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Memorandum

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From: Roy M. Fleming, Sc.D., Director, Research Grants Program *RMF*
Office of Extramural Programs, NIOSH, D30

Subject: Final Report Submitted for Entry into NTIS for Grant 5 R03 OH003405-02.

To: William D. Bennett
Data Systems Team, Information Resources Branch, EID, NIOSH, P03/C18

The attached final report has been received from the principal investigator on the subject NIOSH grant. If this document is forwarded to the National Technical Information Service, please let us know when a document number is known so that we can inform anyone who inquires about this final report.

Any publications that are included with this report are highlighted on the list below.

Attachment

cc: Sherri Diana, EID, P03/C13

List of Publications *None*

Title: Organizational Support: Contribution to CTD Risk
Investigator: Robert Karasek
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Telephone: (508) 934-3274
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Abstract:

The goals of this research were to quantify the associations of psychosocial and biomechanical stressors with indicators of musculoskeletal disorders (MSD) and stress disorders and to examine how organizational characteristics affect these relationships. The investigation analyzed a large database, the Monitor Study, collected in the Netherlands. This database includes interviews from a representative sampling of employers in 782 companies and questionnaires administered to randomized samples of employees in 528 of these companies ($n = 7,717$). From the employee questionnaires, four psychosocial stressor scales (Demands, Autonomy, Skill Discretion and Social Support) and four biomechanical stressor scales (Repetitive Bend/Twist, Static Bend/Twist, Reaching/Prolonged Postures, and Physical Exertion) were constructed. MSD indicators were represented by reports of physical strain and pain. Indicators of stress disorders were reports of exhaustion and tiredness. Both MSD and stress disorders are measured by outcomes of extended sick leave (>3 mo.) and partial disability. Employer interviews provided parallel estimates of stressor levels as well as company-level measures (economic branch, size, disability insurance structure, % temporary workers, market position, etc.). After examining univariate relationships, multivariate linear and logistic models were developed at the individual and company levels. The research design carried out a multilevel analysis of the associations between organizational characteristics, individual-level psychosocial and physical stressors, intermediate measures of musculoskeletal and psychological strain and the health-related outcomes of absenteeism and disability. Several levels of findings are presented.

1. Individual-level analysis of the employee data set.

Psychosocial and biomechanical stressor levels show significant independent associations with MSD indicators. The wide range of work places in the Monitor study permits accurate separation of their relative contribution. Biomechanical stressors have a wide range of associations with physical strain measures, including the strongest associations of the study (e.g., Reaching/Prolonged Postures with the summary Physical Strain scale: Beta = 0.45). Psychosocial stressors show more moderate but less variable associations with physical strain. The measures of pain were associated with most psychosocial and biomechanical stressors at more similar levels (Beta's = 0.07 - 0.15). Extended sick leave was associated with reports of Repetitive and Static Bend/Twist and deficits in Skill Discretion and Social Support at similar levels (ORs from logistic models: 1.4-1.9).

Partial disability was only associated with psychosocial stressors; these associations are probably a description of the return-to-work atmosphere.

The four psychosocial stressors studied show different and characteristic patterns of association with outcomes, which might be indicative of different physiological pathways of action. The relatively less variable magnitudes of association between psychosocial stressors and strain and pain outcomes, compared to the greater fluctuation in biomechanical stressor associations, may demonstrate the central and systemic action of the former in contrast to the anatomically localized effects of the latter.

2. Employer estimates of employee stressor exposure and level of outcome.

Parallel analyses were carried out using employer questions analogous to the employee measures. Employer assessments of the work environment are more optimistic than those of employees and focus on a few stressors that are most visible. Employer identification of biomechanical risk seems to center on force demands, although this is one of the less predictive biomechanical stressors in the models based on employee reports. Employers seem to have a particularly difficult time identifying psychosocial risks; the employer/employee correlations concerning level of biomechanical risks range as high as .44, while most correlations concerning levels of psychosocial risk are not significant.

3. Company-level associations of organizational structure and culture with the individual-level psychosocial and biomechanical stressors--an etiology of risk factors.

Model construction at this level used employee reports of stressor levels as the dependent variables, aggregated for the employee sample within each company. Even in analyses stratified by sector groups, most company independent variables did not demonstrate strong associations with stressor levels. The models demonstrate significant associations between employee stressor estimates and a small set of company-level variables. The strongest and most consistent predictors of aggregated stressor reports are: % of Temporary Workers, Self-Insurance and Health & Safety Policy Plan measures.

"Discrepancy Indices", the difference between employer and aggregate employee estimates of risk level, were created as an hypothesized indicator of organizational culture characteristics. Suitably corrected by the mean employer/employee stressor estimates, Discrepancy Indices are strongly associated with variation in aggregate employee stressor levels. The analyses guarded against possible tautology by using psychosocial Discrepancy to predict biomechanical stressor level and biomechanical Discrepancy to predict psychosocial stressor level.

4. Company-level associations of organizational structure and culture with the individual-level outcome variables of MSD indicators, above.

In the individual-level data set, we imputed to each employee the appropriate company-level measures. The associations of company-level variables, including Discrepancies,

with individual-level MSD indicators operate almost entirely through individual-level stressors. There are virtually no direct relationships of company-level variables to individual-level strain and health-related outcomes.

These findings have potential implications for prevention strategies. Effectiveness of interventions could be improved by addressing the combination of psychosocial and biomechanical stressors in the work environment. New methods of characterizing and measuring key organizational characteristics may add importantly to determining prevention priorities and strategies. This research suggests several marker measures that could be used to "flag" organizations at risk, guide interventions, and assess their results. The Discrepancy Variables, in particular, are expected to be the basis for a new set of tools useful for prevention strategies.

Publications

No publications to date.

Final Performance Report
For
Grant # RO3-OH03405-01

**Organizational Support:
Contribution to CTD Risk**

Original

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This research would not have been possible without the attention, persistence and vision of Dr. Robert Karasek, the thesis advisor and chair of this Committee, whose intellectual rigor and creativity provide the underpinnings of this thesis.

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Significant Findings and Relationship to the Aims of the Project

The significant findings are presented in cursory form in the Abstract (following) and in detail in the attached report. In this section, we relate the findings to the specific aims of the project.

1. **Specific Aim 1:** To characterize the associations between individual-level psychosocial stressors, intermediate levels of musculoskeletal and psychological strain, and musculoskeletal and stress disease outcomes, represented by absenteeism and disability.
 - a. The data cleaning, re-coding (to clarify direction of association), data exploration, selection of appropriate variables to test the model, and data reduction Were completed by late 1996. Scales were constructed for all relevant measures: stressors (levels of physical and psychological demands, autonomy, skill discretion, control of schedule, and social support); strain (exhaustion, psychosomatic complaints, reports of difficulty with various positions or movements, and pain frequency in body parts). For health outcome variables, a long-term absenteeism measure was created, and the disability measure in the data set is used unchanged. Most scales were created using factor analysis and referring to other research; reliability, as measured by Cronbach- α , is acceptable to good for almost all scales. Multivariate linear and logistic regression techniques were used throughout. Within-level, multivariate linear and logistic regression are robust and satisfactory tools to characterize associations. Bivariate and partial correlation analysis was used for initial selection of variables to enter into the models. Graphical analysis, stratified by level of independent variables, was used to detect non-linear relationships that might obscure correlations and to identify interaction relationships.
 - b. Results:
 - 1) Two Mental Strain outcomes were predicted primarily by psychosocial stressor levels, with Psychological Demands and Social Support deficit being the major predictors (β s of .33 and .29, respectively, for the Exhaustion outcome, .16 and .22 for the Tiredness outcome). Biomechanical stressors had low but significant associations with these outcomes.
 - 2) Physical Strain and Sitting Strain outcomes were predicted primarily by biomechanical stressors, with Reaching & Prolonged Postures being the major predictor for Physical Strain ($\beta = .45$, the highest association at this level) and Static Bending & Twisting being the major predictor for Sitting Strain ($\beta = .41$). The psychosocial had consistent but low associations with these outcomes.
 - 3) Both psychosocial and biomechanical stressors show lower but more equivalent levels of association with MSD indicators and Pain reports, with the

strongest associations shown by Social Support deficit (β s between .09-.12) and Static Bending & Twisting (β s between .15 and .16).

- 4) Mild interaction was detected between many biomechanical and psychosocial stressors in these associations.
 - 5) The interactions within psychosocial stressors, predicted by the Demand-Control model, explain variance in outcomes of Mental and Physical Strain, Pain, and Extended Sick Leave
- 2. Specific Aim 2:** To explore the associations between aspects of organizational structure and support mechanisms and the presence of psychosocial and physical load risk factors at the individual level. Having established the coherence and appropriateness of the individual-level measures, the analysis will move up to the organizational-level.
- a. The data cleaning, re-coding (to clarify direction of association), data exploration, selection of appropriate variables to test the model, and data reduction were completed by mid-1997. Aggregation of individual level data by plant was carried out. Employer data was explored for variables that showed associations with employee reports of stressor levels. Although we explored multi-level techniques, within the constraints of the grant it seemed appropriate to continue the use of multivariate regression techniques, using employee data aggregated at the plant level for the outcome measures. A surprisingly small number of employer-reported company characteristics showed significant associations in models explaining employee reports of 9 stressor levels. These measures are associated with increased levels of one or more of these stressors:
 - 1) Company Size
 - 2) Percentage of Temporary Workers
 - 3) Self-Insured for Disability (as opposed to insurance through the Industrial Insurance Association).
 - 4) Existence of an active and integrated Policy Plan (a counter-intuitive finding, which may mean that the creation of the Policy Plan is the result of poor conditions in the companies).
 - 5) Percentage of employees in Teams (this crude measure of team work suggests that the team approach in these companies increases risk as perceived by employees.)
 - 6) Management and/or Employee involvement in health and safety (as above, this involvement may be occasioned by poor conditions in the company).
 - b. The major task of this section has been the creation of discrepancy variables, representing the percentage discrepancy between an employer's estimate of risk level and the aggregate estimation of the employee sample for the plant. These differences are hypothesized to be relatively unbiased indicators of company culture. We used a complex protocol of stressor aggregation and crossover (i.e., using psychosocial discrepancy to predict employee-reported biomechanical stressor levels and vice versa) to protect against possible tautological relationships. We also employed the simultaneous entry of the mean employer/employee risk estimate to control for "true" risk level. These Discrepancy Indices turned out to be

- the strongest organization-level predictors of employee-reported stressor levels. A summary Biomechanical Discrepancy Index shows regression coefficients between .20 and .32 in models explaining variance in psychosocial stressors. The summary Psychosocial Discrepancy Index shows regression coefficients between .51 and .65 in models explaining variance in biomechanical stressors.
- c. We explored these models at the individual level, imputing company-level organizational variable levels (structural, policy and Discrepancy) to individual cases. As expected, the associations persisted, but at a lower intensity, due to the dilution effect of outliers. This type of modeling will be explored further, using hierarchical regression methods.
3. **Specific Aim 3:** To explore the direct associations between the above-mentioned organizational measures (employer-reported and Discrepancy) and the individual-level outcome measures from Specific Aim 1: musculoskeletal and psychological strain, MSD Indicators, Pain Reports and health outcomes of Partial Disability and Extended Sick Leave.
- a. These regressions showed an expected association between organizational measures and individual-level outcomes aggregated at the company level. However, when levels of the 9 stressors were added in a later block, these associations essentially disappeared. The effects of organizational variables on employee-reported strain, pain and health outcome measures appears to be moderated almost entirely through stressor levels
4. **Specific Aim 4:** To characterize the economic environment of the company and its associations with stressor, strain, and health outcome measures at the company-level and the individual-level. This was an additional aim we unwisely added after the first year of the grant. In fact, the original 3 aims occupied all the available resources of the grant, and this last aim, while worthy, was an impossible goal within the limits of the grant. Initial correlations suggest that employee-reported levels of stressors and strain, pain and health outcomes are related to employer estimates of company economic position and market uncertainty. These intriguing relationships will be explored in the future, in the continuing analysis of this data set.

Usefulness of Findings

These results have three practical implications:

1. A focus on only the biomechanical ergonomic risks within an organization may result in prevention approaches that are ineffective, because of the complex association between biomechanical and psychosocial risk factors and health outcomes. A wider characterization of risk types and levels within the company may often be necessary to reduce WRMSD.
2. Organizational characteristics themselves are associated with these risk levels. To more fully control risk of all types, it may be necessary to identify and address the organizational bases of these risks. In particular, the organizational characteristics for which the Discrepancy Indices may serve as an indicator (to be explored in future research) seem to be the most predictive of risk level and thus should be the focus of organizational interventions.

3. The research has identified markers or “flags” at both the individual and the organizational level that could be used to target jobs, departments, and organizations at risk; to develop intervention strategies; and to evaluate success of these interventions.

List of Publications

Present:

1. The Organizational and Psychosocial Bases of Cumulative Trauma and Stress Disorders. Doctoral Thesis, submitted to UMass. Lowell, 1997. UMI # 9726279 587 pp.
2. Research Supplement submitted to the Dutch Ministry of Social Affairs and Employment and TNO, 1998. 168 pp.

Planned:

1. Biomechanical and Psychosocial Bases of Work Related Musculoskeletal and Stress Disorders; Individual-Level Associations
2. Organizational Risk Factors for Work Related Musculoskeletal and Stress Disorders; Company-Level Associations
3. Discrepancy Indices; an Unbiased Measure of an Organizational Culture Dimension
4. The Effect of Employers' Estimates of Company Economic Status on Employee Reports of Risk and WRMSD
5. (Other papers examining longitudinal trends, using later administrations of the Monitor questionnaire by the Ministry of Social Affairs and Employment)
6. (Other papers examining longitudinally the associations found in this research in several United States companies or groups of companies)

PREFACE

This document is intended as a supplement to the doctoral thesis submitted to the Department of Work Environment, UMass. Lowell: The Organizational and Psychosocial Bases of Cumulative Trauma and Stress Disorders. It is a condensation and extension of that work.

The research is designed to compliment the work of Houtman et al (1994a, 1998), using the same data set. Wherever possible, we use similar scales and measures, for reasons of comparability. Where different measures and scales are created, to address specific hypotheses of this research, we note the differences in the text.

ABSTRACT

The goals of this research are to quantify the associations of psychosocial and biomechanical stressors with indicators of musculoskeletal disorders (MSD) and stress disorders and to examine how organizational characteristics affect these relationships. The investigation analyzed a large database, the Monitor Study, collected in the Netherlands. This database includes interviews from a representative sampling of employers in 782 companies and questionnaires administered to randomized samples of employees in 528 of these companies ($n = 7717$). From the employee questionnaires, 4 psychosocial stressor scales (Demands, Autonomy, Skill Discretion and Social Support) and 4 biomechanical stressor scales (Repetitive Bend/Twist, Static Bend/Twist, Reaching/Prolonged Postures, and Physical Exertion) were constructed. MSD indicators were represented by reports of: physical strain and pain. Indicators of stress disorders were reports of exhaustion and tiredness. Both MSD and stress disorders are measured by outcomes of extended sick leave (>3 mo.) and partial disability. Employer interviews provided parallel estimates of stressor levels as well as company-level measures (economic branch, size, disability insurance structure, % temporary workers, market position, etc.). After examining univariate relationships, multivariate linear and logistic models were developed at the individual and company levels. The research design carries out a multilevel analysis of the associations between organizational characteristics, individual-level psychosocial and physical stressors, intermediate measures of musculoskeletal and psychological strain and the health-related outcomes of absenteeism and disability. Several levels of findings are presented.

1. Individual-level analysis of the employee data set.

Psychosocial and biomechanical stressor levels show significant independent associations with MSD indicators. The wide range of work places in the Monitor study permits accurate separation of their relative contribution. Biomechanical stressors have a wide range of associations with physical strain measures, including the strongest associations of the study (e.g., Reaching/Prolonged Postures with the summary Physical Strain scale: $\beta = 0.45$). Psychosocial stressors show more moderate but less variable associations with physical strain. The measures of pain were associated with most psychosocial and biomechanical stressors at more similar levels (β 's = 0.07 - 0.15). Extended sick leave was associated with reports of Repetitive and Static Bend/Twist and deficits in Skill Discretion and Social Support at similar levels (ORs from logistic models: 1.4-1.9). Partial disability was only associated with psychosocial stressors; these associations are probably a description of the return-to-work atmosphere.

The 4 psychosocial stressors studied show different and characteristic patterns of association with outcomes, which might be indicative of different physiological pathways of action. The relatively less variable magnitudes of association between psychosocial stressors and strain and pain outcomes, compared to the greater fluctuation in biomechanical stressor associations may demonstrate the central and systemic action of the former in contrast to the anatomically localized effects of the latter.

2. Employer estimates of employee stressor exposure and level of outcome.

Parallel analyses were carried out using employer questions analogous to the employee measures. Employer assessments of the work environment are more optimistic than those of

employees and focus on a few stressors that are most visible. Employer identification of biomechanical risk seems to center on force demands, although this is one of the less predictive biomechanical stressors in the models based on employee reports. Employers seem to have a particularly difficult time identifying psychosocial risks; the employer/employee correlations concerning level of biomechanical risks range as high as .44, while most correlations concerning levels of psychosocial risk are not significant.

3. Company-level associations of organizational structure and culture with the individual-level psychosocial and biomechanical stressors--an etiology of risk factors.

Model construction at this level used employee reports of stressor levels as the dependent variables, aggregated for the employee sample within each company. Even in analyses stratified by sector groups, most company independent variables did not demonstrate strong associations with stressor levels. The models demonstrate significant associations between employee stressor estimates and a small set of company-level variables. The strongest and most consistent predictors of aggregated stressor reports are: % of Temporary Workers, Self-Insurance and Health & Safety Policy Plan measures.

“Discrepancy Indices”, the difference between employer and aggregate employee estimates of risk level, were created as an hypothesized indicator of organizational culture characteristics. Suitably corrected by the mean employer/employee stressor estimates, Discrepancy Indices are strongly associated with variation in aggregate employee stressor levels. The analyses guarded against possible tautology by using psychosocial Discrepancy to predict biomechanical stressor level and biomechanical Discrepancy to predict psychosocial stressor level.

4. Company-level associations of organizational structure and culture with the individual-level outcome variables of MSD indicators, above.

In the individual-level data set, we imputed to each employee the appropriate company-level measures. The associations of company-level variables, including Discrepancies, with individual-level MSD indicators operate almost entirely through individual-level stressors. There are virtually no direct relationships of company-level variables to individual-level strain and health-related outcomes.

These findings have potential implications for prevention strategies. Effectiveness of interventions could be improved by addressing the combination of psychosocial and biomechanical stressors in the work environment. New methods of characterizing and measuring key organizational characteristics may add importantly to determining prevention priorities and strategies. This research suggests several marker measures that could be used to “flag” organizations at risk, guide interventions, and assess their results. The Discrepancy Variables, in particular, are expected to be the basis for a new set of tools useful for prevention strategies.

CHAPTER I; INTRODUCTION

This document is a condensation of the dissertation, "The Organizational and Psychosocial Bases of Cumulative Trauma and Stress Disorders", completed as partial fulfillment of the requirements for the degree of Sc.D. in Work Environment, University of Massachusetts, Lowell. (Warren, 1997).

A. Specific Aims

The goal of this research is to expand knowledge of work organizational and psychosocial risk factors for stress-related and musculoskeletal occupational illness. The project consists of a multi-level examination and characterization of the associations between organization-level characteristics, individual-level psychosocial and physical stressors, and the health-related outcomes of musculoskeletal and stress-related strain, illness, absenteeism and disability. This research represents an important opportunity to move beyond the measurement of individual-level risk factors to the characterization of organization-level effects on individual health outcomes. The research is based on analyses of a large database collected in the Netherlands, the Monitor Survey, constructed from a representative sampling of employers and employees in 782 companies (n=782 employers, 7717 employees). This Survey represents the best source of currently available data for addressing the goal and specific aims of this research. By focusing on measures of organization-level structure and support mechanisms, this research generates new information about the etiology of disease and its relationship to both individual-level and broader, organization-level influences. The results will expand information that can be used to prioritize and guide future organization-level intervention strategies. The following specific aims, keyed to the 3 parts of the hypothesis detailed in the Methods section, define the structure of the investigation

1. To characterize the associations between individual-level psychosocial stressors, intermediate levels of musculoskeletal and psychological strain, pain measures, and musculoskeletal and stress disease outcomes, represented by absenteeism and disability.
 - a. Using the questions in the Monitor database, measures and scales were constructed that represent each of these steps in the development of disease. These measures were tested for internal consistency and, as much as possible, made comparable to measures used in other research.
 - b. The research focused on extending the present level of knowledge concerning psychosocial associations by more fully controlling for physical load, which is characterized quite well in the Monitor Survey. The wide variety of work places sampled in the Survey provided enough variance to accomplish this separation quite easily.
 - c. This analysis is carried out on the 2 levels of data available in this study:
 - 1) An individual-level analysis of associations, using measures constructed from the employee questionnaires.
 - 2) A company-level analysis of associations, using measures constructed from the employer interviews and from combinations of employer and employee data
2. To explore the associations between aspects of organizational structure and support mechanisms and the presence of psychosocial and physical load risk factors at the individual level.
 - a. Having established the coherence and appropriateness of the individual-level measures, the analysis then proceeds to the organizational-level.

- b. Measures and scales were constructed which capture organizational characteristics, using four different sets of data. These measures were tested for consistency and comparability. These measures are:
 - 1) Simple measures of organizational structure.
 - 2) Measures from the employers' questionnaire that are indicators of organizational support of employees.
 - 3) Measures of employees' perceptions of organizational support, based on data from employee questionnaires, aggregated at a company level.
 - 4) "Discrepancy Indices", comparing within each company the aggregated employee responses and the employer's responses regarding the same measures.
3. To explore the direct associations between the organization-level measures and the individual-level outcome measures from Specific Aim 1: musculoskeletal and psychological strain, pain and health-related outcomes.

B. Background and Significance

1. Importance of the project.

The epidemic of Work Related Musculoskeletal Disorders (WRMSD) in the United States has reached formidable proportions, both in terms of human suffering and of economic cost. In 1994, the Bureau of Labor Statistics Annual Survey of Occupational Injuries and Illnesses (BLS, 1995) reported that 32% of all lost-time injuries and illnesses resulted from "overexertion" (613,224 cases) or "repetitive motion" (92, 576 cases). WRMSD includes both occupationally related upper extremity disorders and low back pain. The term Cumulative Trauma Disorders (CTDs) will be used to refer only to upper extremity disorders. In 1983, NIOSH published its list of "The 10 leading work-related diseases and injuries" (reprinted by NIOSH, 1991). At that time, WRMSDs were already the leading cause of disability during the working years, comprising one-third of annual workers' compensation claims and accounting for the largest amount of lost earnings and workers' compensation costs of any single health disorder. And since that time, the numbers have grown. CTDs rose from 18% of all occupational illnesses in 1981 to 61% in 1991 (Webster & Snook, 1994). Annual medical and indemnity costs for WRMSDs were estimated in 1991 to be in the range of \$20 billion to \$40 billion, not including indirect costs and losses in quality of products and services (Chaffin & Fine, 1992). Added to these losses, enormous, unquantifiable losses are represented by the decline in quality of life and mental health experienced by injured workers. Yelin and Callahan (1995), reviewing the arthritis literature, note the many studies measuring the negative impact of all musculoskeletal conditions on depression, coping abilities, anxiety, cognitive ability, self-efficacy and learned helplessness.

Certainly, some of the rising incidence figures can be attributed to better recognition and reporting of occupationally related musculoskeletal disorders. There is a strong likelihood that the increase also represents an actual rise in exposures to occupational stressors. This increase results from a number of factors, including increased economic competition and the introduction of new technologies. Most important for this research, it is also likely that the continued increase in WRMSD incidence is due, in part, to lack of attention to the psychosocial and organizational components of WRMSD etiology.

To address this lack, NIOSH has explicitly included psychosocial risk factors in its documents on national strategies for prevention of musculoskeletal injuries (NIOSH, 1991, 1996, Chaffin and Fine, 1992). In broad outline, there is a need for:

- The addition of psychosocial risk measurement to physical risk assessment in studying the etiology of musculoskeletal disorders.
- Characterization of a multifactoral model of musculoskeletal disorder causation, including the interaction of psychosocial and physical risk factors.
- Comprehensive, multi-level examination of the organizational characteristics that increase or decrease levels of psychosocial and physical risk factors.
- Combined interventions that focus on the control of both psychosocial and physical risk factors. As with the research, these interventions must take account of the multifactoral and multi-level causation of musculoskeletal disorders.

A number of European countries have already undertaken large scale, nationally representative research initiatives to document the size of the problem and the strength of the associations between psychosocial stressors and WRMSDs. The Swedish MUSIC project (Musculoskeletal Disease Intervention Center, Hagberg & Hogstedt, 1993) has been studying methodologies for assessing WRMSD risk factors and prevention effectiveness. The Danish Work Environment Fund is carrying out psychosocial and physical intervention activities for the Danish textile industry workers--the PRIM project (Scov, 1995). Finally, in the Netherlands, Houtman et al. (1994a, 1998) are carrying out comparable research with a large national sample.

2. Background: Other studies relevant to the research aims and objectives.

This section will extend the argument above, by: a) assessing the current state of research in the areas of interest to this research; b) pointing out the gaps in our knowledge; and c) showing how research using the Monitor database can help fill in these gaps. The sections below examine three different areas of research and knowledge that are relevant to the aims of our research.

The association between psychosocial risk factors and WRMSDs

As noted above, there is increasing effort directed towards characterizing the interaction between psychosocial and work organization factors and WRMSD outcomes internationally, as well as in the United States. The shape of these interactions and the strength of the associations are becoming clear in many studies, in addition to the large national projects noted above. Most of this work has been carried out in Europe. A recent study in Finland (Leino & Hänninen, 1995) presents an excellent model for future research: a 10-year prospective study of the relationship between psychosocial job characteristics and musculoskeletal symptoms and findings, with careful control for physical workload. This research found that social support and work content measures predicted changes in upper extremity, lower back and lower limbs over the 10 year period. P.M. Bongers et al., of the Dutch TNO, prepared a review of the epidemiological literature in 1993. This review of 29 studies that addressed work characteristics directly (two used study populations over 20,000, another 6 studied populations over 4000) suggests that monotonous work, high perceived work load, time pressure, low control and lack of social support are related to musculoskeletal outcomes. Their work analyzed the studies using the framework of the Demand-Control-Support model (Karasek, 1979), the same model that informed the Monitor questionnaire and much of the current psychosocial research. While noting the high degree of col-

linearity between physical and psychosocial risk factors, the Bongers et al. study also pointed out that joint collection of data on psychosocial and physical risk factors is relatively rare. The Monitor database advances the effort to separate physical load from psychosocial risk factors, because of the detailed and simultaneous collection of data regarding both, and because of the wide range of work places sampled.

In the United States, Faucett and Rempel (1994) found that musculoskeletal symptoms in VDT workers were the result of a complex interaction between work posture and psychosocial work factors. Psychological demands, decision latitude, and employee relationship with the supervisor were found to modify the relationship between work posture and symptom reports. NIOSH has undertaken two studies that found a relationship between psychosocial stressors and the development of musculoskeletal symptoms among VDT workers. These were Health Hazard Evaluations (HHE's) at the L.A. Times (Bernard et al., 1992) and at U.S. West Communications (Hales et al., 1992). Sample sizes in these studies were 973 and 533 respectively. Both studies found a high prevalence of musculoskeletal disorders and symptoms in VDT workers, associated with a combination of psychosocial and physical work place factors.

Intervention studies in several countries also help to strengthen confidence in these associations. In Sweden, Sven Kvarnstrom (International Labor Organization, 1992) found that changes in the psychosocial work environment (increased variety, decision-making latitude, and individual control over the work situation) in a small department of a large, multi-national company greatly reduced the high rate of absenteeism and turnover due to musculoskeletal disease. In the United States, Smith and Zehel (ILO, 1992) were engaged by a meat-processing plant to carry out ergonomic job analyses and create engineering changes and training programs to reduce WRMSDs. Significantly, employee focus groups instituted during the implementation phase identified the further need for changes in the psychosocial environment. These resulted in decreased physical symptoms for part of the work force. This model of a broad-based exposure-reduction approach, incorporating both physical and psychosocial work environment changes, is promising for future interventions. The use of worker participation in problem solution is a central tenet of many approaches to work environment change. Pasmore & Friedlander (1982) carried out an early intervention project in a United States electronic assembly facility. The employees themselves determined the data to be collected and recommendations for the use of these data in resolving an outbreak of musculoskeletal injuries (mainly tenosynovitis). The research methods used to address a musculoskeletal problem created crucial changes in psychosocial risk factors, by increasing employee participation and task control and altering role relationships within the organization. As these organizational relationships changed, the tenosynovitis symptoms were greatly reduced. Clearly, this research indicates that the interaction between physical and psychosocial stressors, while complex, is important in the etiology of musculoskeletal outcomes.

These intervention studies also highlight the central hypothesis of our research: to fully understand the genesis of these psychosocial risk factors, themselves and to develop effective strategies to reduce these risk factors, it is important to analyze organization-level precursors. Work organization at the individual level is to a large degree the expression of company structural and cultural characteristics. The level of physical load stressors in the work place is also affected by organizational characteristics. Therefore, uncovering the linkages between organization-level

characteristics and individual-level psychosocial and physical stressors has far-reaching policy implications. The Monitor Study collected data that allow us to construct measures of these characteristics and test their associations with individual-level stressors and health outcomes.

The association of organizational characteristics with injury.

As noted above, it is likely that part of the failure of many control strategies to more strongly affect WRMSD rates lies in their failure to address psychosocial risk factors and their organizational bases. The same failure is seen in studies of occupational injuries. The Ontario-based Institute for Work and Health has suggested in a working paper (Shannon, et al., 1994) that the failure of Canadian health and safety efforts to significantly reduce injury rates, despite "the efforts in health and safety in the last one or two decades," is related to the general lack of attention to organizational factors (this analysis refers to all injury rates, not just musculoskeletal). Shannon et al. collected organizational variables and lost-time frequency rates (LTFR) for Workers' Compensation claims in 718 work places. Their results indicate that lower LTFR were associated with worker involvement in decision making, worker involvement in health and safety decision making, willingness of the Joint Health and Safety Committee to solve problems internally and experience of the work force. The first 3 factors clearly represent organization-level correlates to accident frequency. And the last factor, experience of the work force, is to a degree the result of organizational decisions concerning use of the labor force--e.g., the decision to increase competitiveness by maintaining and training a stable, skilled work force rather than by relying primarily on short-term employment as a means of responding to demand fluctuations in the market. Although this Canadian research deals with all injuries, it is reasonable to assume that the findings apply to musculoskeletal injuries alone. To assess this, the Institute for Work and Health is continuing this work with its Integrated Study of causes of and recovery from soft tissue strains and sprains, which will specifically relate physical and psychosocial risk factors to the development of lower back pain. A second part of the study will examine workers with neck and upper extremity disorders.

The association of organizational factors to employee motivation and attitudes.

The studies cited in this section do not deal directly with musculoskeletal outcomes, and the Monitor database does not contain attitudinal outcomes. However, the this organizational development and psychology literature contains a substantial body of detailed methodological thought concerning the measurement and analysis of organizational variables. These studies show a wide variety of independent organizational-level variables that have been examined in relation to attitude (and often productivity) outcomes. So far, these have not been related to musculoskeletal outcomes in most studies, although some studies do examine the relationship with stress outcomes. It is the intention of our research to extend these organizational measures to examine outcomes of individual-level psychosocial and physical stressors, strain and musculoskeletal as well as stress health outcomes.

In 1982, French, Caplan and Harrison reported the results of their study on the mechanisms of job stress. Their sample of 2010 men was drawn from 23 diverse occupations, representing blue- and white-collar work places. Their research looked primarily at individual-level work environment variables, but these variables are clearly related to organizational culture and environment. They used a person-environment fit model that appears to be extremely sensitive to organiza-

tional influences. An interesting thrust of their research, related more directly with the aims of the present research, is the association of stressful work conditions not only with motivation, work dissatisfaction, anxiety and depression, but also with somatic complaints (although they did not address musculoskeletal symptoms separately). Golembiewski et al. (1986), approaching the field from a consulting and Human Resources point of view, focused on the phenomenon of “burnout”. This is a measure of strain that is also included in the Monitor Study. Their sample compared 295 employees of a private company with 1535 employees of a local division of a federal agency. In identifying the causes of burnout, they examined the organizational correlates, as well as the system costs of burnout. Significantly for the present research, this work indicated that different organizational climates and levels of burnout responded to quite different types of interventions.

Lincoln and Kalleberg (1990) sampled manufacturing populations of 4567 individuals in the United States and 3735 in Japan, with the explicit intention of linking differences in organizational structure to employee satisfaction and commitment. The focus was on explaining differences between United States and Japanese organizational structure and employee commitment. This study broke new ground in its multi-level approach to investigation of individual-, job-, work place-, industry- and country-level variables. Although the authors were not interested in physical outcomes, their research structure is highly relevant to the multi-level analysis used in our research (see Methods).

The field of work psychology also addresses the relationship of organizational characteristics to individual-level outcomes of satisfaction, commitment, etc. The work of Bill Jones et al. (1995) at Carleton University, on a construct termed Perceived Organizational Support (POS), suggests that POS is a stronger predictor of variance in these outcomes than the informal networks characteristic of co-worker support. They hypothesize that immediate supervisor support is the visible indicator to the employee of organizational support; the supervisor represents the organization. Jones found that POS moderates the effects of work stress on employee satisfaction and commitment, as well as on productivity. Earlier work by Eisenberger et al. (1986, 1990) found that POS is associated with a range of individual-level attitudinal and behavioral outcomes, including measures of innovation. The measures of POS, which have been well validated, are comparable to some of the Monitor questions (see Methods). Since Perceived Organizational Support is essentially a measure of organizational culture, Jones’ and Eisenberger’s work is quite relevant to the aims of this research, particularly in relation to the stress outcomes examined by Jones.

Summary

The studies cited above analyze pieces of the larger set of questions included in our study. Many of the organizational and shop floor independent variables that are correlated to attitudes and stress in the organizational studies were sampled in the Monitor Study. The above research highlights the importance of examining organizational-level characteristics to fully understand outcomes at an individual level. To characterize different aspects of organizational structure and support, it is crucial to simultaneously collect information from respondents at different levels in the organization. And to fully characterize the associations between these measures, psychosocial stressors and health outcomes, it is equally crucial to simultaneously collect data on physical

stressors. The Monitor Study is rare in addressing both these needs, thereby providing a unique opportunity for the multi-level analyses necessary to our hypothesis testing.

In addition, the Monitor data set includes measures of stress outcomes. This provides an opportunity to explore the complex interactions between organizational characteristics, individual-level psychosocial and physical stressor levels and musculoskeletal and stress outcomes. Although our research focuses primarily on musculoskeletal outcomes, the possible interaction of stress and WRMSDs requires us to extend the analysis to stress outcomes as well. In the future, this work, combined with Monitor data on the effectiveness of interventions, should contribute to the process of refocusing the ergonomic debate in the United States--from whether WRMSDs exist and whether they have a psychosocial component, to what are the most effective strategies to deal with the problem.

3. Relevance of a Dutch Study to the United States

In the above Background section, we argue that the Monitor Study represents the best instrument available to address the aims and objectives of this research. A crucial question is: can a database gathered from a Dutch population provide results that are applicable to working populations in the United States? There are several approaches to evaluating this question.

Comparability of Dutch and U.S. economies and cultural norms

In an article exploring new forms of work organization in the Netherlands, van Hoof et al. (1989) detail a number of similarities between Dutch and American labor relations:

- In the Netherlands, there is persistent and strong resistance on the part of management to changing the asymmetry of power in the work place. Initial resistance to setting up Works Councils, even after the law mandated them, resulted in many companies lacking this basic consultative body. And once they were established, employers were strongly resistant to expanding their function from consultation to more substantive issues of worker rights, as mandated in the 1971 legislation.
- As in United States, Dutch unions are suspicious of experiments in Industrial Democracy and shop floor participation. Unions in both countries have broad experience with work-place democratization and participation efforts being of limited duration and serving, ultimately, to reinforce the power imbalance in the plant. Often "enriched" jobs were not obtained by participation in planning, and the new jobs were frequently more demanding and fatiguing.
- As in United States, Dutch management has participated in work organization experiments not for humanitarian reasons, but to increase efficiency and control labor behavior--to reduce absenteeism, turnover, quality loss, etc.
- In countrywide labor negotiations in 1986, employers balked at workweek reductions to 36 hours (suggested by labor as a means to reduce unemployment). Instead, since that time there has been a tremendous movement from negotiated flexibility to an increase in temporary labor contracts, outside the scope of collective bargaining. This parallels the rapid rise in temporary employment in the United States.
- As in United States, it does not seem that labor is strong enough in the Netherlands to significantly influence certain areas that management claims as its own. For instance, in

both countries, labor often has not been able to influence the introduction of technology. Even at Philips, the site of 15 years of work organization experiments, workers were not involved in initial design of production and choice of technology.

A second set of similarities stems from the simple fact of the globalization of the economy. As large corporations transcend national boundaries, the nature of work-place pressures and labor relations becomes more similar in different countries. Even companies that are not tied to international corporations are exposed to the competitive pressures of the global economy and tend to respond to these pressures in similar ways (Rahim, et al., 1994). Thus, pressures to reduce absenteeism and turnover, increase production and quality and reduce labor control over the work process are similar in most industrial countries, including the Netherlands and the United States. Corporate cultures in the two countries also share some characteristics. Rahim and Blum (in Rahim et al., 1994), in a cross cultural comparison of managerial styles in 8 countries, found the United States and the Netherlands to be quite close in 3 of the 4 measures their volume used to characterize organizations. These measures were originally developed by Geert Hofstede (1975, 1980, 1994) in a larger study of a multinational company with locations in 66 countries.

- Power distance: a measure of tolerance for authority-based relationships. Both countries have a low score, indicating a strong tendency to believe that power should be based on acknowledged position or on expertise. The only country with a lower score was Norway.
- Uncertainty avoidance: a measure of the need for strict codes of behavior and the tendency to avoid conflict and competition. With Norway, the two countries ranked the lowest of the 8 surveyed, indicating a tolerance for ambiguity and acceptance of dissent and risk-taking.
- Individualism: a measure of the precedence given self-realization over group well being. The two countries ranked well above the other 6.

Certainly the two countries are different in some respects. Emans et al. (1994) examine the phenomenon of “pillarization”, a pervasive (though it has changed in recent history) system of relatively equal, co-existing power hierarchies in Dutch society, based originally on religion. It is hard to find a corresponding arrangement in American society. Dutch society appears to have a more supportive social ethos and certainly has created a more extensive set of social welfare supports than the United States (Emans et al., 1994).

Finally, industrial relations in the Netherlands show some characteristics that are closer to those of other European nations than those of the United States: highly centralized decision making processes, a highly organized and institutionalized machinery of consultation, and the influential role of the government in decision making (van Hoof et al., 1989). But the similarities noted above suggest that the two countries are quite comparable on a number of measures, and different in several respects from other European countries.

Comparability of Dutch and United States Studies

Large data sets in the United States are generally outdated or very limited for the purposes of this research. There are no up-to-date sets of comprehensive data in the United States, and none concerning the association between psychosocial stressors and musculoskeletal outcomes. The National Quality of Employment Surveys, taken in 1969, 1972 and 1977, did collect some information on both psychosocial stressors and pain/symptom reports. Since the QES and HANES surveys, few large databases have been generated. However, some nationally representative studies have been carried out. Karasek's analyses made extensive use of the QES (Karasek & Theorell, 1990). The 1988 National Health Interview Survey (NHIS) collected national data on Carpal Tunnel Syndrome prevalence, but exposure data was limited (Tanaka et al., 1994). Lerner et al. (1994) collected a nationally representative, cross-sectional sample of 1319 male and female workers that quantified significant associations between job strain (as measured by the Job Content Questionnaire Karasek et al., 1985, one of the instruments incorporated in the Monitor Study) and health outcomes. The results of these studies serve to emphasize the need for large, current, nationally representative databases in this country. The above databases will, however, allow us to test the comparability of U.S. studies to the Dutch database.

C. Preliminary Studies

1. Nicholas Warren

The investigator's first work with psychosocial and work organization correlates to musculoskeletal outcomes is contained in a 1993 study of Workers' Compensation cases (Warren, 1993). This research examined, using qualitative methods, the interaction between social support (from supervisor and co-workers) and the development of musculoskeletal disease in support personnel at a large state university. The study also addressed the speed with which an employee's symptoms progressed to a compensable level and the length of time before the employee was able to return to work. The research suggested that, as employees developed symptoms, the social support system within this organization rapidly degenerated, resulting in a large incidence of abuse or harassment (from both supervisors and co-workers) directed towards the injured employee. This pilot study suggested several hypotheses for further testing, some of which are incorporated in the present research: a) the psychosocial environment of the work place affects the initiation and progression of musculoskeletal disease; b) psychosocial factors have an important influence on return-to-work process and schedule; c) there is a negative feedback loop between disease development and social support and d) characteristics of the larger organizational culture affect these events at the "shop-floor" level. The complex causal model proposed here could not be tested with the small number of interviews. In consulting work, data collection relating to these hypotheses is continuing.

The investigator has carried out independent ergonomic consultations in a large number of companies and is presently the Ergonomics Coordinator of the Ergonomic Technology Center of Connecticut and the University of Connecticut Health Center. In these capacities, his focus has been on the interaction between work organization and the development of musculoskeletal injury, resulting in a series of proprietary reports that detail these associations, along with physical load risk factors (Warren, 1995). Work with a large food distribution center detailed the effects of corporate safety incentive policies and production incentives on employee stress and musculoskeletal outcomes. Work with a computer manufacturing company centered on the interaction between jobs with low skill discretion and musculoskeletal outcomes. A longer-term attempt to

establish job-reorganization activities in a plastics manufacturing enterprise also focused on the associations between low control/high demand jobs and outcomes of WRMSDs.

The investigator is co-investigator in a 3-year, NIOSH funded research project in the state of Connecticut. The research used random-digit dialing to interview a large, random sample of the Connecticut workforce ($n = 4100$). The interview instrument, based on a number of previously validated questionnaires, collected information of WRMSD symptoms, exposures (biomechanical and psychosocial) and social and financial consequences of WRMSD. The case-control study (using the NIOSH case definition) established strong associations between WRMSD symptom reports and a combination of biomechanical and psychosocial exposure variables. The exposures with the strongest associations to symptom reports were static postures and low organizational support.

The investigator was first introduced to the Monitor Instrument during meetings in Den Haag, the Netherlands, in July, 1994. Karasek and Warren attended briefings arranged by the Dutch Ministry of Social Affairs and Employment. In a seminar conducted by Irene Houtman and Michiel Kompier, at which the findings of the Monitor Study and the comparability of the Monitor instrument to the JCQ were the main topics for discussion, the Monitor Study was presented as a powerful tool for assessing the causes of WRMSDs in the Netherlands. The importance of the Monitor approach and findings to psychosocial research and policy in the United States was immediately apparent; soon thereafter, Karasek began negotiations with the Ministry and TNO for the use of the database in this research.

2. Robert Karasek

The "Demand-Control" model of occupational strain, developed by Robert Karasek and associates (Karasek, 1979, Karasek & Theorell, 1990), is the basis for the construction of the psychosocial risk measures in the Monitor Study and several other studies noted above. Although originally formulated for and tested in research concerning CHD mortality and morbidity, the extension of the model's intellectual framework to research on stress-related and musculoskeletal illness is valuable both as an explanatory framework and as validation for the model. The Demand-Control model postulates that emotional and physical health outcomes of job-related stressors are not simply the result of job demand levels but of the interaction between job demands and worker decision latitude and skill discretion (these last two job descriptors are collectively termed "control"). Karasek and Theorell (1990), Johnson et al. (Johnson & Hall, 1988; Johnson et al., 1989; Johnson & Stewart, 1993) and others have since expanded the model to include the contribution of social support levels. The original Demand-Control model and the expanded Demand-Control-Support model have been well validated and extensively used to characterize stressful work environments (Karasek et al, 1985, Kristensen, 1995a, 1995b).

Most of the psychosocial measures in the Monitor study are based on the Job Content Questionnaire (JCQ), which Karasek and co-workers developed (Karasek et al., 1985), based on the Demand-Control-Support model. Although there are other models available to characterize psychosocial stress (for instance, the NIOSH Generic Job Stress Questionnaire, Hurrell and McLaney, 1988), the Monitor Study, having drawn heavily on the JCQ, is the ideal instrument for testing the expanded Demand-Control-Support model. The hypotheses of this research are thus framed in terms of this model. The design of the Monitor instrument includes the JCQ (with some recent

additions) as well as several other Dutch and international instruments (Houtman et al., 1994a). Validation studies on the JCQ are thus quite important to our research. The published version of the JCQ (Karasek et al., 1985) contains Karasek's own validity and reliability estimates. Two other studies have successfully extended the validity and reliability estimates of the JCQ to Canadian (Dion et al., in press) and Japanese (Kawakami et al., 1995) populations. Recent work (Karasek, et al., 1998) has extended these international validation studies.

In addition to this pioneering work, Karasek has carried out research in four areas that are relevant to the proposed study. Earlier work (Karasek et al., 1982) was concerned specifically with "shop-floor" social support. This research, using the 1972 QES data, found evidence for a buffering effect of supervisor and co-worker support on the association of task-level stressors with emotional strain outcomes. Some of his more recent work has addressed the relationship between work organization and psychosocial variables and musculoskeletal outcomes. In 1987, Karasek et al. published a cross-sectional study of work and non-work correlates of illness and behavior in a sample of about 8600 Swedish white-collar workers. This study found positive associations between psychosocial work factors and outcomes of musculoskeletal aches. In a later 1990 article, Karasek studied the same population, comparing 1937 workers who had undergone company-initiated job reorganization during the previous several years to those who had not. Many physical and emotional symptoms were used as outcome measures, including musculoskeletal aches. The independent variables make this one of the rare studies that address both a company-related measure ("influence over the change process") and an individually-related measure ("level of control in the resulting job"). The stress of job change itself was generally associated with increased negative health outcome levels. But workers who had influence in the reorganization process and whose new jobs were characterized by increased task control showed the lowest increases. For both males and females, the levels of musculoskeletal outcomes in this "high control" group were roughly equal to those in the comparison group (no job change). Musculoskeletal outcomes in the "intermediate control" group (either high influence/low task control or low influence/high task control) and "decreased control" group (low influence and job control) were significantly increased, relative to the "high control" group. Recently, Karasek and Theorell (1990) published a review of several studies that examined the organization-level correlates to stress outcomes.

D. Research Design

1. The Study Population and the Data Set: Structure of the Dutch Monitor Study

The Wage Control Service (LTD), part of the Dutch Ministry of Social Affairs and Employment, has carried out an extensive questionnaire- and interview-based study of 782 companies. The stated purposes are: examining the level of physical and emotional stress and injury in a cross-section of Dutch business, monitoring effectiveness of prevention activities, and analyzing the influence of external and company variables on prevention activities (Houtman et al., 1994a). TNO, Prevention and Health (Houtman et al., 1994a, Kompier et al., 1994), have performed analysis of the resulting data set. Companies employing between 35 and 350 workers were selected for the study. The original sample selected consisted of 880 organizations; the 782 participating companies represent a response rate of 89%. The study population is generally representative of national distributions: by size (within the 35-350 employee range selected), region,

sector (11 sampled) and branch (3 sampled). There were several minor deviations from the sampling distributions originally planned (Houtman et al., 1998):

- The machine industry is slightly underrepresented
- Transportation industry is slightly over-represented
- “Medium-sized organizations” (50-100 employees) are slightly over-represented.

Before the Monitor questionnaires were administered to the full sample of companies, a preliminary field test was carried out in a sample of 37 companies, assessing acceptability, comprehensibility, and duration of the questionnaire and interview.

The Monitor study was developed for a number of reasons. First, it represents an attempt to generate better evidence concerning the risks for stress and musculoskeletal outcomes as well as a detailed analysis of trends over time and in different branches of industry. Second, in the Netherlands, stress and musculoskeletal injury are the two main causes of lost-time in the work place, representing 60-70% of all disability cases (Houtman et al., 1994a). Third, the Monitor Study was intended to strengthen the empirical evidence for the contribution of psychosocial factors to musculoskeletal disorders. Finally, the feedback of Monitor information to participating companies was intended to be a tool to stimulate prevention efforts in these companies, particularly those in which health and well-being are the worst. This project gathered 3 separate sets of data:

1. 782 responses to a detailed interview protocol (298 variables) by owners (or local managers, if a subsidiary operation) of each company. The questions ask for:
 - a. Indicators of company culture, structure, labor market policies, etc.
 - b. Assessments of the level of musculoskeletal and psychosocial stressors in their work places.
 - c. The amount of injury, disability, sick time, turnover, etc. attributable to these stressors.
 - d. A summary of prevention-related activities undertaken, the goals for their introduction and their effectiveness in achieving these goals.
 - e. A general assessment of the economic position, difficulties, and strategy of the company.
2. 7717 responses to a questionnaire by workers in 528 of these same enterprises. The questionnaire focuses on more detailed employee reports of the same musculoskeletal and psychosocial stressors and outcomes addressed in the employer interview. In addition, employees are asked for a summary of the prevention activities in their workplaces and an assessment of the effectiveness of these interventions. Employers in 254 companies, 1/3 of the sample (32.5%), refused to allow their employees to answer the questionnaire.
3. 296 responses by an employee representative, a member of the Works Council. The Works Council is a representative body, mandated by Dutch law for companies with more than 100 employees. It originally had primarily information and advisory functions, but in 1971 its role was expanded to be a medium for representation of worker rights (van Hoof et al., 1989). This position is thus a crucial link between employee and employer perceptions and interests. The answers of the employee representatives, to the same interview given to owners, provide an important 3rd viewpoint on the discrepancies between employee and employer assessments. This information will be used in future analyses. The number of Works Council responses is smaller than the number of employers interviewed for two reasons. First, since Works Councils are only required in larger companies, a Works Council was

only present in 376 companies (48% of the sample). Second, only 292 of these larger organizations allowed Works Council representatives to be interviewed (78% of the companies large enough to have a Works Council).

Table 1 presents the branches and sectors sampled by the Monitor Study, together with the percentage make-up of each branch and sector at the several levels of analysis. This database is unique and quite valuable for the purposes of the present research project, as well as for future application to intervention strategies and policies in the United States, for several reasons.

1. The database is quite large.
2. The database collects detailed information on biomechanical stressor levels, as well as psychosocial stressors.
3. The Monitor Study collects information appropriate for several different levels of analysis: individual level, plant level and sector level.
4. The Monitor questionnaires and interviews simultaneously collect data from the 3 respondent populations outlined above, providing the unique opportunity to analyze differences in perceptions concerning the same work places: stressors, outcomes and interventions.
5. Data in the Monitor Study was collected from locations in 3 main branches ("industry," "wholesale," "banking/financing") and 11 different sectors within them, allowing analysis of associations by the type of company. For future research, this separation also allows analysis of particular constellations of psychosocial and organizational features that are peculiar to or elevated within sectors or branches.

2. The Research Plan; The Hypothetical Model

One practical goal of this research is to identify which psychosocial stressors, at which level of analysis, have the strongest effects on adverse musculoskeletal and stress outcomes. The expansion of musculoskeletal and stress risk assessment to the organizational level and the focus on the organizational role in the presence and level of the risk factors represent significant new steps toward a full characterization of the causal pathways to occupational illness. We hoped to uncover some of these causes in the organizational culture of the company. A definition of the root causes of and influences on the individual-level risk factors has policy implications for prioritizing, targeting, guiding and evaluating interventions in the work place. The hypothesis relating these data and levels consists of 3 interrelated propositions:

1. Stage I Hypothesis: The levels of psychosocial and biomechanical stressors on the shop floor and their interaction is associated with the following outcomes in employees: prevalence of musculoskeletal and psychological strain, sick leave, and musculoskeletal and psychological disability. This hypothesis examines the basic individual-level associations.
2. Stage II Hypothesis: Psychosocial and biomechanical stressors measured at the individual ("shop floor") level are affected by organizational structure and support characteristics. This hypothesis examines the role of organization-level measures in inhibiting or exacerbating individual-level risk factors—an etiology of these risk factors.
3. Stage III Hypothesis: The levels of organizational structural and support characteristics also have direct associations with the prevalence of the musculoskeletal and mental strain and health-related outcomes outlined in hypothesis 1, above. These associations could be either main effects or effects mediated through other, unmeasured factors.

The model of cause and effect is constructed from the following data:

1. Individual-level reports of psychosocial and biomechanical stressors, musculoskeletal and psychological strain, outcomes of illness and disability and assessments of company health policy. These are gathered in the employee questionnaire. These data are used in Stage Ia of the analysis (see below). When aggregated within each company, these data are used in Stages II and III.
2. Company-level estimates of these measures in the employer questionnaire/interview. Employer estimates of employee stressor and outcome levels are used in Stage Ib of the analysis. Employer reports of employee stressor levels are used to create Discrepancy Indices (see Methods) in Stages II and III.
3. Company level estimates of organizational structure and technology and characteristics that can be used to construct different aspects of “organizational culture”. The data are used in Stages II and III.

The analysis of these data is divided into 3 stages that correspond to the 3 parts of the hypothesis. Stage I actually consists of parallel models examining associations of stressors with outcome variables: Stage Ia uses employee reports of these measures; Stage Ib uses a reduced set of employer estimates of these measures. Stage II explores associations between organizational characteristics and stressor levels. Stage III explores associations between organizational characteristics and Stage I outcomes: strain, sick leave and disability. Details of the analytical methodology are presented in Methods. Figures 1 and 2 show the overall structure of the models. Figure 2 also includes a projected Stage IV to be carried out in the future: analysis of these models in relationship to the economic environment

All Monitor measures used in these models are detailed in Methods. The Organizational Measures in Figure 2 may relate to different aspects or levels of organizational culture. Schein (1992) argues that organizational culture necessarily exists on a number of levels, ranging from easily observable organizational behaviors to the deeper levels of organizational values and assumptions. Ideally, it would be valuable to characterize measures of these levels and perhaps construct an “exposure matrix” at the organizational level--an integrative tool that would help identify which companies were “at risk” for the development of certain stressor levels, strains, and health outcomes. The analysis tests whether these organizational measures a) represent internally consistent measures of different organizational characteristics and b) show different associations with shop-floor level outcomes.

CHAPTER II; METHODOLOGY

Chapter II, Methodology, contains three sections:

- A. Selection and Creation of Variables to Test the Model
- B. Analytical Methodology for Testing the Model
- C. Summary Of Hypotheses

A. Selection and Creation of Variables to Test the Model

This section and the next document the consecutive steps necessary to analyze the Monitor data sets and to test the models presented in the Introduction. The analysis used SPSS versions 6.1 and 7.5 throughout. Section A presents the data reduction process for each of 4 separate sources of data:

- 1. employee data
- 2. employee data aggregated at the company level
- 3. employer data
- 4. created company-level data (variables from combined employer and employee data).

1. EMPLOYEE

As noted above, the Monitor Study collected data from 3 distinct sets of respondents. The present analyses use data from the employee questionnaires and the structured interviews with company owners or managers. The third set of data, from structured interviews of Works Council representatives, was not analyzed in this phase of the research. The incorporation of the Works Council data is an important addition to validation methodology of the present research. We expect to perform this analysis in the near future.

Preliminary data cleaning and re-coding

- 1. All "don't know" responses were changed to a "system missing" value. The variables examined in this research generally contained less than 5% "don't know" responses.
- 2. All dichotomous variables were re-coded to a 0 or 1 value, with 0 representing the exposure or outcome hypothesized to be more favorable and 1 representing the less favorable.
- 3. Wherever possible, categorical variables with more than 2 possible responses were re-coded by the same criteria: lower values represent the more favorable exposure or outcome levels.
- 4. Other variables that record presence or absence of a variable are re-coded to match the Monitor scheme in these dichotomous variables: 0 = "no" and 1 = "yes".

Selection of Appropriate Measures

In order to test the hypotheses of this research, the measure selection focused on 7 major types of question available in the employee data set. TNO (the author of the instrument and holder of the copyright) selected the single items and scales that were combined to create the final instrument from a number of internationally and nationally validated instruments. Details are reported by

Houtman et al. (1994a). The types of data are:

1. Basic demographic and employment status information.

Three basic demographic items are used: sex, age and highest education level attained. We condensed "age" into 4 decile groups: 20-29, 30-39, 40-49 and 50-59. The 52 missing values for this question, 65 respondents under 20 and 60 respondents over the age of 59 (representing 2.3% of the respondents) were excluded from analysis. The Monitor questionnaire identifies 8 levels of education. Following the TNO protocol, we condensed these responses into a 4-part scale:

1: primary education	n = 496
2: lower vocational, apprentice, and secondary education	n = 3547
3: middle vocational and general secondary education	n = 2277
4: higher vocational and academic education	n = 1033
5: missing, and "other" (4.7%; excluded from analysis)	n = 364

The Monitor questionnaire asks 3 dichotomous employment questions: shift work, permanent or temporary contract, and full or part time employment. There was essentially no correlation between permanent/temporary work and full/part time ($r = .076$), so these two questions required separate consideration.

2. Presence of psychosocial stressors. Monitor scales are: Autonomy, Skill Discretion, Psychological Demands, Social Support and "Terms of Employment".

Decision Latitude, Skill Discretion and Psychological Demands.

The first three types of stressor were selected by TNO to reflect the theoretical constructs in the Job Content Questionnaire (JCQ), developed by Robert Karasek et al. (1985) (further developed in Karasek and Theorell, 1990). The JCQ is one of the most widely used and validated instruments in use today. The reader is referred to Karasek and Theorell (1990) for a detailed discussion of the instrument's validity and reliability. Several international studies have also shown its cross-cultural reproducibility (Karasek, et al., 1998, Dion, et al., 1995, Kawakami and Fujigaki, 1996, Kawakami et al., 1995). For the present research, these are particularly important findings, since we are arguing that the results of research on a Dutch database can be relevant to the work place in the United States.

When evaluating evidence for reliability and validity, it is important to remember that the Monitor employee questionnaire presents most questions in dichotomous form. All measures from the JCQ are collapsed from the original 4-point Likert scale (strongly agree, agree, disagree, strongly disagree) to the simpler yes/no answer format.

Social support.

Items comprising the TNO "relations at work" scale were drawn from the JCQ and the Dutch Questionnaire on Work and Health (VAG) (Gründemann et al., 1993).

"Terms of employment, flexible employment"

This grouping contains a set of questions developed by TNO to measure job autonomy and short staffing (see Houtman et al., 1994a) as decision authority over working conditions. This wording distinguishes these questions from the Autonomy set, which assesses decision authority within tasks. All questions have been validated in other studies by these authors. They were first validated in a "Nova-Webb study", by Houtman et al. (1994b).

3. Presence of biomechanical stressors.

These questions are based on a validated Dutch questionnaire on physical stress in work, by Hildebrandt and Douwes (1991, cited in Houtman et al., 1994a). The selection of relevant biomechanical stressors is well documented in the literature. Although there is still intense discussion of mechanism and importance, many of the basic risk factors have been known for years. The Monitor questionnaire assesses most of these major biomechanical risk factors (with the exception of mechanical or compressive forces and dynamic factors in WRMSD causation; see Discussion). These factors are listed below, together with a very select set of historical references for the reader who wishes more epidemiological or clinical documentation. Putz-Anderson, 1991, contains a brief overview of the research; Barnard, 1997, presents an extensive review of the epidemiological evidence for work-relatedness.

- a. Repetition. The Monitor questionnaire includes 3 questions that specifically assess “short cycle, repetitive movements”. See Silverstein et al. (1986), Armstrong et al. (1985), Luopajarvi et al. (1979)
- b. Force. The Monitor questionnaire has 3 questions relating to lifting, pulling/pushing and force exerted on tools and equipment. The instrument does not assess grip force. See Silverstein et al. (1986), Armstrong et al. (1982)
- c. Awkward postures. The Monitor instrument contains 10 questions that address awkward and/or asymmetrical postures of the trunk, neck and wrists. See Armstrong (1985), Van Wely (1970), Hagberg (1984), Feldman et al. (1983)
- d. Static postures. The Monitor questionnaire includes 8 questions relating to static postures, 4 of which overlap with the awkward posture set, above. See Van Wely (1970), Hagberg (1984), Bjelle et al. (1979)
- e. Vibration. The Monitor questionnaire contains 2 questions that assess vibration and vibrating tools. See Grandjean (1990), NIOSH (1989)

4. Strain outcomes.

Three sets of questions constitute this category: Emotional Exhaustion, “a lot of trouble in your work from...” (followed by 11 biomechanical stressors), and a scale of psychosomatic symptoms.

- a. The Emotional Exhaustion questions were drawn from the Emotional Exhaustion subscale of the Dutch version of the Maslach Burnout Inventory (MBI), a well-validated instrument (Schaufeli, et al., 1993). The original English version of the MBI Emotional Exhaustion scale was reported by Maslach and Jackson (1986) to have a Cronbach- α of .84. The Dutch version of the MBI was found to have similar reliability and construct validity (Schaufeli et al., 1995). The version of the MBI Emotional Exhaustion Scale used in the Monitor has been altered in two ways: the original 9 items have been reduced to 7, and the original 7 point scale (from 0 = “never” to 6 = “every day”) has been collapsed to the dichotomous yes/no form. The reliability calculated in the present research is still reasonable: Cronbach- α = .754
- b. “Trouble” items are based on the Hildebrandt and Douwes questionnaire cited above, which in turn draws on the Standardized Nordic Questionnaire on musculoskeletal symptoms (Kourinka, et al., 1987). As of 1995, the Standardized Nordic Questionnaire

had been used in national surveys in Sweden, Norway, Finland and Denmark, with data from the 25,419 questionnaires assembled into a representative reference database. (Lindström et al. 1995).

- c. Psychosomatic symptoms were assessed using VOEK questions (Dirken, 1969, cited in Kompier, et al., 1994). The VOEK questions are taken from a Dutch instrument, which has been validated within that country.

5. Pain outcomes.

Physical pain was assessed by a shortened version of the Hildebrandt and Douwes instrument (op. cit.), again drawing on the Standardized Nordic Questionnaire. These questions, assessing pain frequency in 9 body locations (6 are assessed separately for the left and the right side, making a total of 15 questions) are presented in a 4-point response format: no, once, regularly and continuously.

6. Disability and extended sick leave measures.

The employee questionnaire contains two relatively crude measures of these quantities. One question addresses disability: "Are you presently disabled for work". Extended sick leave can be inferred from a chronic sickness item that asks if, after an absence of more than 3 months, the respondent has returned to an unchanged job, an adjusted work place, or a different job/workplace. A "yes" answer to any of these 3 possibilities constitutes a positive response to long term (>3 months) sick leave. Because of the possibility of external validation, the disability and sick leave questions represent important contributions to the measure of severe negative health outcomes. They can also be compared to employer estimates of disability and extended sick leave at the plant level.

7. Company measures and policy.

The present research seeks to illuminate features of organizational culture or climate that might contribute to levels of exposures and outcomes in the plant. These questions represent an opportunity for employees to report their perceptions of how the company deals with problems of work and health. This category can be subdivided into two sub-categories:

- a. Company health policy. These questions measure who the employee sees with health problems related to work and who is perceived to be responsible for addressing these problems.
- b. Intervention measures undertaken by the company. This category contains an extensive listing of possible measures that might be taken by the company.

Whenever possible, we selected measures with approximately normal distributions. Where normally distributed measures were not available, two options were exercised. First, logistic regression allows analysis of strongly skewed dichotomous outcomes. Second, logarithmic (base 10) transformations were used to correct for strongly non-normal distributions of dependent variables. All individual measures selected had enough variance in their distribution to allow for hypothesis testing.

Data Reduction

Testing the hypotheses of this project requires the examination of a large number of variables. To reduce the number of comparisons, we combined the variables into a reduced set of summative measures. Data reduction at the individual level (employee questionnaires) consists of finding sets of questions that are correlated at a high enough level that they can be combined into a

single measure. The values for each component item can be added to give a single, additive scale value (see Karasek et al., 1985, for descriptions of the summative scales generated by the Job Content Questionnaire). For the present research, we elected to calculate a mean scale value. The dichotomous questions with a value of 0 or 1 that constitute most of the employee data set are thus incorporated into continuous measures, with a value between 0 and 1. There are two reasons for choosing the mean value over a simple sum value. First, because the various scales created contain from 2 to 8 component items, a mean value facilitates comparison among the scales. Second, a mean value makes the scale range comparable to two types of measure available at the plant level: the set of employer questions which are answered with a percentage value and the aggregate (by plant) employee measures. All values are between 0 and 1.

There are several inter-related procedures and theoretical bases for this scale creation.

1. Correlation analysis. Large groupings of variables which were thought to be related were entered in the Bi-variate and, where possible, partial correlation procedure in SPSS. Correlation groupings were based as much as possible on the scale groupings in the Monitor questionnaire, to preserve comparability with the TNO research. Some groupings were based on the hypotheses of this research, particularly those related to organizational factors.
2. Factor analysis. Groups of related measures were entered in the factor analysis procedure in SPSS. We selected these groups using a combination of theoretical hypotheses and correlation analysis. In all cases, Principal Axis Factoring was employed. We employed Varimax rotation, because of its ability to create interpretable factors by minimizing the number of variables that have high loadings on any single factor. With one exception ("Force", below), only factors that achieved an eigenvalue above 1.00 were used. Unless intellectual reasons for retaining an item in a factor were very strong, any item that did not achieve a loading of at least 0.50 in a factor was dropped. Most loadings were between .60 and .80. These loadings only have meaning, of course, in the context of the variable set chosen for factor analysis.

Mean values for each scale were calculated only for cases in which each variable had a non-missing value. The practical result of this procedure is that the greater the number of items in a factor, the smaller the number of cases that are given a score for the factor. In general, the number of missing values was small enough that this did not create an analysis problem.

3. Reliability analysis. The next step in scale development is the calculation of Cronbach- α values for each factor, using the SPSS scale reliability program. Most of the factors used have a Cronbach- α between .70 and .90. Three are in the range of .60-.70, and two are between .40 and .50. These last must have a strong intellectual justification to be used. SPSS reliability analysis includes an option to calculate the Cronbach- α if any one item is deleted. The protocol defined for scale definition starts with reliability analysis of the groupings defined by factor analysis. These are then refined by reliability analysis and intellectually-based adjustment to create the final scale. If deletion of a variable would substantially increase reliability, we considered dropping that item. In some cases, the scale with lower reliability was kept, if retention of the item accomplished an intellectually defensible purpose. Otherwise, the smaller scale with higher reliability was used.

4. Previous research. Scales were created to be comparable to the validated work of previous researchers. Scales similar to those constructed in the Job Content Questionnaire (Karasek, et al., 1985) were relatively easy to draw from the Monitor questionnaire, since the JCQ formed one of the bases for questionnaire content
5. Theory. The Monitor questionnaire was not designed to explicitly test hypotheses about the organizational contribution to CTD risk and outcomes. In several cases, educated guesses had to be made about the organizational meaning of a question or grouping of questions. Several scales were constructed on the basis of a theoretical connection, even though reliability analysis produced a relatively low Cronbach- α . These cases are noted in the discussion below.

Following is a discussion of the factoring process and decision logic for each scale formation. Scale names attempt to encompass the general, shared meaning of the component items. Each scale is presented with a brief summary of the actual questions contained in the scale (and the Monitor item name, to facilitate comparison), the Cronbach- α the scale and the factor loading for each variable. We have created a number of sub-scales to tease out different aspects of the more general scales. Future research will analyze the meanings and associations of these scales; they are not presented below. The scales used here usually are comparable with those used by TNO and thus offer complementarity to TNO research on this data set.

Biomechanical Stressors

The initial cluster of all biomechanical stressor questions was entered in the factor analysis program of SPSS. Vibration questions did not load well in any factor. The remaining items separated into 3 factors; for theoretical reasons, the third factor was separated into 2 scales:

1. "Repetitive Bend/Twist". 6 items. Cronbach- α = .8955.

<u>Monitor name</u>		<u>factor loading</u>
a. V9012a	often bend or twist with trunk	.64
b. V9012b	often bend or twist with neck	.59
c. V9012c	often bend or twist with wrists	.61
d. V9013a	often short cycle, repetitive movements with trunk	.68
e. V9013b	often short cycle, repetitive movements with neck	.65
f. V9013c	often short cycle, repetitive movements with wrists	.66

Correlation coefficients among these 6 variables ranged between .42 and .68. In this sample, which encompasses a wide range of occupations in the wholesale, industry and banking/finance branches, the evidence shows that upper body bending and twisting is often performed in repetitive, short-cycle tasks.

2. "Static Bend/Twist" 4 items. Cronbach- α = .7652.

<u>Monitor name</u>		<u>factor loading</u>
a. V9012d	often work with static, bent or twisted postures of trunk	.62
b. V9012e	often work with static, bent or twisted postures of neck	.74
c. V9012f	often work with static, bent or twisted postures of wrists	.53
d. V9013g	work often requires prolonged work in the same posture	.48

The wider range in factor loadings, compared to Repetitive Bend/Twist, is due to the inclusion of “prolonged work”. We retained it in this scale because of its theoretical similarity to static work. The Cronbach- α rises only marginally if the item is deleted (from .7652 to .7898).

3. “Reaching/Prolonged Postures”; 6 items. Cronbach- α = .8240.

<u>Monitor name</u>		<u>factor loading</u>
a. V9013d	work often requires far reach with hands or arms	.56
b. V9013e	work often requires raised arms	.53
c. V9013f	work often requires working in reaching positions	.63
d. V9014a	work often requires prolonged standing	.65
e. V9014c	work often requires prolonged walking	.63
f. V9014d	work often requires prolonged kneeling	.60

This scale combines two slightly different groups of questions. 3 relating to arm posture and 3 relating to prolonged, whole-body postures.

4. “Heavy Physical Exertion”; 3 items. Cronbach- α = .8003.

<u>Monitor name</u>		<u>factor loading</u>
a. V9011a	must you often lift heavy loads (>5 kg.)	.77
b. V9011b	must you often push/pull/carry heavy loads (>20 kg.)	.72
c. V9011c	must you often exert great deal of force on tools or equip.	.58

Factor analysis did not separate Physical Exertion into a fourth factor; it entered these 3 items into factor 3, above. But this factor (the only factor created with an eigenvalue less than 1.00) still has sufficient reliability to make it useful in analyzing the associations of force-related stressors with the outcome variables. In the literature, force is clearly identified as an independent risk factor, separate from awkward or prolonged posture (see, for example, Silverstein et al, 1986, and Armstrong et al., 1982). In addition, the Physical Exertion questions had high numbers of missing values (3.7%, 6.9% and 9.7%, for V9011a, b, and c, respectively). Separation of these 3 items into a 4th factor avoids creation of an unwieldy, 9-item factor with unacceptably high numbers of missing values.

Since the loading values generated by the SPSS factor analysis program for these 9 variables are calculated in the context of a single factor, they are not relevant to the internal variable correlations within each separate scale. The Cronbach- α is the only useful measure of internal consistency of these scales

Psychosocial Stressors: Demands

A cluster of Demand-related questions was entered in the SPSS factor analysis program. These included V1015c and d (strenuous work), V9016a-e (job demands), V9019e and f (short staffing), V9018f (repetitive work) and V9021a-c (mentally and physically strenuous, time pressure). 3 well-defined factors emerged, but only one was used in the present analyses:

1. “Psychological Demands”; 5 items. Cronbach- α = .7393

<u>Monitor name</u>	<u>factor loading</u>
---------------------	-----------------------

- | | | | |
|----|--------|----------------------------------|-----|
| a. | V9016a | job requires working very fast | .56 |
| b. | V9016b | excessive amount of work | .62 |
| c. | V9016c | work extra hard | .59 |
| d. | V9016d | have enough time to get job done | .49 |
| e. | V9016e | is your job hectic | .55 |

The scale includes all 5 items from the Monitor “job demands” group. Factor analysis added a 6th, “regularly working under time pressure” (V9021c); the 6-item set had slightly higher reliability (.7760). Loadings above relate to this scale. But to maintain comparability with TNO research and the JCQ, the 5-item was used in the analyses. Four of the 5 items in the Monitor “job demands” group are identical to items in the JCQ 5-item Psychological Demands scale. For the fifth question, “hectic work” replaces the JCQ “conflicting demands” variable.

Psychosocial Stressors: Autonomy/Decision Authority

The variable set chosen for factor analysis consisted of 4 variable groups or individual variables: the “autonomy” group from the questionnaire (V9017a-g), 4 schedule-related questions from the “terms of employment” group (V9019a-d), V9018g (“career development and promotion opportunities”) and V9020h (“fully informed of company developments”). The intellectual basis for the inclusion of these diverse variables was the exploration of different levels of control within the company, from direct shop-floor control of tools and equipment, through higher levels of schedule control. The SPSS factor analysis program extracted 3 different factors from this group. In the present analyses, we used only the 7 item Autonomy set from the Monitor questionnaire. Since the factor analysis did not group these 7 items into a single factor, loadings are not presented below.

1. “Autonomy”; 7 items. Cronbach- α = .7226.

Monitor name

- | | | |
|----|--------|--|
| a. | V9017a | determine how work is carried out |
| b. | V9017b | control over tools, machines, information, communication, transportation |
| c. | V9017c | determine order in which work is done |
| d. | V9017d | determine when you carry out a task |
| e. | V9017e | leave workplace for brief period |
| f. | V9017f | interrupt work yourself |
| g. | V9017g | set own work tempo |

Psychosocial Stressors: Skill Discretion

1. “Skill Discretion”; 6 items. Cronbach- α = .7461.

Monitor name

- | | | |
|----|--------|--|
| a. | V9018a | high level of skill/workmanship required |
| b. | V9018b | is your work varied |
| c. | V9018c | required to learn new things |
| d. | V9018d | required to be creative |
| e. | V9018e | opportunity to develop special abilities |

- f. V9018f lot of repetitive work
 - g. V9018g enough opportunities for career development and promotion
- Factor analysis generated a 6-item scale, excluding the last item above, with somewhat higher reliability (.7525). Again, to maintain comparability with the TNO analyses, we used the Monitor skill discretion group. Factor loadings are thus not reported above.

Psychosocial Stressors: "Flexible Employment"

1. "Schedule Control"; 2 items

Cronbach- α : .6199

Monitor name

- a. V9019a determine start and stop of work
- b. V9019b determine pauses

The 6 items in the Terms of Employment group of the employee questionnaire did not hold together well as a single scale ($\alpha = .3699$) TNO researchers found it useful to break this group down into two sub-scales, Schedule Control and Short Staffing (Houtman et al., 1998). The Schedule Control scale was not used as an independent variable in modeling. But it was needed in creating a Discrepancy Index (see below) to represent the employee analog of the employer measure "Flexible Employment".

Psychosocial Stressors: Social Support

The variable cluster identified from correlation analysis for factor analysis centers around the Monitor Supervisor and Co-Worker Support group. These questions are drawn from the Dutch questionnaire on work and health (VAG: Vragenlijst Arbeid en Gezondheid, Gründemann et al., 1993, also cited in Houtman et al., 1994a). Factor analysis did separate this variable cluster into 3 distinct factors, but for purposes of comparability, the full Monitor social support set was used in these analyses. Factor loadings are omitted; this scale did not emerge as a single factor.

1. "Social Support"; 8 items.

Cronbach- $\alpha = .8041$.

Monitor name

- a. V9020a good underlying atmosphere
- b. V9020b frequently irritated by co-workers
- c. V9020c assistance from co-workers
- d. V9020d good daily management
- e. V9020e management takes opinion sufficiently into consideration
- f. V9020f management has true impression of the way you work
- g. V9020g management gives enough support in getting work done

Strain Variables: Mental Strain

The variable cluster initially selected for factor analysis consisted of questions drawn from three groupings in the Monitor employee questionnaire: the "job characteristics" group (V9021d-f), the Emotional Exhaustion scale from the Maslach Burnout Inventory (MBI; Schaufeli et al., 1993) (V9025a-g) and 4 questions from the VOEG group noted earlier (V9026e, j, l, and m). Correlation coefficients among these variables generally range from .3 to .6; the VOEG correlations with the other variables are at the lower end of this range. The TNO researchers call these variables "long term consequences."

Initially, all items except the VOEG variables loaded onto a single scale, resulting in two factors. There is some overlap in meaning between the MBI items and the “job characteristics” variables. Because it was important to maintain the integrity of the MBI items, for comparability with other studies, this analysis was forced into 3 factors. This forced factor analysis does not require a great departure from the protocols adopted in the rest of the factor procedures reported here; the eigenvalue for a third factor was .99, and a third factor adds 7.1% to the variance explained. The 3 forced factors separate into 3 clearly distinct scales. Although two of the MBI items loaded into the other two factors, they were kept with the MBI scale, resulting in poor factor loadings for V9025c and f.

1. “Tiredness”; 4 items.

Cronbach- α = .7761.

	<u>Monitor name</u>	<u>factor loading</u>
a.	V9026e VOEG; frequently feel tired	.58
b.	V9026j VOEG; feel tired more quickly than you would expect	.57
c.	V9026l VOEG; occasionally feel listless	.55
d.	V9026m VOEG; generally wake up still feeling tired	.76

One item from the MBI scale, “exhausted when you wake up in the morning”, loaded well on this scale (.735). However, its inclusion reduces the scale reliability to .7383. This reliability effect, plus the well-validated nature of the MBI scale, made it prudent to keep it in the MBI factor. The difference in meaning which employees attach to the VOEG variables and the MBI variables seems to be one of degree. In general, the VOEG questions are less extreme than “exhaustion”.

2. “Exhaustion”; 7 items.

Cronbach- α = .7544.

	<u>Monitor name</u>	<u>factor loading</u>
a.	V9025a Mentally exhausted by your work?	.57
b.	V9025b Empty at the end of a day of work?	.40
c.	V9025c Exhausted when you wake up in the morning, knowing another work day lies ahead?	.21
d.	V9025d Feel “burned out” by your work?	.63
e.	V9025e Feel frustrated by your job?	.42
f.	V9025f Give too much effort in your work?	.20
g.	V9025g Feel “totally burned out”?	.55

The variables from “job characteristics” loaded onto a 3rd factor. However, the meanings of these items are ambiguous; they may be interpreted as either an exposure or a resultant report of strain. They were excluded from analysis here.

Strain Variables: Physical Strain

The Monitor employee questionnaire contains one grouping of questions that measure physical strain associated with biomechanical stressors: V9022a-k. The TNO research format calls these questions “short term consequences.” These questions are all posed in the form: “Do you have trouble in work from these positions?”. Correlation coefficients among the 11 variables range from 0.2 to 0.7, with most clustering around 0.5. Vibration, because of its poor distribution, did not load well in factor analysis. With vibration removed from the grouping, factor analysis extracted two factors, one with high reliability, one with a lower reliability but an intellectually consistent reason for being retained.

1. "Physical Strain"; 8 items.

Cronbach- α = .8675.

	<u>Monitor name</u>	<u>factor loading</u>
a.	V9022a trouble in work from this position: lifting or carrying	.77
b.	V9022b trouble in work from this position: stooping	.82
c.	V9022c trouble in work from this position: forward bending	.59
d.	V9022e trouble in work from this position: standing	.66
e.	V9022f trouble in work from this position: extending (reaching)	.69
f.	V9022h trouble in work from this position: arms above shoulders	.61
g.	V9022j trouble in work from this position: awkward postures	.60
h.	V9022k trouble in work from this position: continuously making same hand/arm motions	.51

2. "Sitting Strain"; 2 items.

Cronbach- α = .5707.

	<u>Monitor name</u>	<u>factor loading</u>
a.	V9022d trouble in work from this position: sitting	.55
b.	V9022i trouble in work from this position: work in same posture	.78

The loading of items into these two factors represents a considerable loss of distinction among various types of strain. However, as initial, summary indicators of overall physical strain and, more specifically, strain associated with sitting postures, they do make intellectual sense.

3. "VOEG MSD Indicators"; 4 items

Cronbach- α : .5597

	<u>Monitor name</u>	<u>factor loading</u>
a.	V9026d occasionally suffer pain in bones and muscles	.64
b.	V9026g occasionally suffer back complaint	.51
c.	V9026i numbness and tingling in fingers	.35

Factor analysis on all 13 VOEG items resulted in the extraction of 4 factors. The "Mental Strain" section, above, contains one, "Tiredness", (with somewhat different loadings, because of the variable set used). The three musculoskeletal MSD indicators form a factor with moderate reliability. In particular, "numbness/tingling in fingers" has low factor loading. We decided to leave it in the factor, because reliability with that item removed was even lower (.5368). The factor is a relatively non-specific indicator of musculoskeletal strain.

Physical Outcomes; Pain Reports

To assess physical consequences of occupational exposures, the Monitor data set contains a set of questions drawn from the VBA instrument (Hildebrandt and Douwes, 1991, cited in Houtman, et al., 1994a), based on the Standardized Nordic Questionnaires (Kourinka et al., 1987). The Monitor response format allowed for four different responses assessing frequency of pain in various body locations. We recoded these responses to a dichotomous variable, to intensify the separation between responses that clearly do not represent equal intervals on a scale. "None" and "once" responses were assigned the 0 value; "often" and "continuously" responses were assigned the 1 value. Neck, upper back, and lower back pain remain as dichotomous variables in the present data set. Since the questionnaire collected bilateral data for the 6 other body locations, right and left were summed to create scales with 3 possible values: 0 = none or once in both sides; 1 =

often/continuously in one side; 2 = often/continuously in both sides. Finally, two summary scores were created:

1. Upper Body Pain: sum of wrist, elbow, shoulders, neck and upper back
2. All Body Pain: Upper Body Pain, plus lower back, hip, knee and ankle/foot

Health-related outcomes

In the employee data set of the Monitor survey, there are two measures that refer to an externally verifiable health outcome of occupational exposures: Partial Disability Status and Extended Sick Leave.

- a) Partial Disability is assessed by a single question, V909, "Are you presently partly disabled for work?" This measure is highly non-normal in its distribution.
- b) Extended Sick Leave (>3 months) is a variable constructed by combining 3 other variables. Variable V9029L presents the respondent with 4 possible responses to the question: "After a more than 3 month period of sickness, I returned to:"

- 1) "My old job/work place, which was not adjusted"
- 2) "My old job/work place, which was adjusted"
- 3) "A different job and/or a different work place"
- 4) No response

The sum of responses to these 3 alternatives represents the total number of individuals who had been sick for a period longer than 3 months. This is a somewhat crude measure, and its possible drawbacks are examined in the Discussion chapter (under Potential Limitations).

Both these health outcome measures are combined measured of disability or extended sick leave from all causes. This dilutes their relationship to the biomechanical and psychosocial stressors studied in this research. However, TNO notes that MSD and stress disorders represent the highest contribution to disability figures (60-70%, Houtman, et al., 1994a), which justifies their use in this analysis as rough indicators of long-term health consequences.

Company Health Policy

The employee data set contains a number of items that measure employee perception of organizational health and safety policies. One question set, assessing where employees seek medical attention, did not have any strong associations with outcome variables. As the analysis proceeded, it became evident that another question set--assessing employee perceptions of prevention activities--had mixed positive and negative associations with outcome variables. This ambiguity of causal direction made it prudent to leave these out of the analysis. But the following measure did provide one useful indicator of company health policy:

1. Responsibility for action on health problems. Employees are asked, "If problems of work and health must be solved, which people or groups take action?"

		% of employees answering yes
a.	V9028A management	57.9%
b.	V9028B work consultative body	26.8%
c.	V9028C Personnel or Human Resources	20.1%
d.	V9028D Works Council or health and wellness committee	18.1%
e.	V9028E occupational health clinic or company doctor	17.1%

These percentages add up to a number greater than 100%, indicating that several people or groups may take action on health problems in some companies.

2. AGGREGATE EMPLOYEE DATA

In Chapter 4, under “Possible Limitations”, we examine the rationale for and uses of aggregate data. This section presents a brief rationale and explains the process by which aggregate measures were created.

Aggregation Rationale

The aggregation sub-routine in SPSS allows for aggregation of data by a “break variable,” in this case, by company identification number. There are three primary reasons to create aggregate measures for the sample of workers in each company that allowed its work force to be interviewed. First, some researchers (e.g., Michela et al., 1995) feel that creating mean values for any sample of individuals’ data is a partial corrective to the problems of self-report data (see Discussion). In their theory, by diluting the effects of extreme responses and outliers (in either direction) the mean values created represent a “truer” characterization of the work place. Correlations between groups taken at the aggregate level are almost always stronger, because of the elimination of outliers and reduction in standard deviations at the group level. The cost of the process is the reduction in specific correlations of individual data points at the individual level. The specificity of each individual’s association between exposure and outcome is diluted by aggregation.

Second, carrying out some of the analyses at the plant level, using plant-level measures for both employer and employee, avoids some of the pitfalls of cross-level analysis (see Discussion). Most important, a large portion of the analytical methods is directed towards the examination of differences between employer and employee perceptions of the same work environment. To compare employer and employee reports, it is necessary to create for each company a unitary employee estimate of exposures and outcomes in the company--the aggregate mean values of the individual-level response.

Consequences of Aggregation

For every measure selected and/or created in the employee , a parallel mean measure was created at the plant level. Several basic differences between levels in the characteristics of the variables should be noted. The mean values are the same at both the individual and the company level, but the standard deviations of these means are roughly cut in half, because of the “smoothing” function of aggregation. For the same reason, scales created from the aggregated mean values have a somewhat higher Cronbach- α than the same scales created at the individual level. There is no consistent effect of aggregation on the normality of the distributions; in some cases aggregation reduces kurtosis and/or skew, in others these indicators are increased.

3. EMPLOYER DATABASE

Data Cleaning and Re-Coding

We used similar criteria to those used in the employee data. Because these data are collected by

interview, the problems associated with missing data are much reduced in the employer data set. Therefore, most re-coding was involved in creating new variables, not in re-formatting existing variables. Where necessary, the following steps were taken:

1. Where they exist, missing values (original value = 0) and "don't know" responses are re-coded to missing values.
2. As in the employee database, dichotomous and categorical variables are generally re-coded to assign the higher values to the hypothetically less desirable state. This is not possible in the following situations:
 - a. Many of the structural variables are worded to indicate the presence of a factor, and sometimes the level of presence. To make the levels intuitively understandable, these variables are generally coded with the higher codes representing the higher level of presence. This is a departure from 2, above.
 - b. Likewise, dummy variables created for several of the questions in the employer database also depart from the scheme of 2, above. By definition, a "1" in a dummy variable indicates the presence of a particular state, while a "0" indicates its absence. This scheme is unrelated to the desirability or undesirability of that state. Other dichotomous variables indicating presence/absence of a body, measure, etc. receive the same coding.

Selection of Appropriate Measures, Re-Coding and Scale Creation

Variables for analysis were selected from the employer interview database in 5 categories. Because the scale creation process is much simplified in the employer database, it is addressed in this discussion, not in a separate section.

1. Employer Estimates of Employee Stressor Exposure.

The employer estimates of employee stressor levels and outcomes (below) allow company-level analysis of the associations between employee stressor level, strain and outcomes (Stage Ib) that parallels this analysis carried out at the individual level (Stage Ia). Although the parallels are not always exact, the comparison of associations derived from employee data and employer data at the same location provide a unique view of one aspect of company atmosphere: the degree to which employers and employees share (or do not share) an understanding of these aspects of occupational health.

In all cases, the employer risk questions are company-level measures of the same risks assessed at the individual level. All references to the sources from which these questions were drawn in constructing the Monitor interview are presented in Houtman et al. (1994a, 1998). Employers were asked what percentage of their employees were exposed to the particular risk factor, which positions had the highest level of risk, and whether they considered the risk factor to be a cause of illness, disability or turnover. This analysis uses the employer estimate of percentage of employees exposed to the risk factor. It is the measure that can most simply and most directly be compared to employee estimates of the same factors (see Discrepancy Indices, below). As in the employee data set, low percentage estimates indicate the more desirable state.

Employers answered this question for 6 categories of biomechanical risk and 5 categories of

psychosocial risk. Each of these 11 variables is comparable to a scale or a single question in the employee database. The relation between the analogous measures is explored in the section detailing the creation of the Discrepancy Indices. Measures below are assessed as “percentage of workers with this risk factor in your company”.

<u>Variable Name</u>	<u>“% exposed to:”</u>
a. V8x209a	Heavy physical exertion; lifting, pulling pushing
b. V8x209d	Prolonged exertion in the same posture, often
c. V8x209g	Bending or twisted upper body postures, often
d. V8x209j	Repetitive motion with arms and hands
e. V8x209m	Vibration
f. V8x209p	Prolonged sitting
g. V9x209a	Demands of work life: work load, difficulty, or tempo
h. V9x209d	Decision authority or autonomy
i. V9x209g	Lack of flexible employment
j. V9x209j	Contacts/support on the job between workers or with supervisors
k. V9x209m	Skill/intellectual discretion

2. Employer Estimates of Employee Strain, Negative Health Outcomes, and Health-Related Outcomes

As with exposure measures, employer measures of employee strain are much less detailed than those taken in the employee questionnaire. Three questions are used to assess employee strain:

- a. V11x113 Were there complaints in the last 12 months from employees, concerning the neck, back and limbs?
- b. V12x113 Were there complaints in the last 12 months from employees about work stress?
- c. V13 Do employees suffer from other health complaints related to their work?

Employers were asked about levels of sick leave, turnover, and disability in the last 12 months (i.e., in 1992).

- d. V14x309 sick leave: percentage in 1992
- e. V15x209 turnover: percentage in 1992
- f. V16x112 disability: number of employees in 1992 (changed to %)
- g. V17a-c Return from sick leave > 3 months

Employers were also asked the same question that was used in the employee questionnaire to create the Extended Sick Leave measure, so an employer estimate of percentage of Extended Sick Leave could be created.

3. Company Demographic and Structural Measures

This section presents the variables used in Stage II and III analysis. The Monitor structured interview for employers contains questions that address the basic technological and structural features of the company. Most of these questions might be seen as the company analog

to demographic variables asked of individuals: they address the basic measures that define the basic company characteristics that affect the associations analyzed in this research. Many of these measures have been developed and used in previous research (Kuipers & Amelsvoort, 1990, Vaas et al., 1995, cited in Houtman et al., 1998). A small set of these measures was developed for use in the present analysis:

a. V52 number of employees on the payroll

b. gk company size

The latter variable is a data manipulation carried out by TNO. Companies were divided into 3 categories: those of 100 or fewer employees, those between 100 and 200, and those over 200.

c. sbi economic branch and sector

As noted in the Introduction, the Dutch research scheme collected information from companies in 3 branches of the economy. The 9 sectors contained within these branches are presented in Table 1. We created two dummy variables, with the reference branch being Banking & Finance

d. sbi dummy; Wholesale Branch

e. sbi dummy; Industrial Branch

The sampling strategy and the branch and sector make-up of the database has been described in the Introduction. Because the analysis focused on the 285 companies with employee samples ≥ 15 , the small numbers within each individual sector made analysis by sector-difficult. We created a modified sector division, to explore variation in the modeling by sector. The industrial branch was divided into 4 groups, based on disability insurance and prevention policy similarities. The Banking and Financial was divided into Banking/Insurance and Service Sectors

- 1) Food and Entertainment
- 2) Transportation
- 3) Textile/Clothing, Chemical and Electronics
- 4) Graphics/Printing, Metal
- 5) Wholesale
- 6) Banking & Insurance
- 7) Service

f. Percentage of employees employed, expressed as "full time equivalents".

g. Percentage of employees with limited contract.

h. Percentage of temporary employees.

The 3 questions above allow the assessment of the stability of employment for the sample in the Monitor study. Many authors have addressed the effects of down-sizing, the increase in temporary and contract employment, the loss of guaranteed life-time jobs, and other aspects of an increasingly competitive environment, both at the company level and the individual level (see, e.g., Case, 1992, 1995 and Boyett & Conn, 1991). In the present research, the above measures have at least two possible associations. First, they may be seen as a potential organization level stressor, with direct effects on individuals. Second, they may be indicators of organizational culture.

i. V39x112 “In your company or organization, is there group or team work?”
(0 = no, 1 = yes.)

j. V39x209 “If so, what percentage of employees is working in teams?”
We hypothesize that presence of work groups and percentage of employees in work groups are associated with reductions in employee stressor and outcome levels. But these questions do not begin to address the wide range of forms that work groups or teams may take. For a more detailed discussion of the problems with this measure, see Chapter 4 (Issues of Measurement Construction).

k. V41 Levels of hierarchy.
Number of hierarchical levels are certainly related to company size. But the correlation coefficient between these two variables ($r = .34$) suggests that much of the variance in the number of hierarchical levels is explained by something other than company size.

4. **Company Health and Safety Policy**

a. “Self-insured for disability” (3 levels: none, GAK guidance, and fully self-insured)

Variables V5 and V6 ask who is responsible for paying sick workers basic payments and additional payments (any payment “complimenting” the basic payment), respectively. There are three possible answers to this question:

- a) the Industrial Insurance Association (the Dutch acronym = GAK)
- b) the company by itself
- c) the company with GAK guidance and control.

We hypothesize that companies making use of the GAK have reduced individual level stressors and lower levels of strain and adverse health outcomes. Since it was originally unclear which of the two types of insurer involvement (full insurer involvement, or simply assistance from the insurer) would have stronger associations with reduced stressor levels, these 3 answers to V5 were re-coded into 2 dummy variables. Exploration of correlations showed that the hypothesis was wrong; self-insurance is associated with lowest levels of outcomes, while full reliance on the GAK is associated with the highest levels. GAK guidance and control occupies a middle position. Thus a single variable was created for further analysis. Correlations of this variable with company size are non-significant, but self-insurance is strongly affected by sector membership.

b. “Policy Plan”: The plan for analysis and control of workplace risks of physical load and stress.

This measure is a simple sum of 5 questions that assess the existence and thoroughness of the organization’s policy for analyzing and reducing risks. Correlations of most measures with company size are high, making it important to control for company size in the modeling.

		<u>Correlation with Company Size</u>
1) <u>V18</u>	Do you have a yearly policy plan?	.47
2) <u>V19</u>	Is there a yearly review of the plan?	.54
3) <u>V19c</u>	Does the review incorporate employee committees’ recommendations and comments on working conditions and improvement strategy?	.49
4) <u>V20</u>	Is the plan integrated with other company policies?	.27

5) V22 Are there are 1 or more committees which address .27
working conditions?

The first 2 questions have a 3-part categorical answer: 0 = no; 1 = yes, in the future; 2 = yes, now. "Employee input" also has a 3-part categorical answer: 0 = no review; 1 = review present, no employee involvement; 2 = review present, with employee involvement. The last two policy questions (policy integrated, and $\geq$ committees) are dichotomous: 0 = no; 1 = yes. Thus, the summary scale can assume values between 0 – 7. The hypothesis: a more formalized and integrated plan will be associated with reduced levels of individual-level stressors, strain and adverse health outcomes.

c. Bodies and groups involved in the policy plan and health problems.

Variable V23 asks, "If there are problems in health and work, which of the following groups is involved?" Of the 10 choices given, 6 had enough "involved" answers to allow analysis. Responses were recoded to a 4 step categorical variable: not involved, partly, strongly and fully involved. The 6 groups with enough involvement for analysis were:

- 1) directors or management
- 2) middle management
- 3) employees
- 4) regular work consultation groups
- 5) human resources
- 6) Works Council (management/employee council)

We tested two hypotheses in the analyses:

- a) Greater degrees of involvement in work and health problems by any one group are associated with stressor and health outcome reduction.
- b) Because management commitment and employee involvement are so important in establishing the safety climate in a company (Shannon et al., 1995), increasing involvement of these bodies will be associated with greater stressor and outcome reduction.

4. COMBINED DATABASES; THE DISCREPANCY INDICES

The Discrepancy Indices, constructed within each company, are simply the difference between the employer's estimates of 11 risk levels and the corresponding estimates of that company's aggregate employee sample. One of the purposes of the present research is to explore the behavior and distribution of the Discrepancy Indices as well as their associations with outcomes. The analysis uses the Discrepancy Indices as independent variables, predicting individual-level stressors, strain and outcome variables. We hypothesize that these Measures are indicators of as-yet-undefined characteristics of organizational culture. Future research will explore the actual meaning of the Discrepancy Indices.

254 employers, roughly 1/3 of the sample, did not allow their employees to respond to the Monitor survey. For these companies (termed "Refusers" in the analysis), aggregate employee data and Discrepancy Indices are thus not available. The analysis compares these companies to

the 528 companies in which employers did allow employee responses (“Allowers”), to see if there are significant differences between these companies that might be mined for prevention information.

Construction of Discrepancy Indices

The Employee questionnaires contain categorical yes/no variables that match 4 of the 11 employer risk factor estimates. For the other 7 employer questions, employee analogs were selected from the individual-level exposure scales presented above. We selected appropriate employee scales of biomechanical risk on the basis of face comparability to the employer measure, highest reliability of the employee scale, distribution of the resultant Discrepancy Index and highest correlation with other Discrepancy Indices. For reasons of comparability with TNO analyses, the employee scale in 4 of the 5 psychosocial Discrepancy Indices was the scale used in the Monitor questionnaire. The “Flexible Employment” Discrepancy used the employee measure, “Schedule Control”, the 2-item sub-scale from the low-reliability Terms of Employment group.

As at the individual level, all employee scales and individual questions from the employee data are represented by a mean value between 0 (all employees in the company sample answer 0) and 1 (all employees in the company sample answer 1). The Discrepancy Indices are constructed as follows: for each of the 528 “Allower” companies, the employer risk estimate (“percentage of employees exposed”) for each of the 11 stressors is subtracted from the aggregate employee response to the corresponding question or scale. Thus, for each of the 11 measures, each “Allower” company is assigned a discrepancy value between -1 (employer estimates 100% of the work force is exposed; all employees report no exposure) and 1 (employer estimates none of the work force is exposed; all employees report exposure). Finally, factor analysis of these 11 Discrepancy Indices generated two Discrepancy Scales, one biomechanical and one psychosocial. Table 2 presents the brief descriptive name for the Discrepancy Indices (from the 11 employer exposure questions; see above), the employee component name and descriptives of the Indices and Scales.

Discrepancy Scales

The Principal Axis Factoring process, with Varimax rotation, produced 2 factors with eigenvalues greater than 1 from the 11 Discrepancy Indices entered in the procedure. These factors formed along the separation between physical and psychosocial risks. Several Discrepancy Indices did not load well on either scale and were dropped from scale formation. The two scales composed of the remaining indices are:

1. Physical Discrepancy Scale. Cronbach α = .7132. Components:
 - a. Static Exertion Discrepancy Index
 - b. Bend/Twist of upper body Discrepancy Index
 - c. Repetitive Hand Motion Discrepancy Index
2. Psychosocial Discrepancy Scale. Cronbach α = .6935. Components:
 - a. Autonomy Discrepancy Index
 - b. Flexible Employment Discrepancy Index
 - c. Social Support Discrepancy Index

d. Skill Discretion Discrepancy Index

Use of the Discrepancy Indices

For the purposes of the following discussion, let these Discrepancy Indices be called the “raw discrepancy” scores (termed RD). In the analysis, these raw discrepancy scores can now be tested for their ability to explain variance in employee reports of stressor levels (Stage II) and physical and psychological strain, extended sick leave and disability. But the RD score presents three related problems for analysis.

1. The size of the component risk measures (both employee and employer estimates of risk) may be affected by the “true” level of risk. It is possible that the higher the actual risk level, the greater the discrepancy between employer and employee estimates. Employers might be motivated to under-report risk levels, consciously or unconsciously; employees might wish to “send a message” to employers, knowing that the aggregate results would be seen by management. Conversely, it is possible that higher levels of risk are more visible to management and/or employers. The increased precision of estimation associated with a more visible risk level could result in lower RD scores. In either case, analytical procedures should apply a correction factor for the effect of actual risk level.
2. When RD scores are used as independent variables, the association of these scores with the dependent variables will vary with the “true” risk level, around which the discrepancy occurs. For example, a 20% discrepancy between an employer estimate of 0% and an employee estimate of 20% might have a different meaning than a 20% discrepancy between an employer estimate of 60% and an employee estimate of 80%. Again, testing the overall hypothesis--that higher levels of discrepancy represent a less desirable company culture and work organization and will be associated with increased levels of adverse outcomes--requires some correction for “true” risk level.
3. In exploring the Discrepancy Indices, it became evident that the discrepancies, and their component employer and employee estimates, demonstrate non-random distribution patterns as the “true” risk level changes (see Chapter 3).

For reasons detailed in Discussion, the mean employee/employer risk estimate (termed MR in this discussion) was chosen to represent the “true” risk level. Table 3 presents the descriptives for the mean measures that correspond to the Discrepancy Indices. Table 4 presents correlation coefficients for the relationship between the Discrepancy Indices and a) the employer risk estimates, b) the employee risk estimates, and c) the mean value of these two estimates, for both the full set of “Allower” companies and the reduced set of 285 Allower companies whose employee sample was 15 or over. These associations make clear the need for a correction factor related to “true” risk level. It is not possible to divide by the MR to standardize the RD; the complicated and non-random behavior and interrelationship of the RD and the MR makes it difficult to argue that the standardization process is uniform over the range of mean values. It seemed prudent to enter the RD and the MR as separate quantities in the equations. The results of these calculations could perhaps be used to create simpler weighting strategies for use in future research. The initial bivariate model for testing percentage discrepancy associations with dependent variables will consist of bivariate equations of the form:

$$\text{dependent variable}_a (\text{company-level aggregate}) = \beta_{0a} + \beta_{1a}RD + \beta_{2a}MR \quad (1)$$

Clearly, the MR will vary from the risk estimated by an unbiased outside observer. It is unlikely that this variation of MR from unbiased risk is randomly distributed. Risk level estimates, for both employer and employee, have enormous psychological, political and economic meaning. This might mitigate towards random variation, but it seems more likely that one or the other class of estimates is closer to the “true” risk level. It is possible that employers, having generally a larger overview of the company, tend to peg their answer closer to the true risk. It seems more likely, however, that employees have a better idea of the true risk level, since they experience these risks on a daily basis. More important, it is impossible to know how strongly the incentives towards reporting bias affect estimates for both these groups. Since we cannot know how these factors interact in this data set, we settled for the mean measure as an imperfect correction factor.

The analysis also examined these company-level RD and MR scores for their ability to explain variance in individual-level dependent variables of the employee data set (Stage III). The initial bivariate equation, parallel to equation 1 above, is in the form of:

$$\text{dependent variable}_i (\text{individual level}) = \beta_{0i} + \beta_{1i}\text{RD} + \beta_{2i}\text{MR} \quad (2)$$

Because of their relatively normal, continuous distributions (Table 2), the Discrepancy Indices enter the above equations as continuous measures. But, because of the difficulty involved in interpreting the meaning of positive and negative discrepancies, we first tested their associations as 3 dummy variables, to represent a 4-part categorical coding. There are so few negative discrepancies in each measure, compared to those that are positive, that these few are coded into a single, negative category. All values above 0 were then divided into 3 groups of equal size, using the group separation feature of the SPSS “frequencies” procedure.

Using simple bivariate regression equations (entering each Discrepancy Index and its associated Mean) all the Discrepancy Indices were analyzed for their associations with the various dependent variables used in the different stages of the research. Two findings emerged:

1. The two scales created through factor analysis, were acceptable summary measures, combining the various effects of the individual Discrepancy Indices. Therefore, for the present research, the Physical Discrepancy Scale and the Psychosocial Discrepancy Scale were the only Discrepancy Indices used in the regression equations (entered with their associated Mean Scales). For future research, the more subtle effects of the 11 individual Discrepancy Indices will be examined in greater detail.
2. Analysis with the dummy variables revealed that negative discrepancies are not different from the 3 levels of positive discrepancies; they simply represent the lowest level of exposure, with a clear dose-response relationship emerging with increasing levels of positive discrepancy. Therefore, modeling presented in the results was carried out using the continuous Discrepancy Index Scales.

B. Analytical Methodology for Testing the Models

The analytical methodology is deliberately kept simple for the testing of the associations delineated in section I of this chapter. For the present research, classical statistical techniques were used to test the study hypotheses. Several statistical approaches were utilized.

1. Correlation analysis, both Bi-variate and partial, was used as a first pass, to select the dependent/independent variable pairs with the strongest associations.
2. To test multiple associations, multiple linear and logistic regression techniques were chosen because of their robust nature and their wide-spread use in the literature.
3. T-tests were used to carry out tests of differences between mean values. (Comparing “Allowers” to “Refusers” and companies with employee samples >15 to those with employee samples <15—the TNO strategy for insuring statistical stability).

The characterization of associations at two levels, the individual-level and the plant-level, presents unique opportunities for comparative analysis. The work environment of the individual employee can be placed in the context of influences from the individual’s plant and from the general economic environment of the branch and of the country. But these unique opportunities are accompanied by unique problems that are specific to multi-level analysis. These problems, and the solutions employed in this research, are explored in more detail in the Discussion chapter. For the present section, note that two basic procedural rules are followed in the analysis.

- a. Correlation analysis has been shown to be particularly susceptible to the “ecological fallacy” (Robinson, 1950, updated in Feinleib and Leaverton, 1984); correlations calculated at an aggregate level are almost always higher than those derived at the individual level, because of the “smoothing” (reduction in variance) function of aggregation. Thus, correlation analysis in this research is always used as a “first cut”, to identify associations for further analysis by regression techniques. The absolute values of the correlations are less important than the relative values, and they are not used to make conclusions about the strength of individual level correlations.
- b. The major difficulties with multi-level analysis arise when inferences are made cross-level. In characterizing most of the relationships in this research, analysis is carried out within levels, either individual or plant. Where cross-level analysis is employed, independent variables from the higher level of analysis are imputed to cases in the lower level. These cases will be explained in the appropriate section. The Discussion addresses the problems and corrective techniques in more detail.

A level of significance of $< .05$, two tailed is the cut-off point for significant associations in linear regression, logistic regression and T-tests. Overall estimates of model explanatory strength were different for the two types of regression. In tables, if significance is between .05 and .10, these near-significant relationships are reported as such. Associations with a higher level of significance are simply reported as not significant (n.s.). In linear regression, the adjusted R^2 is always reported (the adjustment corrects for the increase in explanatory power due simply to a larger number of independent variables.)

There is no direct analog to an R^2 estimate in logistic regression. The initial and final -2 Log Likelihood figures are reported, together with the Model Improvement and significance of the chi-square distribution. Model building procedures are detailed in the appropriate sections of the Results.

Graphical analysis emphasized simple line graphs and scatter plots. The advantage of the scatter-plot procedure in SPSS is that x/y pairs on the graph can be marked by different levels of a third variable. The program fits separate regression lines (linear, quadratic, and cubic) for x/y points representing these different levels. The analyses made extensive use of this procedure to show the effects of stratification by a third variable. We used graphical analysis in a qualitative fashion in this research. Visual inspection allows identification of trends and/or confirmation of effects detected in mathematical modeling.

Stage Ia Analysis. Individual Level; Employee Data Set (n = 7717)

In this stage of the analysis, data from all 7717 employees was analyzed. All individual-level analyses were controlled for sex, age, and education level. The goals at this stage were four:

- a. to characterize the associations of the physical and psychosocial stressor levels with physical and psychological strain and the two negative health outcome variables.
- b. to separate the effects of physical and psychosocial stressors
- c. to characterize levels of interaction between physical and psychosocial stressors
- d. to determine the best model and strongest associations, which were then brought forward to the Stage II analysis

1. Correlation Analysis. The variable creation process identified and created a large number of variables, to characterize all aspects of individual-level stressors, strain, and negative health outcomes that were assessed in the Monitor questionnaire. Bi-variate and partial correlations were used to identify a smaller number of predictor variables having strong associations with outcomes. At the individual level, the independent variables were always the measures of biomechanical and psychosocial stressors, while the dependent variables (which remain dependent throughout Stages I and III) were measures of strain (psychological and physical), body pain, and adverse health outcomes of Partial Disability and Extended Sick Leave.
2. Graphical Analysis. Non-linear associations between variables can be obscured by simple correlations and by linear regression techniques. In particular, the U-shaped associations which are characteristic of many sociological and physiological processes can be quite strong and yet not be detected by correlation analysis (because of opposing slopes of different parts of the association curve). Since non-linear associations were expected in certain aspects of this research, these relationships were also explored graphically, to detect associations that correlation analysis would miss. Those that showed evidence of a more complicated association pattern were subjected to stratified analysis to see if the associations of dependent variable with different levels of predictor variable were strong enough to bring the variables into the next steps of analysis. (See Karasek et al., 1982b, for an example of a stratified approach to work environment analysis.)
3. Regression Analysis. The independent variables associated with outcomes were then entered into multivariate regression equations (logistic or linear) with the individual-level demographic potential confounders: age, sex, and education level. The analysis also examined the models in different sector groups. Regression was usually run by the “forward” method, with probability of entry and removal set at .05 and .10, respectively. Protocols were also established for the treatment of collinearity and interaction terms.
 - a. Collinearity is always a potential hazard in regression analyses. In this research, in particular, collinearity between biomechanical and psychosocial stressors was expected to be problematic. SPSS provides several types of collinearity diagnostics, which were used to

analyze the relationships between independent variables in these equations. Details and theoretical background are given in Norusis/SPSS (1993). The use of these diagnostics is discussed in more detail by Kleinbaum et al. (1988, pp. 209-218).

- 1) Tolerance and the variance inflation factor (VIF). A low tolerance or a high VIF assigned to a variable mean a high degree of collinearity. In the present research, a conservative VIF value of 3 was used as the acceptable limit for collinearity. If this limit was violated, for intellectual reasons, it is reported in the results.
- 2) Condition Number This measure is derived from analysis of eigenvalues. For a set of non-collinear independent variables, the eigenvalues will not be greatly different. If some eigenvalues are much smaller than the others, this is an indicator of collinearity. The Condition Index, which is the square root of the ratio between each eigenvalue and the maximum eigenvalue, is thus high for eigenvalues that are very low, indicating collinearity. In the present analysis, the smallest condition index, termed the Condition Number, was used as the practical indicator of collinearity. A conservative value of 20 was chosen as the limit of acceptable collinearity. If this limit was violated, for intellectual reasons, it is reported in the results.
- 3) Variance proportion. The diagnostic table generated by SPSS also lists, for each independent measure, the proportion of that measure's variance that is assigned to each eigenvalue. When collinearity is present, a high proportion of variance for two or more variables will be associated with a single eigenvalue. This enables us to determine which of the independent variables exhibit collinearity.
- 4) If two or more variables attained too high a level of collinearity (as indicated by the diagnostics above), they were removed from the equation and the regression with the remaining independent variables was repeated for stratified levels of the collinear predictors.

b. Interaction Terms

One of the hypotheses of the research is that interaction will be detected between biomechanical and psychosocial stressors, in their associations with the dependent variables. Interaction terms might explain some of the dependent measure variance. The SPSS graphing procedures described above created plots for several of the dependent/independent associations that appeared to be most affected by levels of a third variable. In some cases, the relevant associations for this type of analysis were first identified by running parallel regressions on different strata (quartiles) of the modifying variables. A visible change in the slope of the regression lines (the β coefficient in the equation) indicates an interaction between the stratifying variable and another independent variable. However, for all cases in which graphical analysis and stratified analysis indicated interaction, entry of the multiplicative interaction term in the non-stratified model resulted in removal of one or more main effects of the component terms. Thus, we were not able to retain these interaction terms in the final regression models.

c. Stratification by Gender and Job.

To detect associations of different magnitude and/or direction in sub-groups of the full population models, above, we ran two stratified analyses of the final models. One analysis separated the models by male and female gender. The other separated the models by 3 job levels: line worker, supervisory personnel, and managerial & professional positions.

4. Demand- Control Analysis

Finally, the analysis extended the widely used Demand-Control Model (Karasek, 1979) to the study of musculoskeletal and stress disorders. These outcomes were studied by 3 levels of Autonomy and 4 levels of Demands, exploring whether the interaction of Demands and Control was associated with increased outcome levels.

Stage Ib Analysis. Employer Reports of Employee Stressor, Strain and Outcomes (n = 782)

This stage of analysis is a parallel to Stage Ia. The goal is to characterize associations between plant-level estimates (by the employer) of employee stressors and strains. In addition, the employer reports add several outcomes that are not available directly at the individual level: percentages of sick leave, turnover and disability in 1992.

This is the only stage in the analysis in which it is possible to get an estimate of individual-level associations for the companies in which employees were not allowed to participate in the Monitor project. This estimate consists solely of the perceptions of the employer; there is no actual individual-level data from employees to be used for comparison. Because the number of employee-related variables is so much smaller in the employer data set, compared to the employee data set, the correlation analysis steps were much shortened. The analysis focused on the employer analogs to the individual-level equations. At this level, it is only possible to control for the mean values of demographic variables in each employee sample: age, sex and educational level. Branch and company size were controlled in these models. The models that could be estimated were:

1. Physical and mental strain are each represented by one question with a dichotomous, yes/no answer. Logistic regression was used to model this dependent outcome on the 11 employer measures of physical and psychosocial stressors that were significantly associated in correlation analysis.
2. Multivariate regressions were modeled, for continuous outcomes (percent sick leave, disability, and Extended Sick Leave) on the same 11 stressor independent variables.

Stage II analysis. Associations of Organizational Measures with Employee Estimates of Stressors, Aggregated at the Company Level (n = 285)

Following the guidelines laid out above for multilevel research, all associations at this stage are analyzed at the level of the company. The independent variables are interview responses of each employer who was an "Allower" or variables created by combining employer and employee data (Discrepancy Index Scales and Means). These are entered into equations in which aggregate (at the company level) employee stressor levels are the dependent variables. In Stage II, the measures of shop floor risk level (stressors) change from their role as independent variables in Stage Ia and Ib to that of dependent variables. Two preliminary steps are necessary:

1. At this stage, the 254 Refuser companies were removed from further analysis, since there was no comparable employee data set for comparison. T-tests were used to compare mean values of variables from the Allowers and Refusers, to define the areas in which the two groups are not comparable (and selection bias might be operative).

2. We reduced the data set from all 528 Allowers to the 285 whose employee sample is equal to or greater than 15 individuals. In this discussion, these companies are referred to as “over 15” and “under 15” companies. This cut point is the mean of the 528 employee sample sizes. TNO has determined that this size also represents the smallest employee sample for which comparison analysis can be done with any confidence in the representativeness of the sample. To determine differences between the over and under 15 companies, we calculated means for the same variables used to test differences between Allowers and Refusers and used t-tests determine the significance of these means.

Stage II Core Analyses

1. Using the 285 over 15 companies, bivariate correlations served the same function as that described in Stage Ia--as a “first cut”, to allow elimination of variables with no strong associations. Partial correlations could not be used; the reduction in cases was unacceptably large. As in Stage Ia, graphic analysis was also used to identify non-linear associations that would be obscured by correlations analysis. This stage examined all associations of aggregate employee stressors with independent variables of company structure, technology and health policy.
2. The use of Discrepancy Indices, described above, began at this level. The working hypothesis is that the discrepancies are indicators of a construct that is very difficult to measure-- company culture. These variables, together with the mean employer/employee estimates, were used as independent variables and tested for their ability to explain variance in aggregate stressor levels.

The use of Discrepancies as Stage II independent variables, to predict size of individual-level stressors, runs the risk of tautology. One of the two components of each discrepancy and mean measure is the aggregate employee estimate of a stressor level. However, the correlation between each discrepancy and its component employee measure is relatively small: most of the psychosocial discrepancy correlations are in the 0.30 range, with a low of .22 and a high of .55. The physical discrepancy correlations are somewhat higher and more consistent, with most values being just below .50 (and one, vibration, reaching .84; this discrepancy is not part of the Discrepancy Scale). See Table 4 for these figures. Interestingly, Table 4 also shows that the correlations between employee estimate and discrepancy value, for each of the 15 discrepancies used, is lower in the over 15 group than in the full set of 528 Allower companies.

Several other precautions were taken to further guard against the risk of a tautological model. First, factor analysis was used to create the two summary scales of discrepancies. The present research used only these summative scales were, thus somewhat diluting the direct associations between a specific discrepancy and its component measures. Second, a crossover strategy was developed. The scale based on psychosocial risk estimates was used to predict levels of biomechanical stressors, and the physically-based scale was used to predict levels of psychosocial stressors. Perhaps the strongest argument for testing these discrepancies in the Stage II context is the clear evidence (Table 4) that the magnitude of the discrepancy is much more strongly associated with the employer component than the employee component. This is particularly true of the psychosocial discrepancies, for which the correlations of the dis-

crepancy with the employer estimate are generally 2-4 times the magnitude of correlations with the employee estimate.

3. From these operations, the most predictive independent measures were entered stepwise into multivariate models for each dependent stressor variable.
4. We built a parallel set of models at the individual level, to test at the individual level the association of organizational-level predictors (structural, technological, health policy, and discrepancy/mean variables) with individual-level stressors. We anticipated that this procedure would yield weaker coefficients, because of the diluting presence of more outliers at the individual level. This modeling and the parallel Stage III modeling (below) are the only points in the analysis plan where company-level measures are introduced into the individual level. None of the independent variables are aggregate or company-level forms of measures that exist at the individual level. The procedure was as follows:
 - a. The full set of organization-level predictors was imputed into the employee database. Thus each individual employee case is assigned values for his/her company on these measures.
 - b. Partial correlation calculations were performed, controlling for 3 individual-level demographic variables: age, education level, and sex. The analysis identified significant correlations between individual-level stressor measures and the company-level variables.
 - c. The analyses only used employees from the companies with employee samples ≥ 15 . This reduced the number of cases to 5570.
 - d. Parallel to the other company-level Stage II analyses, this procedure developed models with the individual-level stressors as dependent variables and the company-level measures as independent variables. This procedure allowed individual-level assessment of company-level contribution to “shop floor” stressor levels.
5. Finally, the analysis visually examined the relation of Discrepancy Scales and Mean Scales to aggregate stressor levels using the same block diagrams employed in the Demand-Control analysis above. In this case, the 2-dimensional base of the diagram is a 4 x 4 table comparing the 4 levels of Discrepancy Scale (created for initial dummy variable modeling) to quartiles of the corresponding Mean Scale. Using a stratified cross-tabs procedure, we determined the percentage of each cell’s population reporting the highest quartile of the dependent variable—stressor level. Blocks built on the 2-dimensional base graphically represent these stressor levels, in relation to each of the 16 combinations of Discrepancy and Mean.

Stage III. Associations of Company Variables on Aggregate Individual Level Strain and Health-Related Outcomes (n = 285)

The Stage III analysis is aimed at measuring the direct associations of organizational level independent variables with the aggregate dependent measures of strain and health-related outcomes examined in Stage Ia--effects outside those that are mediated through stressor level. There is no foolproof method for determining whether these Stage III associations are truly main effects or simply effects mediated through other, unknown stressors.

1. In this Stage, the same “first cut” techniques were employed as those used above--correlation analysis, Bi-variate and partial, combined with graphical analysis to identify non-linear associations. Again the strongest set of associations was identified to bring forward to the regression analysis.

- a. In this Stage, the independent variables were the same as those used in Stage II:
 - 1) Employer information about company size, branch, structure, technology, and health policy.
 - 2) Discrepancy Indices, constructed from employer and employee data. Stage III use of Discrepancy Indices is one step removed from the concerns of collinearity between Discrepancy Indices and stressor levels noted in Stage II, above. The aggregate employee strain and adverse health measures were not, themselves, involved in the construction of the Discrepancy Indices.
2. The company-level independent variables showing the strongest correlations with the dependent variables enter (forward stepwise) into multivariate equations that include the mean value of the individual-level demographic variables to be controlled (age, sex, and education level).
 - a. The Discrepancy Indices enter into these equations together with their associated mean employer/employee estimates, as above.
3. As in Stage II, a parallel set of regression equations was run at the individual level, to test the relative contribution of company level independent variables and individual-level stressors to individual-level strain, pain and health-related outcome measures. The procedure of imputing company-level measures to individual cases is identical to that employed in the individual-level section of Stage II. The employee data set was filtered, so analysis was only performed on employees from companies with employee samples ≥ 15 ($n = 5570$).
 - a. This procedure adds to the final Stage Ia equations the company-level independent variables that enter significantly into Stage II and III models, above
 - b. This procedure allows assessment of the relative contributions to strain and health-related outcomes of the company level variables and the individual-level stressors.

A. Summary of Hypotheses to be Tested

In addition to the 3 primary hypotheses (Introduction), the following sub-hypotheses were tested.

1. Individual Level (Stage Ia)
 - a. Biomechanical stressors are associated with the strongest increase in physical outcomes.
 - b. Psychosocial stressors are associated at a lower level with increases in physical outcomes.
 - c. Psychosocial stressors are associated more strongly than biomechanical stressors with increases in psychologically-related outcomes.
 - d. Biomechanical Stressors are associated with lesser increases in psychological outcomes.
 - e. Biomechanical and psychosocial stressors interact to explain increased risk of physical and psychological outcomes.
 - 1) Some joint effects are purely additive; that is, the slope of a stressor/outcome association will remain the same, but the intercept at different levels of a modifying variable will change. The regression lines will be parallel.
 - 2) Some interactions are purely interactive. That is, the slope of the stressor/outcome association will change by levels of the modifying variable, while the intercept remains the same.
 - 3) Some joint effects will demonstrate a combination of the two; the modifying variable changes both the slope and the intercept of the stressor/outcome association

- f. Measures which assess employee perceptions of company health policies are associated with reductions in outcomes.
- 2. Company Level (Stage II and III)
 - a. A more integrated and formalized prevention policy is associated with lowered levels of stressors (Stage II) and strain and health outcomes (Stage III).
 - b. Company size is positively associated with reductions in these outcomes, because of greater resources.
 - c. Self-insured companies are associated with reductions in these outcomes, because of the incentive for prevention, compared to GAK insured companies.
 - d. Increased levels of involvement by any of the managerial, employee or joint groups assessed in the employer interview are associated with decreased levels of these outcomes.
 - e. Line driven production structures are associated with elevated levels of these outcomes, compared to product driven structures.
 - f. Discrepancy Indices show a positive association with these outcomes.
 - g. Temporary and part-time employment relationships are associated with increased levels of these outcomes.

One of the primary purposes of this research project is to generate new, testable hypotheses as well as to test the hypotheses presented above. It was expected that a certain number of the above hypotheses would not be supported. In the Recommendations section, the new hypotheses generated from the testing of the old will be presented.

CHAPTER III; RESULTS

The Results chapter contains 4 sections, keyed to the 4 stages of analysis presented in Chapter 2:

- A. Stage Ia: Associations at the Individual Level (Data from the Employee database).
- B. Stage Ib: Associations at the Individual Level (Data from the Employer database).
- C. Stage II: Associations between organizational characteristics and individual-level stressors.
- D. Stage III: Associations between organizational characteristics and individual-level strain and health-related outcomes.

A. Stage Ia: Individual-Level Associations (Employee Database)

1. Correlation Analysis

The variables described in the employee data set, a list of 9 dependent and 20 independent variables was created. We ran partial correlations between these sets of dependent and independent variables, to identify strong correlations that would be entered in further multivariate regression models. The partial correlation procedure controlled for 3 demographic variables (age, sex, education level) and branch. In general, the company level variables of branch, sector, and company size are not entered in the Stage I analyses. At this stage we are not interested in the distribution of stressors and outcome by economic sector (and most variables were only weakly correlated with company size, if at all). But in this initial set of correlations, it seemed useful to look for correlations, independent of branch membership. Table 5 presents the results of the partial correlation analysis.

Note that although the demographic variables are sometimes called control variables in the research, we are also interested in their associations with the dependent variables. Therefore, in the regression analyses, the coefficients of these variables are reported, along with those of the other independent variables. Partial correlations are only used in the Stage Ia correlation analyses. The reduced size of the data sets used in the other stages makes partial correlation analysis too costly; the reduction in cases consequent to controlling for 4 variables reduces the size of the analyzed data set to unacceptable levels.

The other use of correlation analysis is to identify possible sources of collinearity. Bivariate correlations (to make these figures comparable to Karasek's scale correlations, 1985) calculated within the set of independent variables suggested that collinearity, while present, does not exist at extremely high levels between any of the independent variables. This initial impression was borne out later by the collinearity diagnostics developed in the regression analyses. Tables 6-8 show these correlations. Recall that scales are coded with increasing values representing the less desirable state (i.e., high Demands, deficits in Autonomy, Skill Discretion and Social Support).

1. Table 6: correlations among the 4 psychosocial scales. Although these 4 variables measure different aspects of the psychosocial work environment, they are generally correlated with each other at levels ranging between .3 and .4. The highest levels of correlation were found between:
 - a. Social Support is correlated at equivalent levels to Demands, Autonomy Deficit, and Skill Discretion Deficit. The connection between Skill Discretion and Social Support is sup-

- ported in the work of Eisenberger et al. (1986, 1990), which combines measures of social support and skill use into their measure of Perceived Organizational Support.
- b. Autonomy and Skill Discretion. This is the highest correlation in the set. It is this level of correlation which led Karasek et al. (1985) to combine the two scales into the Decision Latitude scale.
 - c. Psychological Demands and Skill Discretion are not correlated, and Psychological Demands and Autonomy are only weakly correlated
2. Table 7: Correlations among the 4 Physical stressor scales (Repetitive Bend/Twist, Static Bend/Twist, Reaching/Prolonged Postures and Heavy Physical Exertion). Although the four scales measure different aspects of physical stress, these correlations are the highest of any in this set of independent variables. Therefore, their collinearity requires the greatest care in constructing regression models with simultaneous entry. The range was:
 - a. The highest correlation is between Reaching/Prolonged Posture stress and Physical Exertion. $r = .637$. This correlation is high enough to suggest that these two independent variables be entered in the same regression equation with caution. Collinearity analysis of the four equations in which these two terms entered simultaneously indicated that the resulting equations were stable.
 - b. The lowest correlation is between Repetitive Bend/Twist Stress and Physical Exertion, with an $r = .276$.
 - c. Other correlations ranged between .46 and .56. Collinearity diagnostics in regression modeling indicated that even equations in which all 4 terms were entered stepwise were within the collinearity guidelines (Condition Number ≤ 20 , VIF ≤ 3).
 3. Table 8: Correlations between psychosocial and biomechanical stressors. A primary purpose of this research is the separation of the associations of psychosocial and biomechanical stressors with strain and adverse health outcomes. The low correlations between the psychosocial and biomechanical stressors ($r = .12-.26$) facilitated this goal.

Initially, as noted in Methods, we created sub-scales from the variables in the Monitor psychosocial scales, to test hypotheses concerning different types of Autonomy and Social Support. Although their associations with the dependent variables are suggestive for future analysis, none demonstrated associations as strong as those of the original Monitor scales. For this reason, and for reasons of comparability with TNO research, these scales are used throughout the analysis.

2. Graphical Analysis

Graphical analyses of selected associations with continuous variables were performed, looking for non-linear effects that cannot be detected by correlations or regression analyses. At the individual level, no non-linear relationships were detected. Graphical analysis was useful, however, in assessing the importance of interaction effects, to be discussed below.

3. Regression Analysis

The correlation analysis allowed creation of an initial set of 9 proposed independent variables with correlation coefficients $> .1$ (absolute value), to be tested for associations with the 9 dependent variables. Two of the variables were eliminated, despite correlations above .1 “See GAK (Industrial Insurance Association) doctor with work-related health problems” showed above-

threshold correlations with Partial Disability and Extended Sick Leave. Likewise, Part-Time Employment correlated with partial Disability. We judged these correlations to be simple tautological relationships and removed them from the modeling. Since these are the highest correlations in the models with Partial Disability and Extended Sick Leave as dependent variables, their strong entry distorted the other relationships that were of interest, without adding new information.

For the initial models, the analysis considered only main effects of the independent variables, not interaction terms. Using the “forward” entry method in both linear and logistic multivariate regression, the best model incorporating only main effects was defined. Table 9 summarizes these models, giving β weights and significance levels for each independent variable in each model. The table reports all significance levels $<.001$ as .000. (With this large database, many significance levels were much smaller.) Models are labeled by their dependent variable, in the horizontal row at the top. An R^2 and Condition Number are reported for each model.

Once this procedure developed the main effect models, we created interaction terms between the psychosocial and biomechanical stressors with the strongest β weights and entered them in the equations. Since the addition of interaction terms introduces higher levels of collinearity, these terms were entered only according to the decision protocols described in Chapter 2. Entry of an interaction term always resulted in removal of one or more main effects in the model, while improving the R^2 marginally or not at all. We removed interaction terms from the models. The main effects models in Table 9 represent the final models at this stage. Interaction effects are only examined graphically. In each case, the regression lines in the graphs were first defined by a linear regression procedure. If substitution of a quadratic function increased the R^2 of the lines substantially or demonstrated a departure from a straight line that might be useful in understanding the nature of the association, the quadratic lines were printed out. A cubic regression line almost never added much explanatory value above the quadratic line. The graphical results are discussed and compared with the relevant regression models, below.

All exposure and outcome variables used at this level of analysis are coded with low values representing the more desirable state. Thus, increasing value in any variable means a worsening of exposure or outcome. The only exceptions to this coding scheme are the variables assessing employee perception of who “takes action in matters of health and safety” (recoded as an indicator variable: 0 = no, 1 = yes). The 9 final models fall into 4 categories, named for the dependent variable:

- | | |
|----------------------------|---|
| 1. Mental Strain | 2 models, dependent variable: Exhaustion and Tiredness |
| 2. Physical Strain | 3 models, dependent variables: Sum Physical Strain, Sitting Strain, VEOG MSD Indicators |
| 3. Pain | 2 models, dependent variables: Upper Body Pain, All Body Pain |
| 4. Adverse Health Outcomes | 2 models, dependent variables: Extended Sick Leave, Partial Disability |

We assume that categories 1-3 represent strain measures on the path towards the long-term adverse health outcomes in 4. The end of this section also presents 2 models using the 7 mental strain, physical strain and pain variables, above, as independent variables, in models with Adverse Health Outcomes as dependent variables.

Mental Strain. The MBI Exhaustion Scale

There are several characteristics of this model that are different from the models explaining the other 8 dependent measures.

4. The strongest independent variables in this model are psychosocial, not biomechanical stressors (similar to the “Tiredness” model, below). (The physical strain models, below, demonstrate a reversed partition of variance.) Psychological Demands and low Social Support show similar levels of association, while deficits in Autonomy and Skill Discretion show only weak associations. In other words, the two components of Karasek’s Decision Latitude or Control scale (Karasek et al., 1985) are poorly associated with the outcome of exhaustion, in contrast to Demands and Social Support.
4. The explanatory power of the model is greater (higher R^2) than all but one of the strain and pain models.
4. This is the only model of the mental and physical strain models in which the assessment of a company characteristic, “management takes action”, shows a significant (though weak) association. The implications of perceived organizational support for occupational health are discussed further in Chapter 4.
4. Graphs of the two strongest psychosocial predictors (Demands and Social Support) vs. Exhaustion, stratified by levels of the strongest biomechanical predictor (Static Bend/Twist) show that interaction effects are minimal to nonexistent. See Figures 3 and 4.
4. Levels of exhaustion appear to be unrelated to gender or education level, and only mildly increased by increasing decile of age.

Mental Strain: Tiredness (VOEG measures of fatigue)

Except for minor differences in associations, this model looks similar to that with Exhaustion as the outcome variable. The two strongest associations belong to Demands and Social Support deficit, but the strength of the Demands association is about half that in the Exhaustion model. Correspondingly, the R^2 of the model is substantially lower. Graphical analysis of possible interaction between biomechanical and psychosocial stressors showed no appreciable interaction.

The Tiredness measure does seem to differ from the Exhaustion measure in several ways.

- a. Tiredness is mildly related to gender (increased for females), while Exhaustion is slightly related to increasing age.
- b. Tiredness has a mild negative association with increases in Physical Exertion, while Exhaustion is slightly reduced in the presence of Repetitive Bending/Twisting exposures.
- c. Tiredness shows no relationship with employee estimates of “management acting in matters of health and safety.”

Sum Physical Strain

The Physical Strain dependent variable is a summary variable. This model reverses the relative importance of physical and psychosocial stressor found in the Mental Strain models. All 4 of the physical stressors had sufficiently high correlation coefficients to be retained in the final model, while collinearity measures remained within limits. The summary measure of Physical Strain is much more strongly related to the Reaching/Prolonged Posture stressor than to the other biomechanical stressors. All 4 of the psychosocial stressors are also retained in the final model, but none has a coefficient reaching above .08. Skill Discretion deficit explains somewhat more of the physical strain variance than the other 3 psychosocial stressors. The entry of all stressors into the model (except for “management acts”) results in the highest R^2 in these analyses, .592.

Although interaction terms could not be retained in the model, the graphical evidence shows strong interaction between psychosocial and biomechanical stressors. The R^2 s of these regression lines are also quite high, showing that the scatter of points around these 4 lines is much less than in the corresponding graphs for the Exhaustion model. Figures 5 and 6 show a clear increase in slope of the Sum Physical Strain-Reaching/Prolonged Posture association by increasing deficit in either Skill Discretion or Social Support. In these two graphs (and particularly in Figure 6, stratification of the relationship by Social Support deficit), increasing psychosocial deficit results in an R^2 increase from the lowest to the highest quartile. At higher levels of deficit, the scatter around the line is reduced.

Finally, while the control variable of gender has no separate association with physical strain, this model demonstrates a slight protective effect for education level. The age effect is similar to that in the Exhaustion model: increasing age is associated with a small increase in Physical Strain.

Prolonged Sitting Strain

The coefficient for Static Bending And Twisting stress was the highest of the biomechanical stressors. In fact, the two biomechanical stressors that involve more whole body motion, Reaching/Prolonged Postures and Physical Exertion, both have negative coefficients in this model. The dual role of “sitting” as a stressor and also a protective factor against some types of stressors is discussed in Chapter 4.

Low Social Support demonstrates the highest of the psychosocial associations with Prolonged Sitting Strain, about double that seen in the Sum Physical Strain model. In the mental strain models, Static Bend/Twist demonstrated the highest associations of the biomechanical stressors, and Social Support deficit demonstrated high or highest associations also. This pattern continues through later models; there seems to be a connection between these two stressors. Graphical analysis, however, shows no evidence of interaction between the two in this model.

With the biomechanical and psychosocial stressors in the model, the association of gender alone is relatively small. This suggests that the elevated incidence of WRMSD in women found in many studies is a function of the type of job into which women are preferentially selected, not to any defining characteristic of gender, itself.

VOEG MSD Indicators

As with Prolonged Sitting Strain, the primary psychosocial stressor in this model is Social Support deficit, with a β weight of .119. The 3 other psychosocial stressors show very mild associations in the same range of .041-.051. The association of Social Support Deficit is in a similar range to that of the two strongest biomechanical predictors: Static Bend/Twist (.146) and Reaching/Prolonged Postures (.118). The three questions making up this scale are a different measure of physical strain from that analyzed above. Rather than questions assessing “trouble with” a motion or a posture, the VOEG items refer to body symptoms: aches, pains, numbness or tingling. This outcome measure is thus closer to the pain scales assessed in the next two models and shows similar associations with stressors.

The model also demonstrates roughly similar associations of both Static Bend/Twist and Reaching/Prolonged Postures with the outcome measure. In other physical outcome models, either one or the other of these two very different stressors has a much higher β . The similarity in this model is probably due to the wide range of body symptoms assessed. Graphical analysis of possible interactions between Static Bend/Twist and psychosocial stressors reveals minimal or absent interaction.

The VOEG MSD indicators are the only outcome measure associated with all 3 control variables. Increasing age shows a moderate positive association, and female gender is mildly associated with increased symptoms. Education level exhibits a moderate protective effect.

Pain in Upper Body

As in the VOEG MSD Indicators model, the use of pain reports (Upper Body and All Body, below) as dependent variables brings the physical and the psychosocial stressors closer together in their associations. The pain models achieve a lower level of explanatory power, however, with R^2 s of .14 and .18. The lower R^2 s are primarily due to the decreased slopes of the biomechanical stressors in these models, while the coefficients of the psychosocial stressors are actually at levels equal to and sometimes higher than those seen in the physical strain models. See the Discussion for an exploration of the meaning of these coefficient levels and their possible relationship to the physiological and social meaning of pain.

The separate associations of both gender and age are substantially increased in these models, relative to the first 4 models. The β weight of female gender is of equal magnitude to that of the primary biomechanical stressor—Static Bend/Twist. And the association of age is in the same range. The increased associations of age with pain reports is understandable in terms of biomechanical models of tissue aging and accumulated trauma. But the strong association of female gender with pain reports is not as easily explained; see the Discussion for further treatment of this finding.

Because of the somewhat non-normal distribution of this dependent variable, the same modeling procedure was carried out, using a logarithmic₁₀ transformation of Upper Body Pain. The resulting model was similar, but fewer of the explanatory variables were retained. Consequently, the R^2 dropped from .139, in the above model, to .10. The model was also somewhat less stable

when terms were entered and removed; we decided that the non-logarithmic model was more useful.

This pain model shows a small association with the organizational perception term: “management acts in matters of health and safety”, thus bringing it closer to the Mental Strain (Exhaustion) model. Finally, graphical analysis demonstrated minimal or no interaction between the biomechanical and psychosocial terms.

Pain in All Body Parts

As in the Upper Body Pain modeling above, the somewhat non-normal distribution of this dependent variable suggested that the modeling process using a logarithmic₁₀ transform of All Body Pain be compared to models using the non-transformed variable as the dependent measure. As above, the resulting models were similar, but fewer of the explanatory variables were retained in the logarithmic version. The final logarithmic model R^2 was .13, lower than that of the non-logarithmic model. As with the Upper Body Pain models, the logarithmic model demonstrated less stability on entry and removal of terms; we opted to present the non-transformed model.

This model is similar to the model explaining only Upper Body Pain. The increasing prominence of the psychosocial stressors (especially Social Support deficit) with respect to the biomechanical stressors is clear. The demographic variables of sex and age have similar effects, but the addition of lower back and lower extremity pain to the outcome measure lowers the association of gender substantially. Again, the picture is of a dependent variable that seems to be explained by a more equal combination of psychosocial and biomechanical independent stressors than that seen in the biomechanical strain models. As in the Upper Body Pain model, the strongest psychosocial predictor was deficit in Social Support ($\beta = .115$). As with most of the models discussed so far, the primary explanatory pattern here is a combination of Social Support deficit with Static Bend/Twist.

These two pain report models, in addition to the Mental Strain model, are the only models in which the variable Management Acts (in matters of work and health) has a significant protective entry. This variable measures employees' perception of who is responsible for addressing occupational safety and health problems--a probable component of organizational support. It may also represent a truly safer work environment, due to management commitment and involvement.

While graphical analysis of interaction in the Upper Body Pain model did not produce any new information, the relationship between All Body Pain and Static Bend/Twist, stratified by quartiles of Social Support deficit, is suggestive (Figure 7). The chart seems to show a combination of interactive and additive relationships. However, the low R^2 s of the regression lines indicate a substantial amount of scatter; these relationships remain suggestive only.

The last two dependent variables, presented below, are dichotomous measures. Logistic regressions were used, controlling for the same 3 demographic variables as above. Correlation analysis was not as useful in predicting which independent variables could be entered into the logistic equations as it was in linear regression. Because of the size of the data set, logistic regression

can create a significant Odds Ratio for associations that have a correlation coefficient below .10. In general, then, the associations noted below, with a few exceptions, are relatively weak.

Extended Sick Leave (Longer than 3 Months)

When the analysis enters the realm of the two adverse health outcomes, the explanatory power of the psychosocial stressors becomes even more important. In this model, two physical stressors are retained—Repetitive Bend/Twist (1.84) and Reaching/Prolonged Postures (1.62) with moderate positive Odds Ratios in the same range as that of Social Support Deficit (1.80); the pain models still assigned the largest β weight to a single biomechanical stressor—Static Bend/Twist. This rough equivalence of association (See Discussion for the problems inherent in comparing these different scales) suggests that, even more than the pain report variables, the outcome of Extended Sick Leave is as much a psychological and a social event as a direct outcome of physically harmful work.. The mild positive OR for age is biomechanically understandable, but the protective effect of increased education, outside of the stressor effects, also suggests a social component to Extended Sick Leave.

Partial Disability

The disability status of employee respondents was assessed by the question, “Are you presently partly disabled for work?” The Odds Ratios for this last measure of adverse health outcomes demonstrate that disability status has no associations with any of the work place biomechanical exposures measured in the Monitor survey. Unfortunately, the work environment characteristics existing prior to the disability were not assessed; it is likely that this pattern of non-associations in the model represents a modified, alternate duty situation for many of the respondents (see Discussion). A relatively strong positive association with Autonomy deficit, the strongest OR in these models, is interesting but, because of this temporal ambiguity, difficult to interpret.

Of the demographic variables, only two are associated with Partial Disability; age and education have the expected positive and protective associations, respectively.

The finding that Partial Disability is completely unrelated to biomechanical exposures in the work place suggests that many respondents have returned to light- or alternate-duty jobs and are reporting on present level of physical stressors, not on the level of stressors that resulted in the disability. To explore the possibility that Partial Disability is associated with work in light-duty jobs, we ran cross-tabs comparing Partial Disability with the 3 categories that comprise the Extended Sick Leave variable (returned after 3 months sick leave a) to the old job, b) to an adjusted job, or c) to a new job). Table 10 shows the results. Of the 200 individuals reporting partial disability status, 110 returned from 3 months or more of sick leave. And of these, 71 (65%) returned to adjusted or new jobs. If a similar percentage of job change is assumed for the 90 respondents who are disabled but did not experience long-term sick leave, roughly 65% of all disabled individuals were working in adjusted or new jobs at the time of the Monitor survey, compared to a 29% figure for the non-disabled returnees from 3 month sick leave. Thus, the reports of the partially disabled population reflect a much higher proportion of light-duty work than that seen in the non-disabled population of individuals returning after long-term sick leave. Most of this group returned to the old, unadjusted job. This seems a logical explanation for the appear-

ance of 2 biomechanical stressors in the model for Extended Sick Leave, compared to the absence of these stressors from the Partial Disability model. This issue will be addressed in more detail in Chapter

Regression of Adverse Health Outcome Measures on Strain (Table 11)

To explore the relationship between strain and adverse health outcomes, the dependent variables (strain and pain) measures above were entered as independent variables in logistic regression equations, with the dependent measures being the two health outcome measures (Extended Sick Leave and Partial Disability).. This table demonstrates that these two adverse health outcomes are somewhat different quantities. First, associations with the control variables are different. As in the above models, Age has a much stronger association with Partial Disability than with Long Term Sick Leave, while education level has a similar protective effect in both. Gender, while non-significant in the Disability model, has a protective relationship to Extended Sick Leave; women are significantly less likely to experience a long period of absence from work.. Perhaps most intriguing, Extended Sick Leave has its strongest association with 2 physical strain measures: Sum Physical Strain (OR = 2.10) and the VOEI MSD Indicators (OR = 2.49) and a moderate association with Tiredness (OR = 1.74). In contrast, Partial Disability has its strongest association with the mental strain measure (OR = 3.28) and no significant association with Sum Physical Strain. Although both adverse health outcomes show similar associations with the VOEI MSD Indicators, Partial Disability appears to me more strongly related to mental strain (and hence to psychosocial stressors) while Extended Sick Leave is more strongly related to physical strain.

Although the two adverse health outcome measures show a lower correlation than one might expect ($r = .22$), the other patterns of association with strain and pain are similar. VOEI MSD Indicators and Upper Body Pain show similar relationships in both models; likewise Exhaustion, Prolonged Sitting Strain and Lower Back Pain associations are not significant in either model. Neither model retains Exhaustion, but both outcomes are significantly related to Tiredness; this despite the finding earlier that Exhaustion reports are more fully explained by the stressor variables one might expect to be associated with adverse health outcomes. As in the models using stressors as independent variables, Extended Sick Leave and Partial Disability are related to a combination of physical and mental strain measures. These strain levels, like the stressor levels in the previous models of these outcomes, are probably related to a modified duty job, or to an alteration of the work place as a result of the injury. They are also a description of the physical and mental states associated with injury. The direction of causation is complicated and ambiguous in these models.

These models introduce a new variable. The correlation ($r = .88$) between measures of Upper Body Pain and Total Body Pain used in as outcomes in previous models introduces unacceptable levels of collinearity if they enter together as independent variables in a logistic regression equation. Total Body Pain includes the Upper Body Pain measure with the addition of 4 lower body pain reports: lower back, hip, knee, and ankle/foot. Correlation analysis shows most of the extra explanatory power of Total Body Pain to be the result of including the lower back measure. Therefore, in this analysis, Lower Back Pain substitutes for the Total Body Pain measure (which,

by itself, has a slightly higher association with these outcomes). However, in the regression models, Lower Back Pain did not make a significant entry.

4. Stratification by Gender and Position in Company

The regression models and graphs examined so far have explored the associations for the entire employee database. Other researchers have found that these associations can be different for males and females (Johnson et al., 1993, 1993a). They may also vary depending on whether the employee is line, supervisory or lower management. In particular, the overall regressions may obscure associations of opposite sign in these subgroups. Tables 12 and 13 present above models, stratified by gender and job level, respectively. To simplify the tables, the 2 measures constructed from the VOEG question set are not included in these tables. Because of space limitations, the tables omit significance levels. All associations shown achieve a significance $< .05$. Near significant associations ($p = 1.00-0.05$) are reported in italics and enclosed by parentheses.

The gender-stratified models show that most of the full models above do not obscure large differences in male and female associations. The exceptions, several of which are intriguing, are as follows. Some of these differences may relate to sample size (males = 5391; females = 2266).

- a. The associations of Skill Discretion deficit with Exhaustion are positive for males and negative for females, resulting in the very low β (.021) in the combined model.
- b. The associations of Age with Prolonged Sitting Strain are positive for males, negative for females, resulting in a non-significant entry in the combined model.
- c. Females generally show somewhat higher associations than males, when they are significant. In particular, the associations of Social Support deficit in the different models are noticeably higher than those of males
- d. By contrast, only males, in general, show significant associations for "Management Acts" in these models. (This may be an artifact of sample size.)

The stratification by job level divides the combined model into 3 very asymmetrical groups:

- | | |
|-----------------------------|----------|
| • Line workers | n = 5880 |
| • Supervisory | n = 1006 |
| • Professional & Managerial | n = 629 |

Because of this asymmetry, the results reported in the full, combined model are reflective primarily of line worker experience. Future research will explore more fully the differences among these 3 groups. A cursory examination of Table 13 reveals that:

- a. While Repetitive Bend/Twist has a negative association with Exhaustion for line workers, the relationship is positive for the professional/managerial group.
- b. The relationship between Static Bending and Twisting with Sum Physical Strain is much higher for supervisor personnel than for either of the other 2 groups, while this relationship is reversed for Reaching/Prolonged Postures.
- c. Associations of several biomechanical and psychosocial stressors with Lower Back Pain are markedly higher in the professional/managerial group than in the other 2. Profes-

sional Low Back Pain is much more strongly related to psychosocial stressors (Autonomy and Social Support deficits) than in the other groups.

- d. The primary predictor of Low Back Pain for the professional/managerial group is Repetitive Bending & Twisting, while Static Bending & Twisting is the strongest predictor for supervisory personnel.

5. The Demand-Control Model Applied to Musculoskeletal and Strain Outcomes

To this point, the research focused on the interaction effects observable between psychosocial and biomechanical risk factors. We then turned to examining musculoskeletal and stress outcomes by levels of Demands and Control. This work is parallel to the research of Karasek et al. (1981, 1988, 1990) and Johnson et al. (1988, 1989, 1993), whose work studied cardiovascular disease and mortality as outcomes. This section extends analysis of the Demand-Control model to the dependent variables in the models above. Figures 8-11 are block diagrams similar to those used by Karasek to demonstrate increasing disease prevalence in high strain jobs (defined by a combination of high demands and low control).

In these diagrams, Psychological Demands are the same measure used in the demand-control model. Autonomy is entered in the diagrams instead of the combined Autonomy/Skill Discretion measure (Decision Latitude) used in the Karasek research. The diagrams were created by stratifying the population of 7717 males and females into 3 levels of the Autonomy. Then, within each Autonomy stratum, the study population was separated by 4 quartiles of Demands, resulting in 12 cells. We also divided each outcome variable into quartiles. The block in each cell shows the percentage of employees in that cell reporting the highest (least desirable) outcome quartile. We chose 4 representative outcome variables for these figures: measures of mental strain, physical strain, pain and adverse health outcome.

These diagrams have not been controlled for demographic variables or, most importantly, for levels of physical stressors associated with these levels of psychosocial stressor. In partial correlations, controlled for sex, age, and education level, the correlation coefficients between Autonomy, Demands, and the 4 physical stressors (Repetitive Bend/Twist, Static Bend/Twist, Reaching/Prolonged Posture and Heavy Physical Exertion) range from .16 to .26. Thus the striking differences seen between the low strain sections of the diagrams (front left; high Autonomy, low Demands) and the high strain sections (back right; low Autonomy, high Demands) might be reduced somewhat if physical stressors were controlled.

The only figure that clearly does not demonstrate a multiplicative effect of the demand-control interaction is the one measuring Extended Sick Leave. This may be partly due to small numbers (only 912 employees experienced Extended Sick Leave), but it is also due to the lack of association between Extended Sick Leave and either Demands or Autonomy. The regression model (Table 9) shows no significant coefficient for either independent variable; the only significant psychosocial stressor retained in that model is Social Support Deficit. The other 3 diagrams, however, show possible multiplicative associations (typical of the cardiovascular morbidity and mortality models noted above) of Autonomy and Demands with the outcome variables. In particular, the model for Sum Physical Strain demonstrates most clearly a cumulative effect between the low strain and high strain cells that is greater than additive.

B. Stage Ib: Individual Level Associations (Employer Data Base).

The purpose of this short section is to test the same hypotheses about individual-level stressor-strain-outcome associations that were tested in Stage Ia. In this case the independent and dependent variables are the employer estimates of stressor, strain and outcome levels on the shop floor. Table 14 presents the measures examined in this section, and the partial correlations among the dependent and independent measures. The partial correlations controlled for company size and branch.

1. Correlation Analysis

The independent variables in this table are employer estimates of the percentage of the work force that is exposed to each of 6 physical and 5 psychosocial risk factor. These are continuous variables with a range from 0 to 1.0 and are thus comparable to the employee estimates of exposure to these same risk factors, aggregated within the employee sample from each plant.

The dependent variables that are comparable to employee aggregate reports of outcomes are those relating to adverse health outcomes: percentage who became disabled in 1992 and percentage of the workforce on sick leave longer than 3 months. The two variables used as strain measures are dichotomous variables: employers' reports of whether they had received complaints in the last 12 months about the neck, back and limbs (Physical Strain) and about work stress (Mental Strain). These measures are treated here as roughly parallel to employee estimates of Sum Physical Strain and Mental Strain (Exhaustion). Percent Sick Leave/1992 was also entered in this analysis as an adverse health outcome, although it is a measure of any length sick leave and not directly comparable to the employer or employee measure of Extended Sick Leave (> 3 months). The employer measure of Extended Sick Leave exhibited significant correlations with only 2 of the independent measures.

The most obvious characteristic of this table is the large number of non-significant correlations between the 11 estimates of physical and psychosocial stressors (the independent variables) and the 5 dependent variables of strain and adverse health outcomes. Those that are significant show correlation coefficients of a generally much lower magnitude than the corresponding partial correlations between employee estimates. (The Spearman correlations, in the columns under "physical complaints" and "stress complaints" give the impression of many more significant correlations, but in practice only those with a magnitude over .2 entered the models.) There are no significant correlations of any of the 3 adverse health outcomes with any of the 5 psychosocial stressors.

2. Graphical Analysis

Graphical analysis can add nothing to the correlations involving the two dichotomous strain measures; these measures have only two possible states, whose associations are fully captured in correlation analysis. But the relationships between continuous dependent and independent measures were examined visually, looking for non-linear relationships that would be obscured by correlation and regression analysis. None of these relationships showed any obvious non-linear characteristics in this analysis. In general, the non-significance of most correlations was corroborated in the graphs.

3. Regression Analysis

The analysis created 3 linear regression models, using the 3 continuous measures of adverse health outcomes as dependent variables and entering, forward stepwise, the independent variables that demonstrated significant partial correlation coefficients for their association with the dependent variable. The models also include terms for Company Size, Economic Branch (the 3-category separation used in TNO analysis) and “Allowed”. This last term is a dichotomous variable, designating those 528 companies that allowed their employee samples to complete the questionnaire, as opposed to “Refused”—the companies that did not allow their employees to participate. In these regression models, collinearity was never a problem. The Condition Number did not exceed 4 in any of the 3 models, and the VIFs never rose above 1.6. Table 15 presents the final models.

Two of the linear regression equations, as expected from the correlation analysis, did not provide any strong explanatory models for the adverse health outcomes. But the first model, predicting Percentage of Sick Leave, does achieve an R^2 of 0.127. The two physical exposures significantly associated with Percentage Sick Leave in the employer database are estimates of Heavy Physical Exertion and Repetitive Motion. Heavy Physical Exertion is the only physical stressor associated with the other two outcome variables; the association with Extended Sick Leave is twice as strong as that with shorter-term sick leave.

The 3 branches in these models are represented by 2 indicator variables, with the coefficient calculated relative to the reference branch: banking/financial. Membership in the industrial branch is most strongly related to Percentage Sick Leave. In the other two models, industrial branch is positively associated, but less strongly, with Percentage Disability, while wholesale branch employers report lower Percentage of Extended Sick Leave than employers in either the industrial or banking/financial branches. In all three models, neither company size nor “Refuser/Allowers” status of the employer had a significant entry. At least with regard to the set of measures examined here, there is no significant reporting difference between employers who allowed their workers to be interviewed and those who did not.

The two strain variables used for dependent variables are dichotomous measures and thus were modeled using logistic regression. Table 16 presents the results of this procedure. These models, while composed of significant terms, are not strongly explanatory. They are able to correctly classify only 65-70% of the cases. Several multiplicative terms were entered into these two models, to assess the degree of interaction between psychosocial and physical stressor reports. Percent Physical Exertion x % Social Support deficit was entered into the Physical Strain model. Two terms were entered into the Mental Strain model: % Psychological Demands x % Bend/Twist and % Social Support deficit x % Bend/Twist. None of these terms approached significance in the models. Although branch has no association with the Physical Strain model, employers in the industrial branch report a lower rate of stress complaints (Mental Strain). From the employers’ reports, banking/financial branch work is more mentally stressful than work in the industrial branch. The physical strain model demonstrates an equal contribution to upper body complaints from a single physical and a single psychosocial risk factor: Heavy Physical

Exertion and Social Support deficits, respectively. By contrast, the only explanatory risk factor in the mental strain model is Psychological Demands.

Pointing to the analysis of the next section, the Odds Ratio for the “Allower” variable is 1.83 in the physical strain model. Status as an employer who allows his/her employees to participate in the Monitor survey is associated with a 1.83 increase in the chances of a “yes” report of upper body physical complaints.

The low levels of association between employer estimates of employee stressor and outcome levels are characteristic of these Stage Ib models. Houtman et al. (1998) report that in this data set, aggregate employee information is not well correlated to information from their employers. Our analyses showed the same results (see Table 4, showing moderate correlations on the physical risk measures and very low or non-significant correlations on most psychosocial risk measures). There is an ironic twist to this lack of correspondence: employers report another outcome measure, Percentage Turnover in 1992; this does not appear above, because it had no significant associations with any of the employer estimates of risk (“percentage of workforce” exposed to the risk). But a model in which Percentage Turnover in 1992 is regressed on aggregate employee estimates of risk, no fewer than 5 stressor estimates are significantly correlated with this outcome. Table 17 demonstrates that, although the Model R^2 is not high, aggregate employee risk estimates are significantly associated with this employer-reported outcome that the employer risk estimates do not predict.

C. Stage II: Associations Between Organizational Characteristics and Individual-Level Stressors.

In this phase, the analysis moves to the etiology of risk factors at the individual level. Company-level independent variables are selected from the interview data of the 528 Allower companies. The general hypothesis of this section is that organization-level variables--company structure, health policy and measures of organizational culture--can be used to explain variance in individual-level stressor variables (risk factors). Note that in this section the independent variables that have shown the most explanatory power at the individual level are used as dependent variables in the Stage II models. Also note that in this stage, these newly dependent variables are analyzed at the organization level; the risk factor measures used in Stage Ia are aggregated by company. Company-level measures of structure, health policy and culture are thus being compared to the mean individual-level stressor assessments of the company's employee sample.

Elimination of “Refuser” Companies and Analysis of Differences

Because 33% (254) of the original employer sample did not allow their employees to be given the questionnaire, these companies could not be used in the Stage II and III analyses. It is important to assess the possibility of bias presented by this large non-participation rate. The 254 “Refusers” and 528 “Allowers” were compared on a representative sample of variables in the employer database, using independent-samples t-tests to detect significant differences (Table 18). Comparison variables were chosen that would assess the several types of company characteristics analyzed in Stages II and III. These are:

1. Company structure

2. Company health policy
3. Estimates of work force risk exposure
4. Reports of physical or stress complaints from employees and estimates of health-related outcomes

The Refusers and Allowers were not significantly different on most measures. There are, however, several suggestive differences between the groups. These are noted, by area:

1. Company Structure. There are no significant differences in production or personnel characteristics except in number of temporary workers. Refuser companies are not significantly larger than Allowers companies. Although the overall percentage of temporary workers in this work force is low, the Refusers hire 59% more temporary workers than allowers.

2. Company Health Policy. Again, most differences between Refusers and Allowers are non-significant. The slight difference in “basic sick payments” means that the Allowers made somewhat greater use of the Industrial Insurance Association (GAK) in paying these replacement wages; fewer of these companies are self-insured. There is a significant difference between Allowers and Refusers in terms of prevention. Although Allowers did initiate more stress prevention measures, both structural and person-based, than Refusers, this difference was not significant. But interventions designed to reduce physical strain are significantly more common among Allowers. They introduced 19% more structural prevention measures and 25% more person-based measures.

3. Estimates of Worker Risk. There is a substantial difference between reporting of physical and psychosocial risk factors in this data set. In their estimates of physical risk exposure, Allowers and Refusers were equivalent. But the differences in the psychosocial reporting were the largest of this comparison. In 3 of the 5 psychosocial risk estimates, Allowers’ reports are significantly higher than those of Refusers: Autonomy, Lack of Flexible Employment and low Skill Discretion. These differences are quite large, ranging from a 60% difference for skill discretion to an 89% difference for autonomy/decision authority.

4. Strain and Outcomes. 5 of the 6 measures examined in this section did not differ significantly between Allowers and Refusers. However, employee physical complaints about the upper body were reported to be 33% higher in the Allowers group.

In sum, the Allowers and Refusers are comparable on most measures. But there are important areas showing highly significant differences. These areas are generally related to stressor and outcome questions, amount of interventions undertaken to reduce physical strain, and to the percentage of temporary workers employed.

Elimination of Companies with Employee Samples >15 and Analysis of Differences

For all analyses in this stage and in Stage III, the employer sample is also reduced from the 528 with employee responses to the 285 companies whose employee samples contain 15 or more cases. This makes the analyses comparable to those carried out by TNO, which has determined this number of employees to be necessary for reliable analysis. Table 19 presents the same comparisons made earlier between Allowers and Refuser companies, this time applied to the differences between the over- and under-15 companies.

There are clear differences between the two employer groups. In particular, there are substantial differences in number of full time employees, percentage of temporary employees and in company health policy. The low percentage of full time employees in the companies with smaller employee samples suggests that these companies employ a much larger percentage of their work force on a part-time capacity. This table shows that the increase in statistical reliability achieved by limiting the analyses to companies with these larger employee samples is purchased at a cost of somewhat reduced generalizability. The implications of reducing the study sample will be discussed in Chapter 4.

1. Correlation Analysis

Stage Ia identified 9 independent variables to be used as dependent variables in the Stage II analyses. The first 8 measures were chosen because they have the highest associations with individual-level explanatory power. The last, "Management Acts", was selected for intellectual reasons: even though the individual-level explanatory power was not high, the analysis was expected to improve information about the ways in which company culture affects individual-level stressors. These new dependent variables are the company-level aggregates of the individual measures.

1. The 4 psychosocial risk scales: Psychological Demands, Autonomy, Skill Discretion, and Social Support.
2. The 4 biomechanical risk scales: Repetitive Bend/Twist, Static Bend/Twist, Reaching/Prolonged Posture and Heavy Physical Exertion.
3. Employee reports of "Management takes action in matters of work and health". This was the only employee assessment of company policy that had any significant explanatory power in Stage Ia.

Independent variables were selected from employer reports of company structure (9 variables) and company health policy (19 variables). The methods section presents the data reduction and selection of these variables that have significant correlations with the outcome variables on Stage II (the Stage Ia stressor variables). Extensive correlations analysis was carried out, stratified by sector, to make sure that the overall correlation analysis was not missing non-linear relationships. These analyses gave confidence that the relatively low number of significantly correlated organizational characteristics was not an artifact of lumping the sectors together. We thus performed the following analyses on the entire set of 285 companies. The final set of organizational predictors consists of the following measures (see Methods for details):

- a. Company size
- b. Percentage of Temporary Workers
- c. Self-Insured
- d. Policy Plan
- e. Percentage of Employees in Teams
- f. Management Involvement
- g. Worker Involvement
- h. Discrepancy Scale: the difference between employer and employee risk assessment
- i. Mean Scale: the corresponding mean of employer and employee risk assessment

2. Graphical Analysis

To further address the possibility that some correlation coefficients obscure more complex, non-linear relationships, classes of these relationships were subjected to graphical analysis, when measures are not dichotomous. The independent variables that present the most complicated set of relationships with the dependent variables are those that ask the employer about the level of involvement of different company groups “in problems of health and work.” For example, Figures 12 and 13 show levels of Social Support Deficit (aggregate employee estimate), plotted against levels of management involvement and employee involvement (employer reports). These U-shaped curves with opposing directions are generally characteristic of the relationships of the other psychosocial stressor levels to management and employee involvement. Graphs depicting the relationship between a physical stressor level (Reaching/Prolonged Posture stress) and management and employee involvement show a similar level of complexity (Figures 14 and 15). The range of variation in stressor level is relatively small, so it is difficult to interpret the importance of these graphs. But these non-linear relationships may contribute to the low associations of these “involvement” variables with stressor outcomes. This graphical analysis suggests that further analysis is necessary to fully understand the relationship between employee-reported stressor levels and employer perceptions of involvement by various groups within the company.

3. Creation and Characterization of the Discrepancy Indices

The creation of the Discrepancy Indices and the rationale for using mean employer/employee estimates as a correction factor are described in Chapter 2. Figures 16-19, showing the distribution of the Discrepancy Scale scores for employers and aggregate employee samples, demonstrate the underpinnings of the Discrepancy Indices. These figures highlight the striking difference between the employers’ estimate of employee percentage exposed and the employees’ own reports of risk exposure. Figures 20 and 21 show the resulting distribution of Physical (Biomechanical) and Psychosocial Discrepancies created from these sets of estimates—calculated by subtracting the employer risk estimate from the employee risk estimate. This combined variable exhibits a fairly normal distribution (see Table 2 for descriptives). In both the psychosocial and physical spheres, employee reports generate a relatively normal distribution of risk estimates. But the distribution of employer reports is highly skewed to the right. The contrast between these two distributions is a description of a collective working environment marked by a high degree of misperception, miscommunication, and/or mistrust.

Table 4 presents correlation coefficients for the relationship between the Discrepancy Indices (that are combined in the 2 Discrepancy Scales) and a) the employer risk estimates, b) the employee risk estimates, and c) the mean value of these two estimates. It also presents the correlations between employer and employee estimates, for each discrepancy variable.

There are several interesting characteristics of these correlations:

- a. The employee risk estimates are positively correlated with the Discrepancy Indices, while the employer risk estimates are negatively correlated—a mathematical necessity.
- b. Discrepancies are generally more strongly correlated to the employer estimate than the employee estimate. This difference is marked in the psychosocial discrepancies; physical discrepancies show a varying, but more equal association.
- c. Perhaps most striking is the negative correlation between many of the discrepancy variables and the mean values. Graphing this relationship (Figures 22 and 23) for the Scales reveals a non-linear relationship. These graphs show that, as the employer/employee

mean risk estimate rises, the average discrepancy value, which rises in the positive range at lower mean risk estimates, becomes smaller and eventually changes sign.

Negative Discrepancies represent the minority of companies in which employer risk estimates are greater than those of the employee sample. A visual inspection of these graphs shows that, although the negative physical Discrepancies are distributed somewhat evenly as the Mean Scale increases, the negative psychosocial Discrepancies cluster towards high values of the Mean Scale. In both graphs, the number of positive Discrepancies is reduced at high Mean Scale values, relative to the number of negative Discrepancies. –

These graphs display all 285 x-y points. The obvious clustering of points along the diagonal line to the upper left represents the many companies in which the employer estimate of risk is 0 or close to 0. (For companies with an employer estimate of 0, the Discrepancy is simply $\frac{1}{2}$ the employee risk report.)

These characteristics are evident in all 11 individual Discrepancy Indices, as well as the Scales, although the proportion of negative Discrepancies varies somewhat. For several discrepancy variables, roughly 20% of the discrepancies are negative. Vibration and Sitting Discrepancy Indices have the lowest percentage of negative values (approximately 7%), while 32% of Physical Exertion discrepancy values are negative. These percentages for the physical and psychosocial Discrepancy Scales hover around 7%. These figures show graphically why it is important to correct the Discrepancy Scale entry in the regression modeling by entering the Mean Scale.

We decided to focus on the two Discrepancy Scales in the analyses for several reasons:

- a. Data reduction. The full set of Discrepancy Indices is cumbersome.
- b. Tautology reduction. One half of each Discrepancy Index is an employee stressor measure; thus using a Discrepancy Index to predict stressor level runs the risk of a tautological explanation. In addition to the crossover strategy described in Methods, aggregation of the individual Discrepancy Indices into a Scale removes the measure one step from direct comparability.
- c. Reliability. The Scale formation averages the unevenness of the individual Discrepancy Indices. In particular, a negative Discrepancy Index may simply be an outlier, related to an anomaly in a particular plant. If the same plant generates a negative Discrepancy Scale value, our confidence is increased that this represents a consistent characteristic of the company culture.

Because the interpretation of negative discrepancies was difficult, we initially converted the continuous Discrepancy Indices and Scales into 4 categories: negative, low, medium and high. Dummy variables created for each level (reference category: low) allowed us to discern non-linear relationships to outcomes for each category. In all cases, these the “dose-response” relationships that emerged from analyses showed that the 4 categories form a continuous measure, with negative discrepancies simply representing the lowest “exposure”. Therefore, we were able to simplify the regression analyses below by entering a single, continuous Discrepancy Scale measure instead of the 3 dummy variables.

4. Regression Analysis

Using the final set of organizational independent variables, 9 regression models were constructed to summarize the relationship between these variables and the 9 dependent variables (Stage Ia Stressors) in this section. The analysis entered the independent variables in 3 blocks:

- a. Block 1: Organizational variables a-g, above—all variables except the Discrepancy Scale and the Mean Scale.
- b. Block 2: Discrepancy Scale. Following the crossover technique described in Methods, the biomechanical Discrepancy Scale entered the models with a psychosocial stressor dependent variable, and psychosocial Discrepancy Scale entered models with a biomechanical stressor dependent variable.
- c. Block 3: Mean Scale. The corresponding mean scales entered the models.

Tables 20 through 28 present the results of this modeling. In general, entry of the block 1 variables did not result in highly explanatory models; the R^2 s ranged between 0 (Social Support; no organizational entries) and .127 (Autonomy). In all cases except one (Psychological Demands), the Block 2 and 3 entry of the Discrepancy Scales and the Mean Measures substantially increased the explanatory power of the models. These variables are the strongest predictors in the models. Collinearity in all models was well within limits.

As predicted, the β of the Discrepancy Scale is increased by the entry of the Mean; showing that the explanatory power of the Discrepancy does vary by levels of the mean risk. This effect is minimal for the biomechanical measures, but it is pronounced for the psychosocial Discrepancies and Means. The entry of the Mean roughly triples the β of the Discrepancy Scale.

As one might expect, these effects also operate in reverse. The two central columns of Figures 20-28 present alternative entry strategies: entry of the Discrepancy Scale followed by the Mean, and entry of the Mean followed by the Discrepancy Scale. The last column is the final model in each case. In the models explaining psychosocial stressor levels, the initial β of the biomechanical Mean is slightly increased by the entry of the Discrepancy Scale. But in the biomechanical stressor models, the initial β of the psychosocial Mean is strongly increased by the entry of the Discrepancy Scale. Below, we briefly summarize the results of each model.

Dependent Variable: Psychological Demands (Table 20)

Within the Stage II analyses, the model based on the dependent variable of Demands is unique in two respects. First, it is the only model in which company size achieves a significant entry; employees in larger companies are more likely to report increased levels of Demands. Second, it is the only model in which the Discrepancy Scale and Mean, the variables with the highest β s in most models, do not have a significant entry.

A structured and well-integrated Policy Plan for assessing risk and controlling negative outcomes is associated with significantly reduced levels of Demands in the company. But an increased Percentage of Temporary Workers in the company is associated with increases in Demands, an

intriguing finding. Most of the variance in the Demands measure is not captured by the variables in this model; the R^2 is only .058.

Dependent Variable: Autonomy Deficit (Table 21)

The only company-level variable that achieves significance in this model is Percentage of Temporary Workers; increases in this measure are strongly associated with Autonomy Deficit. In many of the following models, organizational characteristics that achieve significance in Block 1 entry drop from the model with the entry of the Discrepancy Scales and/or Means. In this case, the β of % Temporary Workers, while reduced, retains most of its strength and significance.

As in all models, the initial entry of the Mean results in a substantially greater increase in model R^2 than the initial entry of the Discrepancy Scale. This is to be expected. The moderate correlation of the biomechanical and psychosocial Discrepancy Scales (.28) allows the crossover strategy to eliminate most tautological relationships (explaining variance in a stressor by a measure composed of differences in related stressors). But the correlation between biomechanical and psychosocial Means is .415. The entry of the Means is necessary to standardize the Discrepancy associations, but care must be taken in interpreting the absolute value of the R^2 increase due to Mean entry. Even though biomechanical Means are entered in models explaining variance in psychosocial stressor outcomes (and vice versa), the R^2 increase is elevated by this level of correlation. But it is clear that the entry of both terms into the final model increases the R^2 well beyond the level due to either term entered alone. This is the model with the highest R^2 of the psychosocial stressor models.

Dependent Variable: Skill Discretion Deficit (Table 22)

Three organizational Block 1 variables make a significant entry in this model. Increase in % Temporary Workers is associated with decreases in Skill Discretion. Companies in which employers report increased levels of Worker Involvement in health and safety demonstrate decreased levels of Skill Discretion. This finding may represent a case of reverse causation or may be due to the non-linear nature of these relationships, explored above. Finally, self-insured companies demonstrate higher levels of Skill Discretion. Only the Temporary Worker association remains significant after the entry of the biomechanical Discrepancy Scale and Mean Scale.

Dependent Variable: Social Support Deficit (Table 23)

None of the company level structural and health policy variables were associated with Social Support Deficit. Although Social Support has strong associations with strain, pain and health-related outcomes in the employee data set, its level is not well related to any of the company characteristics studied here, other than the Discrepancy Scale and Mean Scale. This model and the Demands model are the two least explanatory in the Stage II analyses.

Dependent Variable: Repetitive Bend/Twist (Table 24)

The familiar positive association with Percentage of Temporary Workers and negative association with Self-Insured status is present in this model. The presence of a structured and integrated Policy Plan, while protective in the Demands model, has a positive association in this and the Reaching/Prolonged Posture models. In association with biomechanical stressor levels, the Policy Plan variable may be another example of ambiguous or even reversed causation; improve-

ments in the company plan may be introduced in response to increases in stressor levels and negative outcomes.

While the initial entry of the Discrepancy Scale does not affect these relationships substantially, the initial entry of the Mean Scale reduces the Policy Plan association to marginal significance. The entry of both the Discrepancy and Mean Scales re-enters the Policy Plan variable, but the other two Block 1 variables drop from the model. As with all models explaining levels of biomechanical stressors, the presence of both the psychosocial Discrepancy Scale and the psychosocial Mean Scale substantially elevates the strength of association of each one.

Dependent Variable: Static Bend/Twist (Table 25)

Percentage of Temporary Workers and Self-Insured status have their familiar positive and negative associations, respectively, with this stressor. Both drop from the model when the combination of Discrepancy Scale and Mean Scale enters.

This is the only model in which employer reports of increased Management Involvement are associated with increased levels of stressor. Again, the positive association may represent increased involvement in response to increased levels of stressor and negative health outcomes. The single entry of either the Discrepancy Scale or the Mean Scale does not markedly alter this relationship, and even their combined entry leaves a model in which this independent variable is retained.

Dependent Variable: Reaching & Prolonged Postures (Table 26)

Percentage Temporary Workers, Self-Insured status, and Policy Plan demonstrate associations similar to those seen above. Entry of the Discrepancy Scale alone does not alter these associations greatly. By contrast, entry of the Mean Scale reduces Temporary Workers and Policy Plan to non-significance. But subsequent entry of the Discrepancy Scale re-enters Policy Plan significantly. Self-Insured status retains its significance in all models.

Dependent Variable: Physical Exertion (Table 27)

This model shows patterns similar to the one above. Percentage of Temporary Workers and Self-Insured status enter into the initial model. And again, although the entry of the Discrepancy Scale and Mean Scale removes Percentage of Temporary Workers from the model, Self-Insured status retains its significance.

Dependent Variable: Management Takes Action (Table 28)

As in the Social Support deficit model, no Block 1 organizational measures show significant associations with levels of Management Takes Action (the employee-reported measure). This model is unique in that it allows entry of both biomechanical and psychosocial Discrepancy Scales and Mean Scales; the measure of "Management Takes Action" is distant from measure of both psychosocial stressors and biomechanical stressors, so tautology concerns are absent here. We entered both Discrepancy Scales together and both Mean Scales together. The final model depends on order of entry. If the Discrepancy Scales are entered first, the final model retains the biomechanical Discrepancy Scale and the psychosocial Mean Scale. If Mean Scales are entered first, the final model includes only the psychosocial Discrepancy and Mean Scales. Since it is

difficult to interpret the relationship of the biomechanical Discrepancy Scale to the psychosocial Mean Scale, the second model is preferred.

Summary of Organizational Effects.

The organizational variables from Block 1 that are the most consistently predictive in these models are Percentage of Temporary Workers, Self-Insured status and the presence of a structured and integrated Policy Plan. The first and last of these are more closely related to the characteristics measured by the Discrepancy and Mean Scales, since their entry usually removes these terms from the model. By contrast, Self-Insured status is more likely to remain in the final models, even if its initial β is lower than those of the other terms. The other terms from the organizational variable set of Block 1 only make a single entry in one of the 9 Stage II models. The Discrepancy Scales and Means consistently make the strongest entry in these models.

5. Individual-Level Parallel Models

These analyses used company-level measures, imputed to each employee in the individual-level data set, in models predicting stressor levels. The patterns of association were similar to those seen in the aggregated, company-level models. As expected, the β weights in these models were much reduced from the company-level models in Stage II. This reduction is probably due to the much greater variance in the individual-level stressor measurements, compared to the aggregated stressor measurements used at the company level. Outliers have a much larger effect at the individual level. These models added no new information to the analyses above; they are omitted from further discussion.

6. Graphical Exploration of the Relationship between Discrepancy, Mean and Selected Dependent Variables.

The regression equations, above, demonstrate the complex relations among the discrepancy variables, mean values and their associations with aggregated levels of stressors. The non-linear graphs (Figures 22 and 23) suggest the need for another form of visual representation. Working from the individual-level data set, the procedure used in this section was the same as that employed to test the prevalence of strain, Upper Body Pain and Extended Sick Leave against the Demand-Control model (Karasek, 1979), at the end of Stage Ia. Details of the procedure appear in Methods.

These diagrams use the initial 4 categories for the Discrepancy Scale, negative, low, medium and high, plotted against increasing quartiles of the Mean Scale. Figures 24 and 25 show levels of a representative psychosocial stressor, modeled against Physical Discrepancy and Mean levels. Figure 25 shows the reverse—a physical stressor modeled against psychosocial Discrepancy and Mean levels. The 4 x 4 tables printed below report the percentages reporting the highest quartiles of the stressor, plus the population in each cell. These latter numbers are important because of the strongly non-linear distribution of populations among cells.

Autonomy Deficit

30.2 (199)	30.9 (395)	30.1 (229)	40.8 (488)	Physical 4
10.0 (70)	16.3 (380)	19.5 (267)	28.4 (666)	3
13.0 (46)	14.4 (291)	19.2 (553)	20.0 (472)	2
	10.0 (649)	13.6 (676)		1
neg. low med. high				
Physical Discrepancy Scale				

Static Bend Twist

Psych. 4	26.7 (468)	33.6 (512)	38.6 (88)	46.5 (256)
3	26.7 (15)	17.1 (257)	30.9 (184)	32.0 (826)
2		18.6 (323)	25.7 (456)	31.6 (567)
1	18.8 (16)	17.1 (668)	21.2 (670)	
neg. low med. high				
Psychosocial Discrepancy Scale				

The graphs and diagrams mirror the results of the regression equations. Increasing levels of Mean Scales and Discrepancy Scales both have a positive association with levels of stressors. The cells with missing values make it difficult to determine whether the relationship of these two quantities is additive or somewhat multiplicative, as well. A qualitative assessment suggests that the effects are only additive.

D. Stage III: Associations between Organizational Characteristics and Individual-Level Strain, Pain and Health-Related Outcomes.

In this stage, the analysis moves from the etiology of risk factors at the individual level to the analysis of the associations between company-level characteristics and the dependent variables of Stage Ia: mental and physical strain, pain reports and the health-related outcomes of Extended Sick Leave and Partial Disability. The general hypothesis of this section is that organization-level variables--company structure, health policy and measures of organizational culture--can explain variance in individual-level strain and health-related outcomes (the dependent variables in Stage Ia), beyond the associations mediated through individual-level stressors. One dependent variable was selected from each class of outcome.

As in Stage II, Stage III model-building first analyzes the associations at the organization level; the dependent variables used in Stage Ia are aggregated by company and used in linear regression equations. This stage created 9 models, with dependent variables being the same as those in Stage Ia. The last 2 dependent variables, however, are not normally distributed. The aggregated measures of Extended Sick Leave and particularly Partial Disability have highly non-normal distributions; Extended Sick Leave is somewhat leptokurtotic (+ 13.02) and Partial Disability is highly leptokurtotic (+ 76.97). Both of these variables are also positively skewed. We used $\log_{10}$ transforms of these variables in the modeling. This reduced the kurtosis to 0.03 and 1.23, and the skew to 0.12 and 0.20, respectively. As in Stage II, all analyses using the aggregate values of employee measures for dependent variables were performed on the reduced data set of the 285 companies whose employee samples contain 15 or more cases.

1. Correlation Analysis

We did not perform separate preliminary correlation analyses in this stage. Rather, the analysis used the sets of predictor variables identified as significant by earlier correlations and regressions.

2. Graphical Analysis

The graphs of relationships between company variables and individual outcomes were roughly similar to the graphs in Stage II. Most did not identify any hidden non-linear associations. The major exception, as in Stage II, related to the employer estimates health and safety involvement by various groups in the company. Analysis generated U-shaped curves, similar to those in Figures 12-15, with different directions characteristic of employer and employee involvement. Sample associations were entered in the SPSS curve estimation procedure, calculating significance and R^2 for linear, quadratic, and cubic models. Of the 12 associations plotted, two achieved statistical significance or near-significance. The variance explained was minimal.

<u>Association</u>	<u>Model</u>	<u>R^2</u>	<u>Significance</u>
Mental strain on employee involvement	quadratic	0.025	0.030
	cubic	0.027	(0.056)
Log ₁₀ >3 months sick on employee inv.	quadratic	0.045	0.003
	cubic	0.048	0.007

3. Regression Analysis

We built the models for the 9 dependent variables by a 3-step progressive entry protocol, using the forward stepwise procedure.

- Block 1: the set of organizational variables entered in Stage II.
- Block 2: both Discrepancy Scales.
- Block 3: the set of 9 aggregated stressors.

The risk of creating a tautological model is much reduced in Stage III. The strain and health-related outcomes used as dependent variables in these models are well removed from (although correlated with) the stressor estimates used to create the Discrepancy Indices and Scales. Thus, both the physical and psychosocial Discrepancy Scales enter in Block 2. However, the Mean Scales are simply a summary measure of stressor levels. Their entry with the stressor measures creates unacceptable levels of collinearity, as well as generating a model that is difficult to interpret. The Mean Scales cannot be entered in these models. Since the Mean Scales are necessary to more fully specify the associations of the Discrepancy Scales, the β weights of the Discrepancy Scales are probably underestimated in these models.

Company Level Analyses

Table 29 reports only the final model for the 9 outcome variables. Variables that demonstrated a significant entry in Block 1 or Block 2 are shown in italics, followed by "n.s." Any other non-significant variables are left blank. Any organizational variable or Discrepancy Scale retained in the final model has a dramatically reduced β weight from that shown at initial entry, before the stressor set enters the model.

At this aggregated level, the associations between company level independent variables and aggregate levels of strain, pain and negative health outcomes in each plant are very attenuated, even before the stressors enter in Block 3. In the strain and pain models, Self-insured status and Policy Plan enter in only one model, in Block 1, to be reduced to insignificance by the entry of the aggregate stressor measures. The Discrepancy Scales make consistent entries in Block 1, but they almost always drop out of the final models. The physical Discrepancy Scale is retained, however, in the models explaining Tiredness, Physical Strain, and Prolonged Sitting Strain. Percentage of Temporary Workers shows a “protective” entry in the Partial Disability model; this suggests that disabled temporary workers do not retain their jobs or, alternately, do not wish to report disability in their questionnaires. Policy Plan retains intriguing entries of opposite signs in the two health outcome models. The existence of a structured and integrated policy plan has negative associations with Partial Disability but positive associations with Extended Sick Leave. In general, the aggregate measures of stressors maintain patterns of association that are similar to the patterns in the Stage Ia models. As would be expected, despite the lack of contributions from the company variables, the R^2 s in the Stage III models are uniformly higher than those of the analogous Stage Ia models. This is a result of the aggregation process that reduces the effect of individual-level outliers.

Individual Level Analysis

Table 30 shows the corresponding models carried out at the individual level. Virtually none of the company variables remain significant after entry of the individual-level stressors, leaving models that are roughly identical to those in Stage Ia. The slight differences in β weights and R^2 values are because these Stage III individual-level models did not include the demographic variables of Stage Ia, resulting in somewhat lower β weights and R^2 s in most cases.

In summary, both the company-level and the individual-level models demonstrate that there are virtually no direct associations of company-level variables with individual strain, pain and adverse health outcomes (neither main effects or effects mediated through other unmeasured variables). The effects of company-level variables on these individual-level outcomes are almost entirely exerted through their associations with the stressors.

4. Graphical Analysis of Discrepancy Scales and Means at the Individual Level

To explore the possibility that the regression analyses above obscure non-linear relationships that might be significant, we created block graphs analogous to those created at the end of Stage III. This analysis uses the same 16-cell base diagram of Discrepancy Level vs. Mean Scale quartile. Each cell is assigned a block representing the percentage of the employee population reporting the highest quartile of Upper Body Pain. This graph shows what appear to be additive and perhaps multiplicative effects, suggesting that our inability to enter the Mean Scale values in the regression equations substantially underestimated the Discrepancy effects at this level.

CHAPTER IV; DISCUSSION

The Discussion contains six sections:

- A. Stage Ia Discussion: Individual-Level Stressor Associations with Strain and Health-Related Outcomes
- B. Stage Ib Discussion: Employer Estimates of Individual-Level Associations
- C. Stage II Discussion: Associations of Organization-Level Independent Variables with Individual-Level Stressors
- D. Stage III Discussion: Associations of Organization-Level Independent Variables with Individual-Level Strain, Pain and Adverse Health Outcomes
- E. Possible Limitations of the Study
- F. Issues Related to Measurement Construction

A. Stage Ia: Individual-Level Associations

The Stage Ia analyses constitute the basis for the rest of the analytical steps. It is crucial to characterize and quantify the relative contributions of psychosocial, biomechanical, and demographic variables to models built around the dependent measures in this data set. These associations then serve as the basis for Stages II and III, which examine the contribution of organization-level measures to explaining levels of both the independent and dependent variables examined in Stage Ia. In the discussion below, the results for all 9 models are first examined as a whole, to pull out the overarching patterns defined in this stage. Following are brief discussion sections for individual models or sets of models, if specific issues need discussion. Models are listed by their dependent variable.

1. Overview of Patterns in Stage Ia.

Table 9 presents the 9 full models. For purposes of generalization the models can be separated into 3 categories related to the nature of the dependent variable:

- Indicators of psychological strain: Exhaustion and Tiredness.
- Indicators of physical strain: Summary Physical Strain, Sitting Strain and VOEI MSD Indicators.
- Pain reports: Upper Body Pain and Total Body Pain
- Adverse Health Outcomes: Extended Sick Leave and Partial Disability.

Psychosocial Stressor Patterns in Stage Ia

1. Demands and Social Support deficit are the primary contributors to explanation of the mental strain outcomes. Autonomy and Skill Discretion deficits have only minor contributions
2. Demands, outside of the moderately strong associations in the mental strain models, shows low and relatively consistent levels of association throughout the physical strain and pain report models.
3. Autonomy deficit maintain roughly the same levels of association in all models, except the adverse health outcome set In the linear regressions, the regression coefficients range between .041 and .084.
4. Deficits in Skill Discretion show low levels of association in the mental strain and physical strain models, but this variable has no significant contribution in the pain and adverse health

effects model classes. The strongest β for Skill Discretion deficit is in the Sum Physical Strain model.

5. Deficits in Social Support show the most variable pattern of association. In the mental strain model, it has the second strongest association, comparable in effect to Demands. But throughout the physical strain and pain models, this measure has the strongest coefficients of the psychosocial group. Likewise, Social Support deficit is the only psychosocial entry in the Extended Sick Leave model.

Social Support Deficit has a moderate effect in only one of the physical strain models. It is interesting that Social Support Deficit has its lowest association with Sum Physical Strain and a stronger effect in the Sitting Strain model. These findings may say something about the type of social system associated with primarily seated and non-seated work. In our experience, much of the seated work in the industrial branch, in particular, has a strong social component. Even if the work is not formally group or teamwork, employees are often seated in close proximity to each other, performing similar tasks. The supportive social interactions surrounding seated jobs may be particularly important in moderating the negative effects of the other stressors. Losses of this support may thus be particularly stressful, leading to the elevated association of Social Support deficit with seated static strain seen in this study.

This hypothesized protective relationship of Social Support to seated work may operate for different reasons in different sectors. The banking/financial branch (which includes the for-profit service sector) is characterized by a high percentage of computer work at VDT (Video Display Terminal) stations. An extensive literature exists documenting the reduction in social contact attending the computerization of these jobs in the last two decades (e.g., Garson, 1988). This increased isolation is exacerbated, and combined with perceptions of reduced supervisor support, by the widespread use of electronic performance monitoring in these jobs (Amick and Smith, 1992; Aiello and Kolb, 1995).

Social Support deficit also has a connection to Static Bend/Twist. In all but one model (Extended Sick Leave), if the strongest biomechanical predictor is Static Bend/Twist, the strongest psychosocial predictor is Social Support Deficit. The model in which Social Support Deficit has its weakest entry is also the one model in which Reaching/Prolonged Postures is the strongest independent variable. This connection between these two stressors also appears to operate in the two pain models. Or there may be a separate moderating effect of Social Support on pain perception or pain reporting.

6. These findings concerning the 4 psychosocial dimensions are relevant to the uses of the Job Content Questionnaire in this population. Although Karasek's work often combines Autonomy and Skill Discretion measures into the decision latitude scale (Karasek et al., 1982, 1985; Karasek & Theorell, 1990), this combined scale may be of less use in the Dutch population sampled here. The correlation coefficient calculated by Karasek et al. (1982) for the association between Skill Discretion and Decision Authority (the Monitor survey uses the term "Autonomy") is .491, in a population of 2845 males from the QWL data. This calculation was made at the individual level and is thus comparable to the correlation coefficients

calculated in Stage Ia, for 7717 individual employees (male and female). The corresponding coefficient for the Monitor data set is .388. More important than the overall correlation coefficient differences, the differences in association patterns over the 9 Stage Ia models suggest that the two stressor scales be analyzed separately.

7. The relative consistency of entry seen for Autonomy and Demands (outside of the mental strain models) provides validation for the utility and explanatory value of the basic Demand-Control model. This relative stability of the Autonomy and Demand terms suggests that they may play a role in strain development that is different from and more consistent than that of the other two psychosocial stressors. This stability may explain why they are the best-understood and most statistically reliable of Karasek's job descriptors (Karasek and Theorell, 1990).

Biomechanical Independent Variable Patterns in Stage Ia

The 4 scales of physical stressors also show differences in the patterns of their associations with the different dependent variables in these models. These variables demonstrate a much greater range of effect than the psychosocial stressors.

1. Most negative entries are understandable. Both Reaching/Prolonged Postures and Physical Exertion have negative associations with Prolonged Sitting Strain, since both these stressors have components of whole body work. The negative association with Tiredness is more interesting and may represent an actual protective effect of physical work on mental strain. However, the low but significant negative association of Repetitive Bending/Twisting with Exhaustion is difficult to explain and requires further research.
2. Static Bending/Twisting. Mental strain is essentially a psychosocial phenomenon, as can be seen by the low associations of most biomechanical stressors in the mental strain models. The moderate entries of Static Bend/Twist stress, static bending and twisting of the upper body, is provocative, however. This biomechanical stressor is the only one with consistent associations in models that have an element of mental strain (mental strain models, Prolonged Sitting Strain and pain models), and, as noted above, it's strong entries are always associated with the highest entries by Social Support deficit. This stressor might be seen as the most "psychosocial" of the biomechanical stressors. Karasek and Theorell (1990) also suggest that "'static physical loading'....is associated with many of the same psychophysiological responses as purely psychological demands" (p. 63).
3. Repetitive Bend/Twist shows generally low associations in all models except the Extended Sick Leave model. Its levels of association are in the same range as those of Autonomy and Skill Discretion deficit, and Demands in the non-mental strain models. But this statement is suggestive only. The β -weights of the different scales are not directly comparable, because the constituent items may have different cutoff levels, at which a "no" response shifts to a "yes". See Discussion.
4. Heavy Physical Exertion is the short-hand label for a scale which incorporates any sort of lifting, carrying, pushing, pulling, or exerting force on tools and equipment. Since force is identified as a primary biomechanical stressor, it is interesting that this sample of 7717 employees experiences it in association with the smallest number of the identified strain outcomes. This stressor has only one somewhat strong association, with the Sum Physical Strain variable. Most surprisingly, it has no association with either Upper or Total Body

Pain, and it does not enter into the Extended Sick Leave or the Partial Disability models. This may be in part an artifact of its construction. The 3 component variables of this scale had missing values of 4%, 7%, and 10%, translating into 11% missing values for the scale as a whole. But in a data set this large, the responses contained in the 6861 cases with non-missing values for this scale should have been enough to show any significant associations.

Employee Perceptions of Organizational Support

1. The variable--“Management Acts” if problems of work and health must be solved—is the only significant entry from a set of questions assessing employees’ organizational perceptions. This measure has a weak protective entry in only 3 models (the negative values reflect the different coding of the variable: no/yes = 0/1). Employee perceptions of a management active in health matters weakly reduce exhaustion and both types of pain reports. This latter finding suggests that pain reports are a combination physical and psychosocial event. Stage II and III also show weak relationships between management involvement and individual-level measures of stressors, strain, and health-related outcomes. Jones & Kelloway (1995) have demonstrated the relationship between a quantity labeled POS (Perceived Organizational Support) and stress outcomes. The negative entry of Management Acts into the Exhaustion model in this study corroborates Jones’ findings. Most intriguing for future research, Eisenberger et al. (1986, 1990, the developers of the POS scale) found that increased POS is correlated with increases in employee conscientiousness, involvement in the organization, and innovative activity on behalf of the organization. These findings represent potential organizational benefits in addition to the reduction of sick leave, turnover and disability that usually motivate occupational health interventions by companies. These possible benefits of management involvement in basic prevention activities might be useful selling points for practitioners engaged in promoting organizational prevention strategies.

The separate patterns of association attributable to the psychosocial, biomechanical and organization perception constructs used in this research are possible clues to the underlying physiology of disease etiology. Armstrong et al. (1993) present a model for the multi-factoral causation of musculoskeletal disorders that addresses the dynamic nature of the organism’s response to stressors (biomechanical and psychosocial) in the work environment. They note the differences in tissue and organism capacity to respond to these stressors. The interaction of exposure and capacity will determine the “dose” actually experienced at different levels of organization within the organism. This model suggests the various physiological (and related psychological) levels at which each stressor and combination of stressor could interact with protective aspects of the external and internal environment. It seems reasonable to compare the capacity of the liver, for instance, to detoxify a wide range of chemical exposures to the capacity of different psychological/physiological systems to “detoxify” various combinations of psychosocial and biomechanical stressors. It also seems reasonable to assume that different stressors operate through somewhat different physiological and psychological pathways to produce characteristic patterns of “dose” and “body-burden”. The neuroendocrine research of Marianne Frankenhaeuser (1980, 1986, 1989) and J.P. Henry (1986) documents the different physiological responses of the body to different types of psychosocial exposures. The physiology of disease etiology is beyond the scope of the present research, but our results, viewed in combination with the work noted above, lend support to the concept of stressor specificity in action and outcome.

As noted in the Limitations section below, concerning the validity of self-report data, other investigators have pointed out that complicated patterns of association are difficult to reproduce through rater bias, since the bias itself would have to demonstrate a similar pattern (Michela et al., 1995). The above patterns are quite complex. If rater bias were a predominant determinant of associations, one would expect a much less interesting association landscape, with fewer peaks and valleys. The strength of these patterns of association, for both psychosocial and physical stressors, could be taken as evidence for the validity of the self-report data.

Finally, in many of the Stage Ia models, the 3 individual level demographic measures do not have a strong effect. This finding demonstrates one of the strengths of the Monitor data set; the wide variety of work places weakens the associations of particular measures with demographic variables that can function as strong confounders in smaller scale studies. Age and gender do show stronger associations in the pain and Partial Disability models, as well as in the VOEG MSD Indicator model. Education level is never a strong predictor at this level.

2. Mental Strain Models: Exhaustion and Tiredness

In all the first Stage Ia models, Tiredness (from the VOEG scale) appears to be simply a less explanatory version of Exhaustion (the MBI exhaustion scale). We had hoped that the less intense measures of fatigue contained in the VOEG questions might serve as an indicator of depression. But the patterns of association did not allow that conclusion. Just like Exhaustion, Tiredness has the strongest entries from Demands and Social Support deficit (although the relative strength is reduced—Social Support deficit becomes more important than Demands in the Tiredness model) and from Static Bend/Twist. The R^2 is substantially lower for the Tiredness model than for the Exhaustion model. However, the 2 models in which 7 strain measures are used as independent variables to explain the 2 dependent Adverse Health Outcomes (see below) provides another perspective. In these models, Tiredness entered significantly, while Exhaustion was not retained in the models. Seen as explanatory rather than outcome variables, these two Mental Strain variables evidently measure somewhat different quantities.

Although interaction terms could not be entered in the regression models, since their entry reduced some main effects to non-significance, the graphical modeling suggests that mild interaction does occur between the main biomechanical stressor (Static Bend/Twist) and each of the main psychosocial stressors (Demands and Social Support deficit). See Figures 3 and 4. The moderate R^2 s of the regression lines and the increasing line slope with increasing levels of Static Bend/Twist in each graph suggest that the effect of one stressor is potentiated by the other.

The Demand-Control graph (Figure 8) is particularly informative here. Although Autonomy deficit has a low β in this model (.084), the graphs suggests that, in combination with Demands, it has a stronger effect.

3. Sitting Strain Model

Sitting work occupies an ambiguous position in this research, in that it has protective as well as detrimental relations to health outcomes. This measure did serve as the independent variable in a

moderately explanatory model. Future research on this data set will focus on separating the protective from the stressful aspects of sitting posture. More careful and particular attention must be paid to the physical stressors which actually contribute to a negative report of strain and those which are simply negatively associated with work in a sitting posture. It is likely that working in a seated position does, on average, remove the worker from jobs with high levels of Reaching/Prolonged Postures and Physical Exertion. On the other hand, workers reporting trouble with sitting also report higher levels of Static Bend/Twist and Social Support deficit.

4. Sum Physical Strain Model

This outcome variable appears to be the most purely physical of the 9 models. The independent variables with the strongest effects are 3 biomechanical stressors, resulting in the highest R^2 of these models. Interestingly, Skill Discretion deficit is the psychosocial term with the highest β , but its effect is still relatively low. More research on the association between Skill Discretion and physical outcomes is planned. This connection may simply mean that the jobs with the highest levels of biomechanical stressors, on average, are also the jobs marked by lower levels of Skill Discretion.

This model is the one in which interaction is the most evident, as shown by Figures 5 and 6. We modeled the association of Reaching/Prolonged Postures (the strongest biomechanical entry) and Physical Strain, as modified by quartiles of Skill Discretion and Social Support deficit. These graphs showed the highest regression line R^2 's and the greatest degree of visual slope divergence. Consistent with its stronger entry in the regression model, Skill Discretion deficit has the stronger interactive effect on this relationship.

5. Pain Report Models: Upper Body Pain and Total Body Pain

In both models, Static Bend/Twist, the biomechanical variables hypothesized above to be the most closely related to mental strain, shows moderate effects. The relatively low explanatory power of the other biomechanical stressors in these models (compared to the β 's in the physical strain models) is, at first glance, surprising, since pain is intuitively seen as the result of physical stress. The rough parity between psychosocial and physical stressors, especially in the Total Body Pain model, suggests several possible hypotheses.

- a. First, the increased prominence of the psychosocial stressors in these models probably indicates that pain perception and reporting is responsive to a mixture of physical exposure and psychosocial deficit in the work environment. In both models involving pain reports the coefficients of the biomechanical stressors are much reduced, compared to the models with physical strain as the outcome variable. But the coefficients of the Demands and Autonomy deficits are similar in size to their coefficients in the physical strain models. Social Support deficit achieves β 's equal to its entry in any equation outside of the Exhaustion model. Thus, the strong suggestion is that psychosocial aspects of the work environment, and in particular deficits in Social Support, affect the reporting of pain, the actual perception of pain, or both. (Since pain information is collected by self-report, these two possibilities cannot be separated.)
- b. Second, Dr. Robert Karasek, in reviewing these results, has suggested an alternate explanation for the increased associations of the psychosocial stressors (excluding Skill Dis-

cretion deficits) and decreased power of the biomechanical stressors in these pain models. He points out that the biomechanical stressors act locally, on often on particular body parts or regions. By contrast, the psychosocial stressors operate centrally, exerting their effects through physiological changes that affect the entire body and the brain. Thus, when pain reports are aggregated for the entire body, as they are in the two pain models, the local effects of the biomechanical stressors are diluted, compared to the systemic effects of the psychosocial stressors. This hypothesis is supported by the observation that there is much more variation in the effects of the biomechanical stressors. The strongest combination of regression coefficients for biomechanical stressors is seen in the model for Sum Physical Strain, the summary body Physical Strain measure, while the coefficients for Demands and Autonomy remain at the same level through all models (except Mental Strain).

However, this hypothesis would have to explain why Skill Discretion deficit, after a relatively constant showing in the other physical strain models, drops out of the pain models entirely. This may be more evidence for a particular relationship between Skill Discretion deficit and biomechanical stressors.

These two hypothesis, and those presented below, are not mutually exclusive; both may be operative within the complex set of biomechanical, psychological, societal and political influences that shape pain perception and reporting.

- c. A third hypothesis is that gender strongly affects perception and reporting of pain. This hypothesis is supported by stronger entry of the demographic variables into these models. It is reasonable to assume that pain reports would increase with age; biomechanical models of tissue aging and trauma (both acute and cumulative) could explain this increase (e.g., Putz-Anderson, 1991; Cunningham & Kelsey, 1984). But the relatively strong coefficient for pain reports associated with female gender is intriguing. This investigator (Warren, 1997) has collected many anecdotal examples connected with the entry of women into traditionally male work places. In most instances, both male and female workers agree that the incidence of pain complaints has risen, sometimes to the distress of the older male workers. In general, the men interviewees in this work admit that the work does, in fact, result in pain. But pain is often seen as the hallmark of doing a good job, something to be accepted. Women interviewees, on the other hand, appear to be much less likely to accept the "necessity" for work-related pain. This suggests that the increased pain levels reported by women might represent a difference in the social construction of pain, not in the actual pain experienced by men and women.

There is, however, the alternate hypothesis for increased female reporting: that the positive and significant coefficient relating pain and female gender in this study is a true representation of higher exposure to pain-causing work, relative to men. Hodgeson et al. (1997) have shown a similar phenomenon in the study of indoor air complaints. The suspected higher propensity of women towards registering indoor air complaints was, in their study, associated with air samples that showed higher concentrations of pollutants, relative to the samples for males--a real exposure differential. In the present study, fe-

male gender regression models show β s for Static Bend/Twist of .209 and .185, respectively, for Upper Body and Total Body Pain, while the male model shows .128 and .135 respectively. Women do perform more static, seated tasks, and the physical characteristics of these tasks, themselves, may lead to a higher level of pain outcomes. These hypotheses are also not mutually exclusive.

Finally, the surprisingly low association between pain and physical stressors suggests that worker self-report in the Monitor study is relatively accurate (i.e., relatively unaffected by reporting or recall bias). One of the arguments against reliance on self-report data is the possible tendency of an individual who feels pain to over-report the supposed causes of that pain (see the discussion of Limitations, for a more detailed consideration of this possibility). If this mechanism were strongly operative in this population, one would expect a much higher reporting incidence of physical exposure by those experiencing the pain.

6. Extended Sick Leave Model

The similarity of Odds Ratios for the two psychosocial and the two biomechanical stressors shows that Extended Sick Leave is a combined physical and psychosocial phenomenon. The strongest contributions come from Social Support deficit and Repetitive Bend/Twist stress, indicating that the nature of the work place social system, as well as physical stress, is implicated in Extended Sick Leave. This parallels the workers' compensation research findings of the investigator (Warren, 1993), which discovered that, in the particular organization studied, the progression of an injured worker towards compensable sick leave is accompanied by a severe deterioration in work place social support, from both supervisors and co-workers.

The association of age with Extended Sick Leave raises an issue. Although it is expected that older workers would more often experience Extended Sick Leave, there is the possibility that the OR is partly a problem with the survey instrument, since the time period for reporting was not well specified in the Employee questionnaire. This potential problem is explored in the Limitations section, below. The lack of time specificity may well have resulted in some portion of the respondent group answering "yes" in reference to a lifetime. This could explain the large discrepancy between employee and employer reports (employers are asked for a 12 month period). If this were the case, it would also explain part of the Odds Ratio for age in this model.

Of the 794 employees who returned from Extended Sick Leave, 29% returned to adjusted or new jobs (Table 10). Thus, this model still represents a somewhat diluted picture of the jobs in which the precipitating injury or disorder originated. The entry of 2 biomechanical stressors, in contrast to the complete lack of biomechanical stressors in the Partial Disability model, suggests that this is the case.

The association between Social Support deficit and Extended Sick Leave found in this research is not supported by the work of Theorell et al. (1991), who found that the only psychosocial stressor associated with absenteeism was lack of Decision Authority (Autonomy). The discrepancy is puzzling. Self-report measures were used in many aspects of the Theorell data, as in the present study. The outcome measure in the Theorell study was all instances of absenteeism, whereas the

outcome measure here is Extended Sick Leave. There may be substantial differences in the psychosocial contribution to short instances of absenteeism and Extended Sick Leave.

7. Partial Disability Model

As noted in the Results, Partial Disability status is a somewhat different measure than Extended Sick Leave. Partial Disability is evidently so far removed from the physical stressors in the work place that they do not enter into the model. The probable reason for this non-presence is the strong possibility that respondents are reporting on the stressor level in their present, altered work environments, not the environments in which Partial Disability developed. 65% of partially disabled employees are estimated to have returned to altered or new work (see above).

If this hypothesis is true, the modified jobs to which most of the partially disabled respondents have returned are also characterized by sizable deficits in Autonomy. Referring again to the Workers' Compensation research of the author (Warren, 1993), these losses did characterize the work places that resulted in compensable musculoskeletal sick leave, as well as the work places to which these employees returned. Care should be taken in interpreting these models, however. Only 200 workers reported Partial Disability status, so many of the less strong associations may not have achieved significance.

8. Health-Related Outcomes on Strain Variables

It is clear that entry into either of these outcome states is associated with mental strain, with the association for Partial Disability being stronger than for Extended Sick Leave. The cross sectional study does not allow us to decipher whether mental strain is a cause or an effect of these outcome measures. It is noteworthy that the mental strain variable retained in both models is Tiredness, not Exhaustion. This may describe a characteristic of the return-to-work jobs (although it is difficult to postulate that for the Extended Sick Leave model; see above), or it may describe an essential discriminator between the two mental strain models.

Interestingly, female gender, while having higher scores on self-reported pain, is protective against Extended Sick Leave. It is possible that an increased tendency to report pain may translate into earlier or more effective medical treatment and/or work station changes, resulting in reduced absenteeism. This intriguing finding deserves further research in a prospective study.

Neither Sum Physical Strain nor Sitting Strain are predictive in the Partial Disability model, although the VOEI MSD Indicators have a strong OR. The reason is probably due to question construction. The first two strain measures are assessments of whether the respondent has trouble with a particular activity. If that activity has been eliminated in the return-to-work job, much of the strain has also disappeared. The VOEI questions are about symptoms, which would persist in many cases. This supposition is strengthened by the mild entry for Upper Body Pain. By contrast, Sum Physical Strain is retained in the Extended Sick Leave model and is probably descriptive, on average, of the jobs that caused the problem (see above).

Finally, in both models Upper Body Pain is associated with outcomes, while Lower Back Pain is not. This finding is surprising, in light of the much greater costs in time and medical attention

incurred for low back injury in the United States. More research is required to understand the meaning of these associations.

9. Summary of Interaction Effects

We were unable to enter any of the biomechanical/psychosocial interaction terms in the models, but graphical exploration suggests that mild interaction can be seen in this data set. The strongest examples, presented above, are in the Exhaustion and Sum Physical Strain models. The exploration of interaction effects among the psychosocial variables, to extend the Demand-Control model to MSD and stress disorders, provides strong graphic evidence that this interaction does take place. This finding is different from the results of TNO analysis of a previous Dutch data set, which found no evidence of such multiplicative interaction (Houtman, et al., 1994a). The finding in the present study that interactions between Autonomy and Demands can predict outcomes of mental strain, physical strain and body pain, if supported by further research, is strong validation of the Demand-Control model (Karasek, 1979). These results suggest that further application of the model to musculoskeletal and stress outcomes should be able to detail the nature of the interactions in as much detail as has been done for cardiovascular morbidity and mortality.

Although this research did not address the interaction between biomechanical stressors, there is clear evidence that these stressors do not contribute to WRMSD in a purely additive manner. Barbara Silverstein's groundbreaking work (1985) demonstrated the multiplicative interaction of force and repetition stressors on the prevalence of hand/wrist disorders. Therefore, it should not be surprising to encounter similar multiplicative effects in a broader examination of WRMSD causation.

It is likely that the study of interaction among stressors in association with musculoskeletal and stress disorders will yield a much more precise understanding of disease causation and prevention possibilities. Many physiological processes operate by extremely non-linear mechanisms, sometimes following models best described by chaos theory (see, for example, Lipsitz & Goldberger, 1992, Garfinkel et al., 1992). The models included in this research are crude first attempts to characterize phenomena that seem to be characterized in some instances by the epidemiological concept of a "tipping point" (Gladwell, 1996). This concept views the development of epidemics in populations as the outcome of slight changes in one stressor, changes which are just enough to upset the delicate and dynamic balance of contributory and protective factors within a population (agent transmission rates, death rates, etc.). Likewise, physiological processes within a single organism are the result of a dynamic and constantly shifting balance among competing internal forces and reactions. The most pertinent example in ergonomics is the delicate balance between rate of micro-trauma development during work and waking activity and rate of repair during rest periods. If the organism is operating under stress, with little recovery time, the balance between tissue destruction and tissue repair may be very close but still in favor of the repair. A seemingly small change in available rest time, or a slight increase in biomechanical or psychosocial load can tilt the balance towards tissue destruction and disease--the "straw that broke the camel's back" effect. Future research into interactions between stressors should help determine where the "tipping points" are in the human physical and psychological apparatus and how to keep the organism on the healthy side of this divide.

11. Comparison of Monitor Data Set to the JCQ

The results of this Stage Ia research broadly validate the Demand-Control Model as operationalized in the Job Content Questionnaire (Karasek et al., 1985). The differences in correlation between the Skill Discretion and Autonomy (Decision Authority) scales have been noted above. It is also interesting to note the comparability of the other correlations between scales. The full set of correlations between the 4 psychosocial scales used in the Monitor survey, calculated at the individual level, are presented below. In parentheses are given the individual-level correlation coefficients calculated by Karasek et al. (1982) for the comparable scales in the QWL data from the United States, 2845 male respondents. (The negative signs under Demands are the result of a different coding strategy, not a reversal in direction.)

	Psych Demands	Autonomy	Skill Discretion
Autonomy	.199 (-.003)		
Skill Discretion	n.s (.151)	.388 (.491)	
Social Support	.298 (-.270)	.276 (.268)	.285 (.233)

The correlations of Social Support with the other 3 psychosocial stressors are quite similar between the Dutch sample population and the QWL surveys used in Karasek's work (Quality of Work Life Surveys, 1969, 1972, and 1977). The Autonomy/Skill Discretion correlation, as noted above, is weaker in the Dutch sample. The greatest discrepancies revolve around correlations of Psychological Demands with Autonomy and Skill Discretion. The strengths of these associations are almost reversed, with the Dutch sample showing no association between Demands and Skill Discretion and a moderate association between Autonomy and Demands. There is at present no basis for speculation on the reason for these differences. But they suggest that some caution be exercised in the generalization of the present findings to an American work force.

12. Strengths and Weaknesses of the Monitor Data Set

It may be that the very strengths that allow us to separate the psychosocial from the physical risk factors at the individual level prevent us from finding stronger associations in other areas. In particular, we expected to find stronger evidence of the protective effects of organization-level measures of psychosocial work environment. And the surprisingly low correlations of most independent and dependent measures with the demographic variables may also be evidence of this dilution effect, a consequence of the wide variety of work places surveyed. The results seen in Stages II and III, using individual-level data aggregated at the company level, lend credence to this hypothesis. The large jumps in associations at the company level suggest that a large amount of individual-variance exists and is removed by the aggregation process (see Robinson, 1950, Feinleib & Leaverton, 1984).

B. Stage Ib: Individual-Level Associations (Estimated By Employer)

The Stage Ib analyses are simply modeling parallel (as much as possible) to the Stage Ia analyses, using employer estimates of exposure and outcome within their companies in place of employee estimates of Stage Ia. This analysis allows a general comparison between employer and employee views of the work environment.

1. Comparison of Employer-Estimated and Employee-Estimated Associations.

The most obvious characteristic of the associations estimated by employers is the much lower number and strength of associations between hypothesized exposures and outcomes. This is not surprising, in view of the consistently low correlations between employee (aggregated at the company level) and employer estimates of risk levels (see also Houtman et al., 1998). The first two columns in Table 4 show these correlations, in all Allower companies and in those with an employee sample ≥ 15 . What is striking about this chart is the lack of comparability between employer and employee estimates of the same work environment. No correlation rises above an r of .44, and several are non-significant. These low correlations show that the employers and employees are not really assessing the same work environment, at all. On average, the work environment perceived by employers (not taking into account conscious misrepresentation) is a much safer and more friendly place.

What is also striking about these correlations is the difference between perceptions of biomechanical and psychosocial risk levels. The correlation between employer and employee estimates of psychosocial risk levels seldom tops .20, and more than half are non-significant. The models of strain and health outcomes show this non-comparability most strongly. Of the 3 linear regression models, based on % sick leave, % disabled, and % Extended Sick Leave (Table 15), only the first has any explanatory power. Outside of branch effects, there are 2 explanatory terms in this model: Physical Exertion and Repetitive Motion. Houtman et al. (1994a), in early analyses of this data set, demonstrated that recognition of “force” as a “problem” is the aspect of physical load on which employers and their Works Councils agree most closely. This is followed by relatively close agreement on “posture” and “repetition” as problems. Physical Exertion has the highest β in this model, followed by Repetitive Motion. The other 2 linear employer models, while having very low explanatory value, also assign a significant regression coefficient to Physical Exertion; in fact, this term is the only significant independent variable in either model.

The logistic regressions (Table 16) built on dependent variables of Upper Body Strain Reports and Stress Reports demonstrate a similarly reduced set of independent variables. The surprising entry in the Physical Strain model is that of Social Support deficit. From the above discussion, we would expect to see the strong OR for Physical Exertion in relationship to physical complaints (7.99). (These percentage estimates are in decimal form, so this OR means that a 100% change in Physical Exertion is associated with an eight-fold increase in complaints.) But the similar OR (6.83) for Social Support is unexpected, given the evident difficulty employers experience in identifying psychosocial risk levels. The meaning is intriguing. This may simply be a

representation of an employer tendency to downplay complaints by assigning them to workers' social problems. If so, this model would incorporate competing tendencies of the employer population to blame complaints on a real physical risk and on "discontent" in the work force. The other possibility is that employers actually see Social Support deficit as a legitimate stressor and recognize its connection with physical complaints. However, the employee population assigns Social Support deficit a β of .060, in association with the Sum Physical Strain dependent variable. It seems unlikely that employers would see this stressor as being so much more powerful in their model if it had a similar meaning.

Finally, the mental strain model (Table 16), corroborates the Houtman et al. (1994a) finding that Employees identify Demands as a problem much more readily than other psychosocial stressors. Interestingly, Social Support deficit does not appear in the Mental Strain model.

The main conclusion that can be drawn from the comparison of employer and employee strain models is that the communication between these two groups, concerning work place risk levels and their effects, is a potential target for intervention strategies. With this level of disagreement on risk levels and associations with outcomes, employer-generated prevention strategies may not really address the root causes of health and safety problems.

We have noted above that the employee estimates of stressor levels in the company are much better predictors of employer-reported outcomes of sick leave, turnover, and long-term sick leave.

C. Stage II: Associations of Organization-Level Independent Variables with Individual-Level Stressors

1. Measurement Issues in Stage II

The move to analysis at the company level entailed three substantial changes in the data base. First, the employee data was aggregated by company, to provide the independent variables for Stage II and III analysis and to generate the measurements used, in combination with employer data, to create the discrepancy measures (see Methods). Second, from the original employer sample of 782, 254 "Refuser" companies (those that did not allow their workers to fill out questionnaires, were removed from further analysis. Third, from the 528 Allower companies, the 285 with employee samples ≥ 15 were selected for further analysis. This follows the TNO strategy of using only larger employee samples, for reasons of sampling reliability.

a. Aggregation

The advantages and pitfalls of aggregation are discussed in the Limitations section of this chapter. For the following discussion, the effect of interest is the strong tendency of aggregation to reduce variance in the overall sample, thus increasing correlations between variables. Unless a grouping strategy is chosen that deliberately maximizes variation between groups and minimizes variation within groups, correlation coefficients between group means will always be larger than the disaggregated values.

The work place represents a combination of a “natural” grouping (Hannon, 1991) process (whereby individuals are selected into groups on the basis of neighborhood, culture, beliefs, or other variables that are sociologically significant) and an “artificial” grouping (based on random variables, not integral to the social or biological character of the aggregated individual, such as administrative divisions, census tracts, etc.). Selection into a work place is not a random process. Each work place assembles employees who share some characteristics, to a certain degree. Thus, while there is substantial variation within a work place, there is also substantial variation between work places. Aggregation by company does not approach a situation in which between-group variance is maximized and within-group variance is minimized. Thus, aggregation can be expected to increase the correlations between group means, by “smoothing out” the variance within each work place. The major problems, discussed further at the end of this chapter, are the increase in problems with collinearity and the possible mis-estimation of individual-level associations by the models drawn at the company level.

b. Selection of “Allower” Companies.

We used independent sample t-tests to identify possible bias in the necessary exclusion of Refuser companies from further analysis (Table 18). Concerning most of the measures analyzed, there is not much difference between the Allower and Refuser populations. Most differences are nonsignificant. But the few differences uncovered are, in fact, quite important.

The difference in hiring rate of temporary workers is intriguing. Although the overall number of temporary workers hired is not high (4.3% in the Refuser sample, 2.7% in the Allower sample), the Refusers hire temporary workers at a 60% higher level. Temporary employment is potentially a more stressful hiring status. Temporary work might be work other workers do not want to do. Or a portion of these workers might be working in jobs in which there is a high rate of turnover, either because of physical or stress injury, or because the jobs are too difficult. An increased percentage of temporary workers could represent a management decision to improve flexibility by divesting the company of full-time workers. Stage II analyses (below) indicate that Temporary Employment is the most consistent predictor of stressor levels in the company. Percentage of Temporary Employment is a significant predictor of aggregate employee levels of Autonomy and Skill Discretion. It also has strong associations with levels of biomechanical stressors, but these associations become nonsignificant with the entry of the Discrepancy Scales and Means (see below).

The import of these findings raises interesting questions regarding differences between Allowers and Refusers. Although estimates of percentage of workers exposed to various risk factors are generally the same in the two populations, there are 3 significant differences. Two of those involve estimates of the very stressors examined above--Autonomy and Skill Discretion Deficit. The third, Flexible Employment, is a measure of control over work schedule and thus can be considered related to Autonomy. Interestingly, the Refuser reports of these three risk levels are 53%, 62% and 54% of the Allower estimates. Refusers report that, in these respects, their work places are almost twice as safe as those of Allowers. These findings may indicate a serious problem of bias in the self-selection process by which an employer becomes a Refuser or an Allower. Refusers report a 60% excess in Percentage of Temporary Employment, but an almost

50% reduction in stressor levels that Stage II analysis shows are strongly related to % Temporary Employment. Unless quite different mechanisms of association are operative within the Refuser population, it seems likely that they are systematically under-reporting these stressor levels in their plants. If the associations discovered in the Allower population apply to entire company population, Refuser companies would show actual levels of these 2 stressors that are higher than the Allowers. Assuming comparability, it is unclear whether this striking is due to poor employer perception, poor communication within Refuser plants, outright misrepresentation, or some other factor.

There are several other differences between Allowers and Refusers that may be important. As also indicated in the Stage Ib analyses, Allower status is associated with a 1.83 OR in explaining employee-reported Physical Strain. Refusers report that they receive only 75% of the physical complaints that the Allowers receive. This may provide a clue to the mechanism that may be operative in the risk differences between the two groups of employers. If employers are reporting accurately, Refuser companies may have, on balance, company cultures that discourage complaining about risk levels and symptoms. It seems unlikely that this could be a full explanation, however. The fact that other risk factors are assessed at equal levels by Refusers and Allowers, and that stress complaint frequency is reported at similar levels, means that other mechanisms are operative.

It seems likely that the employers know there are deficits in their work organization and safety measures and do not want that information exposed to outside eyes—hence their refusal to allow employee participation. The Percentage of Temporary Workers data suggest that Refusers may have, on balance, a less safe work place than Allowers. The exclusion of the Refusers' work forces probably leaves a data set that is not completely representative of Dutch companies as a whole. If the reported levels of exposure and outcome were truly as reported by the Refusers, than the results of the present research, limited to the Allowers, would over-estimate some effects. If the hypothesis that Refusers are misclassifying themselves is true, however, the present research probably represents a relatively accurate estimate of stressor/strain/outcome associations for the population as a whole. It is even possible that the employees of the Refuser companies might show stronger associations, making the Stage Ia, II and III results conservative estimates for the business world at large. There is, however, no reason to suspect that this Refuser population would be characterized by an association of exposure to outcome that had a steeper slope than those developed in this research, unless there exist some unmeasured, potentiating factors which are present at higher levels in the Refuser company population. In the absence of evidence for such factors (which does not rule out the possibility), it seems reasonable to assume that the associations generated in this research are generalizable to the larger company population.

c. Selection of Companies with Employee Samples ≥ 15

This reduction in sample size makes it more difficult to achieve a significant association. In general, there seems to be more homogeneity in the larger employee samples. Although a few associations that were significant in the full set of 528 employee samples are eliminated in the smaller set, most of the associations are strengthened. This finding seems to lend support to the TNO strategy, but it also may mean that some findings are obscured by this data set reduction.

Some variance is lost, although much of that variance may have been due to chance--the main reason why the smaller employee samples are excluded.

There is also some reduction in generalizability attendant to this reduction strategy. The companies with larger and smaller employee samples are not comparable on a large number of measures (Table 19). A major difference, perhaps related primarily to the size differential, is seen in the category of Company Health Policy. In addition to having double the prevalence of yearly risk/prevention policies in place, compared to the < 15 companies, the > 15 companies surveyed have carried out a much higher percentage of prevention activities. The estimates of risk factor levels in the company are comparable in the majority of cases, but the > 15 companies report higher levels of risk in Prolonged Sitting, Psychological Demands, and Skill Discretion. This is accompanied by a reported lower level of risk due to Static Bend/Twist of the upper body. Although the companies do not differ in reports of the health-related outcomes, the two strain measures (complaints about the upper body and stress) are significantly elevated in the > 15 companies. This may relate to the higher levels of health policy and prevention in the larger companies.

Overall, these differences between >15 and <15 companies represent a compromise. On the one hand, the reduction strategy increases the reliability of the employee sample, reducing the incidence of extreme outliers that would be expected from a smaller employee sample. On the other hand, the generalizability of the analysis is somewhat reduced, due to the differences between the groups. This must be noted as a possible weakness of the study.

2. Graphical Analysis: Levels of Involvement

The general lack of association between many company-level variables and the individual-level stressors (see below) raises the question of whether some associations are non-linear and thus do not show significant correlation or regression coefficients. In general, the graphical analysis did not reveal many of these more complex associations. The 3-level categorical measure of company size often shows U-shaped curves when graphed against the aggregated employee reports of psychosocial stressors. But the range of variation is too small to be important. The one set of variables which consistently is associated with complex, non-linear curves in the group of employer questions which assesses level of involvement of different company groups "in matters of work and health." These questions are asked about a number of different groups in the company, but the questions assessing involvement of management, midmanagement, and employees show the strongest relationships. Figures 12-15 show representative findings. Although the range within which these curves fit is not large, these curves do obscure the relationship in the models

The graphs dealing with levels of physical stressor (Reaching/Prolonged Postures) are relatively straightforward. It appears that the degree of management involvement rises is somewhat direct proportion to the rise in employee estimates of physical stressor. In this case, it is quite probable that management involvement is driven by recognition of risk factor level in the companies. The alternate explanation, that increasing management involvement causes the increase in stressor, is logically possible, but it seems unlikely. As employee stressor estimates rise, employee involvement initially rises also. But at increasing levels of employee involvement, stressor mag-

nitude decreases. This could mean that increasing levels of employee involvement are effective in reducing this physical stressor. It may even be that the curve in this graph actually represents two intersecting curves and a changing direction of causality, as employer perception of employee involvement increases. The initial rise in employee involvement from “not” to “partly” may be in response to higher levels of stressor. But the subsequent drop in the curve may represent the effect of employee involvement on stressor level reduction. Similar questions apply to the Social Support graphs, which show employee and employer involvement curves of opposing direction. The difficulty in interpreting these cross-sectional relationships can only be resolved by further, longitudinal studies.

These complex graphs are suggestive of some complicated phenomena that encompass many aspects of company culture, health policy, and probably technology and structure. When these curves were analyzed with the SPSS Curvefit procedure, none of them was significant at a p-value below .05, although fits were examined of linear, quadratic and cubic regression lines.

These graphs also serve as examples of the interactive and “configurative” patterns that Michela et al. (1995) suggest are very hard to duplicate through biased reporting. Similar patterns are found in graphical analysis of the other stressors, against levels of management and employee involvement. If this hypothesis is true, these patterns increase confidence that self-report bias is not a primary determinant of the associations found in this research. A valuable test of this hypothesis would be provided by similar analysis performed on data from the next stage of the Monitor survey.

3. Regression Models: Company Structure & Health Policy

Most of the company level measures of structure, technology and health policy did not reach significant associations with the stressors in the correlation analysis and thus did not enter significantly in the regression equations (see Tables 20-28).

The effects of company structure and technology on company-level outcomes have been the subjects of a large number of studies, although most studies do not assess their effects on health outcomes. We expected to find much stronger associations than appeared in these equations. The poor correlations may simply be due to the broad level at which the modeling was done. But even when we calculated correlations within sector groups (to check for effects of opposite sign that might be obscured in the overall correlations and regressions) the same pattern of minimal association applied. Aggregation of employees by company did not separate the responses by type of job and position in the company hierarchy. But the large number of line employees, relative to supervisory and managerial/professional, suggests that results are generally representative of line employees.

The poor entry of most variables into the Stage II models may also be due in part to the low specificity of the company questions in the Monitor survey. For instance, the basic technology is reduced to just 4 possibilities, without any connected questions about how the technology is used. Lincoln and Kalleberg (1990), in their study of job commitment and satisfaction, found that older, simplistic theories linking satisfaction and commitment to the technology of the com-

pany were wrong. Instead, they promote a “dual economy” theory, which links the technology/satisfaction effect to the position of the company as a core producer or a “peripheral” satellite of the core producers. The effects of the type of technology depend on the company’s position in this system. These authors also place more emphasis on a division between unit/small batch production and large batch/mass production, a division that is not well characterized by the Monitor survey.

Likewise, Miles (1980) places emphasis on the fit between type of industry and type of structure. He points to the work of the Harvard Group that studies performance and sense of competence in relationship to formal structure (which might be indicated in the Monitor study by levels of hierarchy). They found that, in industry, performance and competence were positively correlated with a formal structure, whereas in a research laboratory setting, the reverse was true. The lack of separation between companies that provide products, products and services, or only services probably obscures a substantial portion of this variance. Many organizational theorists emphasize the dependence of organizational characteristics on the environment in which the organization is embedded. These “contingency theorists” (see Miles, 1980, Berg, 1979, Schwartz, 1992) note that the organizational variables we are examining exist in a complex relationship with each other and with the environment. This relationship is necessarily a dynamic relationship, since both the environment and the organization are capable of change. The effects of a growing global economy make these changes simultaneously more rapid and more basic (Sackmann, 1992). The environment in the late 20th century has become less forgiving of organizational inefficiencies (Flamholz et al., 1992). It is likely that in the assessment of occupational health, a simplex look at technological and structural determinants may not produce much information.

Despite these reasons for low correlations, several company variables did make robust entries into these Stage II models. First, Percentage of Temporary Workers appeared as a strong independent variable in models explaining levels of Autonomy and Skill Discretion deficit. This variable seems to cut across the sectoral, blue/white collar company position, and economic differences that may have obscured many of the other expected company variable relationships. When the Discrepancy Scales enter the models, % Temporary Workers retained its explanatory power. Interestingly, this variable also enters significantly in Block 1 of all 4 models explaining the biomechanical stressor levels, but it drops out of the model when the Discrepancy Scales enter. The association between the Percentage of Temporary Workers, the Discrepancy Scales, and stressor levels in the company may be different for physical and psychosocial stressors. For the psychosocial work environment, at least, percentage of temporary workers in the company is a consistent indicator of a less healthy work environment. The robust associations between Percentage of Temporary Workers and dependent variables of Autonomy and Skill Discretion deficit are the basis of the above discussion of bias related to Allowers and Refusers status.

The strength and persistence of this variable in the models, given the factors working against the entry of company level variables at this generalized level of analysis, show the over-arching negative influence of unstable employment arrangements on the work environment. To appear in these equations, the effects must span most of the sectors and different job levels within companies. In addition, the presence of this variable in these models is a good example of an association for which it is possible to make strong hypotheses about direction of causation, even in a cross-sectional study (see Limitations, at the end of this chapter). This variable is predictive over

a wide range of sectors and job titles. The reverse causation possibility, that levels of Temporary Employment are caused by Skill Discretion and Autonomy deficits at the individual level, strains credulity.

The second variable that enters into these models is Self-Insured Status, a 3-level categorical describing the relationship of the company with the Industrial Insurance Association (GAK): full reliance on the GAK, GAK in an advisory role, and full self-insurance. These three conditions are roughly comparable to the workers' compensation alternatives open to employers in the United States (only with a multitude of private insurance carriers taking the place of the GAK). The second alternative is similar to the TPA (Third Party Administrator) in the United States, an arrangement in which the company is self-insured but purchases administrative expertise from the insurance carrier. In this data set, Self-Insured status exhibits a negative association with stressor levels. It is significant in only one psychosocial model, Skill Discretion deficit, and drops out upon entry of the Discrepancy Scale. It enters all 4 biomechanical stressor models, retaining significance when Discrepancy Scales enter in two cases: Reaching/Prolonged Postures and Physical Exertion.

Third, the "Policy Plan" variable enters significantly in several models, but its interpretation is more difficult. A structured and integrated Policy Plan for identification and control of physical and stress risks is the strongest predictor in the model explaining levels of Demands. But when it enters the biomechanical models, its coefficient is positive. This suggests two possible explanations. One possibility is a reverse causal direction in these models, in which the presence of higher risks triggers a more extensive Policy Plan. More likely, the better Plan may allow a better identification of risks by employees, although it is unclear why the same phenomenon would not apply to Demands. Again, prospective studies are the only way to sort out the meaning of this measure.

A few entries into single models are suggestive:

1. Percentage of Employees in Teams is positively related to levels of Demands. This is an intriguing finding, worthy of more study. Teamwork is only assessed by 2 questions, and crucial information about the nature of the teams, the reward and incentive structures, etc. is lacking.
2. Worker Involvement and Management Involvement (as estimated by employers) are only significant in one model each; Worker Involvement drops from the model when the Discrepancy Scale enters. Worker Involvement is related to a psychosocial measure (skill Discretion deficit), while Management Involvement is associated with a biomechanical measure (Static Bend/Twist). Static Bend/Twist is the biomechanical measure we hypothesize to have the closest relationship with psychosocial factors; Management Involvement probably has strong meaning for the psychosocial characteristics of the work environment. Both measures have positive coefficients, which raises questions about the direction of causation in these associations. Graphical analysis shows the complexity of these associations. The measures would need to be more precisely specified to study its associations.

One of the purposes of this research is to find "marker variables" or "flags" that practitioners could use to identify organizations at risk. This analysis identifies two with the potential to ful-

fill that role: Percentage of Temporary Workers and Self-Insured status. However, the Discrepancy Scales, examined in detail in the Results section, appear to be the most predictive markers. The next section examines their meaning and associations.

4. Addition of the Discrepancy Scales and Means

The consistent difference between Refusers and Allowers, concerning reports of individual-level psychosocial risk levels, is related to the concept of Discrepancy Scales, laid out in the preceding 2 chapters. The percentage of Temporary Employment in the Refuser population suggests that these employers are systematically under-reporting levels of Autonomy and Skill Discretion deficit in their companies. If so, these companies would represent a population of companies characterized by high positive discrepancies, were we able to measure the employee estimates.

It is important to be explicit about the meaning of the Discrepancy Scales. The component variables are simply measurements of work environment stressor levels, estimates of risk level within each company made by the employer and the aggregated employee sample. But the resulting variable, created by subtracting the employer estimate from the aggregate employee estimate is no longer a measure of individual-level risk. It is a measure of organization-level culture, a company-level risk factor, created by combining employer and employee information. The actual meaning of this organizational measurement is not possible to discern, given the epidemiological level of analysis in this research. Increased discrepancies, as defined in this research, are markers of organizations in trouble. Without a more micro-level understanding of the organizational characteristics and mechanisms that result in discrepant risk estimates by employers and employees, they do not give much guidance for actual intervention techniques. It is possible that the discrepancies measure several different mechanisms within organizations. One could be simple misrepresentation by one or both of the measured groups. The discrepancies could indicate a climate of mistrust between employers and employees. Or they could be indicative of the level of communication and shared overview in the company; outside of issues related to lying and mistrust, simple misunderstanding could contribute to discrepancies. This may relate to the levels of hierarchy, which could insulate employers from knowledge of shop-floor risks (although level of hierarchy, in this research, did not have significant associations). Or it might relate to a Tayloristic division of labor, which is often associated, by design (see, for example, Boyette and Conn, 1991), with a fairly rigid (and non-productive) division of information and understanding. This research has noted elsewhere the strong political meaning attached to risk perception and risk reporting. The discrepancies probably capture some aspects of the political climate in the company. Discrepancies may also be associated with different types of incentives and disincentives to accurate reporting established by company policy. Further research will untangle the contributions to the magnitude of discrepancy measures. For the present research, they serve as a summary measure for unknown aspects of company culture, including the “artifacts” (visible structures and processes), the “espoused values” (explicit strategies, policies, values), and “basic, underlying assumptions” (unconscious beliefs and feelings). These are the basic levels of company culture defined by Schein (1992).

The Discrepancy Scales are, of course, not the only indicators of organizational culture in the analyses. The company-level variables collected under the heading of “company health policy”

certainly contain elements of this measure. But these variables are made difficult to interpret by possible reverse causation effects. By contrast, the Discrepancy Scales are less subject to this ambiguity; this may help explain their generally higher explanatory power, compared to the health policy variables. Discrepancy Scales are not, however, entirely free from ambiguity concerning causal direction. The cross-sectional study design often does not allow a decision between two competing theories concerning causal direction. For instance, the Stage II analysis found a positive association between the highest levels of discrepancy and Autonomy deficit at the individual level. Longitudinal studies are necessary to determine if the discrepancy is a result or a cause of the Autonomy deficit, or if both vary in response to some other, unmeasured confounder.

The Discrepancy Scales and Means are the strongest predictors in all models except that built on Psychological Demands. The lack of Discrepancy Scale or Mean entry in the Demands model is perhaps a validation of the crossover strategy used in this analysis. In contrast to the other 3 psychosocial stressors, Demands is not significantly correlated to 3 of the physical stressors (the one exception is Static Bend/Twist, which the Stage Ia analyses have shown to be the physical stressor most closely related to psychosocial stressors; $r = .14$, $p = .02$). Thus it is clear why the Mean Physical Scale could not enter into the model. The non-significance of the Discrepancy Scale, however, is puzzling. The fact that in all other models the crossover Discrepancies do have an effect suggests that the lack of Discrepancy association is related to characteristics that are peculiar to the Demands construct. Given the difficulty that Karasek and Theorell (1990) point out in conceptualizing and measuring Psychological Demands, this lack of association with an otherwise strongly predictive construct is incentive for a deeper look at the meaning of Psychological Demands in this population.

The original use of dummy variables generated a dose-response relationship in most models; this is visually apparent in Figures 24 and 25, which used these Discrepancy levels (negative, low, medium and high) in the base of the diagram. In epidemiology, a dose-response curve is considered evidence supporting (but not proving) the hypothesis of causality (Hennekens et al., 1897). The consistency with which it appeared Stage II models strengthens the hypothesis of causation (over an hypothesis of an unmeasured confounder).

The crossover strategy employed in this research (using psychosocial Discrepancies to predict biomechanical stressor levels, and vice versa), in addition to guarding against tautology, also mitigates towards the directional hypothesis that Discrepancy causes stressor outcome. The discrepancies used in any biomechanical or psychosocial model, being generated by employer/employee differences in the opposite realm, seems to be a measure of a more general organizational phenomenon. This likelihood is increased by our use of only the summative scales of Mean and Discrepancy Scales. It is thus less likely that the level of a specific stressor, in the opposite realm of measurement, causes strong variation in this more general measure of an organizational characteristic.

Finally, the strong interaction between the associations of the Discrepancy Scales and their related Means in these models is an important characteristic of these measures. Especially in the

biomechanical stressor models, the β of the Discrepancy Scale, entered first, was substantially elevated upon entry of the Mean in the next step. Tables 20-28 also show the alternate strategy—entry of the Mean, followed by the Discrepancy Scale. In this case, the initial β of the Mean was also substantially elevated by entry of the Discrepancy Scale. The psychosocial stressor models (with biomechanical Discrepancy Scales and Means) demonstrate the same phenomenon, but at a much lower level. Further research is necessary to explore the reasons for this strong interaction of effect and for the difference in strength of this effect between the biomechanical Discrepancy/Mean set and the psychosocial Discrepancy/Mean set.

5. Individual-Level Modeling with the Company Level Variables.

We carried out the process of importing the company-level variables into the employee data set, assigning values of these variables to each individual, and performing the analogous regression analysis to make sure that the aggregation process had not created relationships that were not evident on the individual level. We performed the analyses only on the 5570 employees of the companies with employee samples >15 . The patterns of relationship were quite similar, although at a lower level of association, due to the re-introduction of greater variance by the disaggregation process. As noted in Results, no new information was added by this analysis.

We note here a potential objection to this imputation strategy. By taking an organization-level characteristic and imputing it to each individual within the organization, the degrees of freedom in the analyses are artificially increased. We employed this strategy twice: here and in the individual-level analogous equations for Stage III. In each case, there was little information gained by the process, but the exploration of possible effects visible only at the disaggregated level was deemed to be worth it. The degrees-of-freedom expansion means care must be taken not to artificially elevate significance levels. But the company-level measures can be seen as analogous to a departmental air sample, when sampling for a chemical exposure. The department sample figure is imputed to each individual in the department. There is, of course, some loss of exposure specificity. Likewise, in the present research, it is unlikely that each individual in the company experiences the company-level variable in the same way.

The multi-level pitfalls of this analysis are explored below.

6. Graphic Exploration of Discrepancy Relationships

This analysis was carried out as a safety measure, to make sure that the highly structured mathematical associations of the Discrepancy Scales and Means are not artifacts of hidden distributional patterns. This analysis uses the 5570 employees who are part of the employee samples in the companies that have samples larger than 15. Performing this analysis on this large group of employees, each individual with his/her assigned company characteristics, allows a more detailed look at the interactions studied here. There are two primary findings of this analysis. First, the graphs show visually why it is appropriate to substitute a continuous Discrepancy Scale measure for the 3 dummy indicator variables.

Second, this 4-part scale of discrepancies and the 4-part scale of mean employer/employee risk estimates have separate distributions in the population of employees. The discovery that the Dis-

crepancy Scale and Mean Scale variables have separate distributions that interact in predicting levels of stressors and (looking ahead to Stage III) Extended Sick Leave lends confidence to the Stage II conclusions concerning the value of Discrepancy analysis. The distributions are not unrelated, as a study of the population in each cell reveals. The negative Discrepancy column confirms the earlier findings about Discrepancy distribution. Graphical analysis also showed the strong selection of companies with negative Discrepancies into the highest Mean category. We explored this relationship, to see if it is a mathematical artifact, but there does not seem to be any mathematical prohibition against finding negative discrepancies at low mean risk estimates. This seems to be a sociological and/or psychological phenomenon, worthy of further exploration. The meaning of the phenomenon is difficult to guess however. It seems that most negative discrepancies are found in companies exhibiting a high level of risk, by both employer and employee estimates. This is especially true in relationship to the psychosocial Discrepancy and Mean Scales. There are several possibilities that might contribute to this distribution. We know from the discussions above that employers have a more difficult time recognizing psychosocial risk than physical risk (compared to employee risk assessment). It is possible that risk level has to be quite high before full employer recognition is achieved. And this perceptual "tipping point" may be higher for psychosocial than for physical risk, given these identification difficulties; hence the more extreme asymmetry of the distribution in the psychosocial model. Because of employer identification difficulties, when Mean risk is low, it may be extremely rare for employees to estimate risk levels lower than employers. In the psychosocial Discrepancy/Mean figure (showing the distribution of highest level Skill Discretion deficit), there are no individuals at all in the lower left cell. (The empty lower right cell in all the diagrams is a mathematical artifact; it would be impossible to have a high Discrepancy at a low mean risk estimate.) Likewise, in the physical model of Static Bend/Twist reports, there are only 16 individuals in this cell, while 468 are concentrated in the top left cell (high Mean/negative Discrepancy).

At high levels of risk, why would an increasing number of employers tend to estimate risk at a higher level than their employee samples (or, conversely, why would more employee samples tend to underestimate, relative to their employers)? One is left with very tentative hypotheses. Perhaps at this high level of risk, a large proportion of employers feels anguished and guilty about the exposures of their employees. Perhaps at this level of risk, more employers take more serious prevention actions, leading employees to report lower out of respect for and/or sympathy with their employer. (This leads to the interesting hypothesis that these high-risk work places might have a better psychosocial atmosphere.) Perhaps these are jobs in which the employees have strong incentives to under-report stressor levels. Eventually, analysis at the level of the in-plant dynamics is necessary to discover the actual mechanism by which these relationships are created.

The Stage II analyses generated 3 potentially useful "marker variables"—Percentage of Temporary Employees, Self-Insured Status and level of Discrepancy Indices. All 3 of these may be the visible manifestation of deeper organizational characteristics that should be the focus of intervention efforts. In particular, further study of the Discrepancy Index meanings is important. As defined by this research, these measures appear to have an ability to identify organizations at risk. But they cannot yet be used to identify appropriate intervention techniques (although they could be used to assess efficacy of organizational intervention). Measures designed to alter or-

ganizational culture, while not simple to design or implement, are available. For example, much of the late 20th century focus on “employee involvement” and employee ownership strategies (e.g., Boyette & Conn, 1991, Blinder, 1990, Levine & Tyson, 1990) can result in organizational changes that over time lead to longer term alterations in company culture. In fact, much recent organization development literature focuses on the organizational culture and how to undertake the complex process of making it visible and changing it (e.g., Schein, 1990; Golembiewski, 1986)

D. Stage III: Associations of Organization-Level Independent Variables with Individual-Level Strain and Health-Related Outcomes

1. A Correlation Analysis Overview of Organizational Variables

The 9 dependent variables analyzed in this section are Strain, Pain and Adverse Health Outcome dependent variables from the Stage Ia models. Correlations of these outcomes with organization level variables were, in general, low, with most relationships not being significant. This relatively low level of correlation is expected, given the correlation results in Stage II, measuring associations between organization-level variables and aggregate individual-level stressors. The continuation of this pattern of low correlation suggests that there are not any unexpected strong main effects of these independent variables on the Stage III outcomes. Regression analysis bore out this impression. The Discrepancy Scales and associated Mean Scales show strong correlations to the outcome variables at this stage.

2. The Graphical Evidence for Non-Linear Associations

As in Stage II, graphical analysis identified non-linear relationships when examining the associations of the groups “involved with matters of work and health”. The graphs of these relationships were so similar to those created in Stage II, that they were not repeated. However, unlike Stage II analogues, two of the employee relationships do achieve significance if considered as quadratic or cubic relationships. This provides reason to pursue these analyses in more focused sub-groups of this data set. Many the models show an increase in employee-reported strain, pain, and health-related outcomes at early stages of employee involvement (employer-reported). In All Body Pain and Extended Sick Leave graphs, this level never decreases, but in the other graphs, outcome levels do drop off after a peak. Again, it seems reasonable to propose a competing effects model. The rising portion of the curve could represent increasing employee involvement as a response to increasing levels strain, pain, sick leave or disability, while the decreasing portions of the curve could represent the effect of increased employee involvement in reducing the problem. Other explanations are possible, however. These involvement ratings are employer reports, so they may represent illusory levels of employee involvement. In particular, if the medium levels of employee involvement, as reported by employers, depict situations of employee involvement, without real “influence” (Israel, et al., 1989, 1992; Baker et al., 1996), this could explain the increasing reports of outcome. This effect is most pronounced in the Mental Strain graph for employee involvement, one of the two curves that achieved statistical significance.

It is also possible that these increasing levels of employee outcomes are related to relatively recent organizational changes promoting employee involvement (with or without associated “influence”). Karasek (1990) has demonstrated the increase in mental and physical symptoms that accompanies organizational change events, even if they involve both participation (perhaps similar to the “involvement” construct here) and influence. Further study of these relationships should also pay attention to the different meanings managers and employees attach to management and employee involvement in matters of work and health. These graphs show a disturbing pattern: as in the Stage II diagrams (Figures 12-15), the relationships of employer and employee involvement to strain, pain and adverse health outcomes are often diametrically opposed. It is possible that these opposite patterns are artifacts of the competing tendencies incorporated within these graphs. But if they are representations of a non-cooperative relationship between employees and management in company health and safety, they show a recipe for failure of prevention efforts.

3. Regression Models

The relatively small proportion of company variables that have significant associations in the correlation analysis is even further reduced in the regression modeling. Almost of the entries suggested by correlation analysis were not retained in the, even before the entry of the Discrepancy Scales. The paradoxical relationship of Policy Plan to the 2 adverse health measures is noted in Results. It seems possible that the existence of a structured and integrated Policy Plan increase the incidence of Extended Sick Leave, as an example of good, secondary prevention reducing the progression of disease to Disability. Other explanations are possible.

Of the Strain and Pain models, only the Physical Strain model shows an initial entry of Self-Insured and Policy Plan, which disappear upon entry of the Discrepancy Scales. Finally, the Partial Disability model retains Percentage of Temporary Workers in the final model, with a negative coefficient. In this case, increasing percentage of Temporary Employees was associated with decreasing Disability. This is not surprising. It is a description of one reason employers move towards increasing levels of temporary and contract employees: the employer can off-load responsibility for occupational illness and its consequences. The employer of many temporary workers can easily have a low level of Partial Disability, since this consequence of an unhealthy work environment is borne by the individual and the state.

As in Stage II, the strong entry of the Discrepancy Scales shows the importance of these variables as indicators of another set of individual level variables. However, the entry of the aggregated stressors reduces these Discrepancy entries to non-significance in most cases. Even in the case of the Discrepancy Scales, the associations with outcomes in this analysis are mediated almost entirely through the individual level stressors.

4. Parallel Regression Models at the Individual Level

This final modeling step completes the picture by imputing the company-specific measures of company structure, health policy and discrepancies to the individuals who work in these companies. This allows simultaneous analysis of individual-level and company-level variables.

Note that none of the company-level variables are analogues or aggregations of the individual-level variables, thus avoiding problems of collinearity and resultant model instability.

Table 20 does not add much information to the conclusions made at the aggregate, company level. As expected, model R^2 s at the disaggregated level are lower than at the company level. There are a few more entries by the company variables, but, except for weak entries of Policy Plan and Worker Involvement in the logistic regressions built on the adverse health outcomes of Extended Sick Leave and Partial Disability, they all drop from the final model. Only physical Discrepancy Scales enter the initial models, and they uniformly drop out of the final models. The conclusion is the same: the associations of the company-level variables with individual level strain, pain and adverse health outcomes are mediated almost entirely through the individual-level stressors. The organization-level variables of structure and health policy are completely excluded from these models.

The Mean Scales were omitted from these models, because of collinearity concerns. Thus, the coefficients of the Discrepancy Scales are underestimated. The full Discrepancy/Mean effect can be examined graphically, using the block diagram approach and modeling Upper Body Pain (highest quartile reports) against the psychosocial Discrepancy and Mean Scales (Figure 26). But this graph does not account for the later entry of the individual-level stressors.

Thus, the central hypothesis of Stage III, that organization-level variables will have effects on individual-level strain and health-related outcomes independent of those mediated by individual-level stressors is not supported by this analysis. The results of Stage III indicate that practitioners and policy makers do not need to conduct a search for other, unmeasured mediators of these effects. They are almost fully explained by the individual-level stressors.

E. Possible Limitations of the Study

1. Bias

There are several possible sources of bias in the Monitor survey. This section will explore their importance and identify some reasons for confidence in the validity of the research results.

Observation Bias

This type of bias is probably not a primary contributor to problems in this data set. Trained interviewers, using a standardized questionnaire and relatively simple questions, gathered the information from employers. Some of the information asked of employers requires a knowledge of company statistics that may not have been easily at hand (e.g., percentage of absenteeism). Issues in this data set are much more connected to various types of information bias related to self-reporting design. See below.

Selection Bias

Selection bias is a much larger potential problem. The bias introduced by self-selection of companies into Allower or Refuser status is explored above and may compromise generalizability of the findings.

A second possible source of selection bias is the self-selection process involved in the employee decision about whether to fill out his/her questionnaire. The Monitor project selected a random employee sampling within each of the 528 companies that allowed questionnaires to be administered to their employees. The sampling strategy was to select 25 employees in each organization with 100 or fewer employees. In companies with a work force greater than 100, a random sample of 35 employees was selected to receive the employee questionnaire. Of the 528 companies, 395 employed 100 or fewer workers, while 133 employed over 100. These 7717 questionnaires collected compare to an estimated combined work force in the 528 companies of approximately 74,000. The employee sample thus represents approximately 10% of the total number of employees.

Despite the planning of sample size, a large number of employees did not fill out the questionnaires that were left for them. The mean number of employee questionnaires filled out per company was 15. Calculating the total number of questionnaires distributed, the smaller companies (≤ 100 employees) account for 9875 and the larger companies (> 100 employees) account for 4655, the grand total being 14,530. Thus the total of 7717 employee questionnaires represents a response rate of 53%. TNO determined that 15 was the minimum number of employee respondents necessary to provide a representative sample of employee perceptions and limited its analyses to the 285 companies whose employee sample was this size or larger. The 47% non-response rate clearly presents the researcher with issues of possible selection bias in the sample that did fill out the questionnaires. TNO found (Houtman et al., 1998) that the total sample of 7717 employees was distributed by sector in proportions that roughly corresponded to the distribution of companies across the sectors sampled. The major exception was the response rate in the Banking and Finance branch, which was somewhat higher than in the other two branches (Wholesale and Industry). The distribution of job titles across the 3 branches was representative of national reference data, with the exception that supervisors were somewhat over-represented.

Although the present research does not have the scope to examine it, this over-representation of supervisory personnel probably has an effect on the associations analyzed here. The position of an individual in the company hierarchy can profoundly influence the way stressors and outcomes are perceived. Huuhtanen (1992), in a study of bank directors and supervisors experiencing changes (in products, organization or service systems), documented position-related differences in perceptions of the change process. He found that the supervisors, consistent with their difficult position as moderators or buffers between demands of the directors and the employees, often reported a more negative assessment of change implementation than either the directors or the employees. This suggests that supervisors occupy a particularly difficult position within a company hierarchy. In the assessment of work place stressor and strain levels, it is valuable to separate the supervisors and analyze them separately, in an attempt to characterize the consequences of a supervisory position. But the overwhelming majority of the employee data set consists of line workers; it is unlikely that the supervisor contribution has a major effect of estimated associations.

There are issues of potential bias outside of those associated with position in the hierarchy. Confidence in the broad representativeness of the data set is increased by the determination of a) a parallel between the Monitor employee sample and national reference data and b) its representative distribution by sector and by profession. But this representativeness does not protect the data from possible systematic selection bias within plants and within profession or job title. The large non-response rate in the originally selected employee sample introduces the question of whether certain factors could systematically affect the returning of the questionnaire, of which individuals would be motivated to fill out the questionnaire. Employees with greater physical and psychosocial load and/or higher levels of strain and negative health outcomes might be more strongly motivated to register their dissatisfaction. On the contrary, these individuals might be the most discouraged or the least likely to cooperate in an effort carried out through the employer. Different versions of these motivators and disincentives could operate in different companies or different sectors. It is, of course, impossible to correct for any potential selection bias at this point in the analysis. Thus, the relatively low response rate simply has to be noted as a weakness in the research.

2. Self-Report Data: Possibilities for Information Bias

There are several ways in which information bias could enter into the collection of data from any of the respondent populations: employees, employers, or Works Council. This section starts with a listing of potential areas of bias in the self-report data. Then research will be presented which increases confidence in the use of self-report data in this type of study. Finally, the concept of a "Triviality Trap", as expanded by Kristensen (1995b) will be explored in greater detail. The section will conclude with a detailing of the ways in which this study, to the degree possible, is protected against some of these problems.

Possible Sources of Information Bias in Self-Report Data

1. The possibility of elevated reports of stressor or strain, depending on levels of the other. This could be termed recall bias, in some formulations. This is a difficult concept, particularly in relationship to mental strain. If a respondent reports a higher level of mental strain, as a result of elevated exposure to psychological stressors, an argument can be made that the report is an accurate appraisal of the strain level he/she is experiencing. The evidence from the present research suggests that strain is never a simple result of only physical or psychological stressors. Thus, the effect of stressor level on perceived and reported strain level is what we wish to measure. By calling it "bias" and thus defining it out of existence, the investigator is deprived of a source of useful data. The strain report is also a report of the coping mechanisms, de-toxifying mechanisms, and resultant dose experienced by the individual.
2. The possibility of elevated reports of stressor or strain, depending on status of health outcome. This compromises the use of the two health-related outcome measures at the individual level as validators of the strain reports. However, the research showed that health-related outcomes (the Extended Sick Leave and Partial Disability variables) are also a combination of psychological and physical reaction to work place exposures. Again, the researcher should be careful not to eliminate useful information disguised as "bias".
3. The possibility of "negative affectivity" (Watson & Pennebaker, 1989) or "plaintive set" (Stansfeld, et al., 1993) biasing reports. These constructs refer to extensively studied personality characteristics that are presumed to influence a respondent's tendency to over-report

physical and psychological symptoms. The concept may relate to a basic optimism or pessimism in approach to life, or to deeper problems of “neuroticism” (Stansfeld, 1993). This construct certainly affects a) individual coping strategies and mechanisms and b) realistic assessment of actual risk level, which is important in the present research. Watson and Pennebaker (1989), in their extensive review of the literature, found that, although negative affectivity strongly affects reports of physical symptoms (thus necessitating some of the precautions we have employed in this study; see below), it is not strongly correlated with “actual, long-term health status.”

“Common Instrument Fallacy” vs. the validity of self-report data

It is reasonable to question the possibility of reporting bias in studies that rely on self-report data for both independent and dependent variables, collected in the same questionnaire or interview. The possibility exists for the first type of information bias, above. The possible positive bias introduced into data collection by simultaneous collection of self-report exposure and outcome information has been variously labeled the “triviality trap” (Frese and Zapf, 1988) and the “common instrument fallacy” (Kristensen, 1995b). This biasing problem is particularly relevant to cross-sectional studies, like the Monitor survey, to which the possibility of recall bias is often added.

There are, however, several lines of evidence by which researchers can evaluate the validity of self-report data and evaluate the degree to which data collection by a common instrument may bias the information. Houtman et al. (1994c) propose that their self-report independent and dependent variables are not strongly affected by the so-called “common measure variance” (their term for the “common instrument fallacy”), because their odds ratios are of a similar magnitude to those developed in studies with more objective dependent variables. The Odds Ratios in this study generally range between 1 and 2. In comparison, for instance, Karasek et al. (1988), analyzing self-reported psychosocial independent variables from the HES and HANES studies for their association to past myocardial infarction prevalence (a more objective measure, derived from medical records), reported Standardized Odds Ratios between 1.5 and 2.0. If a “common instrument fallacy” were strongly operative in the Houtman et al. study, one would expect to see larger (spurious) associations between independent and dependent variables.

Other researchers have approached the problem by comparing self-report assessments with the presumably more objective (see below, for a discussion of the validity of this presumption) estimates of trained, “expert” observers. In general, the correlation between “expert” ratings and employee self-reports is high for measures resembling Decision Latitude, generally ranging above .70. The agreement is lower when measuring Psychological Demands. Users of Hackman and Oldham’s Job Diagnostic Survey (JDS; Hackman and Oldham, 1975) have reported good convergent validity for expert ratings (correlation between estimates of different raters) and high correlations of these ratings with employee self-report ratings (Aldag et al., 1981). Hackman and Lawler (1971) report correlation coefficients above .80 between expert and employee ratings of autonomy and variety.

Jeffrey Katz et al. (1996) addressed the combined issues of reliability, validity and responsiveness of self-report measures of symptom severity, functional status and satisfaction (with sur-

gery), using a population of CTS patients. They compared those who had received workers' compensation with those who had not (workers' compensation status is thought to produce strong incentives for biasing self-reports). The overall reliability, validity and responsiveness were found to be comparable between recipients and non-recipients. The authors note that the study design included a component that might have reduced bias: the subjects were told that they were participating in a research project that would not affect their compensation benefits. It is significant that the Monitor participants, also, had no reason to expect that their anonymous responses would materially affect them. The Katz et al. study suggests that, at least in this type of research situation, a self-report questionnaire/interview is a reliable and valid way of collecting data.

Frese and Zapf (1988) argue that neither self-report nor expert assessment can be said to be *a priori* superior, since the strengths and weaknesses may be very specific. They propose aggregation of several employee responses, as a way of weeding out outlier estimates. Michela et al. (1995) present a similar argument, suggesting that an aggregation process naturally results in a partial or total cancellation of the bias components inherent in individual reports, leaving the investigator with the "true" measure, plus the classical error component. The problem with this conception is that it pre-supposes a random distribution of error among the aggregated respondents, to actually arrive at a "true" estimate of the work environment. As we have found in this research, however, the aggregation process does, by its nature, reduce the effects of outliers. At the same time, it does not guarantee a bias-free report.

Kristensen (1995a) suggests that, as long as more than 5 workers' assessments are pooled, the reliability attained avoids the "triviality trap". However, he notes that the attendant possibility for non-differential misclassification of exposure creates the opposite problem--an underestimation of association. Frese and Zapf think that, while self-assessment of work factors and disorders seems to overestimate the association, expert, "objective" assessment tends to underestimate it.

Finally, certain findings of the present research increase confidence in the low contribution of bias to these data. The surprisingly low association between pain reports and physical stressor reports (see Stage Ia pain models) lends support to the hypothesis that worker self-report in the Monitor study is relatively unaffected by common-instrument or recall bias. If high levels of pain increased employee estimation of stressor exposure, or vice versa, one would expect a much higher reporting incidence of exposure to physical stressors by those experiencing the pain. But in fact, in the Upper Body Pain model, the explanatory power of gender comes close to that of the one physical stressor in the model. And in the Total Body Pain model, gender and social support deficit are both similar in explanatory power to the two physical stressors included. This suggests that physical exposure is not being strongly over-reported in this study.

There are aspects of the individual's experience of the work environment that cannot be obtained in any way other than self-report. The most sophisticated instrumentation cannot measure the combined, interacting effects on the individual of the set of work place and outside stressors, moderators, buffers and protective elements. The human mechanism should be seen as an extremely sophisticated integrative mechanism, able to report a summary measure of experienced

strain. This information combines estimates of external influences with internal coping mechanisms, both physiological and psychological, which affect the received “dose” of physiological and psychological stressors and the longer term “body burden” that results. Thus the effort to find ways to gather self-report information with the least amount of bias becomes very important in determining appropriate prevention strategies. Elo (1986) also points out that, as the job becomes more complex, the worker creates or redefines the job. To the degree that this redefinition process is operative, the “objective”, expert-based assessment of the job becomes more difficult. It could thus be argued that, as a job becomes more complex, the subjective report of the operator (and re-definer) becomes more crucial and a more accurate indicator of the job content and stressors.

Effect of personality variables on self-report validity

It has been suggested that the validity of self-report data is compromised by its sensitivity to personality variables of the respondents. As noted above, several authors have suggested that constructs such as trait anxiety (Payne, 1988) or negative affectivity (Watson & Pennebaker, 1993) might bias self-reports of job stressors and strain. Both these effects, if strongly active, could artificially elevate odds ratios. Assuming that the study populations of Houtman et al. (1994c) and Karasek et al. (1988) both contained a sampling of various personality types, the odds ratio similarities between these two studies (the former based entirely on self-report data, the latter incorporating objective outcome data) again suggest that personality-based bias does not operate strongly in this type of epidemiologic study.

Carrère et al (1991) also addressed these questions through a process of comparisons. They developed two partial checks on the self-report data in their study of public transit operators. First, if these personal factors strongly effect self-report scores, one should be able to see correlations between reports of job strain and individual-based variables, controlling for other extrinsic variables. The authors measured individual characteristics such as instrumental coping and emotion-focused coping strategies; these measures (as well as demographic variables such as education, age, marital status and job seniority) were not related to job strain outcome reports. As a second check on the self-report validity, the authors measured perceived occupational strain among a small subset ($n=24$) of transport operators matched with participants who drove the same routes at the same time of day. The correlation coefficient for the relationship between the job strain reports of these matched pairs was .85, as contrasted to an r of .03 between job strain reports of this subset and other study participants driving different routes. This finding strongly suggests a) that job strain is primarily a function of the job characteristics, not personal characteristics and b) that personal psychological characteristics do not bias self-report strain variables in any major way, at least under the conditions of this study.

Other Issues of self-report validity

It is undeniable that a relationship exists between physical and psychological strain symptoms and between adverse physical and psychological health outcomes. The literature on rheumatoid arthritis appears to have paid especial attention to this relationship, because of its important implications for treatment and long-term disability outcomes. A particularly good overview is contained in the summary article, The Economic Cost and Social and Psychological Impact of

Musculoskeletal Conditions, by Yelin & Callahan (1995). While focusing on all musculoskeletal conditions, including traumatic and arthritic, the findings of the many studies cited in this article apply to the narrower category of WRMSDs. Musculoskeletal conditions have been assessed for their impact on depression, coping strategies, anxiety, cognitive changes, self-efficacy and learned helplessness. In particular, the authors note the interrelationship between depressive symptomatology and musculoskeletal symptomatology. Given the devastating effects that serious musculoskeletal disease can have on an individual's physical abilities and social environment, the association is not surprising. And the causal relationship may not be unidirectional; depressive symptoms may predict clinical outcomes, as well (Yelin & Callahan, 1995). For the purposes of the present research, it should be noted that the outcomes of physical and psychological strain and adverse health outcomes cannot truly be disentangled. Although each is analyzed separately here, it is likely that there is a feedback loop between the physical and the psychological, so that the summed outcomes in the physical and the psychological arenas give the truest picture of the full impact of the multi-level stressors examined in this paper.

Avoiding the "Triviality Trap"

This section addresses in more detail the concept of the "Triviality Trap", a description of a methodological pitfall, coined by Frese and Zapf (1988) to describe studies which rely only on "subjective" measures to study the relationship between stress and ill-health. The coinage is the basis of their call for more "objective" methods of measuring the work environment, by which they mean measures "not to be influenced by an individual's cognitive and emotional processing" (Frese & Zapf, 1988, p. 378). In Tage Kristensen's construction of the term (1995b), epidemiological data collected by methods that rely exclusively on self-report are open to serious criticism. Kristensen argues for a "triangulation" strategy, which combines data from three sources: self-report measures, reports of external observers (presumably, but not necessarily, more "objective") and direct physical measurement (e.g., blood levels of corticosteroids, surface EMG recordings, etc.).

The usefulness of multiple sources of data cannot be disputed. But given the nature of the Monitor data set, it is desirable to approach Kristensen's suggestion of triangulation from a different direction. In the Monitor data set, there are no actual physical measurements of either exposure (e.g., measures of load lifted or acceleration levels from vibrating tools) or outcome (e.g., range of motion or nerve conduction data), so the third side of Kristensen's triangle cannot be addressed. The second side of the triangle is less clear. We do not have "objective" (meaning, in this context, third party) measurement of exposure levels, since exposure is reported by employee questionnaire or by employer interview. Most other information in the study is thus not "objective", although health outcome data could be verified by records.. Employers and employees do generate a type of outside observer estimate of each others' self-reports. But one would be hard pressed to characterize either as being more objective, and neither class of observer is external to the political and social realities of the company.

We have presented the argument above that self-report data is the only way to obtain certain types of information about the work environment and the associated perceptions and health status of employees. Self-report is crucial to assess the actual additive and/or multiplicative impact of the myriad facets of work and non-work life on the respondent. Thus, in the absence of the sec-

ond and third leg of the “triangle”, the present research project has concentrated on the development of 3 additional ways to approach the question of validity. Given the complete absence of instrument measurements of employee health status, and the partial absence of third party verification, this analysis uses measures that do not rely on the individual (either employer or employee), but on the combination of data from a larger number of individuals. These measures are the Aggregation Measures and Discrepancy Measures. We also make use of a third, qualitative way to approach the dilemma of the “triviality trap”, the attempt to uncover “configurative or interactive” patterns in the interrelationships among self-report measures.

1. Configurative Relationships

Michela et al. (1995) propose this idea in examining the effects of company climate dimensions, arguing that it is harder to invoke rater bias to explain more complex patterns of results. We have noted these patterns several times in the course of this research. An example of the unique interactive relationships in this research are the U-shaped curves defining employee stressor reports in relation to increasing levels of management involvement in health and safety issues. These examples demonstrate a complicated pattern of relationships among self-report data from the employer and the employee data bases. These relationships lend credence to Michela et al.’s (1995) contention: that “configurative or interactive” patterns would be very hard to duplicate if bias were the primary or even an important determinant of the levels reported. If bias were the primary determinant of these lines, one would not expect to see such complicated relationships repeated so often.

2. Aggregation Measures

The use of aggregation measures is well established in the sociological and biological literature. As noted above, both Frese and Zapf (1988) and Kristensen (1995b) are convinced of the tendency of aggregation processes to promote a canceling-out of individual level biases or random measurement errors. We have also noted above the interesting argument presented by Michela et al (1995) for using aggregate independent variables as more accurate predictors of individual-level outcome variables.

3. Discrepancy Measures

The discrepancy measures protect against certain aspects of self-report bias potential by describing an interaction between 2 different and complimentary sets of data, the employer and employee data sets in the Monitor survey. The Discrepancy Scales created for the analysis of the Monitor databases are simply a quantification of reporting differences between employees and employers. As such, they are proposed as a measure of company culture. Discrepancy analysis also represents another means of addressing issues of bias. These measures of discrepancy are at least one step removed from the classical issues of observational bias: over- or under-reporting by the respondent. The difference between employer and employee estimations of exposure and outcome is a new quantity that is related to, but not the same as the actual reported exposures and outcomes. An hypothesis of this paper is that discrepancy measures represent one way of characterizing organizational culture that is relatively unbiased, in comparison to reports of either constituent group. This is because the use of discrepancy measures does not depend on the accuracy or “truth” of the constituent reports; only the difference between employee and employer estimates is important. If employer and/or employee reports are biased, towards either an over-

or an under-estimation of the “true” quantity being measured, this level and direction of bias, itself, is hypothesized to be a valid and repeatable measure of company culture. In other words, the discrepancy measures avoid issues of bias by incorporating bias as a quantity to be measured.

The analysis also enters the Mean of employer and employee risk assessment in the modeling process (explained in Methods). The exact relationship between the mean employer/employee estimate and the “true” risk level in the company is unimportant in this research. It is simply used as a correction factor in the analyses, to partition dependent measure variance between that associated with the discrepancy (an organizational culture measure) and that associated with the stressor, itself. Depending on one’s theoretical priors, it would be possible to use the employer estimate, the employee estimate, or any value in between as the correction factor. In addition to political neutrality, the use of the mean correction factor has a desirable mathematical feature: it is the value that is numerically farthest from both employee and employer estimates. Thus, when entering discrepancies, means, and employer or employee measures as independent variables in the same regression equations, collinearity among these measures is reduced to its lowest level.

Either or both of the respondent groups (employer or employee) may over- or under-report, for a variety of reasons, some conscious, some unconscious. It is probable that these reporting biases, to the degree that they are present, are systematically related: in companies with high discrepancies, the organizational culture may be characterized by higher levels of mistrust, miscommunication, or misinformation, compared to low-discrepancy companies. Employers will tend to systematically under-estimate exposure and outcome, while employees may systematically over-estimate these quantities. But the differences between these estimates are still an unbiased measure of organizational culture. Rather than biasing the discrepancy measures, they simply increase the degree of variance between “good” and “poor” organizational cultures.

These 3 ways to address questions of self-report validity are not included in Kristensen’s analysis of the “triviality trap”. It appears that using the combination of these methods in this research has allowed the full use of the invaluable information contained in self-report data while still incorporating comparative verification from other sources of measurement.

3. Misclassification

Issues of misclassification are intimately intertwined with issues of bias. If any of the self-report biasing mechanisms explored above is operative, there is the possibility that a respondent will classify him/herself into the wrong exposure and/or outcome category.

Putz-Anderson (1991) and others think that a simple, dichotomous structure (such as was used in the Monitor employee questionnaires and much of the employer interviews) is the appropriate level of detail for a self-report instrument. However, it also presents a stronger problem of misclassification at the border region, between “yes” and “no”. If the guesses at the border region are purely random, than non-differential misclassification is the outcome, resulting in a general reduction in strength of calculated associations (regression towards the null). The preceding discussion, however, has noted the numerous opportunities for this misclassification to be directional, due to biasing tendencies. The problem is just as great in the employer questionnaire, although the presence of the trained interviewer may have helped reduce non-differential misclas-

sification. The much weaker exposure/outcome associations found at the employer-estimate level (Stage Ib), compared to the employee level (Stage Ia) suggest that misclassification, probably due to bias, may be present in the Monitor survey. Again, its presence has to be noted as a possible limitation on the study.

4. Confounding

Confounding is defined as the presence of a third factor that is associated with the independent variable(s) and is also independently associated with the outcomes of interest. This research looked at the correlations of possible confounders with the independent and dependent variables to be used in the analysis. Whenever possible, age, sex, and education level were controlled at the individual level by including these terms in the regression equations. We opted to study company-level effects without controlling for sector. However, correlation analysis showed that the sector and size effects were simply the result of non-random stressor distribution. Since we are interested in the effect of stressors, not sector or size, the removal of these terms from the regression equations is warranted. But because many company-level variables were correlated with company size, this variable was entered in the regression equations.

The technique of confounder inclusion in the individual-level regression equations produced relatively stable models. However, it does not protect against multiple confounding among independent variables. The regression equations do this naturally, by estimating a regression coefficient for each independent variable, controlling for all other variables. These techniques are valuable if the primary intent is to control the effect of confounders and to estimate the associations of each single independent variable. This function of regression equations can be misleading, however, if there is interaction among the independent variables. While trying to control the effects of possible confounders, this research also was looking for real interaction (i.e., actual biological and sociological effects) among independent variables--effect modification, as opposed to confounding. We graphically explored interaction among the physical and psychosocial stressors. The results indicate that mild interaction exists among many of the biomechanical and psychosocial stressors. Interaction within the psychosocial independent variable set was only addressed by figures validating the Demand-Control model as a predictive model for musculoskeletal disorders, at the end of Stage Ia. The stability of the models, the generally low Variance Inflation Factors, and the protocol for keeping the Condition Number in the low 20's or below all suggest that the interaction is not high enough to invalidate the models.

4. Collinearity

Collinearity among psychosocial and physical risk factors, used as independent variables in regression equations, has generally been considered problematic in work environment research. Since there is a correlation between jobs with high levels of physical stressors and those with high levels of psychosocial stressors, care must be taken not to confound the effects of one with the other.

There are two major problems presented by collinearity. First is this confounding effect. By definition, if two independent variables are collinear in this data set, they are found, in association, in many of the same work places sampled by the Monitor project. And each is associated both with the other and with the outcome being modeled. If this association is strong enough, the separate variances of the two measures may not be high enough to accurately separate their asso-

ciations with the dependent variable. Regression estimates will demonstrate higher p-values, and the model R^2 will be reduced. (However, as demonstrated in many of the models explored earlier, effect modification is more likely to be found than mutual confounding. Effect modification is of great interest in this research; it is not desirable to control it out of existence.) Second, high collinearity between independent variables in a regression equation can make the model unstable. The entry or removal of one variable may result in large changes in the β 's and p-values of other variables. These effects destroy confidence in the explanatory value of such a model.

In the present research, we assessed collinearity using the collinearity diagnostics available in the SPSS package. Those used in this research were the VIF (variance inflation factor), Condition Number, and variance proportion associated with the eigenvalues of the principal components generated in the diagnostic process. These diagnostics are discussed in more detail in Chapter 2 and by Kleinbaum, et al. (1988, pp. 206-218), and Norusis/SPSS, Inc. (1993) .

It appears that with this data set, we were overly concerned about possible collinearities at the individual level. Kleinbaum et al. (1988) recommend, as "rules of thumb", that caution be exercised whenever the VIF is ≥ 10 or the condition index is ≥ 30 . These figures are associated with quite high levels of collinearity, a correlation coefficient of .95 for two predictor variables. In the present research, the protocol developed was to address collinearity if the VIF (Variance Inflation Factor) of a term was larger than 3 or the Condition Number exceeded 20. (It is important to look at the condition index in association with the VIF, because high levels of collinearity can, themselves, affect the computation of the VIF, in addition to destabilizing the model estimates.) One of the primary purposes of this research is the separation of psychosocial and biomechanical stressor associations with outcomes. To that end, we paid close attention to controlling collinearity, so that biomechanical and psychosocial measures could be entered into the same regression equations. In many of the analyses, this was surprisingly easy to do. At the individual-level, the amount of scatter in association points reduces the correlations between all variables. In fact, in performing analysis at the individual level (Stage Ia), we never encountered situations in which the VIF was greater than 3, and very few final models resulted in a condition index exceeding 20. This is consistent with partial correlations among individual-level independent variables that never exceeded 0.65 and generally stayed well below 0.4.

In the aggregate (company) level equations, the increase in association strength might have made collinearity a larger problem. But the reduction in the number of independent variables, consequent to data reduction and correlation analysis, created models in which collinearity was never a problem. The Condition Number of all linear regression models is reported in the tables of results. Only one model reached the cut-off level of 20—the Stage Ia individual-level model explaining the VOEG MSD Indicators (Table 12).

The main variables that exhibited high levels of collinearity were the 4 physical stressor scales: Repetitive Bend/Twist, Static Bend/Twist, Reaching/Prolonged Postures, and Heavy Physical Exertion. The correlation matrix for these 4 variables shows the extent of the relationships at the individual level (Table 7). These are partial correlation coefficients, controlling for age, sex and education level. This Table is encouraging for two reasons. First, it demonstrates that the 4 measures of physical stress in the workplace, while exhibiting some of the expected correlation,

clearly capture differing aspects of physical stresses. Secondly, with the exception of the correlation between Reaching/Prolonged Postures and Heavy Physical Exertion, the correlations are low enough to avoid the harmful effects of collinearity in models containing any other combination of physical stressors. There were four Stage Ib models in which this combination was retained; in each case, careful analysis revealed that the collinearity did not compromise the stability of the models.

This collinearity between physical stressors is, in addition, of secondary concern to collinearity between psychosocial and physical predictor variables. The purpose for the construction of 4 separate physical stressor scales is to make the representation of physical stress more realistic and more connected to biomechanical theory. But the major purpose of this research is to characterize the main and moderating associations of the psychosocial stressors with the dependent variables selected. Thus, we directed substantial attention to controlling possible collinearity in these relationships. In fact, it turned out that, in this data set, this expected collinearity never approached a level that would prevent separation of effects or destabilize the models (see Table 8).

6. Issues of Multilevel Analysis

There are compelling reasons to perform multilevel analysis. First, some of the comparisons used in this research could not have been analyzed without the aggregation of employee data at the company level. The creation of the Discrepancy Scales, by definition, requires a mean employee estimate of risk level for each plant. Second, analysis at the individual level alone is not capable of fully explaining the multiple causal interrelations that affects health outcomes (or, for that matter, most factors of interest in the study of human behavior). Brown and Saks (1980), using an economic model, effectively demonstrate this inability of individual-level data to explain productivity of a multi-product shop as well as training outcomes in schools and prisons.

Third, there are some interesting things to be learned about so-called group effects in multi-level analysis. The concept of “frog-pond effects”, well defined and explored by Firebaugh (1979, 1980) and others, formalized the common-sense perception that individuals are not isolated units, reacting to and interacting with a set of stressors, moderators, promoters and inhibitors in their environment. Rather, it is obvious that an individual’s perception and experience of risk, selection and use of coping mechanisms, and resultant strain and health-related outcomes are strongly related to the social environment in which these interactions take place. The experience and expectations of an individual’s family, community, and larger society all moderate the complex interactions explored in this research. Of particular interest to the present research is the degree to which membership in a particular organization can affect an individual’s response to risk factors for stress and musculoskeletal disorder. Thus, it is not surprising that terms would be included in some of the company-level models of Stages II and III that did not enter into the individual-level modeling of the same (disaggregated) outcome. Conversely, some independent variables that were significant predictors at the individual level disappear from the parallel, company level model.

The main potential problem associated with multi-level research is encountered in cross-level inference: making causal inference between levels. Fienlieb and Leaverton (1984) clearly demonstrate problem of “ecological fallacy” (Robinson, 1950) which is associated with cross-level

inference. Even though a regression line can be created through a set of points at the aggregate level, there is no guarantee that a regression line in each of the populations represented by the aggregate points would have the same slope, or even the same direction. As Robinson (1950) pointed out half a century ago, we must be very careful in inferring individual-level associations from associations discovered at the aggregate level. Also, most modern literature on the subject (see references above) identifies the use of correlation coefficients to make cross-level inference as a primary source of error. In the present research, only regression analysis was used in cross-level inference.

Thus, although the associations found at the company level in the present research are of interest for prevention efforts, they do not necessarily represent the associations at the individual level. It is this ability of aggregate associations to obscure differences between component groups that may explain the relative lack of strong associations found in Stage II and III between company-level variables and aggregate employee estimates of stressor levels (Stage II) and strain, pain and adverse health outcomes (Stage III). The aggregate measures included groups of line workers, supervisory personnel, support workers, and other employees, each with its own association between company variables and stressor levels. One direction for the continuation of this research is to carry out the analyses for each of these groupings separately. For the present, the equations defined at the aggregate level were also carried out in the individual data set, to test for the ecological fallacy. In general, this technique showed that, in this data set, the relationships defined at the aggregate level are good reflections of those found at the individual level.

This last technique represents the only instance in which company-level variables and individual-level variables were entered as independent variables in the same regression equation. This was necessary, because there are no individual-level analogues to the company descriptive variables (structure, technology, health policy, etc.) and to the Discrepancy Scales. Problems of collinearity and confusing inference were avoided in this technique because the company-level variables entered are measures that exist only at the level of the organization; they are not aggregations of individual-level variables used in the equations. Techniques for simultaneously analyzing the effects of individual-level independent variables and their aggregate analogues (useful for studying the group effects noted above) have been developed (e.g., Firebaugh, 1979), but they were not employed in this research.

7. Cross-Sectional Studies

The standard disclaimers concerning cross-sectional study design apply to the Monitor study. Although several of the employer questions assess conditions retrospectively, thus embedding a longitudinal element in the data collection, the study has all the limitations of a cross-sectional study. It can, in general, only define associations. Because of the lack of information concerning the temporal relationship of “exposure and outcome”, it is always possible to suggest that the causal arrow runs in the opposite direction, that the “outcome” actually preceded and caused the “exposure”. Thus cross-sectional studies are often seen as most useful for defining hypotheses, to be tested for causality in longitudinal studies (Hennekens, et al, 1987, p. 21). In general, the findings of this research have thus been reported as associations, without emphasis on causal relations. Wherever possible, when it is possible to make reasoned judgements about the most likely direction of causation, these have been suggested in the preceding text.

F. Issues of Measurement Construction

Scale Comparability

The scales used in this analysis consist of many different types of individual items, each with its own response pattern. Different item types may have different meanings to respondents, resulting in different exposure or response levels at which a respondent would choose a yes or no answer. Thus, the scales composed of these items also show different distributions of responses. TNO (Houtman et al., 1994a) reports the different response characteristics of their scales, many of which we have duplicated. The practical result of these differences is that β weights and ORs may not be directly comparable between scales. Thus, we report rough classes of effect intensity, but it is inappropriate to make more detailed judgments concerning which scale has the greater or lesser effect.

Unavailable Measures and Ambiguities in the Data Set

Although the Monitor questionnaire as a whole is very well thought out and constructed, our research used the data sets in ways the authors had not necessarily intended. Several measures that would have improved our analyses did not exist in the data set. None of these presented serious problems in the present analysis, but their inclusion in future questionnaires would improve epidemiological characterization of exposure/outcome relationships.

1. The employee questionnaire did not contain a question assessing exposure duration (e.g., number of years in the job). "Age" can be used as a surrogate and does show some of the expected effects, but other research by this author (Warren et al., 1998) indicates that "years in this job" is a stronger and more accurate predictor of outcome status.
2. There is no assessment of grip force or grip type (pinch, power, etc.) required to hold and manipulate tools and workpieces. These factors have been shown to be important in the development of hand tendonitis and epicondylitis (Barnard, ed., 1997)
3. There are no questions assessing dynamic factors: linear and angular velocity and acceleration of body segments. Recent research (Marras and Schoenmarklin, 1993, Marras et al., 1995) suggests that these factors are important in the etiology of upper extremity and lower back disorders.

As with any large-scale study, unexpected and unintended problems with questionnaire items were encountered in the Monitor data sets. There are several other measures that presented difficulties in the analysis:

Estimates of Extended Sick Leave (Sick Leave Greater than 3 Months)

There is a large discrepancy between employee and employer estimates of Extended Sick Leave (> 3 months). For 1992, the mean employer estimate of Extended Sick Leave was 2% (SD: 2%). The corresponding employee mean was 12% (SD: 32%). We constructed this variable in both employer and employee data sets by combining the number of respondents who answered "yes" to any of 3 alternatives: "after 3 months sick leave, returned to a) the same, non-adjusted job, b) the same, but adjusted job and c) a different job or work place. The reasons for the employer/employee discrepancy in this summary measure are not easy to determine. One possibility is a systematic under-reporting by employers and/or a systematic over-reporting on the part of

employees, but the size of the discrepancy makes this unlikely. The most plausible explanation lies in the construction of the questionnaire. The question that assesses long-term sick leave in the employee database comes at the end of a long list of questions assessing the types of interventions that the employers have undertaken. These lists are preceded by instructions asking the employee to report which interventions have taken place in the last 12 months. This preceding instruction is supposed to apply to Extended Sick Leave, as well. But many employees may not have related this question to the preceding instructions. This possibility is made more likely by the fact that the answer format changes for this question to a single blank space, for each of the 3 positive options. The preceding questions are all followed by 4 choices, which explicitly present the option of an intervention occurring in previous years. The questions relating to Extended Sick Leave change to a dichotomous, yes/no format. It was difficult for this researcher, in fact, to determine the time period specified for the question. It is likely, therefore, that a percentage of the employee respondents answered this question with reference to a longer time period (most probably, the entire working life). By contrast, the employer question is asked in the context of several other questions relating to 1992. It seems likely that this difference in question application is a primary reason for the employer/employee discrepancy.

There may well be other factors involved in this discrepancy. Not knowing the source or extent of the problems, it is not possible to correct either employee or employer estimates with any certainty. Thus, this measure was only used as a relative quantity. At the individual level, employees can be compared for associations of stressors with strain and long-term sick leave. At the company level, work places can be compared by percentages of sick leave in their aggregate employee sample, and by the size of the discrepancy between employer and employee estimate. But no confidence can be placed in the absolute levels of Extended Sick Leave.

Social Support

The VAG social support questions used in the Monitor instrument are not directly comparable to the Karasek (Karasek et al., 1982) or the Johnson (Johnson & Hall, 1988, Johnson et al., 1994, Johnson & Stewart, 1994) formulations of social support. First, there is not a clear distinction made in these questions between instrumental and socio-emotional support. Second, the questionnaire did not allow any detailed assessment of co-worker support. Supervisor support is measured with 5 items, but there are only 2 questions about co-workers. The one item about instrumental co-worker support did not load well on any factor. The other item ("frequently irritated by co-workers") is probably related to emotional support, but its meaning to respondents is not clear. It is thus not possible to analyze co-worker support directly. These distinctions between supervisor and co-worker support, and instrumental and socio-emotional types of support, while not the only distinctions to be made, are acknowledged to be important determinants of outcomes related to social support (Karasek et al, 1992a, House, 1981, Israel, 1982). It was not the intent of the Monitor instrument to measure social support in detail. Israel's extensive literature review (1982) details the disagreements in the field concerning how to conceptualize and measure different aspects of social support. Her work (1982, 1989, 1992) also points to the importance of social networks (unmeasured in the Monitor survey) and negative social interactions. The single Monitor question, "frequently irritated by co-workers", is an intriguing reference to this latter concept. It may be that the question asking about "Atmosphere" can measure the contribution of negative social interactions to health outcomes.

For the present research, the combined social support scale must be taken as an overall summary measure of social support. The fact that the scale has significant associations in the models created for physical and mental strain, pain reports, and Extended Sick Leave suggests that the summary assessment of social support is predictive of health outcomes. But the more precise estimation of the effects attributable to different types, levels and directions of social support remains a goal for future research.

Mental Strain

The primary measure of mental strain in this research was the Dutch version of the Maslach Burnout Inventory (MBI), specifically, the Exhaustion scale. Karasek (1979) and Karasek & Theorell (1990) refer to consistent findings that the exhaustion measured by the MBI is more closely related to high Psychological Demands (and more prevalent in professionals and executives) while measures of depression are more closely related to low Decision Latitude (combined Autonomy and Skill Discretion). These findings suggested that a parallel scale of depression-related items in the present research might be able to distinguish different associations with stressor levels. Our attempt to create such a scale from the "Tiredness" items included in the Monitor instrument did not succeed. The Tiredness scale mimicked the association with stressors found for the Exhaustion scale, but at a lower level. (The only, but provocative, exception to these results was the finding that Tiredness, used as an independent variable, predicted levels of the health-related outcomes of Extended Sick Leave and Partial Disability more powerfully than Exhaustion. Further research will explore the meaning of this anomaly.)

The lack of depression measurement in this research must be noted as a limitation.

Presence of Work Groups or Teams

There are two variables in the employee questionnaire that begin to assess a crucial dimension of the work environment: whether employees work together in teams, and, if so, what percentage of the work force is in teams. The simple distinction between presence or absence of teams does not begin to address the wide range of forms that work groups or teams may take. (This may partly explain the relative lack of associations with these variables in the Stage II and Stage III analyses.) And it does not give us any information about whether the groups are functioning in ways that improve the psychosocial characteristics of the work environment or degrade them. Boyett & Conn (1991) present a well-organized overview of the spectrum on which different work team experiments can be placed (pp. 244-249). Their schema focuses on the role of a group leader in different work groups. This role can range from a "focal point of group dynamics, which he or she initiates and manages", through the roles of coordinator and "team boundary manager", to "team resource person"--the role the authors identify with teams that are truly self-managed and autonomous. These authors also note the range of obstacles to smooth functioning of work groups:

1. Employees' resistance to internally handling disciplinary and evaluative functions traditionally carried out by management. Work teams can be used as vehicles for management to transfer policing activities to team members.
2. Difficulties encountered by members in coordinating with and understanding the work of other individuals and groups.
3. Members' lack of experience with self-motivation and management.

4. Covert and overt resistance and sabotage from managers and, especially, supervisors, who fear change or loss of their jobs.
5. Employee loss of traditional pathways for exerting covert control over some aspects of the work environment.

Other authors (e.g., Diamond, 1993) note the dark side of work groups and teams: the opportunity for poorly understood unconscious motivations and behaviors to wreak havoc with the social structure within and between work groups. In his study, "The Unconscious Life of Organizations", Diamond details 4 different types of work group structure, 3 of which do not create a work environment that promotes autonomy and improved social support:

1. The homogenized work group, which is apparently leaderless but exists in a state of tension and opposition to the larger environment
2. The institutionalized work group, in which a rigid bureaucracy emerges, reminiscent of a strongly hierarchical, traditional company.
3. The autocratic work group, in which a single leader takes the role traditionally occupied by a charismatic "boss" of the company.
4. The resilient work group, which incorporates the ideals of the autonomous, supportive employee task group generally envisioned in the literature on self-directed work groups

Production may or may not be facilitated by each of these structures (although Diamond thinks that work generally suffers in the bureaucratic work group), and organizations may have reasons for promoting and facilitating one or the other form. But only the last form could be considered to contribute to an improvement in the psychosocial quality of the work environment.

Lincoln and Kalleberg (1990) found that, in the United States, quality circles (a type of work team with generally low levels of self-regulation) are usually associated with more centralized authority and decision making. These authors feel that this type of group work is only a control device, instituted to create the perception but not the reality of employee involvement.

Different forms of work groups will, of course, also be associated with different company structures, cultures and core technologies (Miles, 1980). Hofstede (1994), in identifying indications of a "Third Industrial Revolution" (the humanization of work, p. 39) notes that the introduction of certain technologies is, in fact, antithetical to the formation of humanizing group structures, because of the impact of the "technological imperative" on work content. This is simply another way of saying that technology developments which mitigate towards a Tayloristic division of labor will be in conflict with efforts to democratize the work place through the medium of self-directed work groups.

Time is also a factor. The Monitor employer interview does not ask how long work groups have been operating in the organization. Karasek (1990), following the process of organizational change in a sample of Swedish white collar workers, found that any change, even if the end result was increased participation and control within the organization, resulted in an increase in psychological and psychosomatic strain reports. Thus, the amount of time that has passed since the inevitably stressful introduction of a new work organization may strongly affect the level of stressors, strain and health outcomes in the employee population. The amount of time that work

groups have been in existence may also strongly affect where they are on the continuum of development towards true self-directed work groups (Boyett & Conn, 1991). In addition, Diamond (1993) notes that at any time, "critical organizational events" (p. 114) can radically alter the nature of the groups if members perceive themselves threatened.

The main conclusion to be drawn from this brief sampling of the very extensive literature on work groups is this: the Monitor items (the presence of work groups and the proportion of the work force involved in work groups) are only the beginning of an understanding of work group meaning to the work environment. The presence of work groups within an organization may be an indicator of a smoothly functioning, autonomous work environment that enhances social support and encourages skill use; or it might be an indicator of a degraded and stressful work environment. In the present research, the presence of work groups or teams in an organization and higher proportions of the work force involved in work groups were both hypothesized to be, on balance, a positive force in the work environment. The considerations outlined above represent directions that should be explored in the future, in the attempt to fully document the effects of work teams on the work environment.

CHAPTER V; SUMMARY & CONCLUSIONS

1. The Monitor Study, because of the wide variety of work places sampled and its strategy of collecting data from employees, employers and Works Council representatives in these work places, allows the development of new analytical tools to study the bases of occupational disease.
2. The results concerning the primary hypotheses of this research are:
 - a. Stage I Hypothesis: The levels of psychosocial and biomechanical stressors on the shop floor and their interaction are associated with outcomes of musculoskeletal and psychological strain, pain, sick leave, and disability. This hypothesis is supported.
 - b. Stage II Hypothesis: Psychosocial and biomechanical stressors measured at the individual level are associated with organizational structural, policy and support characteristics. This hypothesis is supported.
 - c. Stage III Hypothesis: The levels of organizational structural, policy and support characteristics also have direct associations with the prevalence of the outcomes studied in hypothesis 1, above. This hypothesis is not supported
3. The wide variety of work places sampled in the Monitor survey provides a large amount of variance in prevalence of psychosocial and biomechanical risk factors. Contrary to our expectations, it was not difficult in the analysis of the employee database to separate the associations of biomechanical and psychosocial risk factors with strain, pain and adverse health outcomes. The research identified 4 psychosocial risk factors, 4 biomechanical risk factors, and one employee measure of management involvement as the predictor variables to be studied.

The research analyzed the associations of these stressors with 9 dependent variables: 2 measures of Mental Strain, 3 measures of Physical Strain, 2 measures of Pain Levels, and 2 adverse health outcomes: Extended Sick Leave (> 3 months) and Partial Disability. A combination of psychosocial and biomechanical stressors demonstrated significant associations in all models constructed to explain variance in these dependent variables, except the model explaining Partial Disability. Only one of the psychosocial stressors (Autonomy deficit) was associated with this outcome.

4. Considerable effort was directed towards the creation of valid scales from the Monitor employee questionnaire and employer interview questions. Scale construction employed a combination of factor analysis, correlation analysis, reliability analysis and manipulation based on theoretical constructs. Wherever possible, these scales were made to be comparable to those used in previous research, in particular, that of Houtman et al. (1998) of TNO.
5. At the individual level, the associations of the 4 psychosocial stressors and the 4 biomechanical stressors with different measures of strain, pain, and adverse health outcomes exhibit individual but related and overlapping patterns. Social Support deficit has generally the strongest associations of the psychosocial stressors. The results suggest that, of the biomechanical stressors, Static Bending and Twisting of the upper body is most related to stress.

These characteristic patterns of association may have implications for the physiology of stress. Other researchers have found that different combinations of corticosteroids characterize different types of psychosocial exposures. The present epidemiological study shows

signature patterns of stressor-outcome association that may be the visible indication of these physiological differences. These patterns also have implications for intervention strategies. For maximum intervention effectiveness, different patterns of outcomes in an organization may require prevention actions that are focused on different aspects of the psychosocial and physical work environment.

This is not a surprising or new idea in the practice of ergonomics. When analyzing a work environment for biomechanical stressors, ergonomics teams or practitioners put a primary emphasis on quantifying levels of different biomechanical stressors. The aim is to prioritize and control the exposures that are most relevant to the symptoms and injuries seen in the particular work place. At the same time, surveillance and control strategies focus on combinations of and interactions between these exposures

The same level of specificity is appropriate in surveillance, exposure characterization, and control strategies directed toward the combination of psychosocial and biomechanical stressors in the work place. The characterization of specific outcome patterns in relation to specific psychosocial and biomechanical exposure combinations is a largely unexplored area. The results strongly suggest that the control of work-related musculoskeletal and stress disorders could be focused and enhanced by a broad, “full-spectrum” analysis of the workplace.

6. While the biomechanical stressors have strong levels of association that fluctuate over a wide range, depending on the outcome variable studied, the psychosocial stressors have a lower but much more constant level of association with most of the outcome variables. In the models of Body Pain, the associations of the biomechanical stressors are reduced and the associations of Social Support are elevated. These findings lend support to Karasek’s recognition (personal communication) that the biomechanical stressors act in a relatively local fashion, compared to the central and systemic action of the psychosocial stressors.
7. We carried out parallel analyses of these relationships, using employer questions analogous to the measures used in the employee models. These models show that employer perceptions of the work environment are narrower than those of employees and that they are less likely to see causal connections. Employer identification of biomechanical risk seems to center on force demands (the area of highest agreement with employee perceptions; see Houtman et al., 1998), although this is one of the less predictive biomechanical stressors in the employee-level models.

Employers seem to have a particularly hard time identifying psychosocial risks; the employer/employee correlations concerning levels of biomechanical risk range as high as .44, while most correlations concerning levels of psychosocial risk are not significant. The organization appears to be a setting characterized by relatively low levels of agreement concerning risk perception.

This picture is strengthened by the analysis of differences between “Allowers” and “Refusers”—companies that allowed their employees to participate in the Monitor survey and those that did not. The evidence of systematic bias in Refuser reporting of risk levels suggests that, despite their reports to the contrary, these companies might actually have higher levels of risk and negative outcomes than those found in the Allowers sample.

8. At the organizational level, this research created a new type of measure as a proposed indicator of certain organizational culture aspects. These measures, called “Discrepancy Indices” are simply the difference between employee estimates and employer estimates of certain risks, both biomechanical and psychosocial. Discrepancy analysis sidesteps the formidable issue of self-report validity (both employer and employee data are self-reported) by placing emphasis on the magnitude of the difference between these estimates. Whatever biases may effect individual self-reports, this difference itself is a useful measure of a company characteristic. The detailed analysis of the Discrepancy Indices and their behavior shows them to be robust predictors stressor levels characterized by employees. Several aspects of the Discrepancy analysis are of note:
 - a. We used factor analysis to create two summative Discrepancy Scales—one from the psychosocial discrepancies and a second from the biomechanical discrepancies. To reduce the chance for tautology, the biomechanical Discrepancy Scale was used in models predicting individual-level psychosocial stressors. And the psychosocial Discrepancy Scale was used in models explaining biomechanical stressor levels.
 - b. The associations of the Discrepancy Scales with individual-level stressors are strong and consistent and are heightened when the Mean of employee/employer estimates enters the models. This procedure standardizes the Discrepancy Scales by different levels of “true risk”. The Mean Scales and the Discrepancy Scales have separate distributions that are related in a non-linear fashion.
 - c. The two Discrepancy and Mean predictor pairs (one psychosocial, one biomechanical) have somewhat different associations with the individual-level outcomes. Because of their differences in behavior, it is possible that Discrepancies based on psychosocial and biomechanical risk may measure somewhat different qualities within the organization.
9. The effects of all organization-level variables—structural, health policy, and Discrepancy Scales—on individual-level strain, pain and adverse health outcomes are mediated almost entirely through the 4 biomechanical and 4 psychosocial stressors identified in this research, with a small contribution from the Management Acts variable. The few main effects (or effects through unmeasured mediators) identified are isolated and usually weak. The only exceptions to this finding are:
 - a. Associations of the physical Discrepancy Scale with several strain variables in the aggregate company models (β range: .047 - .108) that persist after the entry of stressors into the models.
 - b. Associations of the Policy Plan variable that remain in the Extended Sick Leave and Partial Disability models, after entry of the stressors
10. The multi-level analysis extends the concept of a “full-spectrum” analysis and prevention approach presented above, at the individual level. This approach, to be maximally effective, must also be a multi-level approach. The wider identification of individual-level psychosocial and biomechanical stressors and their interactions (proposed above) already opens important opportunities for control strategies. But the identification of organization-level correlates to these individual-level stressors is crucial for effective control. Interventions at an organizational level may be the best or only way to reduce certain types of exposure. The results of this research also imply that analysis and intervention at even higher levels may be necessary, although even more difficult. Obviously, in the case of large, multi-

location or multi-national organizations, the characteristics of the local- and the corporate-level organizational structure and culture are important. The larger economic, cultural, and political environment of the organization may also contain important determinants of organization- and individual-level risk. For occupational health risks to be fully addressed, intervention strategists and their allies may want to consider implications of prevention activities directed to each level.

11. One of the purposes of the research was to identify organizational markers of organizations at risk, to be used in prioritizing interventions and assessing their effectiveness. Below is the beginning of a list, in order of associative strength, that future, continuing research will sharpen and expand.
 - a. Degree of shared risk perception. The Discrepancy Indices developed in this research appear to be the strongest predictors of individual-level risk.. This requires duplication of the dual employer/employee sampling strategy employed in the Monitor Study.
 - b. Percentage of Temporary Employees
 - c. Self-Insurance for disability, compared to full or partial interaction with an insurance carrier.
 - d. Level of employer involvement. These results are preliminary but suggestive of the importance of graded management involvement in company health and safety. Over-involvement may be as detrimental as under-involvement. Employee and employer perceptions of employer involvement are another aspect of organizational culture.
12. These findings have a number of implications for intervention and prevention strategies.
 - a. Multilevel interventions, addressing simultaneously “shop-floor” problems, organizational deficits and, where possible, higher-level cultural and political “stressors” may be more effective than efforts targeted to the most visible examples of individual-level stressors.
 - b. At the organizational level, the quality and characteristics of the organizational culture are seen to be generally more important than the structural and technological characteristics of the company. This is a tentative conclusion, because the Monitor survey was not intended to measure structural and technological characteristics of the company in anything other than a general way.
 - c. The different patterns seen in the associations of the 4 psychosocial stressors and the 4 biomechanical stressors suggest strongly that a “one-size-fits-all” approach to changing work organization may turn out to be, in some cases, of little value or even counter-productive. Intervention strategy development should be prefaced by a thorough characterization of stressor type and level.
 - d. The finding that organizational health effects are mediated almost entirely through individual-level stressors makes the identification of these stressor levels an important indicator of “healthy” or “unhealthy” organizations. Measured levels of these stressors, if fully characterized could thus serve as indicators for evaluation of the effectiveness of organizational interventions.
 - e. The further development of marker variables or “flags” becomes even more important when the end goal is the development of multilevel intervention strategies, because of the complex nature of organizational risk factors and their assessment.

CHAPTER VI; RECOMMENDATIONS

1. Longitudinal studies are a necessary next step in this research direction. The associations characterized here need to be studied longitudinally to determine the direction of causation. Following are some questions posed by the present research:
 - a. Are the associations at the individual level between psychosocial deficits and physical outcomes causal? In which direction?
 - b. Are the associations of the Discrepancy Indices with individual level stressors a cause or a result of those stressors?
 - c. Are there unmeasured third variables in some of these associations that are causing both measures to vary together? In other words, are there confounding and effect modification relationships that are not evident in the cross-sectional study?
 - d. Are there differences between the association patterns of biomechanical and psychosocial Discrepancy Scales with physical and psychosocial strain?
2. Research should continue into the physiological bases of musculoskeletal and stress disorders. This is an important part of the future research agenda. Although epidemiological studies such as the present research can quantify and clarify exposure/disease relationships, the more detailed understanding of disease causation mechanisms is important for at least two reasons.
 - a. Understanding of the physiological mechanisms involved in disease causation can help the epidemiologist focus further investigation. Physiological understanding can allow the separation of the broad exposure categories used in this research into the components primarily responsible for negative health outcomes. This will enable the construction of more focused and effective work environment assessment techniques, instruments and intervention strategies.
 - b. The understanding of the organism's internal capacities and "detoxification" mechanisms can provide information useful to the development of more effective secondary and tertiary prevention approaches. Although the focus of this research is a strong preference for primary prevention strategies, there is a place for person-based stress-reduction and work behavior modification. In our experience, at their best, these person-based methods can help increase the individual's sense of control. This may increase the internal resources available for modifying the "dose" or "body-burden" of work environment risk exposures.
3. More detailed data-gathering methodology is needed to separate different aspects of organizational culture. Because the Monitor project focused on factors that promote or inhibit company prevention efforts, a large amount of information was gathered on company health policy. This research suggests that health policy and disability insurance characteristics are indicative of an aspect of company culture. The association patterns of these measures appear to be somewhat independent of those measured by the Discrepancy Scales. Company culture and climate are multidimensional; these measures may assess different aspects of these constructs. Different aspects of company culture may have different levels of effect on health outcomes.
4. The development of Discrepancy Indices using the Works Council is an important next step in understanding the types and degree of miscommunication and misunderstanding between employees and employers.

5. Continuing, detailed research into the meaning of the Discrepancy Indices is important for intervention efforts. The present research has defined the construct of a Discrepancy Index as an indicator of company culture characteristics that have strong negative associations on worker health, through their association with stressor levels. But these discrepancy variables are indicators, not descriptions of the actual company-level cultural characteristics that affect stressor levels and health. The next step should be detailed studies of a range of individual organizations, to determine the underlying cultural mechanisms that are measured by the discrepancy variables.

This micro-level research is analogous to uncovering the physiology of disease in an individual. Epidemiologic research can determine the associations necessary to identify pathways of disease causation. But individual-, organ-, tissue-, cellular- and even molecular-level studies are required to uncover the mechanism of disease causation and develop strategies for cure and prevention. Similarly, the associations of the Discrepancy Indices serve as markers of trouble; at the present level of knowledge, they do not give detailed guidance to prevention efforts. The study of individual organizations, focused on factors that result in employer/employee discrepancies, is needed to develop and focus the appropriate prevention techniques and strategies.

6. More research should be aimed at characterizing the complex combination of physical, psychosocial, sociological, economic and political factors influencing pain reports, the decision to seek medical care, sick leave and disability status. The present research has suggested some of these interactions, but the level of detail contained in the Monitor survey does not permit anything more than the generation of hypotheses. The questions to be addressed include:
 - a. How do men and women differ in their perceptions and reporting of pain?
 - b. Do women tend to seek medical attention sooner for work-related symptoms?
 - c. If so, is this early reporting trend predictive of reduced sick leave and disability?
 - d. What aspects of the organization promote or inhibit pain reporting and seeking medical attention?
 - e. What aspects of the organization (and its environment) promote or inhibit the progression from symptoms to Extended Sick Leave and Partial Disability?
7. Future research should characterize the structure and technology of the companies in much more detail. The organizational literature suggests that these aspects of the company are crucial in channeling the development of the company culture. A more detailed assessment would allow a more balanced analysis of cultural, structural and technological contributions to occupational health and the identification of more precise flags or guidelines to identify organizations at risk and develop intervention programs. Among other data, the following are important measures:
 - a. The precise characteristics of work group formation, structure and function should be detailed, to allow assessment of the work group characteristics that promote or degrade occupational health.
 - b. To address the many questions about the relationship of production structure (or service-providing structure) to employee health, a more detailed characterization of production structure and its interrelation with other organizational characteristics is needed.
8. Future research of this type should assess several other classes of information:

- a. Other types of measures that could be used to generate employer/employee Discrepancy Indices. Discrepancies relative to other areas of company function might be measures of different aspects of company culture.
 - b. Measures of job satisfaction and level of motivation
 - c. Depression measures
9. The multi-level approach to occupational health requires more knowledge about the interaction of the organization with stressors at higher levels of economic, societal and political activity.
- a. A primary institution in the United States, through which these upper-level stressors impinge on the organization and the individual worker, is the Workers' Compensation System. This author received his initial impetus towards the present research through a study of how the Workers' Compensation system affects the incidence and development of occupational disease, the progression towards disability, and timing and success of return to work strategies. We gained first-hand knowledge of how the Workers' Compensation laws mold and distort organizational response to WRMSD. The Workers' Compensation system is a primary conduit through which the contradictions and exigencies of the surrounding political and economic systems are transmitted to the organization and the individual-level work place. Research on these relationships is of crucial importance to the broader, multi-level approach to occupational health.
 - b. A related issue is how managed care and the general tightening of controls in the medical insurance system as a whole affect the prospects for thorough and effective care of occupational injury.

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COLLECTED TABLES

Table 1:
Composition of the Monitor Samples, by Branch (Bold) and Sector.

<u>Branch (bold)</u> <u>and Sector</u>	<u>Full Sample</u> <u>of</u> <u>Employees</u>		<u>Full Sample</u> <u>of</u> <u>Employers</u>		<u>with</u> <u>Employee</u> <u>Interviews</u>		<u>with Works Council</u> <u>Interviews</u>		<u>with Over 15</u> <u>Employee</u> <u>Interviews</u>	
	7717		782		528		296		285	
	n	%	n	%	n	%	n	%	n	%
1. Industry	3568	46.2%	382	48.8%	256	48.4%	139	47.0%	133	46.7%
a. Food & Entertainment	636	8.2%	74	9.5%	46	8.7%	28	9.5%	23	8.7%
b. Textile & Clothing	477	6.2%	44	5.6%	35	6.6%	10	3.4%	15	6.6%
c. Graphics & Printing	624	8.1%	52	6.6%	43	8.1%	22	7.4%	21	8.1%
d. Chemical Industry	341	4.4%	38	4.9%	22	4.2%	20	6.8%	13	4.2%
e. Metal Industry	629	8.2%	79	10.1%	49	9.3%	30	10.1%	20	9.3%
f. Electronics Industry	445	5.8%	48	6.1%	32	6.1%	18	6.1%	16	6.1%
g. Transportation	416	5.4%	47	6.0%	29	5.5%	11	3.7%	14	5.5%
2. Wholesale Trade	1319	17.1%	146	18.7%	93	17.6%	50	16.9%	49	17.6%
3. Banking & Finance	2430	31.5%	198	24.3%	141	26.7%	101	34.2%	103	26.7%
a. Banking & Insurance	651	8.4%	48	6.1%	35	6.6%	23	7.8%	28	6.6%
b. Service Sector (profit)	1779	23.1%	150	19.2%	106	20.1%	78	26.4%	75	20.1%
4. Other (excluded)	400	5.2%	56	7.2%	38	7.2%	6	2.0%	38	7.2%
Total: 3 Branches + Other	7717	100%	782	100%	528	100%	296	100%	285	100%

Table 2:
Discrepancy Indices; Worker Estimates of Work Environment Measures Minus Owner Estimates

<u>Employer Risk Variable</u> (Name of Discrepancy Index)	<u>Employee Risk Variable</u> (aggregate)	<u>Min.</u>	<u>Max.</u>	<u>Mean</u>	<u>S.D.</u>	<u>Distribution</u>	
						<u>Kurtosis</u>	<u>Skew</u>
Physical							
1. Physical Exertion	1. Physical Exertion	-0.85	0.95	0.08	0.24	1.05	-0.05
2. Static Exertion	2. Static Bend/Twist	-0.71	1.00	0.23	0.25	1.49	-0.72
3. Bend/Twist Upper Body	3. Rep. Bend/Twist	-0.80	1.00	0.31	0.28	1.38	-0.73
4. Repetitive Hand Motion	4. Rep. Hand Motion (V9013c)	-0.82	1.00	0.40	0.28	1.91	-0.64
5. Vibration	5. Vibration (V9015a)	-0.55	1.00	0.10	0.17	3.42	0.77
6. Sitting	6. Trouble w/ Sitting (V9014b)	-0.37	1.00	0.34	0.28	-0.50	0.26
Physical Scale (mean 2, 3, 4)		-0.69	0.95	0.31	0.22	2.11	-0.69
Psychosocial							
7. Psychological Demands	7. Psychological Demands	-0.78	0.80	0.22	0.29	1.07	-1.03
8. Autonomy	8. Autonomy	-0.95	0.71	0.09	0.28	2.31	-1.47
9. Flexible Employment	9. Schedule Control	-0.95	1.00	0.62	0.30	2.38	-1.31
10. Social Support	10. Social Support	-0.89	0.88	0.23	0.23	5.47	-1.85
11. Skill Discretion	11. Skill Discretion	-0.87	0.82	0.22	0.23	2.33	-0.82
Psychosocial Scale (8, 9, 10, 11)		-0.66	0.68	0.22	0.17	3.77	-1.49

Table 3:
Mean Worker/Employer Risk Estimates

<u>Employer Risk Variable</u> (Name of Discrepancy Index)	<u>Employee Risk Variable</u> (<u>aggregate</u>)	<u>Min.</u>	<u>Max.</u>	<u>Mean</u>	<u>S.D.</u>	<u>Distribution</u>	
						<u>Kurtosis</u>	<u>Skew</u>
Physical							
1. Physical Exertion	1. Physical Exertion	0.00	0.93	0.21	0.19	0.91	1.08
2. Static Exertion	2. Static Bend/Twist	0.00	0.93	0.25	0.15	1.86	1.29
3. Bend/Twist Upper Body	3. Rep. Bend/Twist	0.00	0.96	0.32	0.19	0.92	1.09
4. Repetitive Hand Motion	4. Rep. Hand Motion (V9013c)	0.00	1.00	0.33	0.19	0.82	0.96
5. Vibration	5. Vibration (V9015a)	0.00	0.59	0.08	0.10	4.93	1.92
6. Sitting	6. Trouble w/ Sitting (V9014b)	0.00	0.98	0.33	0.21	0.17	0.67
Physical Scale (mean 2, 3, 4)		0.01	0.87	0.30	0.16	0.76	0.95
Psychosocial							
1. Psychological Demands	1. Psychological Demands	0.00	0.84	0.28	0.16	1.05	1.15
2. Autonomy	2. Autonomy	0.00	0.82	0.16	0.15	2.20	1.63
3. Flexible Employment	3. Schedule Control	0.00	0.95	0.38	0.16	2.22	0.71
4. Social Support	4. Social Support	0.00	0.79	0.20	0.12	4.51	1.89
5. Skill Discretion	5. Skill Discretion	0.00	0.80	0.21	0.14	3.23	1.74
Psychosocial Scale (8, 9, 10, 11)		0.02	0.69	0.21	0.10	4.30	1.75

Table 4:
Correlations Between Employer and Employee Risk Estimates.
Correlations of Discrepancy Variables with Employee, Employer, and Mean Estimates Of Stressor Levels.
Comparison of the Full 528 “Allower” Companies with the 285 “Allower” with Employee Samples ≥ 15 .

Discrepancy Index Name	Correlation: Employee with Employer Estimate		Correlation: Discrepancy with Employee Estimate		Correlation: Discrepancy with Employer Estimate		Correlation: Discrepancy with Mean	
	full	≥ 15	full	≥ 15	full	≥ 15	full	≥ 15
Physical Exertion	0.401	0.389	0.498	0.486	-0.595	-0.617	n.s.	n.s.
Static Exertion	0.213	0.193	0.464	0.366	-0.767	-0.842	-0.352	-0.504
Bend/Twist Upper Body	0.330	0.362	0.463	0.427	-0.684	-0.688	-0.204	-0.231
Repetitive Hand Motion	0.291	0.439	0.618	0.486	-0.573	-0.572	n.s.	n.s.
Vibration	0.144	0.225	0.837	0.835	-0.422	-0.348	-0.469	-0.498
Sitting	0.379	0.421	0.624	0.475	-0.486	-0.598	0.120	n.s.
Physical Scale	0.352	0.421	0.580	0.421	-0.558	-0.596	n.s.	n.s.
Psychological Demands	0.119	0.123	0.420	0.305	-0.851	-0.909	-0.501	-0.681
Decision Latitude	n.s.	0.183	0.386	0.228	-0.887	-0.916	-0.601	-0.714
Flexible Employment	0.091	n.s.	0.421	0.368	-0.865	-0.896	-0.104	n.s.
Social Support	0.087	n.s.	0.489	0.427	-0.826	-0.871	-0.413	-0.546
Skill Discretion	0.223	n.s.	0.458	0.375	-0.764	-0.787	-0.317	-0.393
Psychosocial Scale	0.141	0.225	0.420	0.313	-0.839	-0.855	-0.475	-0.550

Table 5:
Stage Ia: Initial Correlations
(Partial Correlations, Controlling for Sex, Age, Education, and Sector)
(Dependent Variables Horizontal; Independent Variables Vertical)

	Exhaustion	Tiredness	Sum Physical Strain	Sitting Strain	Upper Body Pain	All Body Pain	Partial Disability	Sick Leave > 3 mo.
Demands	.46	.27	.22	.16	.17	.19	n.s.	.03
Autonomy	.26	.20	.28	.14	.16	.19	.04	.07
Skill disc.	.18	.20	.26	.15	.12	.15	n.s.	.07
Social support	.44	.33	.25	.19	.19	.23	.03	.08
Rep. bend/twist	.16	.15	.50	.20	.21	.25	n.s.	.10
Static bend/twist	.24	.20	.48	.39	.25	.28	n.s.	.10
Prolonged post.	.20	.16	.66	.05	.17	.25	n.s.	.10
Physical exert.	.12	.08	.50	n.s.	.14	.19	n.s.	.09
Shift work	.03	.03	.09	n.s.	n.s.	.03	n.s.	n.s.
Temp. work	n.s.	n.s.	n.s.	-.03	n.s.	n.s.	.03	-.04
Part-time work	-.04	n.s.	n.s.	.06	n.s.	n.s.	.16	.04
See occ. doc.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	.03
See GAK doc.	.05	.05	.09	-.03	.05	.05	.11	.17
See own doc.	n.s.	n.s.	.07	.04	.05	.05	n.s.	.05
See boss	-.03	-.03	-.03	.04	n.s.	n.s.	n.s.	n.s.
Mgmt. Acts	-.17	-.14	-.11	-.09	-.10	-.11	-.03	n.s.
Wk. Council acts	-.05	-.04	-.03	n.s.	-.03	-.03	n.s.	n.s.
HR acts	-.06	-.04	-.08	n.s.	-.04	-.04	n.s.	n.s.
Wk consult. acts	-.07	-.05	n.s.	n.s.	n.s.	n.s.	-.04	n.s.
Occ. doc. acts	-.05	-.04	-.03	-.03	n.s.	n.s.	n.s.	.03

Table 6:
Correlation Matrix for the 4 Psychosocial Stressor Scales; n = 7717

	Demands	Autonomy	Skill Discretion
Demands	1.00		
Autonomy	0.12	1.00	
Skill Discretion	n.s.	0.39	1.00
Social Support	0.30	0.28	0.29

Table7:
Correlation Matrix for the 4 Physical Stressor Scales; n = 7717

	Repetitive Bend/Twist	Static Bend/Twist	Reaching/ Prolonged Postures
Repetitive Bend/Twist	1.00		
Static Bend/Twist	0.56	1.00	
Reaching/Prolonged Postures	0.55	0.44	1.00
Heavy Physical Exertion	0.46	0.28	0.64

Table 8:
Correlation Matrix for Physical and Psychosocial Stressors (n = 7717)

	Repetitive Bend/Twist	Static Bend/Twist	Reaching Prolonged Post.	Heavy Physical Exertion
Demands	0.16	0.22	0.18	0.12
Autonomy	0.26	0.21	0.26	0.21
Skill Discretion	0.26	0.20	0.21	0.17
Social Support	0.17	0.19	0.20	0.16

Table 9:

STAGE Ia: Individual Level Models: MSD and Stress Disorder Indicators on Stressors (Controlled for Age, Sex and Education Level)

	Linear Regression														Logistic Regression								
	Mental Strain: Exhaust.		Mental Strain: Tiredness		Physical Strain		Prolonged Sitting Strain		VOEG MSD Indicators		Upper Body Pain		Total Body Pain		Extended Sick Leave		Partial Disability						
	β	Sig.	β	Sig.	β	Sig.	β	Sig.	β	Sig.	β	Sig.	β	Sig.	OR	Sig.	OR	Sig.					
Control																							
Age	.036	.002			.034	.000			.174	.000	.118	.000	.120	.000	1.26	.000	2.26	.000					
Gender			.085	.000			.031	.022	.064	.000	.141	.000	.102	.000									
Education					-.028	.008			-.055	.000					0.71	.000	0.73	.000					
Stressor																							
Demands	.330	.000	.163	.000	.044	.000	.055	.000	.045	.001	.080	.000	.071	.000									
Low Autonomy	.084	.000	.056	.000	.058	.000	.051	.000	.041	.004	.063	.000	.073	.000			2.77	.007					
Low Skill Discretion	.021	.018	.068	.000	.080	.000	.063	.000	.051	.001			(.027 .077)										
Low Social Support	.290	.000	.223	.000	.055	.000	.105	.000	.119	.000	.091	.000	.115	.000	1.80	.000							
Repetitive Bend/Twist	-.061	.000			.062	.000	.048	.008	.076	.000	.086	.000	.077	.000	1.84	.000							
Static Bend/Twist	.098	.000	.094	.000	.169	.000	.411	.000	.146	.000	.156	.000	.149	.000									
Reach./Prolong. Postures	.043	.004	.054	.005	.445	.000	-.176	.000	.118	.000			.097	.000	1.62	.005							
Physical Exertion			-.059	.001	.118	.000	-.073	.000	.061	.023													
Management Acts	-.036	.007									-.033	.015	-.027	.038									
Condition Number	10.6		5.87		19.2		6.46		20.0		10.7		11.2										
R ²	.337		.184		.592		.218		.229		.137		.175										
Units:	All variables continuous, 0 – 1.0 except:									-2 Log Likelihood, initial					3736		1064						
Age:	Deciles; 4 categories				Education: 4 categories					-2 Log Likelihood, final					3516		973						
Gender:	Dichotomous; 0/1 = M/F				Logistic Outcomes: Dichotomous					Model Improvement					220		91						
Pain:	Upper Body: 0-8; Total Body: 0-15																						
															Sig., (dF)					.000 (5)		.000 (3)	

Table 10
Crosstabs Between Partial Disability and Extended Sick Leave (>3 Months)

	No Absence >3 Months	After Absence >3 Months, Returned to:		
		Old, Unadjusted Job	Old Job, Adjusted	New Job
Not Disabled	6675	567	104	123
Disabled	90	39	32	39

Table 11:
STAGE Ia; Dependent Variables: Long Term Adverse Health Outcomes
Independent Variables: Strain and Pain Measures

Description	Extend. Sick Leave			Partial Disability		
	OR	95% CI		OR	95% CI	
		Lower	Upper		Lower	Upper
age, in deciles	1.15	1.06	1.25	1.82	1.52	2.16
education level	0.70	.062	0.79	0.76	0.61	0.96
sex	0.79	0.66	0.96	n.s.		
Exhaustion	n.s.			n.s.		
Tiredness	1.74	1.36	2.23	3.28	2.00	5.40
Sum. Physical Strain	2.10	1.57	2.80	n.s.		
Sitting Strain	n.s.			n.s.		
VOEG MSD Indicators	2.49	1.89	3.28	2.21	1.26	3.86
Upper Body Pain	1.07	1.01	1.14	1.14	1.03	1.27
Lower Back Pain	n.s.			n.s.		
initial -2 log likelihood	4707			1373		
final -2 log likelihood	4314			1224		
improvement	393; 8 df; (.000)			149; 5 df; (.000)		

Units: Strain measures:

Upper body pain

Lower back pain

education level and age:

all other measures: dichotomous (sex: female = 1)

0 - 1.0

0-8

0,1

1 - 4

0, 1

Table 12: Individual Level Regressions; MSD and Stress Disorder Indicators On Stressors, Stratified By Gender

MSD Indicator	Sex	Age	Educa- tion	Dem- ands Stress	Auto- nomy Deficit	Skill Disc. Deficit	Social Suppt. Deficit	Repet. B/T	Static B/T	Prol. Post.	Phys. Exer- tion	Mgmt. Takes Action
Linear Regression Standardized (β) Coefficients												
Exhaustion	M	.038	.036	.315	.076	+.067	.279		.085			-.029
	F			.361	.088	-.045	.313		.073	.056		-.039
Physical Strain Sum	M	.038	-.030	.043	.046	.076	.046	.077	.169	.423	.112	-.020
	F		-.051	(.028)	.068		.085		.183	.498	.192	
Prol. Sitting Strain	M	+.042		.050	.047	.059	.088	.070	.388	-.168	-.077	
	F	-.047		.099	.069	.094	.124		.430	-.168	-.073	
Upper Body Pain	M	.117		.066	.047		.088	.064	.128		.066	-.050
	F	.096		.094	.075		.142	.074	.209			
Total Body Pain	M	.120		.066	.059		.117	.061	.135		.066	-.047
	F	.098		.081	.080		.145	.088	.185	.080		
Logistic Regression Odds Ratios												
Lower Back Pain	M	1.16		1.37		1.88	2.21	1.80	1.69	1.58		0.80
(OR)	F			1.41			2.91	2.11	2.09	1.88		
Extend. Sick Leave	M	1.31	0.69				1.93	1.74	1.51			
(OR)	F		0.64				2.35	2.25				
Partial Disability	M	2.00	0.67	0.54	2.72							
(OR)	F	1.72					4.31					0.38

Units:

All variables continuous, 0 – 1.0 except:

Age: Deciles; 4 categories Education: 4 categories
Gender: Dichotomous; 0/1 = M/F Logistic Outcomes: Dichotomous
Pain: Upper Body: 0-8; Total Body: 0-15

Table 13: Individual-Level Regressions: MSD and Stress Disorder Indicators on Stressors, Stratified by Job Level

MSD Indicator	Job Cat.	Age	Educa- tion	Dem- ands	Auto- nomy Deficit	Skill Disc. Deficit	Social Suppt. Deficit	Repet. B/T	Static B/T	Prol. Post. Stress	Phys. Exert. Stress	Mgmt. Takes Action	R ²
Linear Regression Standardized (β) Coefficients													
Exhaustion	L	.025		.358	.083	.036	.278	-.070	.100	.045		-.037	.327
	S			.325	.100		.290		.260	.071			.366
	P			.329		.113	.326	.091			-.093		.342
Physical Strain Sum	L	.033	-.030	.054	.053	.077	.058	.063	.166	.432		(-.018)	.580
	S		(-.047)		.069	.062	.159	.140	.493				.567
	P	.068			.097	.154	(.061)		.272	.457			.530
Prol. Sitting Strain	L			.065	.054	.076	.105		.423	-.192	-.065		.212
	S			.081		.131		.093	.316		-.147		.179
	P				.096	.133			.388		-.086		.208
Upper Body Pain	L	.078		.075	.049	.063	.076	.035	.138			(-.028)	.107
	S				.097		.126	.152	.163				.133
	P	.154	(-.076)		(.087)	.116			.170			-.088	.113
Total Body Pain	L	.092		.073	.071	.060	.118	.053	.173	.054			.151
	S	.068		.085	.085		.102	.205	.172				.189
	P	.113	-.149		.126		.169	.141	.088				.170
Logistic Regression Odds Ratios													
Lower Back Pain	L	(1.07)		1.30	1.45	1.69	2.38	1.94	1.84	1.34			
	S	1.26		1.96			2.34		6.32			(0.69)	
	P		0.69		4.08		5.76	2.20					
Extend. Sick Leave	L	1.22	0.75				2.13	1.77		1.58			
	S	1.35	0.57						2.95				
	P	1.69	0.50										
Partial Disability	L	2.12		0.37	3.01		(1.81)						
	S		0.46									0.32	
	P	2.44					13.63						

L: Line Workers

S: Supervisory

P: Professional & Managerial

Units: All variables continuous, 0 – 1.0 except:

Gender: Dichotomous; 0/1 = M/F Logistic Outcomes: Dichotomous

Age: Deciles; 4 categories Education: 4 categories

Pain: Upper Body: 0-8; Total Body: 0-15

Table 14: Stage Ib: Initial Correlations
Partial Correlations between Employer Estimates of Individual-Level Stressors,
Strain, and Adverse Health Outcomes

	Dependent Variables				
	Strain		Adverse Health Outcomes		
	physical complaints	stress complaints	% sick leave	% disability	% sick >3 months
Dep. Variables:					
phys. complaints	1.0				
stress complaints	0.202	1.0			
% sick leave	0.201	0.129	1.0		
% disability	ns	ns	0.336	1.0	
% sick >3 mo.	ns	ns	0.228	0.144	1.0
Indep. Variables:					
% phys. exer.	0.267	0.110	0.124	0.107	0.176
% static exer.	0.122	0.082	ns	ns	ns
% bend/twist	0.148	0.073	0.161	ns	ns
% rep. motion	0.159	ns	0.154	ns	ns
% vibration	0.141	0.098	ns	ns	0.081
% prol. sitting	ns	0.112	ns	ns	ns
% psych. demd.	0.081	0.320	ns	ns	ns
% autonomy	0.098	0.104	ns	ns	ns
% flex. employ.	0.121	0.106	ns	ns	ns
% soc. support	0.205	0.239	ns	ns	ns
% skill discretion	0.117	0.124	ns	ns	ns

(Note: Correlation coefficients related to Physical Complaints or Stress Complaints are Spearman coefficients, because these two dependent variables are dichotomous. All other correlations, involving continuous measures, are Pearson correlation coefficients.)

Table 15: Stage Ib: Linear Regression Models; Adverse Health Outcomes

Dependent Variable	Excluded	Retained		Model R ²
			β	
% sick leave, 1992	% bend/twist (.075) company size branch: wholesale allowed	% phys. exertion % rep. motion branch: industry (ref: bank/fin.)	.093 (.001) .106 (.007) .243 (.001)	0.127
% disabled, 1992	company size branch: wholesale allowed	% phys. exertion branch: industry (ref: bank/fin.)	.106 (.005) .084 (.026)	0.019
% sick leave > 3 months	% vibration company size branch: industry allowed	% phys. exertion branch: wholesale (ref: bank/fin.)	.193 (.001) -.088 (.016)	0.041

Table 16: Stage Ib: Logistic Regression Models of Physical and Mental Strain

Dependent Variable	Excluded	Retained	Odds Ratio
<u>Physical Strain</u> (complaints about upper body) correct class: 66.2%	% bend/twist; upper % repet. motion % vibration (.061) branch: wholesale branch: industry (ref: bank/financial)	% phys. exertion % soc. sup. deficit allowed company size	7.99 (.001) 6.83 (.001) 1.83 (.001) 1.63 (.001)
<u>Mental Strain</u> (complaints about stress) correct class: 64.7%	% bend/twist, upper % soc. sup. def (.073) branch: wholesale allowed	% psych. demands branch: industry (ref: bank/financial) company size	5.29 (.001) 0.73 (.048) 1.70 (.001)

Units: all percentage measures:

company size: 1 = < 100 employees, 2 = 100 - 200, 3 = >200

all other measures: dichotomous

0 - 1.0

1 - 3

0, 1

Table 17: Employer Turnover Estimates on Aggregate Employee Stressor Estimates

Aggregate Stressor	β Weight	Significance
Psychological Demands	.153	.008
Skill Discretion Deficit	.207	.003
Static Bend/Twist	-.151	.043
Reaching/Prolonged Postures	.310	.013
Heavy Physical Exertion	-.345	.003
Condition Number	11.7	
Model R ²	.082	

Table18: Comparison of “Allower” and “Refuser” Companies

Description	Refusers n = 254	Allowers n = 528	p-value (2-tail)
<u>Company Structure</u>			
no. of employees	104	92	ns
% full time employees (vs. part time)	90.9%	89.5%	ns
% contract employees	5.8%	5.0%	ns
% temporary workers	4.3%	2.7%	.008
teamwork in company	.65	.61	ns
production structure	2.24	2.15	ns
# of hierarchy levels	3.67	3.62	ns
<u>Company Health Policy</u>			
basic sick payments: by GAK	1.37	1.25	.018
≥1 committees on working conditions	0.51	0.56	ns
mgmt. involved in health problems	2.32	2.35	ns
mid-mgmt. involved in health problems	2.60	2.55	ns
employees involved in health problems	1.75	1.75	ns
use of external help for work environment	0.57	0.62	ns
prevention budget?	0.08	0.06	ns
structural physical prevention	0.42	0.50	0.043
structural stress prevention	0.25	0.27	ns
person-based physical prevention	0.40	0.50	0.006
person-based stress prevention	0.17	0.22	ns
<u>% Estimates of Workers at Risk</u>			
physical exertion	17.60	17.26	ns
static exertion	13.80	13.91	ns
bend/twist upper body	13.72	16.20	ns
repetitive motion, arms/hands	11.81	13.66	ns
vibration	3.66	3.01	ns
prolonged sitting	16.96	16.30	ns
demands	16.24	16.58	ns
autonomy	6.42	12.13	.000
lack of flexible employment	3.78	6.99	.014
social support	6.09	7.93	ns
skill discretion	6.26	10.02	.007
<u>Strain and Outcomes</u>			
physical complaints: upper body	0.48	0.64	.000
stress complaints	0.34	0.38	ns
% sick leave in 1992	6.5%	6.7%	ns
% turnover in 1992	9.7%	9.1%	ns
% disabled in 1992	1.1%	1.1%	ns
% sick leave > 3 months	2.5%	2.4%	ns

Table19: Comparison of Companies with Employee Samples < 15 and ≥15

Description	<15 n = 243	≥ 15 n = 285	p-value (2-tail)
<u>Company Structure</u>			
no. of employees	74	108	.000
% full time employees (vs. part time)	59.4%	97.5%	.000
% contract employees	3.9%	5.0%	ns
% temporary workers	1.9%	3.5%	.005
teamwork in company	0.60	0.62	ns
production structure	2.00	2.06	ns
# of hierarchy levels	3.49	3.73	.001
<u>Company Health Policy</u>			
basic sick payments by GAK	1.28	1.22	ns
≥1 committees on working conditions	0.43	0.68	ns
mgmt. involved in health problems	2.41	2.29	ns
mid-mgmt. involved in health problems	2.58	2.51	ns
employees involved in health problems	1.71	1.76	ns
use of external help for work environment	0.49	0.73	0.000
prevention budget?	0.01	0.09	0.000
structural physical prevention	0.44	0.55	0.014
structural stress prevention	0.18	0.34	0.000
person-based physical prevention	0.42	0.58	0.000
person-based stress prevention	0.16	0.27	0.001
<u>% Estimates of Workers at Risk</u>			
physical exertion	17.70	16.88	ns
static exertion	12.92	14.76	ns
bend/twist upper body	19.42	13.46	0.009
repetitive motion, arms/hands	15.49	12.11	ns
vibration	3.33	2.74	ns
prolonged sitting	12.28	19.73	0.000
demands	12.14	20.36	0.000
autonomy	12.18	12.08	ns
lack of flexible employment	6.45	7.45	ns
social support	8.03	7.84	ns
skill discretion	9.09	10.81	0.007
<u>Strain and Outcomes</u>			
physical complaints: upper body	0.62	0.70	0.044
stress complaints	0.34	0.46	0.004
% sick leave in 1992	6.81%	6.63%	ns
% turnover in 1992	9.39%	8.91%	ns
% disabled in 1992	1.22%	1.11%	ns
% sick leave > 3 months	2.29%	2.35%	ns

Table 20: Stage II Models; Dependent Variable: Demands

Organizational Measure	Initial: Org. Variables		First Add Discrepancy		First Add Mean		Discrepancy & Mean	
	Beta	Sig.	Beta	Sig.	Beta	Sig.	Beta	Sig.
Company Size	.183	.007					.183	.007
% Temp. Workers								
Self-Insured								
Policy Plan	-.236	.000					-.236	.000
% in Teams	.134	.024					.134	.024
Mgmt. Involvement								
Worker Involvement								
Physical Disc.								
Mean Phys. Risk								
Condition Number	3.75						3.75	
Model R ²	.058						.058	

Table 21: Stage II Models; Dependent Variable: Autonomy Deficit

Organizational Measure	Initial: Org. Variables		First Add Discrepancy		First Add Mean		Discrepancy & Mean	
	Beta	Sig.	Beta	Sig.	Beta	Sig.	Beta	Sig.
Company Size								
% Temp. Workers	.361	.000	.326	.000	.276	.000	.236	.000
Self-Insured								
Policy Plan								
% in Teams								
Mgmt. Involvement								
Worker Involvement								
Physical Disc.			.244	.000			.271	.000
Mean Phys. Risk					.558	.000	.571	.000
Condition Number	1.51		3.98		4.73		6.25	
Model R ²	.127		.182		.431		.501	

Table 22: Stage II Models; Dependent Variable: Skill Discretion Deficit

Organizational Measure	Initial: Org. Variables		First Add Discrepancy		First Add Mean		Discrepancy & Mean	
	Beta	Sig.	Beta	Sig.	Beta	Sig.	Beta	Sig.
Company Size								
% Temp. Workers	.281	.000	.241	.000	.212	.000	.165	.000
Self-Insured	-.118	.040	(-.094)	(.086)	n.s.		n.s.	
Policy Plan								
% in Teams								
Mgmt. Involvement								
Worker Involvement	.137	.017	.146	.008	n.s.		(.078)	(.081)
Physical Disc.			.293	.000			.322	.000
Mean Phys. Risk					.518	.000	.536	.000
Condition Number	5.94		7.65		8.04		9.84	
Model R ²	.115		.197		.370		.470	

Table 23: Stage II Models; Dependent Variable: Soc. Sup. Deficit

Organizational Measure	Initial: Org. Variables		First Add Discrepancy		First Add Mean		Discrepancy & Mean	
	Beta	Sig.	Beta	Sig.	Beta	Sig.	Beta	Sig.
Company Size								
% Temp. Workers								
Self-Insured								
Policy Plan								
% in Teams								
Mgmt. Involvement								
Worker Involvement								
Physical Disc.			.195	.001			.201	.001
Mean Phys. Risk					.267	.000	.272	.000
Condition Number			3.71		4.41		5.94	
Model R ²			.034		.068		.105	

Table 24: Stage II Models; Dependent Variable: Rep. Bend/Twist

Organizational Measure	Initial: Org. Variables		First Add Discrepancy		First Add Mean		Discrepancy & Mean	
	Beta	Sig.	Beta	Sig.	Beta	Sig.	Beta	Sig.
Company Size								
% Temp. Workers	.194	.001	.185	.001	.117	.035	n.s.	
Self-Insured	-.128	.030	-.110	.056	-.121	.026	n.s.	
Policy Plan	.135	.022	.161	.006	(.097	.074)	.139	.002
% in Teams								
Mgmt. Involvement								
Worker Involvement								
Psychosocial Disc.			.215	.000			.652	.000
Mean Psych. Risk					.338	.000	.770	.000
Condition Number	5.27		6.49		7.09		10.9	
Model R ²	.069		.112		.210		.490	

Table 25: Stage II Models; Dependent Variable: Static Bend/Twist

Organizational Measure	Initial: Org. Variables		First Add Discrepancy		First Add Mean		Discrepancy & Mean	
	Beta	Sig.	Beta	Sig.	Beta	Sig.	Beta	Sig.
Company Size								
% Temp. Workers	.159	.007	.153	.009	n.s.		n.s.	
Self-Insured	-.139	.019	-.126	.032	-.132	.019	(-.084	.096)
Policy Plan								
% in Teams								
Mgmt. Involvement	.151	.011	.148	.012	.139	.013	.117	.020
Worker Involvement								
Psychosocial Disc.			.153	.009			.509	.000
Mean Psych. Risk					.319	.000	.622	.000
Condition Number	7.56		8.64		9.19		12.1	
Model R ²	.061		.081		.156		.326	

Table 26: Stage II Models; Dependent Variable: Reaching & Prolonged Postures

Organizational Measure	Initial: Org. Variables		First Add Discrepancy		First Add Mean		Discrepancy & Mean	
	Beta	Sig.	Beta	Sig.	Beta	Sig.	Beta	Sig.
Company Size								
% Temp. Workers	.133	.024	.126	.030	n.s		n.s.	
Self-Insured	-.209	.000	-.195	.001	-.203	.000	-.150	.002
Policy Plan	.120	.041	.140	.017	n.s		.121	.012
% in Teams								
Mgmt. Involvement								
Worker Involvement								
Psychosocial Disc.			.168	.004			.551	.000
Mean Psych. Risk					.352	.000	.674	.000
Condition Number	5.27		6.49		7.09		10.9	
Model R ²	.073		.097		.188		.387	

Table 27: Stage II Models; Dependent Variable: Physical Exertion

Organizational Measure	Initial: Org. Variables		First Add Discrepancy		First Add Mean		Discrepancy & Mean	
	Beta	Sig.	Beta	Sig.	Beta	Sig.	Beta	Sig.
Company Size								
% Temp. Workers	.172	.004	.166	.003	(.101	.075)	n.s.	
Self-Insured	-.185	.002	-.173	.005	-.177	.001	-.128	.010
Policy Plan								
% in Teams								
Mgmt. Involvement								
Worker Involvement								
Psychosocial Disc.			.151	.010			.526	.000
Mean Psych. Risk					.346	.000	.658	.000
Condition Number	4.42		5.54		6.34		9.87	
Model R ²	.061		.081		.174		.355	

Table 28: Stage II Models; Dependent Variable: Management Acts
(No significant Entries from Organizational or Sector Variables)

	Model 1: Disc. Entry 1st					Model 2: Mean Entry 1st			
	Initial: Both Discrepancies		Add Both Means			Initial: Both Means		Add Both Discrepancies	
Organizational Measure	Beta	Sig.	Beta	Sig.		Beta	Sig.	Beta	Sig.
Company Size									
% Temp. Workers									
Self-Insured									
Policy Plan									
% in Teams									
Mgmt. Involvement									
Worker Involvement									
Physical Disc.	-.199	.001	-.190	.001					
Mean Phys. Risk									
Psychosocial Disc.								-.414	.000
Mean Psych. Risk			-.279	.000		-.285	.000	-.516	.000
Branch: Wholesale									
Branch: Industry									
(ref: Bank./Finan.)									
Condition Number	3.71		5.63			4.22		7.31	
Model R ²	.036		.111			.078		.194	

Table 29: Stage III Individual Level Models: MSD and Stress Disorder Indicators on Company Variables & Individual Stressors

	Linear Regression																	
	Mental Strain: Exhaust.		Mental Strain: Tiredness		Physical Strain		Prolonged Sitting Strain		VOEG MSD Indicators		Upper Body Pain		Total Body Pain		Extended Sick Leave (Log ₁₀)		Partial Disability (Log ₁₀)	
	β	Sig.	β	Sig.	β	Sig.	β	Sig.	β	Sig.	β	Sig.	β	Sig.	OR	Sig.	OR	Sig.
<u>Block 1</u>																		
Company Size																		
% Temporary Workers																	-.164	.035
Self-Insured					-.151	n.s.												
Policy Plan					.095	n.s.									.107	.024	-.177	.025
% in Teams																		
Mgmt. Involvement																		
Worker Involvement																		
<u>Block 2</u>																		
Physical Disc. Scale	(.188	n.s.)	.108	.017	.049	.037	.105	.023	(.222	n.s.)	(.174	n.s.)	(.216	n.s.)	(.201	n.s.)		
Psychosocial Disc. Scale	(.134	n.s.)	(.114	n.s.)	-.047	.038			(.135	n.s.)	(.138	n.s.)	(.104	n.s.)			(.193	n.s.)
<u>Block 3</u>																		
Demands	.390	.000	.225	.000														
Autonomy Deficit					.091	.001					.157	.005	.171	.000				
Skill Discretion Deficit			.114	.012	.109	.000	.165	.000	.162	.000	(.099	.052)						
Social Support Deficit	.286	.000	.245	.000	.071	.002	.213	.000	.177	.000	.157	.001	.222	.000	.101	.046	.317	.000
Repetitive Bend/Twist							-.248	.001										
Static Bend/Twist	.161	.000	.180	.000	.165	.000	.562	.000	.213	.000	.277	.000	.278	.000				
Reach./Prolong. Postures			.168	.041	.426	.000	-.250	.000	.280	.000					.386	.000		
Physical Exertion			-.309	.000	.259	.000					-.175	.001						
Management Acts																		
Condition Number	9.49		12.7		14.1		14.2		9.78		10.5		8.82		8.59		7.50	
R ²	.410		.281		.804		.326		.349		.208		.258		.203		.196	

Table 30: Stage III Individual Level Models: MSD and Stress Disorder Indicators on Company Variables & Individual Stressors

	Linear Regression														Logistic Regression			
	Mental Strain: Exhaust.		Mental Strain: Tiredness		Physical Strain		Prolonged Sitting Strain		VOEG MSD Indicators		Upper Body Pain		Total Body Pain		Extended Sick Leave		Partial Disability	
	β	Sig.	β	Sig.	β	Sig.	β	Sig.	β	Sig.	β	Sig.	β	Sig.	OR	Sig.	OR	Sig.
Block 1																		
Company Size																		
% Temporary Workers					(.077	<i>n.s.</i>)					(.040	<i>n.s.</i>)	(.055	<i>n.s.</i>)				
Self-Insured					(-.082	<i>n.s.</i>)												
Policy Plan					(.052	<i>n.s.</i>)	-.033	.021							1.07	.000	0.89	.014
% in Teams																		
Mgmt. Involvement																		
Worker Involvement									(.031	<i>n.s.</i>)					1.11	.030		
Block 2																		
Physical Disc. Scale	(.069	<i>n.s.</i>)	.032	.045	.033	.002	(.064	<i>n.s.</i>)	(.108	<i>n.s.</i>)	(.087	<i>n.s.</i>)	(.097	<i>n.s.</i>)	(1.95	<i>n.s.</i>)		
Psychosocial Disc. Scale																		
Block 3																		
Demands	.324	.000	.166	.000	.044	.000	.069	.000	.052	.000	.074	.000	.081	.000			0.39	.008
Autonomy Deficit	.072	.000	.068	.000	.048	.000	.052	.001	.033	.048	.053	.002	.061	.000			2.76	.025
Skill Discretion Deficit	.039	.014	.120	.000	.080	.000	.088	.000	.044	.009	.059	.001	.051	.003				
Social Support Deficit	.286	.000	.205	.000	.053	.000	.092	.000	.129	.000	.097	.000	.125	.000	1.82	.000	2.07	.011
Repetitive Bend/Twist	-.078	.000			.088	.000	.077	.000	.094	.000	.092	.000	.081	.000	2.06	.000		
Static Bend/Twist	.100	.000			.156	.000	.379	.000	.134	.000			.066	.000				
Reach./Prolong. Postures	.056	.002			.435	.000	-.131	.000	.109	.000			.086	.000	1.91	.001		
Physical Exertion			-.042	.009	.113	.000	-.111	.000	.074	.001								
Management Acts	-.042	.002	-.031	.042							-.031	.044						
Condition Number	12.2		13.9		14.7		12.0		12.3		11.8		11.3		-2LL ₁ : 2865		-2LL ₁ : 863	
R ²	.325		.178		.593		.211		.187		.122		.169		-2LL ₂ : 2712		-2LL ₂ : 839	
															Improve: 153		Improve: 24	
															.000 (7 df)		.000 (4 df)	

COLLECTED FIGURES

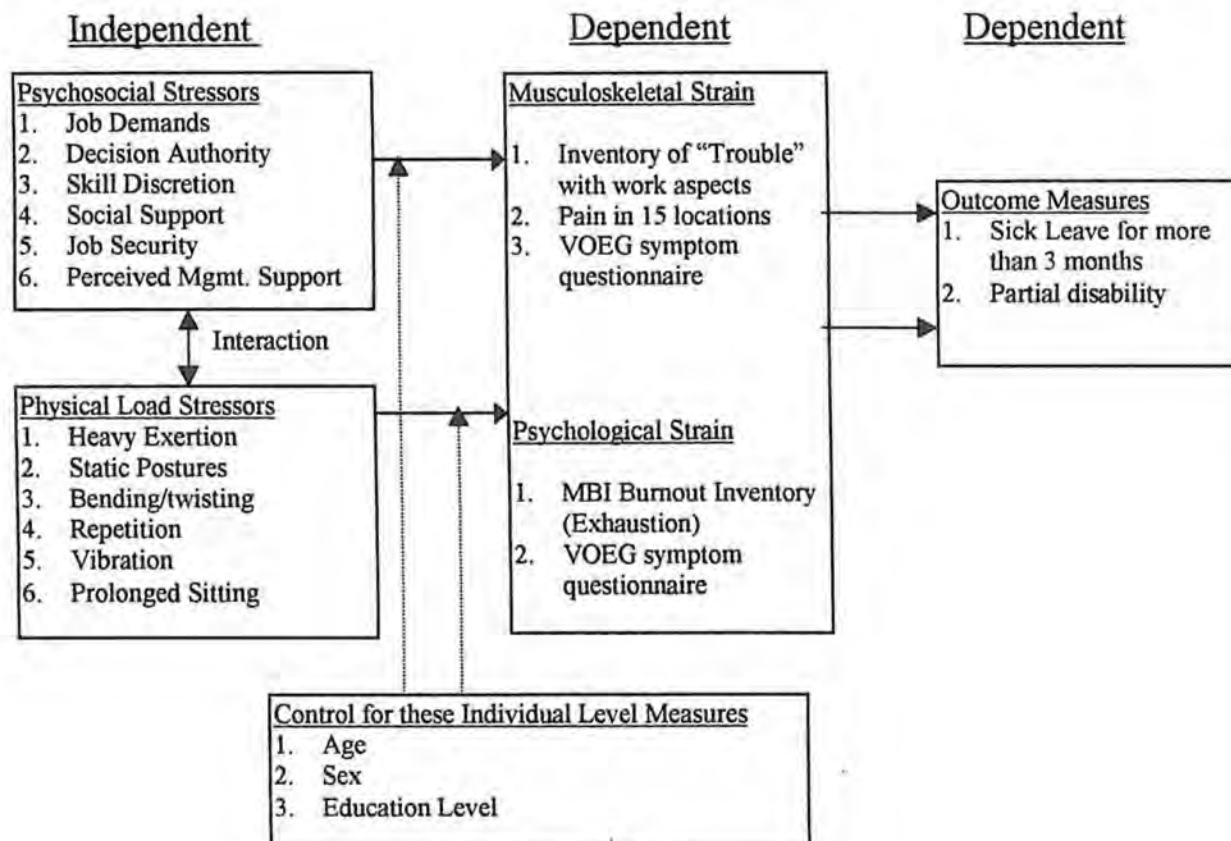


Figure 1: Model for Stage I Analysis

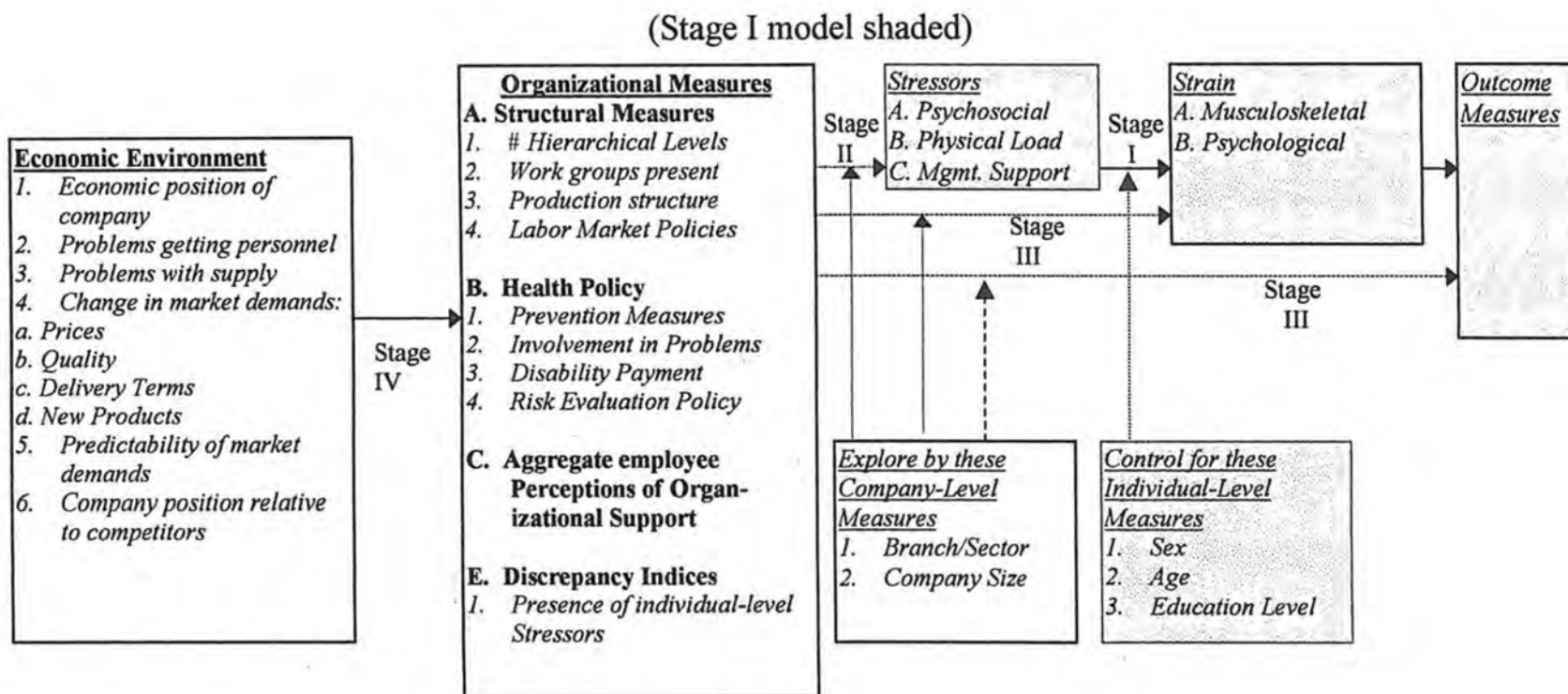


Figure 2: Model for Stage II, III and IV Analysis

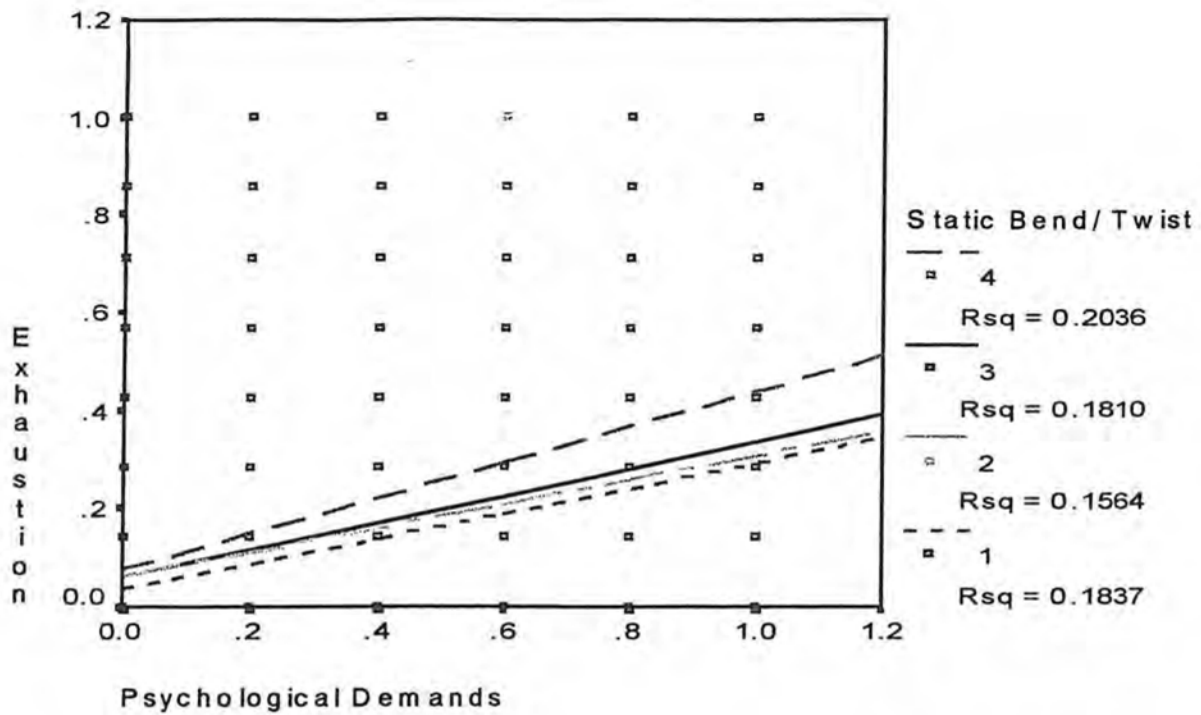


Figure 3: Exhaustion on Psychological Demands, by Quartiles of Static Bend/Twist

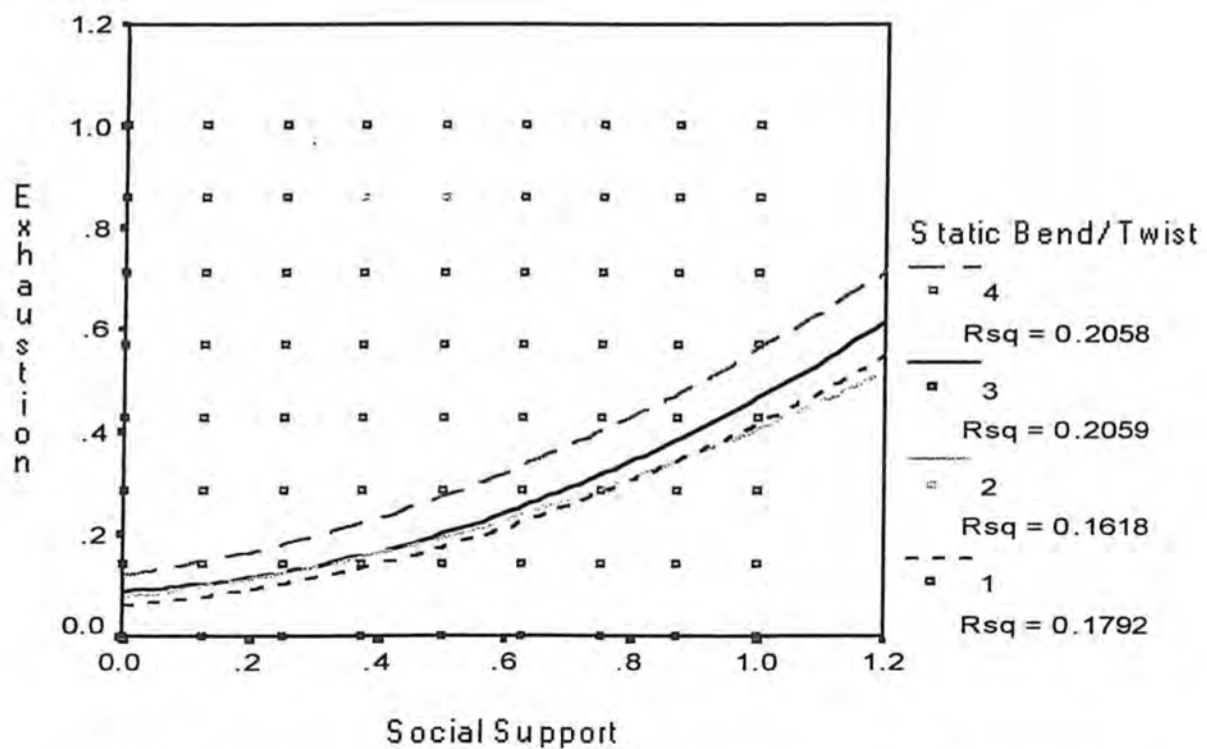


Figure 4: Exhaustion on Social Support Deficit, by Quartiles of Static Bend/Twist

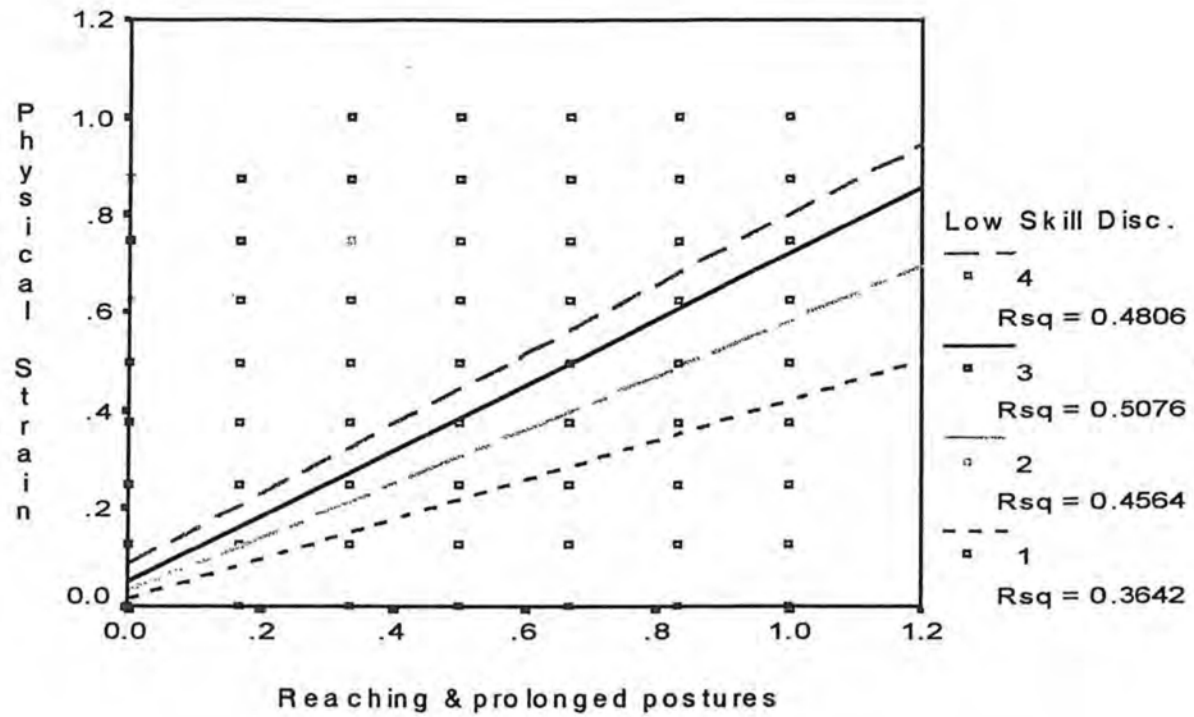


Figure5: Physical Strain on Reach/Prolonged Postured, by Quartiles of Skill Discretion Deficit

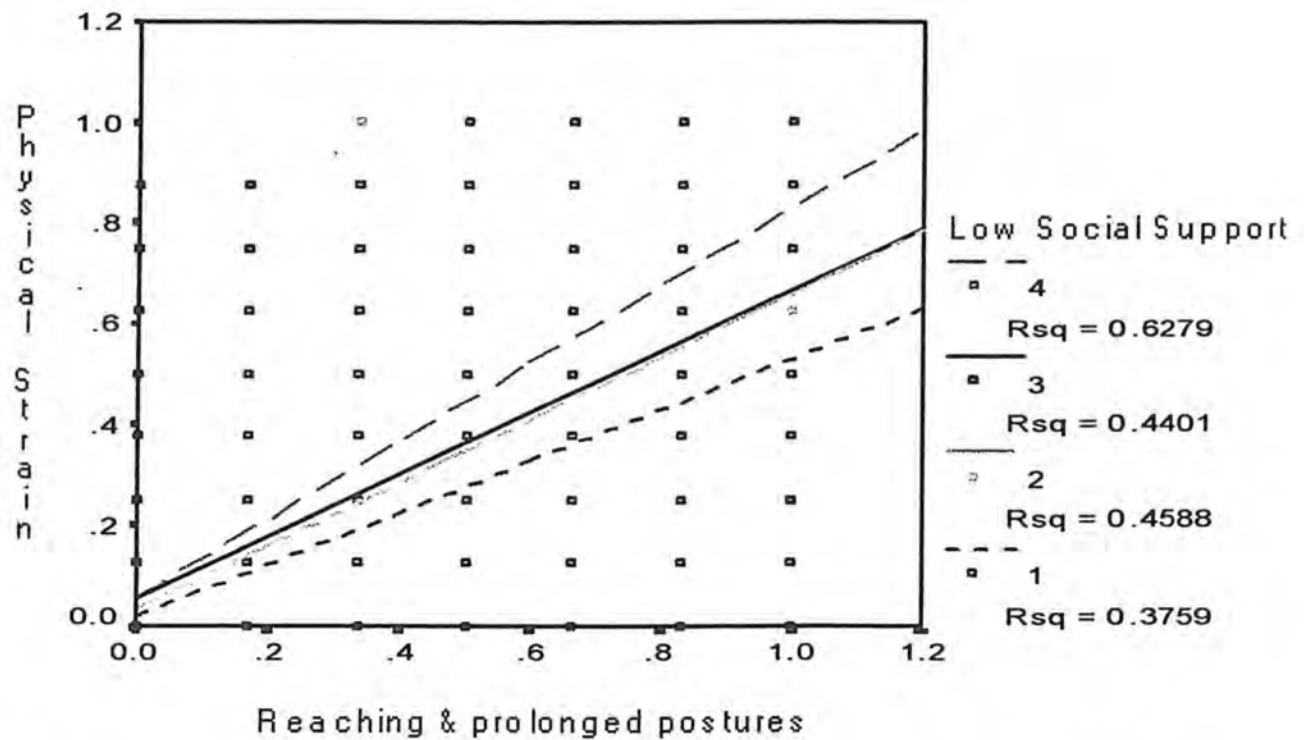


Figure 6: Physical Strain on Reach/Prolonged Postures, by Quartiles of Social Support Deficit

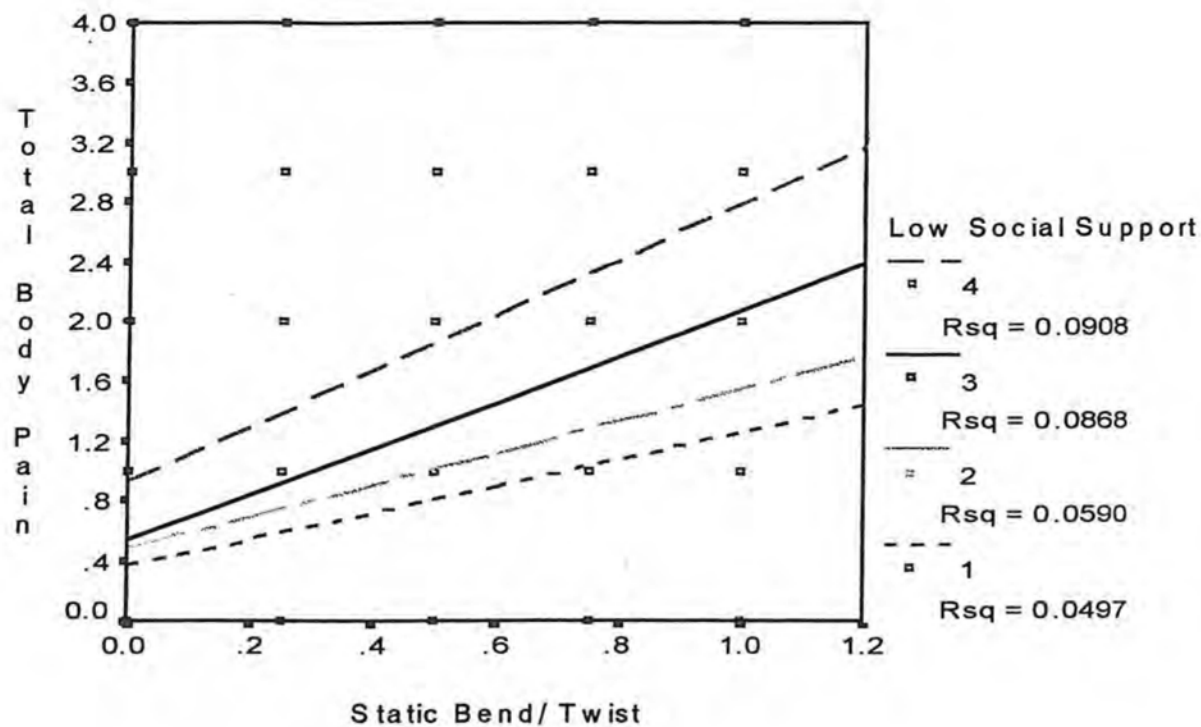


Figure 7: All Body Pain on Static Bend/Twist, Stratified by Quartiles of Social Support Deficit

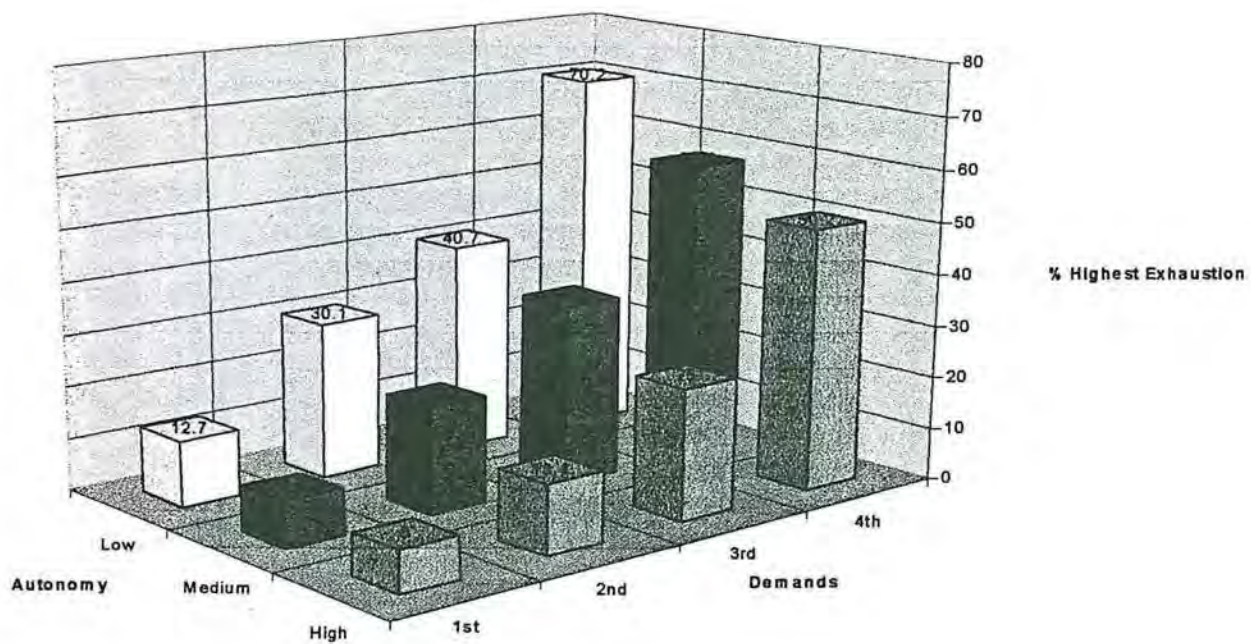


Figure 8: Exhaustion by Levels of Demands and Autonomy

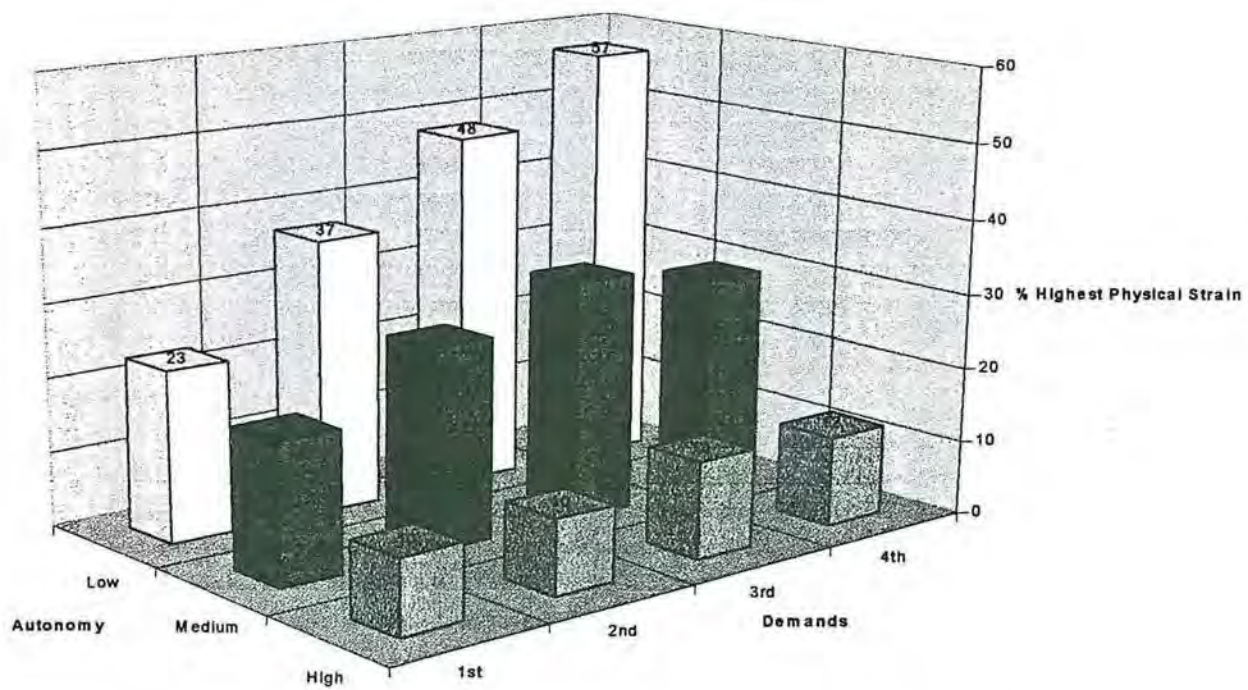


Figure 9: Sum Physical Strain by Demands and Autonomy

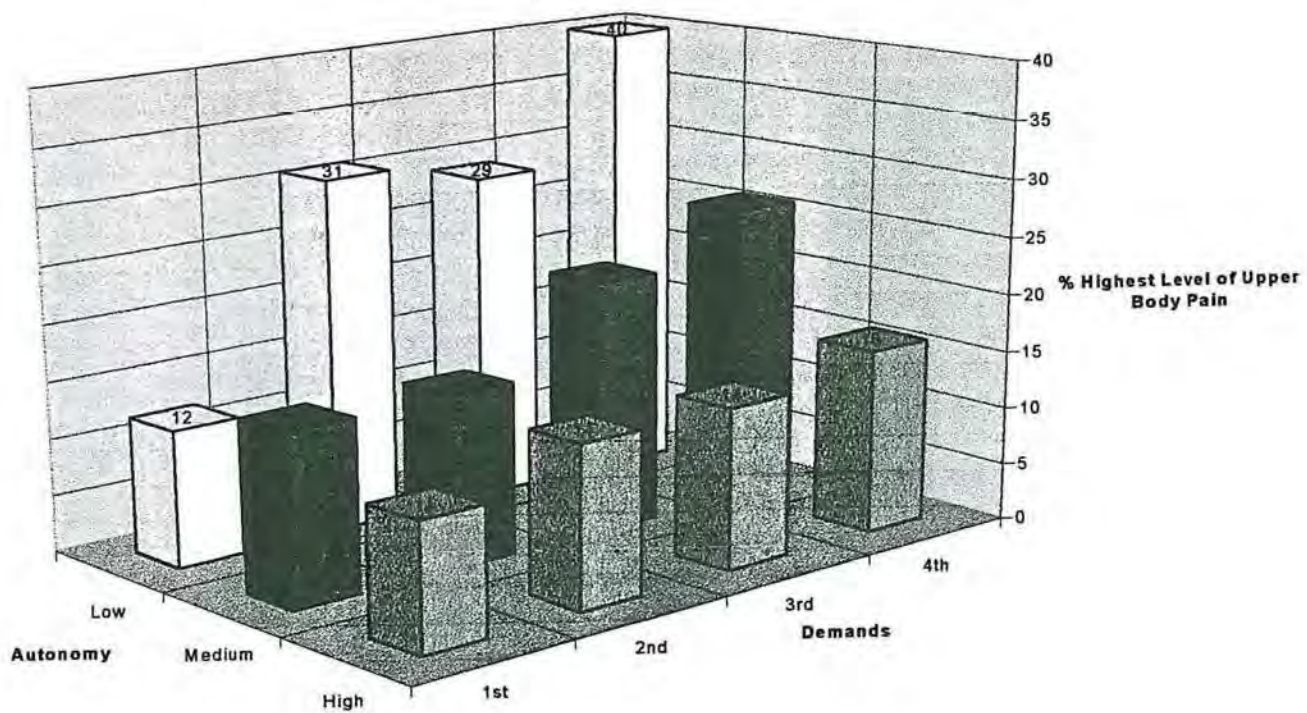


Figure 10: Upper Body Pain by Demands and Autonomy

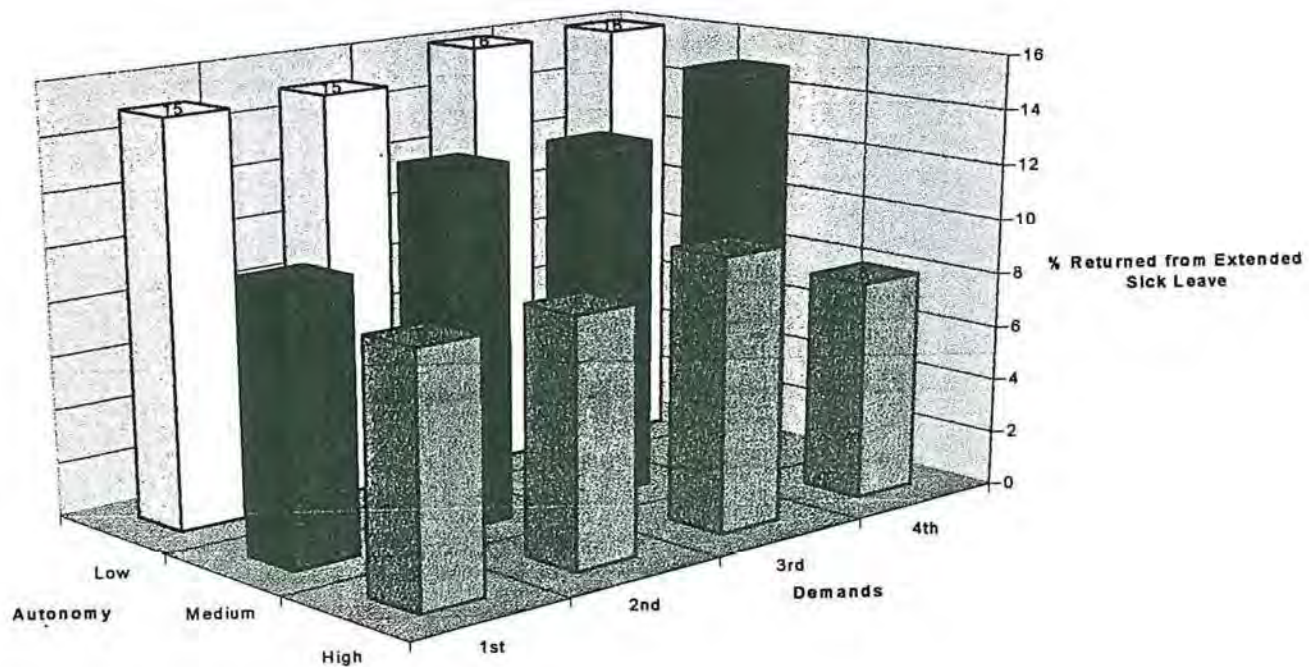


Figure 11: Extended Sick Leave by Demands and Autonomy

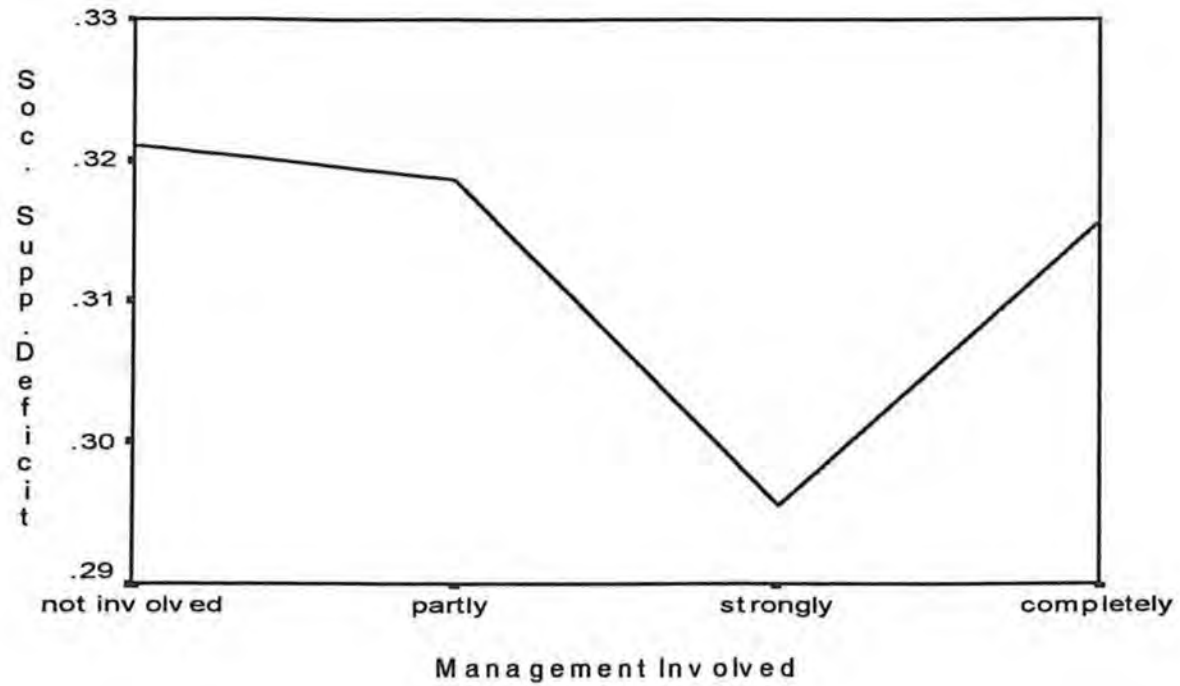


Figure 12: Aggregated Social Support Deficit by Management Involvement

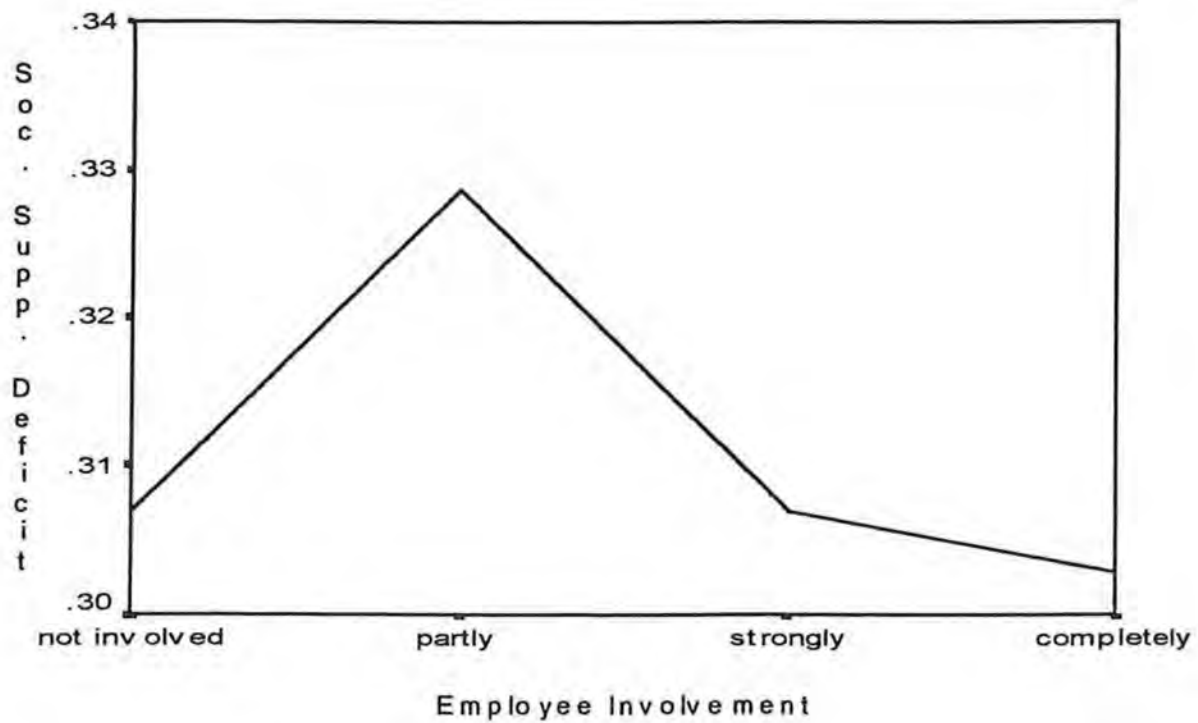


Figure 13: Aggregated Social Support Deficit by Employee Involvement

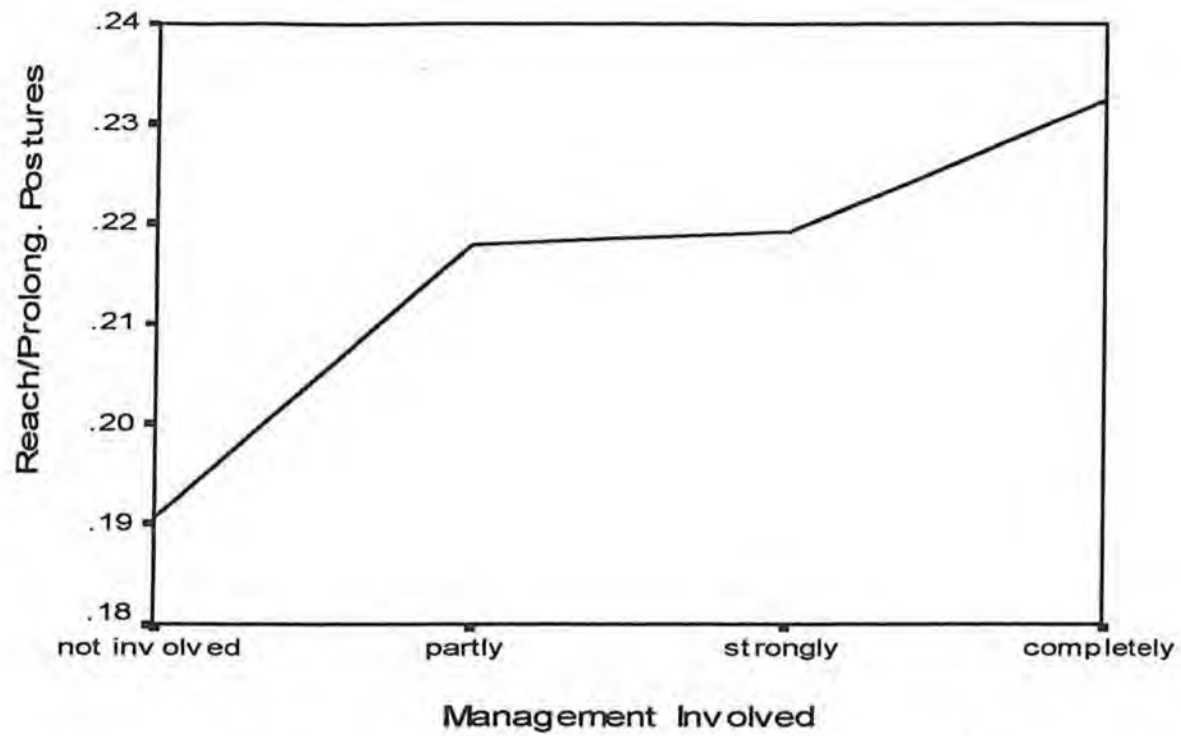


Figure 14: Aggregated Reaching/Prolonged Postures by Management Involvement

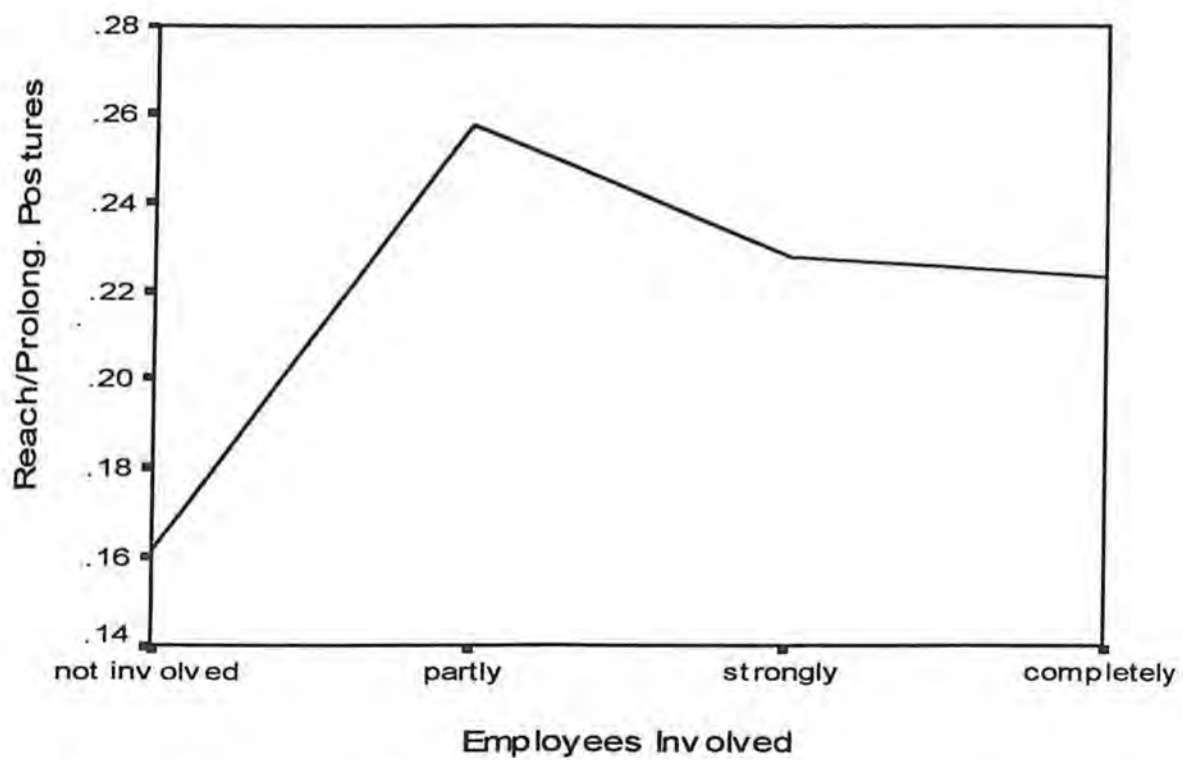


Figure 15: Aggregated Reaching/Prolonged Postures by Employee Involvement

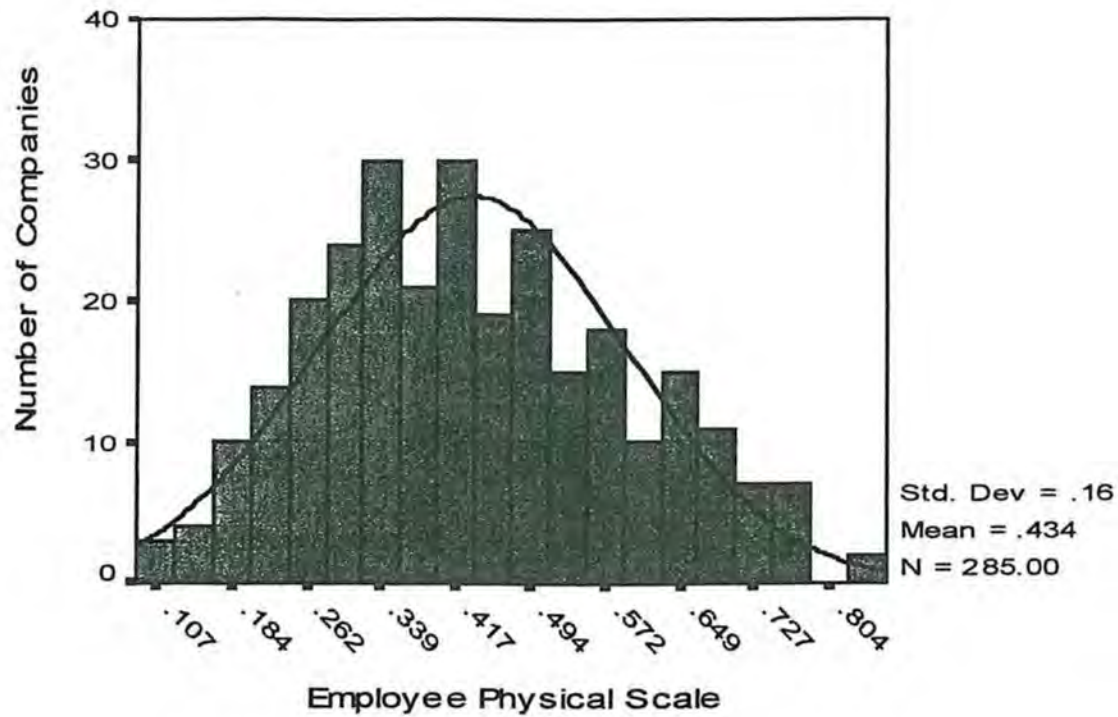


Figure 16: Distribution of Aggregate Employee Physical (Biomechanical) Scale

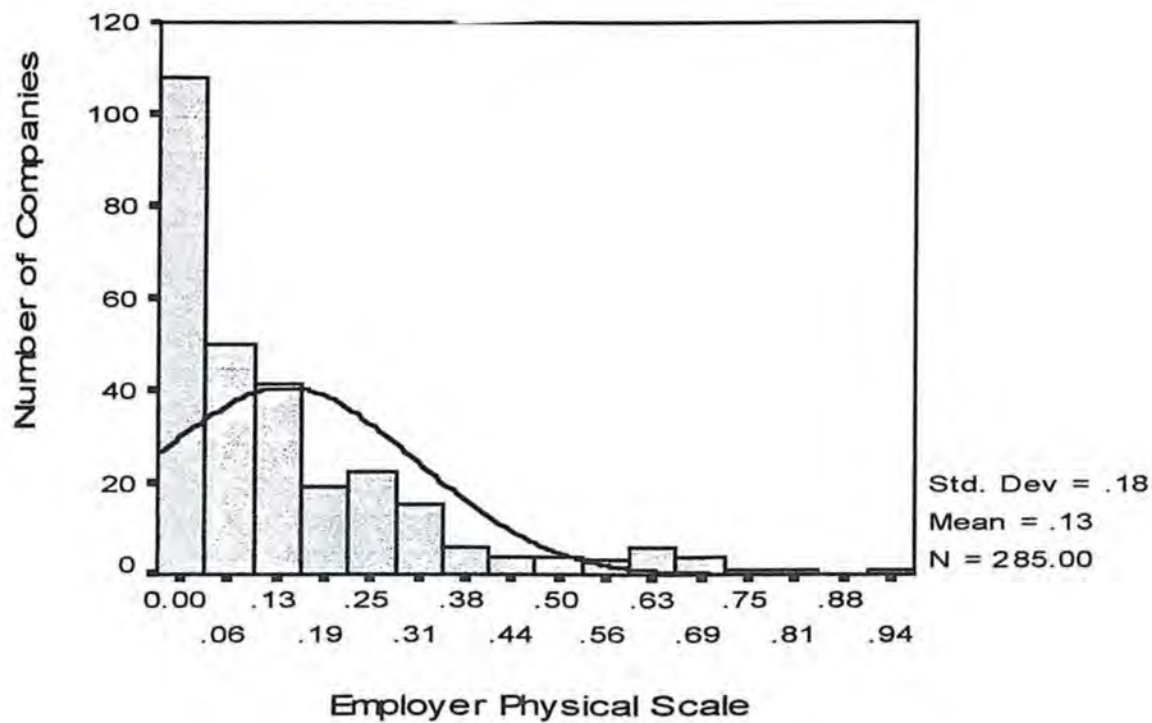


Figure 17: Distribution of Employer Physical (Biomechanical) Scale

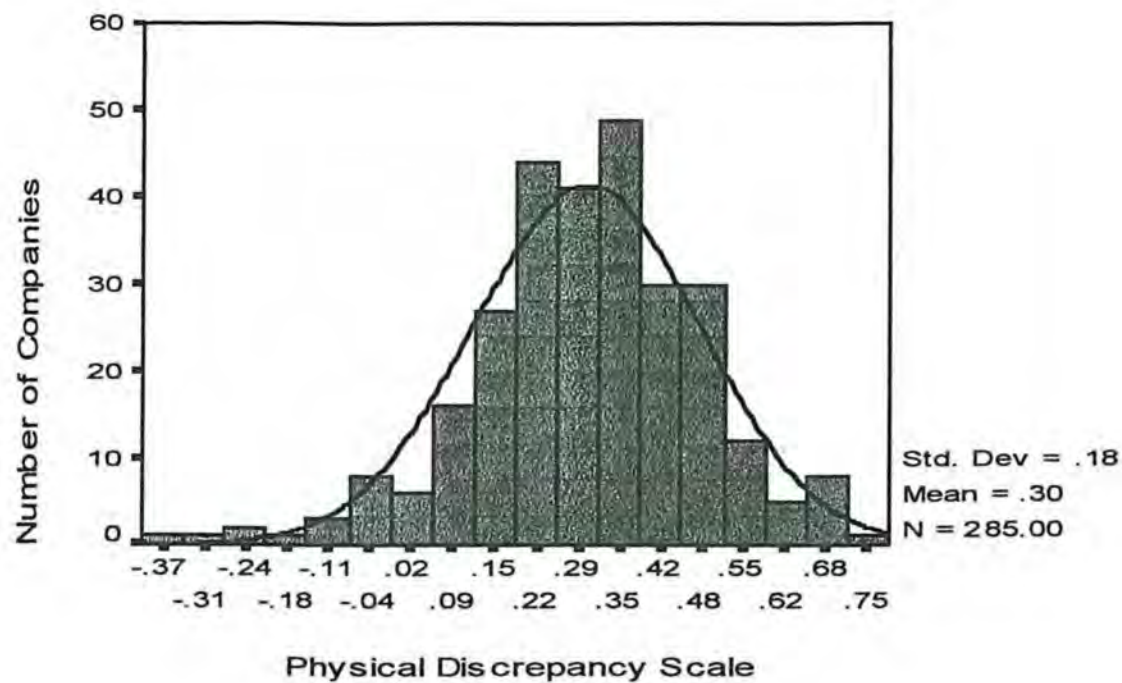


Figure 20: Distribution of Physical (Biomechanical) Discrepancy Scale

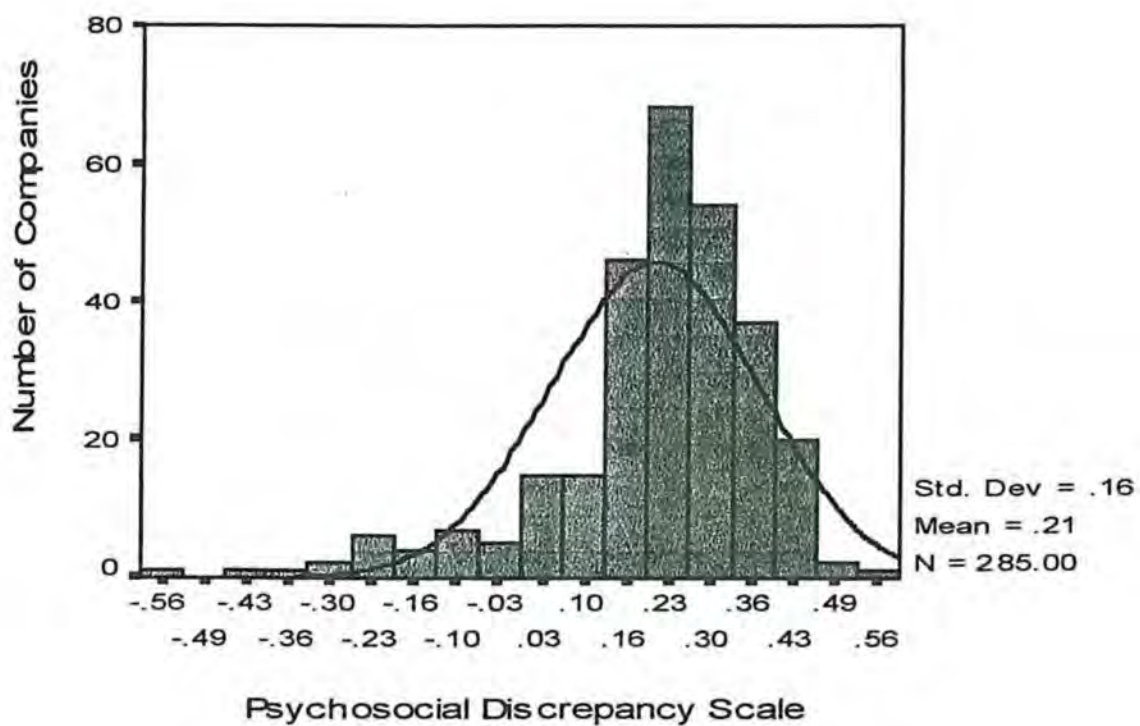


Figure 21: Distribution of Psychosocial Discrepancy Scale

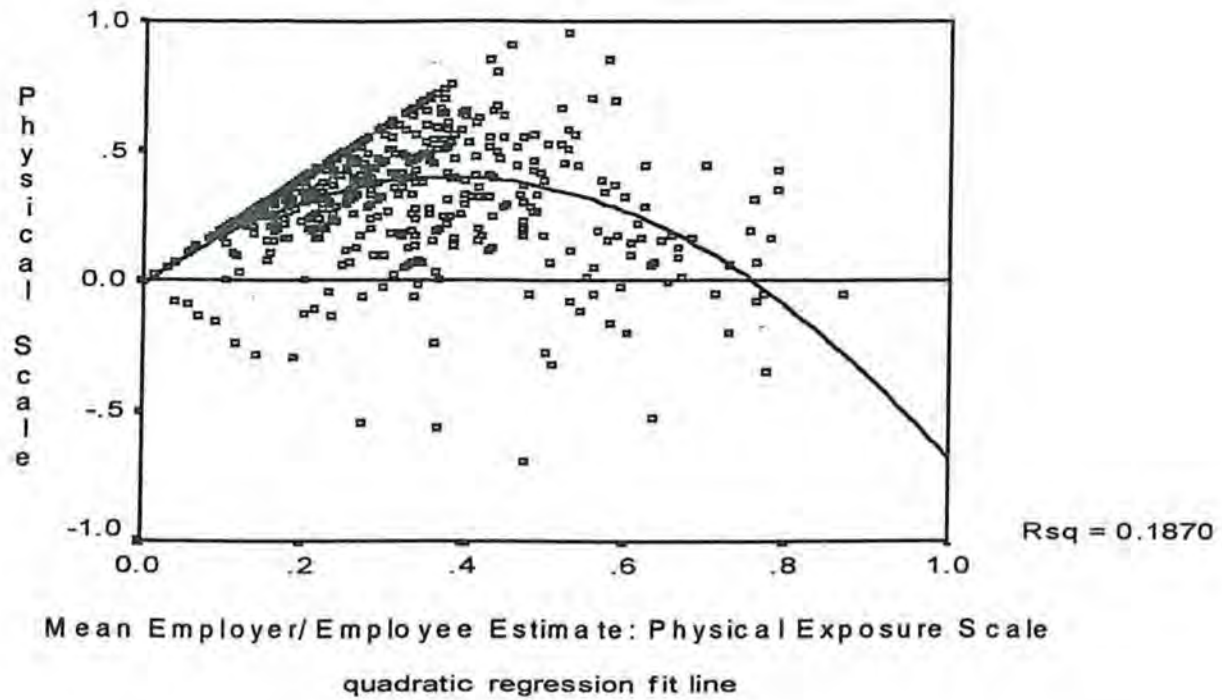


Figure 22: Physical Discrepancy Scale against Physical Mean Scale

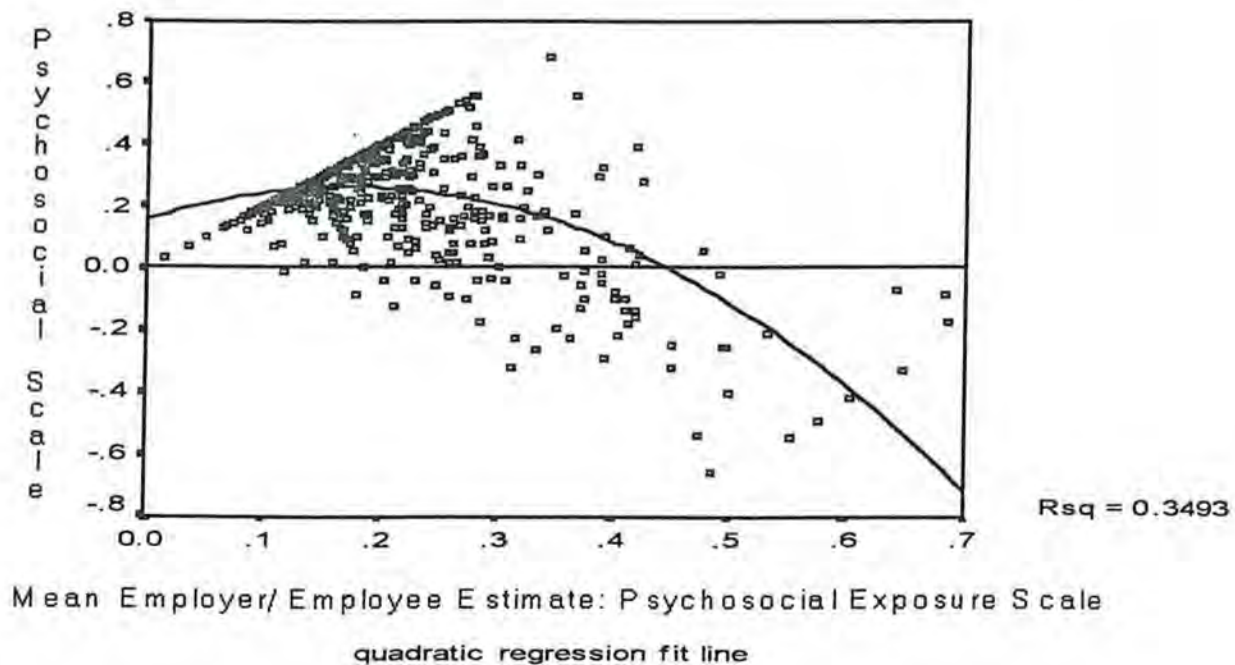


Figure 23: Psychosocial Discrepancy Scale against Psychosocial Mean Scale

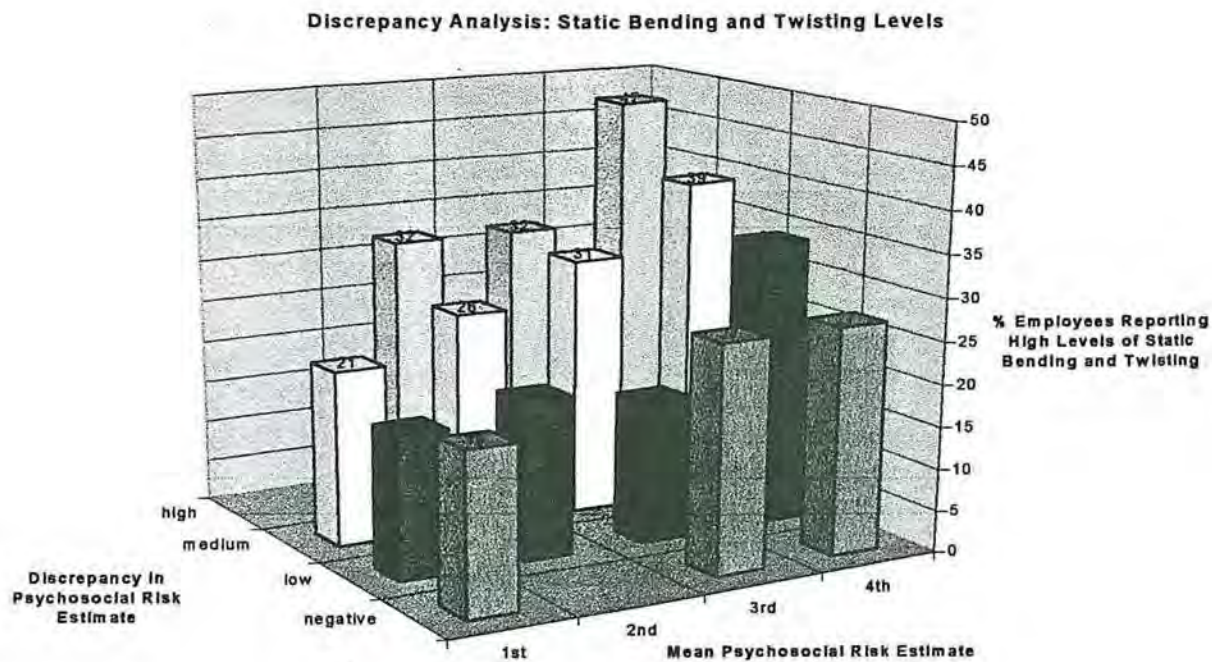


Figure 24: Static Bend/Twist by Psychosocial Discrepancy and Mean Scales

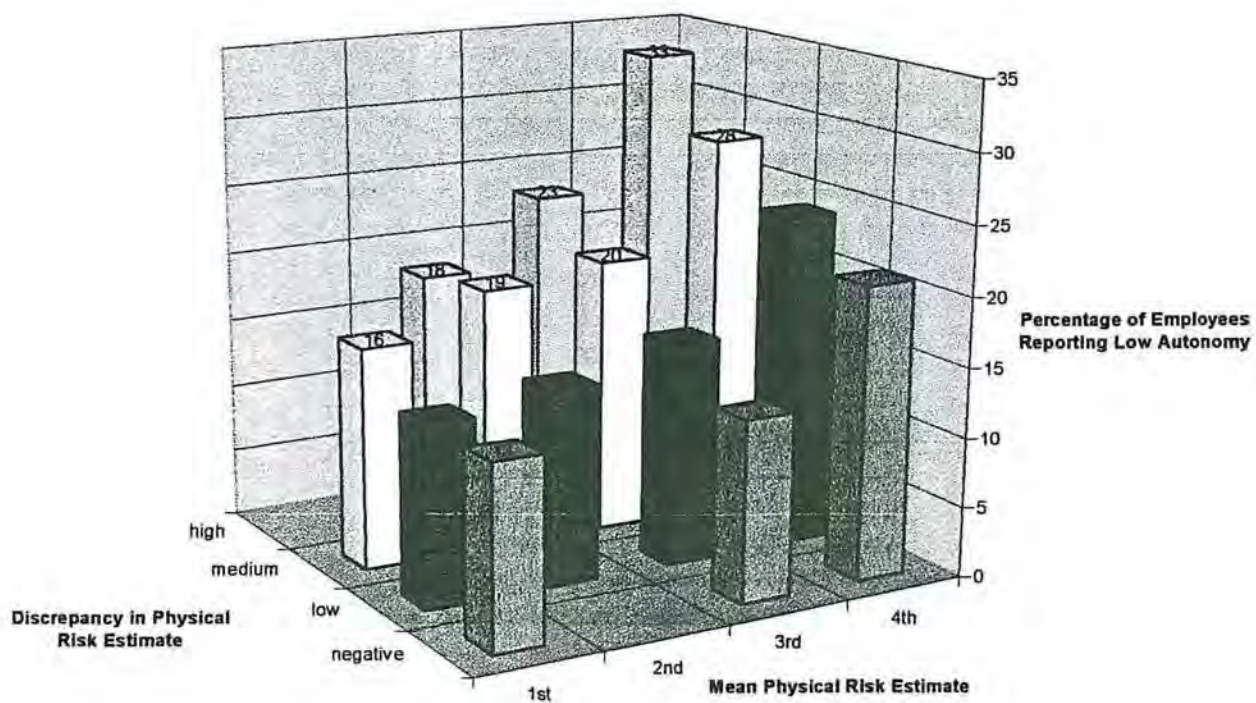


Figure 25: Autonomy Deficit by Physical Discrepancy and Mean Scales