with 5- and 10- Years of Follow-up

Variable	5-year OR	5-year CIs	10-year OR	10-year CIs
Duration	1.06	1.05-1.07	1.05	1.04-1.06
Year hired	0.94	0.93-0.95	0.94	0.93-0.95
Age hired	1.06	1.06-1.07	1.08	1.07-1.09
Control a*	1.02	1.00-1.04	1.01	1.00-1.03
Control b**	1.00	0.98-1.02	0.99	0.98-1.01
Ps a	0.95	0.85-1.06	0.99	0.90-1.09
Ps b	0.91	0.82-1.01	0.95	0.87-1.05
Physical a	0.80	0.71-0.90	0.83	0.75-0.92
Physical b	0.90	0.80-1.01	0.93	0.84-1.04
Social a	1.03	0.94-1.13	1.06	0.98-1.15
Social b	1.05	0.96-1.15	1.08	1.00-1.16
Noise a	0.94	0.84-1.05	0.96	0.88-1.06
Noise b	0.99	0.89-1.10	1.02	0.92-1.12
Int1 a	1.00	0.99-1.01	1.00	0.99-1.01
Int1 b	1.00	0.99-1.01	1.00	0.99-1.01
Int2 a	0.99	0.98-1.01	1.00	0.99-1.01
Int2 b	0.99	0.98-1.01	1.00	0.99-1.01

* a= Model 1 controlled for age hired and year hired;
**b=Model 2 controlled age hired, year hired, and duration of employment.
Physical=Physical demand; Ps=Psychological demand; Social=Co-worker social support; OR= Odds Ratio; CI= 95 percent Confidence Interval. Int1=control*ps; Int2=control*social.

Table 54: Logistic Regression for All-Cause Mortality: Multivariate Analysis with 5 and 10 Years of Follow-up

		Model 1		Model 2	
Follow -up	**Variable**	**OR**	**CI**	**OR**	**CI**
5 year	Year hired	0.95	0.94-0.96	0.97	0.96-0.98
	Age hired	1.05	1.04-1.06	1.06	1.05-1.07
	Duration			1.03	1.02-1.04
	Physical	0.80	0.71-0.90		
10 year	Year hired	0.95	0.94-0.96	0.96	0.95-0.97
	Age hired	1.05	1.04-1.06	1.08	1.07-1.09
	Duration			1.03	1.02-1.04
	Physical	0.80	0.71-0.90		

Ps=Psychological demand.

Univariate analyses controlling for age and year hired showed, as in the case of CHD, that physical demand was inversely associated with all-cause mortality. And, in the case of all-cause mortality, univariate Odds ratios for physical demand were approximately 10 percent less than those obtained with CHD. Unlike logistic models with CHD, the association with physical demand disappeared after controlling for employment duration.

In multivariate models odds ratios for physical demand obtained with all-cause mortality were also less than those obtained with CHD. And, as in the univariate models, controlling for employment duration eliminated the association between physical demand and all-cause mortality.

Table 55 shows results from a univariate analysis with 5- and 10-years follow-up for accidental mortality. Table 56 presents the multivariate results for accidental mortality.

Table 55: Logistic Regression for Accident Mortality: Univariate Analysis with 5- and 10- Years of Follow-up

Variable	5-year OR	5-year CIs	10-year OR	10-year CIs
Duration	0.97	0.96-0.98	0.96	0.95-0.97
Year hired	0.99	0.98-1.01	1.00	0.99-1.01
Age hired	0.99	0.98-1.01	1.00	0.99-1.01
Control a*	0.97	0.92-1.01	0.95	0.92-1.00
Control b**	0.99	0.95-1.04	0.95	0.94-0.96
Ps a	0.77	0.58-1.03	0.81	0.63-1.05
Ps b	0.80	0.59-1.09	0.85	0.65-1.12
Physical a	0.97	0.72-1.30	1.06	0.81-1.39
Physical b	0.81	0.60-1.09	0.87	0.67-1.14
Social a	1.02	0.82-1.28	0.99	0.81-1.20
Social b	0.99	0.79-1.24	0.95	0.77-1.16
Noise a	1.05	0.79-1.39	1.13	0.88-1.45
Noise b	0.96	0.72-1.27	1.03	0.80-1.32
Int1 a	1.00	0.99-1.01	1.00	0.99-1.01
Int1 b	1.00	0.99-1.01	1.00	0.99-1.01
Int2 a	1.00	0.99-1.01	1.00	0.99-1.01
Int2 b	1.00	0.99-1.01	1.00	0.99-1.01

* a= Model 1 controlled for age hired and year hired;
**b=Model 2 controlled age hired, year hired, and duration of employment.
Physical=Physical demand; Ps=Psychological demand; Social=Co-worker social support; OR= Odds Ratio; CI= 95 percent Confidence Interval. Int1=control*ps; Int2=control*social.

Table 56: Logistic Regression for Accident Mortality: Multivariate Analysis with 5 and 10 Years of Follow-up

		Model 1		Model 2	
Follow-up	**Variable**	**OR**	**CI**	**OR**	**CI**
5 year	Year hired	1.00	0.99-1.01	0.98	0.97-0.99
	Age hired	1.00	0.99-1.01	1.00	0.99-1.01
	Duration			0.96	0.94-0.97
10 year	Year hired	1.00	0.99-1.01	0.98	0.97-0.99
	Age hired	1.00	0.99-1.01	1.00	0.99-1.01
	Duration			0.95	0.93-0.96
	Control	0.95	0.92-0.99		

Ps=Psychological demand.

Univariate models show no association with age hired or year hired and accident mortality. With 5 and 10 years follow-up the odds ratios for employment duration were, respectively 0.97 and 0.96 with confidence intervals excluding one indicating a 3 to 4 percent protective effect from accidental death with each year of employment. In the univariate model with 10 years follow-up after controlling for age and year hired and duration of employment odds ratios for control were 0.95 with confidence intervals excluding one indicating a 5 percent protective effect from accidental death with each unit increase in average control. This was the only statistically significant association demonstrated with psychosocial variables in univariate models.

In multivariate modeling, the statistically significant association between control and accident mortality was found only for the model with 10 years follow-up controlling for age and year hired. On adding duration of employment to the model no association with control was observed.

Table 57 shows results from a univariate analysis for suicide mortality.

Table 57: Logistic Regression for Suicide Mortality: Univariate Analysis with 5- and 10- Years of Follow-up

Variable	5-year OR	5-year CIs	10-year OR	10-year CIs
Duration	0.99	0.97-1.01	0.99	0.97-1.01
Year hired	1.00	0.99-1.02	1.00	0.98-1.02
Age hired	0.99	0.98-1.02	1.00	0.99-1.02
Control a*	0.95	0.88-1.04	0.95	0.88-1.03
Control b**	0.96	0.88-1.05	0.96	0.89-1.04
Ps a	0.52	0.30-0.87	0.53	0.33-0.83
Ps b	0.51	0.30-0.87	0.53	0.33-.084
Physical a	1.06	0.61-1.83	1.07	0.66-1.73
Physical b	1.03	0.56-1.79	0.99	0.61-1.60
Social a	1.09	0.72-1.65	1.12	0.78-1.60
Social b	1.08	0.71-1.64	1.10	0.76-1.58
Noise a	1.37	0.81-2.33	1.25	0.79-1.98
Noise b	1.36	0.80-2.31	1.21	0.76-1.91
Int1 a	0.99	0.98-1.00	0.99	0.98-1.00
Int1 b	1.00	0.99-1.01	1.00	0.99-1.01
Int2 a	0.99	0.98-1.00	0.99	0.98-1.00
Int2 b	1.00	0.99-1.01	1.00	0.99-1.01

* a= Model 1 controlled for age hired and year hired;
**b=Model 2 controlled age hired, year hired, and duration of employment.
Physical=Physical demand; Ps=Psychological demand; Social=Co-worker social support; OR= Odds Ratio; CI= 95 percent Confidence Interval. Int1=control*ps; Int2=control*social.

Table 58 presents the multivariate results for suicide mortality.

Table 58: Logistic Regression for Suicide Mortality: Multivariate Analysis with 5 and 10 Years of Follow-up

		Model 1		Model 2	
Follow -up	**Variable**	**OR**	**CI**	**OR**	**CI**
5 year	Year hired	1.00	0.99-1.01	1.00	0.98-1.02
	Age hired	1.00	0.97-1.02	1.00	0.97-1.02
	Duration			0.99	0.97-1.02
	Ps	0.51	0.30-0.87	0.51	0.30-0.87
10 year	Year hired	1.00	0.98-1.02	0.99	0.97-1.01
	Age hired	1.00	0.98-1.02	1.00	0.98-1.02
	Duration			0.98	0.96-1.00
	Ps	0.53	0.33-0.83	0.53	0.33-0.84

Ps=Psychological demand.

Univariate models show no association with age hired, year hired, or employment duration and suicide mortality. In the univariate model with both 5 and 10 years follow-up after controlling for age and year hired and duration of employment odds ratios for psychological demand were, respectively 0.51 and 0.53 with confidence intervals excluding one indicating an approximately 50 percent protective effect from suicidal death with each unit increase in average psychological demand. This was the only statistically significant association demonstrated with psychosocial variables in univariate models. In multivariate modeling, he protective and statistically significant association between psychological demand and suicide mortality was found in all models.

To determine whether elimination of the last five years of exposure, during which unemployment rates were unusually high in the cohort, might affect the results logistic regression analyses were undertaken with all five mortality outcomes. Results from these analyses were compared to the above logistic regression analyses. No differences were observed in odds ratios or confidence intervals.

8.8 Summary

SMR analyses indicate no elevated major causes of death for the sawmill cohort in comparison to the general population. Workers in this cohort were healthier, as expected, than the general population. Poisson regressions were terminated after analyses with atherosclerosis as collinearity with cumulative psychosocial variables precluded any further modeling. Results with Poisson regression did indicate a strong age effect and a weaker inverse effect on atherosclerosis with advancing calendar period.

Time-weighted average exposures to the five psychosocial variables were modeled using logistic regression. The main results from this analysis were that exposure to sedentary physical and noisy jobs was associated with increased risk for mortality from atherosclerosis. Sedentary jobs (in terms of TWA exposure) were also associated with greater all-cause mortality. With 10-years follow-up only, psychological demand was associated with increased risk of CVA mortality. And, with 10-years follow-up only, control was inversely associated with increased mortality from accidents. Finally, exposure to psychological demand was inversely associated with increased risk for suicide.

The results for all regression analyses are summarised in table 59.

Table 59: Summary of Regression Analyses

Table No.	Analysis	Follow-up	Outcome	Significant Variables
40	Poisson Univariate	5-years	Atherosclerosis	Dur, Age
41	Poisson Mulitvariate	5-years	Atherosclerosis	Age, Cal
42	Poisson Univariate	10-years	Atherosclerosis	Dur, Age
43	Poisson Mulitvariate	10-years	Atherosclerosis	Age, Cal
49	Logistic Univariate	5 &10-years	Atherosclerosis	Dur, Cal, Yr, Ph
50	Logistic Multivariate	5 &10-years	Atherosclerosis	Dur, Cal, Yr, Ph, Noi
51	Logistic Univariate	5 &10-years	CVA	Dur, Age, Yr,Ps*
52	Logistic Multivariate	5 &10-years	CVA	Age, Yr, Ps*
53	Logistic Univariate	5 &10-years	All-Cause	Dur, Age, Yr, Ph
54	Logistic Multivariate	5 &10-years	All-Cause	Age, Yr, Ph
55	Logistic Univariate	5 &10-years	Accidents	Dur, Con*
56	Logistic Multivariate	5 &10-years	Accidents	Con
57	Logistic Univariate	5 &10-years	Suicides	Ps
58	Logistic Multivariate	5 &10-years	Suicides	Ps

Con= Control; Ph=Physical demand; Ps=Psychological demand; Dur= employment duration; Yr= Calendar period in Poisson regression or Year-hired in logistic regression; Age= Age period in Poisson regression or Age-hired in logistic regression; Noi= noise; CVA= cerebrovascular accidents; Ps*= with 10 years follow-up only.
Con*= with 10 years follow-up only.

CHAPTER NINE

9.0 Discussion

The discussion is divided into five sections. The first describes main findings and contextualises these within the literature on coronary heart disease and the demand/control model. The second section outlines secondary findings including the reliability and validity of the exposure assessment. In the third section potential limitations to the study arising from bias are reviewed. In section four the potential for confounding in the analyses is outlined. The final section is a discussion of the broad implications of the results of this investigation.

The main positive findings of this dissertation were that time-weighted average (TWA) exposure to physically sedentary and noisy jobs was associated with increased risk of mortality from atherosclerotic heart disease. The main negative findings were that TWA exposures for control, psychological demand and co-worker social support were not associated with atherosclerosis mortality. Although cumulative exposures to psychosocial variables were modeled, definitive results were not found because of collinearity between psychosocial variables.

Secondary findings included an inverse association between TWA physical demand for all-cause mortality and an inverse association between TWA psychological demand and suicide mortality. Also, a weak direct association between psychological demand and cerebrovascular accidents was found which disappeared after controlling for employment duration. As well, the expert rater method used in this investigation was able to estimate exposures reliably and with validity to four psychosocial work conditions: control, physical demand, co-worker social support, and noise. Psychological demand was estimated with less reliability than these four variables and was not shown to be valid using tests for concurrent and predictive validity.

9.1 Main findings

Time-weighted average exposure to physical demand was inversely associated and noise directly associated with increased mortality from atherosclerosis. Two detailed reviews of the literature concluded definitively that there is a causal relationship between physical inactivity at work and CHD (Powell and Paffenbarger 1985; Kristensen 1989b). The results of this dissertation conform with these findings for physical inactivity.

Approximately 200 studies on the non-auditory effects of noise and CHD have been published (Cohen and Weinstein 1981; Dejoy 1984; Kristensen 1989b; Schwarze and Thompson 1993; Thompson 1993, 1996). Of the nearly 50 "good quality" epidemiological investigations "about half of the studies revealed a positive correlation between noise and CHD, while a fifth showed weak or inconsistent correlation, and one-third gave no correlation. And, "research yields reasonable support for the noise-CHD hypothesis" (Kristensen 1989b, 171) . The direct association between TWA noise exposure and CHD observed in this investigation is in accord with most of the studies found in this literature.

In this investigation, with both 5 and 10 years follow-up, TWA physical demand and noise accounted for, respectively, approximately 0.1 and 0.05 percent of model variance compared to approximately 8 percent explained by age at hire, and 2 percent of variance each contributed by year of hire and duration of employment. Thus, while findings for noise and physical demand were statistically significant and in the expected direction, their explanatory power was limited. These positive results are discussed in more detail at the end of this section after outlining the reasons for negative findings obtained with psychosocial work condition variables.

The main purpose of this investigation was to determine the effect of both cumulative and TWA exposures to psychosocial variables of control, psychological demand, and co-worker social support. Because of collinearity the Poisson models were uninterpretable so that results for cumulative exposure were not obtained in this investigation and will not be discussed further. In contrast, TWA exposures to psychosocial variables were successfully modeled and, although results were negative, these are discussed.

The purpose of this section is to explain the findings in this dissertation with reference to the literature mainly on cohort studies with CHD outcomes and the demand/control model (or analogues) to determine to what extent study design (or mis-design) explains the negative findings for psychosocial variables and the positive findings for physical demand and noise.

Twelve cohort studies have been conducted using the demand/control model (or analogues) with CHD morbidity or mortality outcomes. Of these, 7 were positive in that "high strain" and/or low control was statistically significantly associated with CHD morbidity or mortality and 5 were negative. Four of the seven positive studies demonstrated both a protective effect for control as well as a direct effect for psychological demand on CHD morbidity or mortality (Alfredson and others 1985; Karasek and others 1981; Siegrist and others 1990; Theorell and others 1977). Two of the three remaining positive cohort studies did not measure the direct effects of psychological demand or control but modeled "job strain" (Haan 1988; Johnson and others 1989). The final positive study showed protective effects for control but no effect for psychological demand (Bosma and others 1997).

Of these studies, one (with only one year of follow-up) consisted of approximately one million Swedish workers (Alfredson and others 1985), five consisted of cohorts with from 3,000 to 10,000 members (Bosma and others 1997; Johnson and others 1989; Karasek and others 1981; Reed and others 1989; Theorell and others 1977), and six consisted of cohorts with between 400 and 3,000 members (Alterman and others 1994; Haan 1988; Hlatky and others 1995; Netterstrom and Suadicani 1993; Siegrist and others 1990; Suadicani and others 1993). This sawmill study with over 26,000 workers is the second largest cohort investigation on the effect of psychosocial work conditions and CHD outcomes.

Four of the 12 cohort studies were conducted with prevalence data and eight used incidence data. This dissertation also used incidence data. Alfredson's study of 985,000 Swedish workers used CHD prevalence outcomes so that this dissertation is the largest cohort study based on the demand/control model which also used CHD incidence data.

The main design strengths of this investigation arises from the modeling of time-weighted average exposures for psychosocial work condition variables and use of the complete sawmill job history of cohort members to develop these exposures. In 11 of the 12 cohort studies, exposure was measured at one point in time and was usually based on a worker's current or usual job at the beginning of the study. The one exception, the Whitehall study, measured exposure for each cohort member at two points in time (Bosma and others 1997).

None of the 12 cohort studies used the entire job history of cohort members to develop exposure scores and none incorporated duration into their exposure variables. This dissertation therefore represents the first cohort study based on the demand/control model and using CHD outcomes to model both the intensity and duration of psychosocial variables. One other study has used entire job history profiles, the demand/control model, CHD outcomes, and also modeled cumulative exposure to these (Johnson and others 1996). This nested case-control investigation found that workers with both the least cumulative control and least cumulative co-worker social support had the greatest risk for CHD.

As outlined earlier in this dissertation, this is the first investigation which has used multiple jobs to determine exposure scores. Using multiple sawmill jobs to develop exposure scores and modeling these as time-weighted averages are design elements that should be expected by theory to increase the probability of finding associations between psychosocial work condition variables and CHD outcomes (if these are true risk factors) compared to cohort studies with cross-sectional intensity measures. This is because single point-in-time intensity measures, whether of current or usual jobs, will be more vulnerable to misclassification than those which use all or most of a worker's jobs to develop exposure scores. In spite of the positive design elements of this dissertation, negative results were obtained at least for the psychosocial variables. This means either that no association was present for TWA exposures to psychosocial work conditions or that some other aspect of study design, or bias, or confounding were responsible for the negative findings. In the next portion of the discussion, the 12 cohort studies are compared with this study to determine whether limitations in study design may have contributed to the negative results.

One way to begin this process is with an analysis of the national differences in outcomes among the 12 cohort studies. The American cohort studies were negative (Alterman and others 1994; Hlatky and others 1995; Reed and others 1989) as were the Danish studies (Netterstrom and Suadicani 1993; Suadicani and others 1993). The remaining seven studies, mainly from Sweden (Alfredson and others 1985; Karasek and others 1981;

Theorell and others 1977) but also from Finland (Haan 1985), Germany (Siegrist and others 1990) and the U.K. (Bosma and others 1997) were all positive.

One reason for these national differences may lie in the different questionnaires used. For example, the two negative Danish studies contained a smaller number of psychological demand and control items than are ordinarily used in the demand/control questionnaire so that it is not clear to what extent these two studies incorporate the "full spectrum" of the psychological demand and control constructs as developed in the model. The German study used the effort/reward imbalance model but is included in this literature as effort and reward may be regarded as more broadly defined analogues to, respectively, psychological demand

and control (Karasek and Theorell 1996). [20] The negative American studies used five questions to measure psychological demand whereas the positive Swedish studies used two completely different questions to measure this same construct. And, in two of the Swedish studies, broader (organizational-level) questions supplemented the two task-level questions on psychological demand so that this construct was broader and different than in the American instrument.

As well as employing entirely different questions for psychological demand, the Swedish studies incorporated a dimension of control not found in the American version. This so-called "personal schedule of freedom" measures the ability of workers to leave their job station at will and plan the use of their time at work with independence. One could argue that this dimension is really a component of decision authority. Even if this is the case, addition of personal schedule of freedom to a questionnaire already with a decision authority dimension may increase the importance of decision authority relative to skill discretion in the Swedish instrument. And, the Swedish questions for decision authority and skill discretion, are also different and broader (in the sense that they appear to measure organisational aspects of the job) than those used in the American instrument. The Swedish instrument may therefore measure quite a different control construct than the American version.

Whenever American questions for psychological demand or control have been used in a cohort study with CHD outcomes, whether modeled by themselves or as "strain", they have never produced statistically significant associations with outcomes (Alterman and others 1994; Bosma and others 1997; Hlatky and others 1995; Reed and others 1989). (Bosma's study of Whitehall civil servants used the five American questions for

[20] The analogy is more true in the case of psychological demand as this construct is measured at the task-level by

psychological demand producing negative results and most of the control questions derived from the Swedish instrument producing positive results for this construct.) It is important to explore these limited but consistent findings with the American instrument further because a modified version of this questionnaire was used in the present investigation.

Both the Swedish and American instruments were empirically derived from random and representative national labour force surveys. In both surveys workers were interviewed and psychosocial conditions of work assessed by direct self-report. These were then averaged within occupational code so that pooled self-report scores were obtained for most Swedish and American occupations. Each labour force survey was also subject to factor analysis to identify principle components and the questions which best reflected these. Thus, the specific questions developed for the demand/control model in both countries may, in part, reflect culturally specific attitudes of workers in relation to psychosocial work conditions.

However, there is another possible explanation for these differences. The surveys in Sweden were large and carried out regularly. The questions obtained from the Swedish instrument were based on factor analysis with over 11,000 workers. In contrast, the American instrument was developed by fusing 3 nationally representative surveys carried out in 1969, 1972, and 1977 (Karasek and Theorell 1990). These surveys were not routine as in Sweden and the amalgamated surveys from which the American questions were derived consisted of only 4,503 workers.

Thus, the American instrument was developed from a much smaller sample of workers. One might argue that it is necessary to use a much larger sample in the United States compared to Sweden in order to develop an empirically valid questionnaire for

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Siegrist. But, his measure of control is much broader than Karasek's. This is elaborated further in section 9.5.

psychosocial work conditions because the United States is more occupational and culturally heterogeneous than Sweden. It is quite possible that both the questions derived from the American labour force surveys and the occupation-based scores for psychosocial work conditions derived from these same surveys may be less valid and less precise than those obtained from the Swedish labour force surveys.

The American instrument may have produced negative results for another reason related to a different aspect of study design. Two of the three cohort studies which used the American instrument also measured exposure indirectly by imputing scores (based on occupational codes) from the American labour force surveys to cohort members (Alterman and others 1994; Reed and others 1989). None of the 10 other cohort studies used indirect exposure assessment methods but instead relied on direct self reports.

The negative results observed with the two American cohort studies could have occurred because of the particular indirect measure of exposure assessment they both used or because, in general, as is well known, indirect exposure assessments are more prone to misclassification than direct self reports (Karasek and Theorell 1990; Theorell and Karasek 1996). As already discussed, questions were derived using factor analysis with the American labour force surveys. In these same surveys psychosocial work conditions were pooled within occupational codes and these scores were the ones attributed to worker's in the two cohort studies. Given that the empirical basis of the American labour force surveys may be "weak" relative to the Swedish surveys, the accuracy of occupation-based scores used in these two cohort studies may be less than those obtained in Swedish studies.

These observations have relevance for this dissertation for several reasons. First, the differences in questions obtained from Swedish compared with American labour surveys point to cultural specificity in how people perceive and estimate psychosocial conditions of work so that the validity of an instrument developed in a non-Canadian setting but applied in Canada may be suspect. Second, this problem could be exacerbated because the demand/control instrument was designed to measure conditions across a broad range of occupations. The instrument may not be optimal for measuring conditions across a narrow range of blue-collar jobs in a B.C. resource-manufacturing industry.

Third, as well as using the American instrument in this investigation, it was used with an indirect exposure assessment method. Thus, three possibly weak elements of study design (as identified from reviewing similar cohort studies) were incorporated into the current investigation. However, one cannot attribute use of the American instrument in combination with an indirect exposure assessment to the negative results for psychosocial work condition variables obtained in this investigation, particularly as one of the variables measured both indirectly and with the American instrument, physical demand, showed an association with CHD.

Other possibilities must first be explored. As was shown in Chapter 3, over half the studies with the demand/control model and non-CHD outcomes and conducted either with occupationally homogenous groups or when controlled for social class, produced negative results. In comparison, studies (with non-CHD outcomes) based on heterogeneous occupations tended to demonstrate proportionately more positive results. And, most cohort studies with CHD outcomes demonstrated an association with the demand/control or demand/control/support model after controlling for social class or when the cohort was homogenous for class. As outlined in Chapter 3, these results with well-designed studies and CHD outcomes indicate that positive effects (if they are in fact present) should be detectable in a homogenous cohort such as the one used in this investigation.

While the social class homogeneity of this cohort should not preclude obtaining positive findings, because homogeneous cohorts will contain fewer occupations with a narrower range of jobs than heterogeneous cohorts, the range in scores for psychosocial work condition variables may be too narrow to produce an observable effect. To determine the likelihood of this claim it is necessary to examine and compare the range in scores usually found for psychosocial variables in other cohort studies with those obtained in this dissertation.

In 3 of the 12 cohort studies the means and standard deviations for control have been published. In the Whitehall study the average control intensity score was 68.4 with standard deviation 15 (Bosma and others 1997). This score was created by transforming the control scores found in the study to a one-hundred unit scale. And, in both Alterman's and Reed's studies, the means for control (converted to a scale with one-hundred units to facilitate comparison) were the same at 64.6 and the standard deviations were, respectively 15.4 and 13.4. (It should be noted that comparison between Whitehall and the two American studies is problematic as these Whitehall scores were obtained in 1997 using the Swedish instrument for control whereas the two American studies were obtained mainly in the 1970s and by using the American questions for control.)

In the present investigation, the mean and standard deviation for control (converting to a scale with 100 units) were respectively, 40.8 and 17.8. The mean score for control in the sawmill cohort was approximately 30 percent less than control scores obtained in the three other cohort studies with CHD outcomes. Furthermore, the lowest employment grade of Whitehall civil servants had an average control score of 46.5 (Bosma and others 1997) which was approximately 6 percent greater than the mean control score in the sawmill cohort. Again comparison with the Whitehall study and the sawmill cohort are inexact because of differences in study design and the 30 year difference in when control scores were obtained.

A more accurate way to contextualise the control scores obtained in this study within the literature is to compare them with scores obtained in the nationally representative labour surveys used by Karasek to develop the American instrument. Averaged over the 3 surveys, Karasek obtained control scores of 37.8 with a standard deviation 6.5 (Karasek and Theorell 1990, 336). This score is a measure of control in the American labour force obtained between 1968 and 1977 and although the retrospective estimates for the sawmill cohort were, for a slightly earlier time (1965) these are temporally fairly close. Converted to a one-hundred unit scale for purposes of comparison, Karasek's score for control was 71.0. This means that the average control score obtained in the sawmill cohort was approximately 40 percent less than was obtained in a representative sample of the American labour force at about the same time.

This reinforces the conclusion that sawmill jobs were, compared to most jobs at the time, likely very low in control. This conclusion is further reinforced by analyzing the distribution of control scores in the sawmill cohort. As was shown in Table 48, the median time-weighted average score for control was 34.9 (compared to a mean of 40.8) indicating the distribution of TWA control in the sawmill cohort was skewed away from zero towards the right.

What about scores for the other four psychosocial variables? It is difficult to compare scores for noise, physical and psychological demand and social support to other cohort studies as these variables are either unmeasured or if measured not published. But, it is instructive to analyze Table 48 to describe the distribution of these scores within the sawmill cohort.

The inter-quartile range, means, and medians for physical demand, noise, and co-worker social support were fairly similar suggesting a similar distribution for these variables within the sawmill cohort. However, the distribution of both control and psychological demand was different from these three variables. As already discussed, control scores were skewed away from zero. Also, the mean and median control scores were approximately 20 percent less than the scores for the four other psychosocial variables. As well, the distribution of psychological demand was much more restricted than for the other variable with an inter-quartile range of 8 compared to an average inter-quartile range for the remaining four variables of 25.3. Thus, the two key psychosocial variables in this study were either skewed or restricted reducing the chance of finding associations with outcomes.

In summary, comparison of designs between 12 cohort studies and this dissertation indicate that the use of entire job histories, TWA exposure modeling, and a very large cohort must be balanced against the use of a possibly "weak" questionnaire instrument derived in a different cultural milieu than a B.C. sawmill, and applied by indirect exposure assessment. Given this balance of positive and negative study design features, given that the indirect exposure assessment method used in this dissertation was reliable and valid, (except for psychological demand), and given that positive results were found for noise and lack of physical demand, if an association between psychosocial conditions of work and CHD was in fact present than it should be found. The reason why negative results were obtained for the psychosocial variables in this investigation must therefore be sought largely outside any of these potential limitations in study design.

The review of the seven cohort studies which controlled for class or were conducted with relatively homogeneous cohorts reinforces this assessment because it was clearly shown that for the majority of cohort studies with the demand/control model, positive associations with CHD outcomes were found after controlling for social class. This means that in a cohort study, such as this one, with a fairly homogenous class structure, it should be possible to find positive associations between CHD outcomes and psychosocial variables if they were in fact present.

That the study design was adequate is also shown because of the positive associations between physical demand and noise with CHD. And, as was demonstrated, the distribution of TWA noise, physical demand, and co-worker social support was both similar and broader than the distribution for TWA psychological demand and control. The restricted distribution for psychosocial demand and the skewed and unusually low scores for control likely meant that even if associations were present between these variables and CHD outcomes that these would not be found.

If co-worker social support distribution was similar to the two variables that showed an association with CHD (physical demand and noise) why were negative results obtained with this variable, particularly, as will be discussed in detail in the next section, as co-worker social support was reliably and validly measured? The answer may lie in the incomplete nature of the variable as operationalised in this study. Social support at work is usually measured by questions which assess both supervisor support and co-worker support. It may be that, particularly in conditions of very low control, supervisor social support is very important.

9.2 Secondary Findings

The secondary findings of this study were that all-cause mortality was inversely associated with TWA physical demand for both 5 and 10 years follow-up. It is likely that the all-cause mortality findings were the result of the inverse association of physical demand with CHD both because CHD mortality accounts for 36 percent of all-cause mortality and because the association with physical demand is attenuated for all-cause mortality compared to CHD. Unlike for CHD, TWA noise exposure was not associated with all-cause mortality. Noise was only peripherally associated with CHD so that the fact that noise was not associated with all-cause mortality is not surprising.

A weak association (OR=1.42 CI= 1.01-2.01) was shown between psychological demand and cerebrovascular accidents with 10 years (but not for 5 years) follow-up. This association disappeared after controlling for duration of employment. Another secondary but stronger finding in this dissertation was the inverse association of suicide with TWA psychological demand with both 5 and 10 years follow-up. Because the ability to evaluate findings for both CVA and suicide is dependent on a review of the supplementary reliability and validity studies carried out on the exposure assessment method, particularly for psychological demand these findings are discussed after reviewing the reliability and validity of the exposure assessment.

9.2.1 Exposure Assessment

The exposure assessment methods were a unique form of indirect exposure assessment as they were retrospective, conducted at arm's length from an actual worksite, used a type of expert never used in job strain studies, and because they were based on a shortened form of the American questionnaire.

The 1965 estimations showed "excellent" reliability for control, physical demand, co-worker social support, and noise but only showed "good " reliability for psychological demand. Although intra-rater reliability for psychological demand was "poor" and inter-rater reliability at the individual level was also "poor", because group-level reliability (i.e. measures averaged for the four expert raters) was "good" there was enough justification to proceed with using this variable in the analyses.

However, this justification was marginal because all variables except psychological demand demonstrated concurrent validity. The concurrent validity test was limited in scope as it included only 30 of 86 job titles. As a limited test it provided some assurance as to the concurrent validity of control, physical demand, co-worker social support, and noise and cast doubt on the validity of psychological demand as measured in this investigation.

One reason for the lowered reliability and lack of concurrent validity for psychological demand may arise from use of the shortened 13-item demand/control instrument. In reducing the length of this instrument two items were removed from the psychological demand dimension and three items were removed from the control dimension. Although the specificity and sensitivity of the shortened instrument was nearly 90 percent, shortening the instrument may have had a greater effect on the reliability of psychological demand compared to control.

The reliability for control was virtually the same for the 13- and 18-item versions, but the reliability for psychological demand in the 13-item instrument was approximately 15 percent less than with the 18-item instrument. On the other hand, it should be noted that the two items dropped from psychological demand were items identified as possibly measuring physical as well as psychological demand particularly in blue-collar work forces. Therefore the 13-item instrument with psychological demand may represent the "best" possible measure for psychological demand and therefore the "best" reliability achievable with this variable.

Findings of lower reliability and lack of validity for psychological demand in an indirect exposure assessment are not entirely unexpected. According to (Theorell and Karasek 1996) "decision latitude (control) is determined to a greater extent by the content of work in the occupation, whereas demands and social support reflect to a greater extent local work site conditions and individual perception." Frese and Zapf, as outlined in Chapter 6, have also stated that "the resources (moderators like control) can be well observed and without much interference from cognitive and emotional processing; in contrast, the judgement of stressors is more private and therefore more strongly related to cognitive and emotional processing" (Frese and Zapf 1988, 382). If this is true then any indirect exposure assessment method, particularly if conducted at arms-length and therefore excluding consideration of local work site conditions, will necessarily produce less valid measures for psychological demand compared to control.

Control, as opposed to psychological demand, was the most reliably measured variable and although it did not demonstrate the largest concurrent validity it did show predictive validity. This is important as control, usually measured as a self-report, has, more than any other psychosocial work condition variable, consistently shown associations with health outcomes in epidemiological studies. There is good evidence that control was reliably and validly measured in this study so that it is unlikely that its lack of association with CHD was due to lack of validity.

Before moving to a discussion of the secondary findings for suicide and cerebrovascular mortality the following deals with three potential threats to the construct validity of the exposure assessment. First, scores were assessed retrospectively in 1965 and then applied to job titles for the entire study period. Thus, although, unlike other cohort studies to date, all of a worker's sawmill jobs were used to develop exposure scores, these were all based on an assessment near the mid-point of the study period and are therefore vulnerable to exposure misclassification if the psychosocial conditions for these job titles changed during the study period. Second, 3 management and one union evaluator conducted the exposure assessment so there was potential for a "management" bias. Finally, this exposure assessment was conducted at arms-length from an actual sawmill unlike other exposure assessments which rely on reports directly from a worksite or a series of worksites.

By measuring psychosocial job conditions at two time periods 32 years apart, any within-job title changes in these could be ascertained to determine the extent to which misclassification might occur by applying scores from 1965 to job titles throughout the study. Nearly one quarter of the 86 core job titles estimated in 1965 were either eliminated or rare in the industry by 1997. These jobs had less control, less co-worker social support, and more physical demand than jobs that remained in the industry. For jobs remaining in the industry, changes in psychosocial conditions of work over this 32 year period were negligible, indicating that technological change eliminated jobs with "bad" psychosocial work conditions but did not appreciably change the psychosocial conditions of work for surviving job titles. (As far as is known, these are the only data to measure psychosocial work conditions at different times and to link these to changes in technology as well.) The relative invariance of the psychosocial conditions of work at both times provides evidence that the cross-sectional estimation of exposure in 1965 and attribution of these scores to job titles throughout the study time frame was not a threat to the construct validity of the method.

Another threat to the exposure assessment method arises because of the potential for "management" bias. Job evaluators have never been used in psychosocial job strain studies as experts. The question of the suitability of these particular experts was evaluated as well as the particular configuration of experts (3 industry and 1 union) used here.

The high reliability with which expert raters estimated exposure could result from 30 years of shared experience in evaluating sawmill jobs. This possibility is heightened by the "political" nature of job evaluation as it is directly linked to the wage negotiation process in the industry. There may be some incentive for the industry experts to under-evaluate adverse psychosocial and other job conditions in order to keep wages down. This tendency (if it exists) might be balanced by the union evaluator, though not necessarily. If industry evaluators rate jobs differently from union evaluators then the particular configuration of raters used in this investigation could bias estimations.

To determine the extent to which industry raters might differ in their assessments from the union rater, estimates from the three industry raters were pooled and compared to those of the union evaluator. There were no significant differences among the three industry raters for the five psychosocial variables. However, there were significant differences in scores between the pooled industry rates and the single union evaluator. Differences in score were more marked for 1965 compared to 1997 estimations. In terms of absolute differences for 1965 estimations the union rater scored control and psychological demand, respectively 5.2 and 8.4 percent lower than the industry raters. And, the union rater scored physical demand

and co-worker social support, respectively, 5.5 and 6 percent higher than the industry raters.

One might expect that, if biases were overtly political in nature, the union rater might score moderators lower than industry raters and stressors higher. Such a pattern was not discernible. Instead, the union rater scored social support higher than industry raters and psychological demand lower. While there were absolute differences, it is not clear that these were systematic or related to the different vested situations of the job evaluators. In other words, the observed differences between the union and industry raters may just as likely reflect different personal judgments for these particular individuals as any systematic bias. Even if the differences between the union and industry raters were systematic and a result of their relative and different political situations, they were small so that a second union rater (if one had been available) would likely not have altered scores in a significant fashion.

The arms length character is also a potential concern with the expert rating. Estimation based on an abstract or generic work site rather than a specific one may not be as valid as one based on an actual worksite. The arms length component of this method could be eliminated by either using expert worker raters or the 4 expert evaluators in each of the 14 study sawmills.

While these approaches may have been better, there is one advantage of arm's-length rating. That is, task-level exposures were truly task-level with no possible contamination from stress-producing organizational factors within a sawmill. In the only other large-scale epidemiological investigation involving expert raters (Whitehall), 140 supervisors rated job titles within their civil service departments (Bosma and others 1997). These estimations were carried at less distance from job titles than in this dissertation where experts were completely at arm's length. In the Whitehall study even though experts were evaluating task-level exposures, their own involvement in and knowledge of the organization and psychosocial conditions arising from the organization may have contaminated what were supposed to be purely task-level exposures.

Such contamination could not have occurred in this investigation so that the estimations by the four experts were truly task-level measures. At the same time this might make these estimations less comparable to both Whitehall expert estimations and estimations based on pooled self-reports. Usually with pooled self-reports actual sites are assessed with full knowledge of organizational dimensions of the psychosocial work environment. This could influence the way in which a rater might answer questions about task-level psychosocial conditions.

Finally, there are two factors related to the basic design of the response categories for the demand/control/support instrument which may limit the instrument's utility especially for expert raters and particularly in relation to measuring psychological demand. First, the response categories for the instrument ask raters to agree or disagree with statements about psychosocial work conditions. It is not clear what exactly these responses measure. Ideally, one would want to measure exposure intensity as this could be multiplied by duration to produce true cumulative exposure scores. While agreeing or disagreeing whether a particular job title has "alot of conflicting demands" may say something about the amount of conflicting demand in the job it cannot provide a true measure of intensity. Therefore the construction of cumulative and TWA exposure scores are based on a less than perfect intensity measure. In the only other study with cumulative exposures and CHD outcomes this was not raised as a limitation (Johnson and others 1996).

Second, and this is most important in relation to psychological demand, these response categories may also affect the extent to which the instrument is amenable to adaptation by expert raters. Because they ask experts for an attitude or opinion (extent of agreement or disagreement with a statement), they promote cognitive/emotional processing. If the responses asked for intensity measures (never, sometimes, usually, always), the question and the responses would be better framed to elicit more objective answers. As shown in Chapter 6 framing and wording of questions to reduce the level of emotional/cognitive processing will make instruments measuring psychosocial work conditions more adaptable for expert use. And, as suggested in Chapter 6, questions measuring stressors like psychological demand may be further towards the emotional/cognitive continuum than moderators like control and therefore less amenable (at least as presently constructed with the model) to expert rating. It is possible that use of more specific and objective response categories to measure intensity might increase the reliability of measurement for psychological demand.

9.2.2 Suicide, Cerebrovascular Accidents and Psychological Demand

As outlined at the beginning of the discussion on secondary findings, the exposure assessment methods were first reviewed, particularly in relation to psychological demand as this was the construct associated with TWA exposure to CVA and suicide mortality. This review shows that psychological demand was measured with "borderline" reliability by the four expert raters and with no construct or predictive validity. As well, as already mentioned, the distribution of average psychological demand scores was, compared to the 4 other psychosocial variables, tightly restricted around the mean with an inter-quartile range which was approximately one third the inter-quartile range found for the other variables.

The association between increasing psychological demand and increasing mortality from cerebrovascular accidents was weak (OR= 1.42 CI=1.01-2.01) and only found for the model with 10 years follow-up. This association disappeared after controlling for duration of employment. This may indicate that the association with 10 years follow-up in combination with lack of association with 5 years follow may be largely due to misclassification of exposure.

If the association had been observed in the model with 5 years follow-up and after controlling for employment duration, it would still be difficult to argue that it represented a true association because of threats to the validity of the exposure assessment for this variable. It is therefore likely that the observed association between CVA and psychological demand for the model with 10 years follow-up is spurious.

The marginal reliability with which psychological demand was measured and complete lack of validity in supplementary analyses, indicates that although an association was found with suicide mortality its meaning is unclear. If psychological demand had been reliably and validly measured and an association with suicide found then this result would be unequivocal. Clearly this was not the case. This association should promote further research with better measured psychosocial work condition variables and suicide mortality.

It is possible that the association between suicide mortality and low psychological demand (or something resembling it) may be enhanced by life-style risk factors. If people who are mentally ill, alcoholic, or troubled in some way tend to be assigned jobs that are low in psychological demand then a selection effect could account in part for the association between psychological demand and suicide. Also, if jobs with low psychological demand tend to be entry-level mill jobs, which are most vulnerable to downturns in the business cycle, then unemployment could also confound this association.

To this point the discussion has been organized around an explanation of main and secondary findings. While the exposure assessment methods have been critiqued in detail and the main and secondary findings discussed within the context of the literature on cohort studies with the demand/control model and CHD outcomes, a detailed discussion of the potential for bias and/or confounding to affect the results of this dissertation has not yet been undertaken. In the next section the potential for bias and confounding are outlined.

9.3 Bias

Bias in epidemiological studies can take one of three general forms: selection bias, information bias (misclassification), or confounding. Before considering the potential for these in the current dissertation, the potential for selection bias arising from the original cohort study design is first assessed

9.3.1 Potential for Selection Bias Arising from the Original Cohort Study

Two limitations could arise from the way in which the original chlorophenol study was carried out. In particular, the original cohort enumeration and vital status ascertainment may have been incomplete. Many sawmills had either no personnel offices or barely functioning ones in the immediate post World War II era so that records may have been lost, particularly prior to 1960. The labour demography analysis showed the cohort workforce was smaller in this era than after the 1960s. This demographic pattern was similar throughout the sawmill industry so that reduced numbers in the cohort prior to 1960 may not be due to under-enumeration. Even if under-enumeration did occur this would not cause bias as inefficient record keeping for sawmills in the 1950s would not likely be associated with both exposure and disease risk, after adjustment for temporal trends.

For large cohort studies, vital status tracing of 90 percent is the minimum acceptable and tracing of 95 percent or more is the most desirable (Checkoway and others 1989). The actual vital status tracing rate was 85.7 percent. The mortality ascertainment rate for the CMDB linkage was approximately 97 percent and the Statistics Canada tax file linkage reduced those with unknown vital status to 14.3 percent. This linkage left 895 persons (with SINs) unlinked. Given that these individuals were not found in the mortality linkage and given that not all people who are alive will file tax returns, most of these workers were probably alive as of 1990. With this assumption, the vital status ascertainment rate for the original cohort is 91 percent. And, if some proportion of the 2,896 workers with no SIN and unknown vital status were also alive in 1990 then the real ascertainment rate would be higher than this. Therefore the likelihood of selection bias from under-enumeration of the cohort or under-ascertainment of outcomes is extremely low.

9.3.2 Misclassification

Misclassification is also a potential source of bias. Nondifferential misclassification occurs if the likelihood of misclassification is the same for both groups being compared and will bias the effect estimate towards the null (Copeland and others, 1977). Nondifferential misclassification is therefore a particular concern in studies which show no association between exposure and disease.

Nondifferential exposure misclassification could be a threat to the validity of this investigation and arises in five ways. First, misclassification of exposure could be due to inaccurate personnel records resulting in the assignment of wrong job titles and/or start and end dates. Second, incorrect reduction of "raw" job titles (obtained from personnel records) into the 86 basic job titles used in this investigation could result in misclassification. Third, misclassification could occur if expert ratings were not reliably or validly measured. Fourth, even if reliably and validly measured, misclassification may arise due to differences in psychosocial work conditions for given job titles both across sawmills and across time. Finally, lack of exposure information for large parts of the working lives of many cohort members could result in a differential and systematic under-ascertainment of exposure for workers with short employment duration in a study sawmill. This was corrected by reducing length of follow-up to 5 and 10 years and is discussed later.

As already discussed, personnel offices were largely unimportant departments in sawmills prior to the 1960s so the potential for inaccurate gathering and updating of personnel information like job titles and job start and end dates was possible. Because personnel office assignment of job titles and job start and end dates occurred before assessment of workers mortality outcomes, it is highly unlikely that any misclassification arising in this way would differ for alive and dead workers. The potential for misclassification from this source is therefore only nondifferential.

It is not possible to measure record accuracy particularly for these early time periods so that the extent of such nondifferential misclassification is difficult to assess. Because worker's pay was based on their job title and job start and end dates, it is likely that these three basic elements of the personnel record keeping systems (even early in the study time period) were kept reasonably accurately thereby limiting the potential for nondifferential misclassification from this source.

The second source of misclassification could arise from the "job-title reduction" phase of the study. Approximately 4,500 unique job titles in the job history data base were reduced to 86 job titles for the analysis. Reduction to 500 unique job titles was achieved by resolving spelling differences among job titles and by resolving job title name differences across mills and time. This phase of job title standardization likely involved minimal error and where error occurred resulted only in nondifferential misclassification.

The second phase involved a group of expert workers and managers who resolved 500 job titles into 86. This phase of the standardization process may have resulted in some misclassification. However, it is not clear how one could have proceeded to categorize job titles in another manner. And, it is unlikely that the process either produced large errors or led to differential exposure misclassification. The job-title reduction process may have contributed to misclassification but only slightly and nondifferentially.

Lack of validity and/or reliability of psychosocial work conditions as estimated by expert raters is a third potential source of misclassification. The potential for misclassification due to unreliable and invalid measurement of the psychosocial variables is clearly nondifferential. In the previous section a more complete discussion of validity and reliability was undertaken. The results of this discussion showed that control was the most reliably and validly measured by experts. Physical demand, co-worker social support and noise were measured both reliably and with concurrent validity. Psychological demand was measured with "poor" reliability and showed neither concurrent or predictive validity.

Therefore the potential for misclassification may be higher for psychological demand compared to the other four psychosocial work condition variables. And, conversely, the potential for misclassification, from this source, was likely least for control.

A fourth potential for misclassification arises from the attribution of scores for psychosocial conditions of work to workers based on their job title. It is possible that the psychosocial conditions of work may vary across mills and time to such an extent that the arms length cross-sectional method of exposure assessment used in this study may result in misclassification. Such misclassification would be nondifferential.

Another area where misclassification could be a problem arises because of the ubiquitous nature of exposures to psychosocial work conditions. In occupational epidemiology, exposure is restricted to the work site and to the time worked at this site. When a worker leaves the work site, and is followed up for some period, the follow-up period is assumed to be exposure-free.

With non-ubiquitous exposures such as rare industrial dusts or chemicals, this assumption might still result in under-ascertainment of total work-life exposure if workers leave the worksite under investigation and move to a similar site where they might encounter the same exposures. The likelihood of this uncounted exposure occurring increases in situations where job availability is high and there are provisions for seniority retention and a tradition of within industry job mobility. Thus, for example, a worker lost to follow up at age 40 in a chlorophenol study sawmill might, for the purposes of the chlorophenol study be followed until age 65. This same worker might between the age of 40 and 65 find work in another non-study sawmill and be exposed to chlorophenols for 25 years. This last 25 years of chlorophenol exposure would not be recorded. If many workers followed this pattern, then an under-ascertainment of exposure would occur, resulting in misclassification of exposure.

In occupational epidemiology the potential for this type of misclassification is usually ignored. But, for ubiquitous exposures the problem must be addressed. For occupational studies where complete work-life exposure data are available the potential for this kind of misclassification will not be a problem. For example, in Johnson's study using cumulative psychosocial variables, over 95 percent of subjects had complete job exposure information for the 25-year period preceding the beginning of the follow-up period (Johnson and others, 1996).

In this investigation if a worker left a study sawmill to work, for example in an office, exposure to physical demand and noise may cease but exposure to differing levels of control, psychological demand and co-worker social support would still occur. And, if a worker left a study mill to work in another branch of the forest products industry, such as a pulp mill, he may continue to be exposed to physical demand and noise for the rest of his working life. Therefore the post-study sawmill job experience of working age men represents time during which exposure to, at least, control and psychological demand is both certain and unmeasured. And, even if a working-age worker is terminated from a study mill and remains unemployed for years, this will also carry a psychosocial exposure burden (Jin and others 1995).

In table 4, for follow up to 1990, it was shown that nearly half the person-years in the cohort represented time during which exposure to psychosocial conditions of work may have occurred at work sites other than a study sawmill. But, this exposure remained unmeasured. By reducing follow up for all workers to 5 and 10 years these unmeasured person-years were reduced to 23.1 and 33.5 percent of all person-years, respectively. This process of restricting follow up for the internal analyses is a nondifferential method for reducing misclassification because it was applied to all workers regardless of vital status.

However, this method was not complete as even with five years of follow up nearly one quarter of person-years in the analysis were still potentially misclassifiable. Reduction of follow up for the internal analysis acts to reduce misclassification in a nondifferential manner but it is not completely eliminated (the potential for this will obviously be greater in the case of 10-year compared to 5-year follow-up).

9.3.3 Potential for Bias Resulting from Restriction of Follow-up in the Regression Analysis

Restricting follow-up to 5 and 10 years results in a reduction both of person-years and mortality outcomes. This restriction could reduce the power of the regression analysis particularly for outcomes like suicide and CVA with relatively few cases. Also, because restriction of follow-up will lead to different proportional reduction of observed deaths depending on the particular average age of death for a particular outcome, restriction of follow-up will have effects specific to each mortality outcome. For example, for outcomes with high average ages of death, such as cerebrovascular accidents, restricting follow-up will exclude relatively more deaths than for mortality outcomes which occur at younger ages such as accidents and suicides

As is shown in table 39, restriction of follow-up to 5 years reduces the number of deaths due to CVA from 292 to 69, a reduction of 76 percent. And, restriction of follow-up to 5 years reduces the number of suicidal deaths from 145 to 69 a reduction of 48 percent. The average age of death from CVA is approximately 30 years more than suicides so the proportionate reduction in observed deaths is greater for CVA.

However, another more serious problem of bias arises with restriction of follow-up due to effect modification. For example, a worker who works at a study sawmill for a few years and subsequently lives a life of transient employment may be at high risk for CHD both because of exposure to adverse psychosocial conditions at his various jobs and also because of exposure to stressful life experiences due to both the threat and reality of unemployment. Because these same workers will have low cumulative and TWA exposure scores, unemployment will likely have a larger impact on these workers compared to workers with high cumulative exposure.

If the relative effect of unemployment is greater for workers with low cumulative exposure and if these workers are followed for 5 or 10 years only, then an effect is more likely to be observed for mortality outcomes which occurs fairly immediately in relation to both unemployment and psychosocial work conditions and at a relatively young age. This is particularly important in the case of workers who enter a study sawmill for a year or two in their early 20s. They will have low cumulative exposure but be exposed to unemployment and bad psychosocial work conditions, possibly all their life. For such workers, accidental mortality (which could be a more acute effect of both exposure to bad psychosocial work conditions and unemployment) within 5 or 10 years may be observed. However, for outcomes like CVA, atherosclerosis and CHD in general, (which do not generally develop until middle and old age) restriction of follow-up in the presence of effect modification by unemployment might produce few cases.

9.4 Confounding

There were five categories of potential confounders that could have affected results. First, age at hire, year of hire, and duration of employment were controlled in the logistic regression analyses so that it is unlikely that any of these factors confounded the analysis. The second category of potential confounders, located in the workplace environment were shift work, unemployment and strikes. Shift work, unemployment, and strikes were not controlled but an attempt was made to determine the extent to which unemployment late in the study period might have confounded the analyses. Third, it is possible that chemical exposure, to chemicals such as carbon monoxide (which are known to affect CHD), would be more likely for workers in physically sedentary and noisy jobs. Fourth, "traditional" biomedical (such as cholesterol, blood pressure, and obesity) and life-style risk factors such as smoking, diet, alcohol use, and exercise were not measured in this study. The final potential confounder was social class.

Age of hire, duration of employment, and year of hire were controlled statistically in the logistic regression analysis. These statistical controls would have minimized confounding for these factors.

No person-specific data was available for shift work or unemployment. The labour demography analysis showed that labour turnover for the bulk of the study period averaged 13 percent and was more due to hirings than terminations. Net termination rates were negative for most of the study period, again showing relative employment stability for the period 1950 to 1980. Because no person-specific information on unemployment was available controlling for unemployment was not possible.

As well, no person-specific information was available on the extent of layoffs due to strikes. Mill-specific information on strikes was also unavailable so that any "wild-cat" strike action was not captured in this database. However, the number of industry-wide strikes during the study period was remarkably infrequent so that is it unlikely that failure to obtain data on strikes will contribute to confounding in any way.

The greatest potential for confound may be due to the recession which occurred in 1981. After 1981 there were many layoffs in study sawmills so that the era prior to 1981 was very different from the post-1981 period in terms of unemployment. The potential for confounding due to unemployment may have been increased during the last four years of the study period. Stratified analysis using logistic regression with exposure measurement only to December 31st, 1980 was undertaken. No difference in results was found for analysis to 1980 versus 1985 indicating that the potential for confounding of results by unemployment may have been minimal.

The third potential confounder in this analysis could be chemicals. For example, it is possible that workers in physically sedentary and noise jobs, such as forklift driving, are also exposed to carbon monoxide or other cardio-toxic chemicals. Although this is possible, it is unlikely because noisy jobs are located fairly ubiquitously throughout the sawmill. Also, as pointed out in Kristensen's exhaustive review of chemicals and CHD, the chlorophenols, the most widely used chemical in the sawmills, are not cardio-toxic (Kristensen 1989b).

While carbon monoxide is cardio-toxic, its distribution in the sawmills will not likely be associated with either noise of physically sedentary work. The most noisy jobs are in the middle of the assembly line which is also the place most removed from carbon monoxide exposure. While carbon monoxide exposure may be quite high for carrier drivers and forklift drivers (physically sedentary jobs) other workers with physically sedentary jobs such as foremen and security guards will have low exposure to this gas.

The fourth potential confounders biomedical and life-style risk factors were not measured. Smoking, drinking, and other life-style risk factors might confound the analyses. Partial control for life-style and biomedical risk factors may have been achieved because of the class homogeneity of the cohort. Checkoway has noted that "an indirect approach to controlling for life-style confounders is to control for social class" (Checkoway and others 1989, 91). The blue-collar nature of this cohort offers some control for confounding due to life-style and biomedical risk factors as it is homogenous in terms of class. Of course because persons-specific data on these risk factors was unavailable the extent of life-style and biomedical confounding unrelated to social class (i.e. residual confounding within the cohort) could not be estimated.

However, this might not matter because biomedical and life-style risk factors may be intermediate variables in the pathway between "stress" and coronary heart disease (Marmot and others 1995). According to Checkoway, "control for life-style is not appropriate if modification of life-style is an intermediate step in the causal pathway leading from occupation to disease." (Checkoway and others 1989, 91).

For these risk factors to be an intermediate variable they would have to both show positive associations with psychosocial work condition variables and be positively associated with CHD morbidity and mortality outcomes. There is mounting evidence that psychosocial conditions of work are positively associated with many of these risk factors. And, as demonstrated in Chapter 5, a majority of investigations with the demand/control model indicate positive associations between psychosocial work conditions and CHD risk life-style and biomedical risk factors (see Table 3).

Furthermore, Marmot has shown clearly in the Whitehall studies that CHD risk factors such as obesity, smoking, blood pressure (in males), lack of exercise, and "unhealthy" diet increase in a smooth gradient from high to low employment grade in the British civil service. This study also shows that psychosocial work conditions also vary in a smooth gradient with "worse" conditions of work found at lower levels in the civil service and "best" conditions in the upper hierarchy. The Whitehall data indicate that "to focus on behaviour as an explanation for social inequalities in health is to take a step backward along the causal chain" (Marmot and others 1995, 202). This means that leaving CHD life-style and biomedical risk factors un-controlled in the analyses may be appropriate in this investigation.

The final potential confounder in this investigation is social class. In Chapter 3 studies with the demand/control model and CHD outcomes which controlled for social class were reviewed. These showed that positive associations with the model were obtained in the majority of investigations even after controlling for class. As mentioned previously, Marmot has shown a relatively smooth gradient in psychosocial work conditions across employment grade in the British civil service (Marmot and others 1995). In the most recent analysis of Whitehall data, after controlling for social class psychosocial work conditions (mainly control) "explained" most of the variance in CHD outcomes (Bosma and others 1997).

In summary, partial control of life-style and biomedical risk factors were obtained in this investigation because the sawmill cohort is composed of working class men. There is a strong argument against tighter control for life-style and biomedical risk factors in this and other investigations with psychosocial work conditions as these risk factors are likely intermediate in the pathway between stressors and development of diseases such as atherosclerosis.

9.5 Implications of Study Findings

9.5.1 Implications of the Main Findings

Noisy and physically inactive jobs in this study were associated with increased mortality from CHD. Although, in an academic sense, this information is not new, it is not clear to what extent stakeholders in B.C. sawmills, and those responsible for health and safety in the industry, know that noisy and sedentary jobs have CHD risks associated with them. Most of the health and safety concern about noise in sawmills is currently in terms of protection against hearing loss. Similarly, too-much physical activity in sawmill jobs is usually the focus health and safety concern particularly as it relates to heavy lifting and back injury.

These main findings should therefore be publicized with the sawmill industry and the Workers' Compensation Board. Also, further research should be undertaken in the industry with more accurate noise and physical demand instruments to characterise the risks and how best to develop interventions to reduce these. [21]

[21] An investigation into noise and its effect on CHD is presently underway in this cohort using more sophisticated measures for both current and historical noise exposures. And, a joint industry/union study is developing tools to measure physical demand in forest industry jobs.

9.5.2 Implications for the Use of Expert Raters

This investigation demonstrated that job evaluators may be used as expert raters to estimate psychosocial work conditions. Up until now experts have usually been supervisors. While small worksites and industries do not usually have job evaluators available, some large industries have them so that the expert rater method in this investigation will be generalizable in some industrial situations. Increasingly in human resources departments experts in job development, and job classification are being hired so that in the future more experts of this type may be available for estimation of psychosocial work conditions. As well, with the increasing recognition of the importance of psychosocial work conditions in the etiology of back pain and other strain injuries, it is possible that Workers' Compensation Boards, or other agencies, will have to train industrial hygienists to assess psychosocial conditions of work.

Findings from this study show that job evaluators are suitable for estimating psychosocial work conditions. But, it is not clear whether care needs to be taken in balancing union and management evaluators. Comparison of scores for psychosocial work condition variables showed there were no statistically significant differences among the three industry raters. There were statistically significant differences between pooled industry scores and the single union rater. These differences were not in an expected direction and so provided a rationale for pooling scores for all four raters. But, because there were no differences among industry rates and there were differences between union and management raters it points to the need, in future research with expert raters, to measure the potential for union or management bias.

9.5.3 Theoretical Implications of Study Findings

The results of this investigation have several implications for the psychological demand construct as used in this investigation. First, as the literature review in Chapter 5 showed, prior to the 1980s, aspects of psychological demand such as the amount of overtime worked, job pressure, monotony, working more than one full-time job, going to school and working full-time, were associated with CHD outcomes. However, with the increasing use of the demand/control model after 1980, most of the positive associations with the model were for the direct effects control rather than psychological demand and attention in the psychosocial job strain literate has shifted from its pre-1980s concern with demand to a 1990s concern with control.

This investigation shows that psychological demand was estimated with borderline reliability and no predictive or concurrent validity by expert raters whereas the other psychosocial variable were both reliable and valid. Of course, psychological demand was operationalised in this investigation with three instead of the usual five questions used in the model. But, even when all 5 questions were estimated in 1997 by the 4 experts, reliability was still less than for the other psychosocial variables. As well, review of studies with CHD outcomes conducted with the 5 "American" questions for psychological demand demonstrated that these have never produced positive associations. These results, particularly when contextualised with the pre-1980 literature on psychological demand and CHD indicate that psychological demand as operationalised in the American version of the demand/control model may lack construct validity. This, the greater difficulty in measuring stressors compared to moderators, and the results of this dissertation indicate that more effort should be placed to develop better indicators of psychological demand before abandoning the interaction thesis of Karasek's model.

The other model which is increasingly used in psychosocial job strain research, Siegrist's effort/reward imbalance model, also postulates an interaction between demand and control (as well as a worker's "need for control") (Siegrist and Matschinger 1989; Siegrist and others 1990). In this model effort is analogous to task-level psychological demand and reward is somewhat similar to a combination of control and social support.

The effort component of Siegrist's model consists of questions about piecework, shiftwork, noise, time pressure, work pace, and workload. Like Karasek's model, these questions measure demand at the task-level although much more comprehensively. Siegrist's reward questions measure occupational instability, status inconsistency, promotion prospects, wages, and self-assessed status relative to peers at work. The focus of these measures is on reward in terms of money and status and self-perception of status within one's work peer group. This constitutes a major difference with the demand/control model which measures none of these broader dimensions of control but instead focuses on control measured at the task-level. It should be noted that Siegrist's model does not measure task-level control at all. Thus Siegrist's model appears to operationalise a more comprehensive measure of task-level psychological demand than Karasek's but omits task-level measures for control which have been consistently associated with diverse morbidity and mortality outcomes when operationalised with the demand/control model.

One of the major difference between the two models is the way in which control is conceptualized and measured. A disadvantage of the Siegrist's conception of control is that, except for income levels, it is unclear what policy remedies are available to ameliorate most of his elements of low status control. Using the effort/reward imbalance model rather than the demand/control model therefore has major implications for the thrust and focus of any remedial policy which might be based on the results of the models. It is therefore important to improve the psychological demand component of the demand/control model before abandoning either it or the underlying interaction hypothesis.

One way in which this could be achieved in future research would be to use both models together and besides comparing them, use the Siegrist measures for psychological demand in conjunction with Karasek's measures for task-level control. If Siegrist's psychological demand is a "better" construct than Karasek's then this would be useful augmentation to the demand/control model. And, in another modification, Karasek's task-level measures for control could be used in conjunction with Siegrist's broader control construct to see if these add any explanatory power to the effort/reward imbalance model.

As well as these possible directions for future research with the demand/control model, there are a number of implications for future study design which arise from this investigation. First, when one restricts an investigation involving psychosocial work conditions to one social class, this also means that partial control for life-style and behavioural factors is in fact implemented. If life-style and biomedical risk factors are intermediate rather than confounding variables this restriction introduces the potential for conservative bias in the study design because the range of variables is restricted by the social class homogeneity of the group under investigation. Second, restriction of social class may also attenuate of the range for psychosocial work condition variables further introducing a conservative bias in terms of design.

As Kristensen has pointed out, "in analytical studies where possible causal relationships are elucidated, it is the variation of exposure that matters." (Kristensen 1995, 21). If, as in this study, the range for psychosocial work condition variables is skewed or restricted, then variation in exposure will be restricted making it difficult to show positive results. Therefore, in future studies with homogenous cohorts it is necessary to ensure that psychosocial conditions of work across job titles or occupations within the cohort are evenly distributed across as broad a range as possible.

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APPENDIX A

Data Abstracted from Personnel Records

1. Personal Identifying Information:

Personal study number

Mill number

Surname

Middle name

Firstname

Marital status

Birth date

Birth place

Spouse's first name

Spouse's birthdate

Social Insurance Number

Employee number

Mill hire date

Mill termination date

Termination code

Pension number

Last known vital status

Death date

Death place

Death cause

Last known year alive

Last known place alive

2. Occupational History Data:

Job number

Job start date

Job end date

Job title

Department

Comments

APPENDIX B

Core Job Title list (86) Used for 1965 Estimations

BARKER OPERATOR	LUMBER STRAIGHTENER
BENCHMAN	MACHINIST
BLOCKMAN	MANAGER/SUPERINTENDENT
BOAT OPERATOR	MARKER
BOOMMAN	MECHANIC
BREAKDOWN	MILL FOREMAN
CARPENTER	MILLWRIGHT
CARRIER DRIVER	OFFBEARER
CASUAL LABOUR	OILER
CAT OPERATOR	PACKAGE PRESS OPERATOR
CHIPNSAW OPERATOR	PAINTER
CHIPPER FEEDER	PIPEFITTER
CHIPPER MAINTENANCE	PLANER FEEDER
CHIPPER OPERATOR	PLANERMAN
CLEANUP	PONY EDGER OPERATOR
CLERK	POWER HOUSE MAINTENANCE
CRANE OPERATOR	RESAWYER
CUT-OFF SAWYER	SAWFILER
DEPT FOREMAN	SAWFITTER
DOGGER	SCALER
DROPSORTER	SCOWMAN
EDGER OPERATOR	SETTER
ELECTRICIAN	SHORTAGE CLERK
END LOADER OPERATOR	SLAB PICKER
END SEALER	SLIPMAN

FIRE PROTECTION
FIRST AID
FORKLIFT
GANG SAWYER
GRADER
HEAD SAWYER
HELPER
HOG OPERATOR
HOIST OPERATOR
J-BAR SORTER PATROLMAN
J-BAR/SORTER OPERATOR
JUMP ROLLS OPERATOR
KILN OPERATOR
LABOUR
LEVERMAN
LOG DECK OPERATOR
LOG LOADER OPERATOR
LOGS FOREMAN

SPOTTER
STACKER OPERATOR
STEAM ENGINEER
STENCILLER
SWAMPER
TAILSAWYER
TALLYMAN
TIMBER DECKMAN
TRIMMER OPERATOR
TRUCK DRIVER
UNSCRAMBLER OP.
UTILITY
WATCHMAN
WELDER
WIRE TIE
WOODPICKER
YARD FOREMAN
YARD LOCOMOTIVE

APPENDIX C

13-item Questionnaire Used for 1965 ESTIMATIONS

(Raters responded to the 13 statements with one of the following answers. Strongly disagree, disagree, agree, strongly agree.)

1. The job required learning new things.
2. The job involved a lot of repetitive work .
3. The job required a high level of skill.
4. The job had a variety of tasks.
5. The worker had a lot to say about what happened on the job.
6. On this job, the worker had a lot of freedom to decide how to do the work.
7. The job did not involve an excessive amount of work.
8. The worker had enough time to get the job done.
9. The job was free from conflicting demands.
10. The job required lots of physical effort.
11. The worker could leave this job to talk with co-workers.
12. The worker could interact with co-workers while they worked.
13. The job was noisy.

APPENDIX D

18-item Questionnaire Used for 1997 ESTIMATIONS

(Raters responded to the 18 statements with one of the following answers. Strongly disagree, disagree, agree, strongly agree.)

1. The job requires learning new things.

2. The job involves a lot of repetitive work.

3. The job requires a high level of skill.

4. The job has a variety of tasks.

5. The job requires creativity.

6. The job allows opportunity for the worker to develop his own special abilities.

7. The worker has a lot to say about what happens on the job .

8. On this job, the worker has a lot of freedom to decide how to do the work.

9. The job allows the worker to make a lot of decisions on his own.

10. The job requires working very fast.

11. The job requires working very hard.

12. The job does not involve an excessive amount of work .

13. The worker has enough time to get the job done.

14. The job is free from conflicting demands.

15. The job requires lots of physical effort.

16. The worker can leave this job to talk with co-workers.

17. The worker can interact with co-workers while they work.

18. The job is noisy.

APPENDIX E

Job Title list (54) Used for the 1997 Estimations

BARKER OPERATOR
BOOMAN
CARPENTER
CARRIER DRIVER
CAT OPERATOR
CHIPNSAW OPERATOR
CHIPPER OPERATOR
CLEANUP
CLERK
CRANE OPERATOR
CUT-OFF SAWYER
DEPT FOREMAN
DROPSORTER
EDGER OPERATOR
ELECTRICIAN
FIRST AID
FORKLIFT
GANG SAWYER
GRADER
HEAD SAWYER
HOIST OPERATOR
J-BAR/SORTER OPERATOR
KILN OPERATOR
LABOUR
LOG DECK OPERATOR
MACHINIST
MANAGER/SUPERINTENDENT
MARKER
MILL FOREMAN
MILLWRIGHT
OFFBEARER
OILER
PACKAGE PRESS OPERATOR
PIPEFITTER
PLANER FEEDER
PLANERMAN
RESAWYER
SAWFILER
SCALER
SCOWMAN
SLIPMAN
STACKER OPERATOR
STENCILLER
SWAMPER
TAILSAWYER
TALLYMAN
TRIMMER OPERATOR
TRUCK DRIVER
UNSCRAMBLER OP.
WATCHMAN

LOG LOADER OPERATOR

LOGS FOREMAN

WELDER

YARD FOREMAN

APPENDIX F

Obsolete* (2) or Rare Jobs (18) in 1997

BLOCKMAN

CASUAL LABOUR

DOGGER*

END SEALER

HELPER

JUMP ROLLS OPERATOR

LEVERMAN

LUMBER STRAIGHTENER

PAINTER

SCOWMAN

SETTER*

SHORTAGE CLERK

SLAB PICKER

SLIP MAN

SPOTTER

STENCILLER

TIMBER DECK OPERATOR

WIRE TIE

WOODPICKER

YARD LOCOMOTIVE

APPENDIX G

Job Title list (30) Used for the Test of Concurrent and Predictive Validity

BARKER OPERATOR	MILL FOREMAN
BOOMMAN	MILLWRIGHT
CARRIER DRIVER	OILER
CAT OPERATOR	PACKAGE PRESS OP.
CHIPPER OPERATOR	PLANER FEEDER
CRANE OPERATOR	PLANERMAN
DROPSORTER	RESAWYER
EDGER OPERATOR	SAWFILER
ELECTRICIAN	STENCILLER
FIRST AID	TAILSAWYER
FORKLIFT	TALLYMAN
GANG SAWYER	TRIMMER OPERATOR
GRADER	UNSCRAMBLER OP.
LABOUR	WELDER
MANAGER/SUPERINTENDENT	YARD FOREMAN