## Characterizing Long-Term Trajectories of Work and Disability Leave

The Role of Occupational Exposures, Health, and Personal Demographics

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**Objective:** This article characterizes trajectories of work and disability leave across the tenure of a cohort of 49,595 employees in a large American manufacturing firm. **Methods:** We employ sequence and cluster analysis to group workers who share similar trajectories of work and disability leave. We then use multinomial logistic regression models to describe the demographic, health, and job-specific correlates of these trajectories. **Results:** All workers were clustered into one of eight trajectories. Female workers (RR 1.3 to 2.1), those experiencing musculoskeletal disease (RR 1.3 to 1.5), and those whose jobs entailed exposure to high levels of air pollution (total particulate matter; RR 1.9 to 2.4) were more likely to experience at least one disability episode. **Conclusions:** These trajectories and their correlates provide insight into disability processes and their relationship to demographic characteristics, health, and working conditions of employees.

**Keywords:** cluster analysis, disability leave, sex, occupational exposure, particulate matter, sequence analysis, short-term disability, sickness absence

A growing body of research explores the complex relationships between health, employment, and disability leave (also known as sickness absence). Transitions from work to disability leave have a range of direct, negative effects on labor force participation,<sup>1,2</sup> employment,<sup>3,4</sup> lifetime earnings,<sup>5</sup> and permanent exclusion from the labor market.<sup>6</sup> Transitions into short- and long-term disability are associated with higher morbidity, mortality, and medical costs,<sup>7</sup> as well as increased psychological distress.<sup>8</sup> Given the significant consequences associated with use of disability leave, studies have explored the health- and job-related factors associated with its onset. A number of health conditions are associated with increased risk of workplace disability, including rheumatoid arthritis,<sup>9–11</sup> diabetes,<sup>12</sup> musculoskeletal problems,<sup>13,14</sup> depression,<sup>15–17</sup> and asthma.<sup>18,19</sup> Aspects of working conditions, including psychosocial factors,<sup>20,21</sup> task monotony,<sup>22</sup> and experienced stress of daily activities, have also been found to be associated with disability leave.<sup>23</sup>

Previous research on these topics, however, is limited by two problems. First, most studies rely on data collected over short time frames, with either restricted or delayed follow up. Such data limit the conclusions that can be drawn about long-term trajectories and

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- Clinical significance: The present findings suggest that job-related and demographic characteristics of individuals—and not simply experienced health conditions—are significant predictors of experiencing a disability leave from work. These findings suggest the benefit of considering job-related exposures in assessing the risk of health-related disability leave.
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may mask significant variation. For example, many studies that observe rates of transitions back to work after a health shock or disability episode find that rates of return to work (a measure of success) are quite high.<sup>24,25</sup> Longer term data, however, come to different conclusions if returns to work are limited in duration. In a study of Ontario workers, the rate of successful returns to employment measured by first return to work is 85%; over a longer follow-up, this rate of success declined to only 50%.<sup>26</sup> Moreover, studies with short-term observation times do not allow a full examination of the dynamics of multiple transitions into disability and are unable to assess how many workers take more than one leave of disability and the correlates of such patterns.

Second, with a few exceptions, most studies on disability leave are focused on European cases, where longitudinal employment and health registry data are more readily available than in the United States. Although these studies have helped to craft a better understanding of the antecedents and sequela of disability leave, conclusions may not be directly generalizable to the US case. The institutional, economic, and political systems in Europe are quite different from the United States, especially as they shape labor law and worker protections.

This study seeks to address these gaps in the literature through two contributions. First, we characterize long-term trajectories of transitions from work into short- and long-term disability leave for a cohort of workers in the United States across a nearly 20year observation window. We make use of payroll data for workers in a large American manufacturing firm; these data are linked to individual-level job characteristics and health claims. Sequence and cluster analysis are used to derive a typology of workers' workdisability transitions. Second, we examine variations in trajectories as a function of employees' job characteristics, health, and demographic characteristics. Multinomial logistic regression is used to model varying likelihood of trajectory membership by worker and job characteristics. We hypothesize that there will be disparate patterns of disability leave among the cohort, and that the increased probability of disability leave will be associated with poor health, less advantageous job characteristics, and higher levels of exposure to poor air quality at work.

## DATA AND METHODS

#### Data

This study employs a set of administrative data, the American Manufacturing Cohort (AMC), that track the employment, health, and disability of a large cohort of workers at a major American manufacturing firm. These data are both dynamic—capturing changes to employees' job characteristics, health, and employment status as they occur—and long term, following individuals for an observation window of nearly twenty years. These data are used to characterize trajectories of work and disability across the employment tenure and to explore variations in trajectory as a function of a worker's demographic characteristics as well as their health and working conditions. We draw on multiple sources of administrative data from AMC. The primary data are human resources (HR)

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records that detail all changes in work status (ie, hiring, firing, retirement, entering or returning from leave status, promotion, and so on) for all employees. We combine these records with health claims and disease diagnoses, data on job characteristics, and measures of physical occupational exposures.

Our analytic sample includes 49,595 individuals employed by the firm at their 26 largest plants (across 15 states) for at least 20 weeks between January 1, 1996 and December 31, 2013. Employment can be both left- and right-censored: individuals could have started working for the firm before this time period and may still be working after it. These data allow for detailed exploration of the interactions between work, disability, health for a large number of employees across much of the life course. Although the sample is not nationally representative, sample characteristics are close to national averages across a number of demographic characteristics.<sup>27</sup>

## Measures

## Measures for Sequences and Cluster Analysis

#### Disability and Leave of Absence Events

The human resources data record every job-related event a worker experienced during the observation window. This includes a time-stamped record of the first day of hire, last day of work, first and last day of short- and long-term disability leaves, and any other administrative leave. Using these reports, we define five mutually exclusive states: working; absent due to short-term disability leave (STD); absent due to long-term disability leave (LTD); on-leave; and having left the company (referred to as "terminated").

STD insurance is an employer-provided benefit for all active, full-time workers. This coverage provides wage replacement during spells of medical work absence of up to 26 consecutive weeks. For hourly employees, work absence due to injury, hospitalization, or outpatient surgery is compensable beginning on the first day of the absence spell; there is a 7-day waiting period for illnesses. STD benefits are offered for most benefits-eligible employees at most firms in the United States, though the degree of wage-replacement coverage varies largely. The firm also offers LTD benefits to all active, full-time employees. LTD coverage is available after STD benefits expire for employees who are deemed "totally disabled" and unable to work. Disability benefits are offered for free at 60% coverage of base pay for nonunionized hourly and salaried workers and 80% for unionized workers. Workers can opt for higher income coverage during benefit enrollment periods. All other forms of leave were coded as Leave of Absence (LOA). This includes family leave, maternity leave, union-based leave, military leave, unpaid leave, paid leave, and leaves due to disciplinary action or suspension.

If an employee leaves the company, they are coded as "terminated" after their last day of work. This is a general term for having left the company and does not differentiate between having been laidoff/fired and voluntary decisions to leave the company. Workers can, and sometimes do, come back to work at the firm, but those rehires are not included in the data; once a worker is terminated once, they are considered a permanent termination. The data do not accurately distinguish workers who leave because of retirement, so terminations due to retirement are included in the termination category.

### Measures for Multinomial Logit Modeling

After we have clustered workers based on their transitions into and out of disability, we examine a number of demographic, job-related, and health characteristics of workers that may be associated with cluster membership.

## Demographic and Employment Variables

Age is defined using date of birth and is standardized to the worker's age on January 1, 2012. Racial category is self-reported

based on HR forms, and includes a classification in which Hispanic is not separately categorized as ethnicity. Tenure is defined as the total time a worker is employed at the firm; it is measured in days worked and aggregated up to year and month. In many cases, a worker's tenure is longer than the observation window. Timevarying characteristics are measured at the baseline year, which is either 1996 for those hired in or before that year, and year of hire for those hired after 1996. Hourly versus salaried work is defined by the job grade and category listed in the HR data and is defined at baseline year. Compensation rate is the standard hourly rate for the worker and does not include overtime pay. W2 wages include the total stated yearly amount of wages listed on their tax documents, including any overtime pay, at baseline year.

## Health Variables

Health measures are counts of inpatient and outpatient hospitalizations for each worker for seven chronic diseases: depression, ischemic heart disease, hypertension, arthritis, asthma, and musculoskeletal conditions. These counts come from the medical records that are linked to the administrative data; disease coding comes from International Classification of Diseases (ICD-9) codes from the medical records.

We also utilize workers' health risk score, a measure of baseline general health. The health risk score, which is produced by Verisk Health, is computed using an individual's Current Procedural Terminology (CPT) and ICD codes and use of health care services from the previous year. These inputs are used to predict an individual's health expenditures in the coming year. The scores are standardized such that a score of 1 indicates that the individual's health expenditures are likely to fall at the median in the following year. Each unit increase predicts a 1-fold increase in expenditures above the median. Past work has shown that these<sup>28</sup> scores are a close measure of general health. Scores are available for all workers on a yearly basis; we use baseline data for every worker.

## **Occupational Exposure Measures**

Within the company, industrial hygiene data have been sampled and collected for over 25 years, and include two measures of air pollution: total particulate matter (TPM) and particulate matter 2.5 (PM 2.5). Both of these measures gauge exposure to acids, organic chemicals, metals, and soil or dust particles that have deleterious health effects.<sup>29</sup> PM 2.5 is a measure of exposure to the smallest such particles-those 2.5 µm in diameter or smallerwhich pose the greatest risk to health. Given the nature of manufacturing work, workers in some jobs and some of the study plants are exposed to extremely high levels of TPM and PM 2.5.30 TPM assessments come from a job-exposure matrix derived from an extensive industrial hygiene database at the company. Occupational exposures are categorized by job titles across plant locations, and individual workers are assigned exposure levels based on their current job title. The occupational exposure measures are available for hourly workers for 13 major plants. Figures S1 and S2, http:// links.lww.com/JOM/A638 in the supplemental materials show the distribution of TPM: those in the top quartile are exposed to total particulate matter on an annual basis of between 2.96 and 24.67 mg/ m<sup>3</sup>. Cumulative exposures, based on a worker's total tenure, are much higher: the top quartile of exposure levels ranges from 39 to  $650 \text{ mg/m}^3$ . More detail on the job exposure matrix can be found elsewhere.<sup>30</sup>

#### Methods

Our empirical strategy consists of two parts. First, we use sequence and cluster analysis to identify individual trajectories of work-disability transitions and group, or cluster, workers with similar trajectories. Second, we use multinomial logistic regression

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to identify worker characteristics associated with membership to a specific cluster.

## Sequence and Cluster Analysis

The human resources data described above allow us to create a matrix of worker-months spanning 49,595 workers over 216 months (running from January 1996 to December 2013). Each month is coded with one of the five previously described states: working, on short-term disability, on long-term disability, on other forms of leave, terminated (no longer working at the company). A month is coded as "disability" if an episode of disability leave spans any part of that month. Figure 1 presents a schematic of the matrix of trajectories. We then use cluster analysis to group workers by similar work-disability trajectories. We attempt clustering using a number of algorithms and find the most robust results (judging by average silhouette width) with the Partitioning Around Medoids (PAM) method. This method yields eight clusters that we in turn reduce to four composite groups (described below).

We then use multinomial logistic regressions to examine the associations between a number of demographic, job, and healthrelated characteristics and membership in the four composite groups. All regressions include plant and year fixed effects and are relative to the probability of being in the "Regular Work" typology (described below). All time-varying covariates are included only for the first year when the worker is observed in the data, with the exception of TPM, which is measured in the last observed year, and health-related inpatient and outpatient, which are summed over a worker's tenure in the observation window.

The result of our cluster analysis is a categorical variable that assigns each worker to one cluster. We replicate the analysis using a continuous measure of work disruptions: observed turbulence. Turbulence is a continuous variable that is based on the number of distinct subsequences that can be extracted from each sequence as well as the variance in duration of subsequences.<sup>31,32</sup> We use zero-inflated regressions to model turbulence; results are reported, along with details on the turbulence measures, in the Supplemental Materials (http://links.lww.com/JOM/A638).

## RESULTS

## **Description of Work-Disability Clusters**

The clustering process described above yields eight groups (ASW of 0.723). Two of these clusters center on patterns of continuous work with no disability; five clusters describe tenures with increasingly frequent disability spells; the final eighth cluster includes all workers who use long-term disability benefits. Although HR data are available for all 49,595 workers, we focus subsequent analyses on the 28,843 workers for whom all covariates are present. Table 1 provides descriptive statistics for this sample of 28,843 workers and then for workers in seven of the eight clusters (the eighth cluster, which includes those workers who experience LTD, is described in Table 2).

We reduce these clusters to four composite groups defined by the frequency of interruptions to work: "regular work," "short STD," "disruptive work," and a group for workers who have ever been on LTD ("Ever LTD"). Descriptive statistics for these four groups are provided in Table 2. Note that there are large gradients in risk score across the different clusters, with workers in clusters with more transitions into disability having higher health risk scores, implying poorer health. Figure 2 displays the sequence distribution plots for the groups. Sequence distribution plots can be read as the relative proportion (of 100%) of the sample (y-axis) in a particular state at a particular date (x-axis).

The "regular work" group is made up of two large clusters: longer-term workers who are relatively free of injury and disability, as well as a group of younger workers who start at the firm and leave soon afterward. The largest cluster is of employees who work regularly and then leave the firm permanently. Workers in this cluster have a younger average age and have shorter tenure at the company than workers in other clusters (ANOVA tests, *F*-statistic = 462, P < 0.001; *F*-statistic = 118.19, P < 0.001, respectively). The second group is made up of those in continuous work who are right-censored. This group is also younger and works longer. These two groups represent a large majority (54%) of all workers in our sample.

ID	<u>Month 1</u> (Jan. 1996)	Month 2	<u>Month 3</u>	<u>Month 214</u>	<u>Month 215</u>	<u>Month 216</u> (Dec. 2013)
111	Unhired	Work	Work	STD	Work	Terminate
112	Work	Work	Leave	Work	Work	Work
113	Work	STD	STD	Work	STD	Work
114	Work	Work	Work	Work	Work	Work

## Fictional example full trajectories data

Example of condensed, distinct-state-sequence form for above data

ID	State1	State2	State3	State4	State5
111	Unhired	Work	STD	Work	Terminate
112	Work	Leave	Work		
113	Work	STD	Work	STD	Work
114	Work				

FIGURE 1. Stylized schematic of data and data reduction used in sequence and cluster analysis.

	Full Sample		Cluster: Work		Cluster: Work-Term		Cluster: Work-STD-Work	
Personal Characteristics	Mean/Percent	SD	Mean/Percent	SD	Mean/Percent	SD	Mean/Percent	SD
Age	52.6	12.0	47.6	53.5	53.5	10.7	66.3	4.6
Male	82		86		84	0.38	91	
Ethnicity								
White	80		82		83		91	
Black	10		7		8		5	
Other	10		11		9		4	
Job characteristics								
Unionized	51		35		59		48	
Tenure, yrs	13.4	9.3	12.0	15.4	15.4	8.7	18.0	9.2
Wages (W2, 2012 dollars)	42,440	21,706	49,216	43,348	43,348	24,112	39,730	27,840
Smelter plant	39		37		0.45	0.47	57	
Hourly worker	75		57		0.83	0.47	69	
Health (number of inpatient an	d outpatient visits)							
Risk score	1.00	1.29	0.72	1.00	1.00	1.02	1.21	1.29
Asthma	0.46	2.83	0.25	0.45	0.45	1.85	0.41	1.83
Arthritis	1.83	4.47	0.85	1.73	1.73	3.21	1.72	4.10
Depression	0.26	1.32	0.14	0.23	0.23	1.09	0.15	0.96
Diabetes	1.75	6.72	0.84	1.71	1.71	5.95	2.58	7.36
Ischemic heart disease	0.74	3.53	0.16	0.87	0.87	2.34	1.13	4.05
Hypertension	3.18	6.54	1.93	3.56	3.56	5.56	4.88	7.67
Musculoskeletal	0.69	1.55	0.30	0.67	0.67	0.95	0.56	1.22
Ν	28,843		4,755		2,970		2,330	

## **TABLE 1.** Descriptive Statistics for Full Covariate Sample and Seven Clusters of Workers.

Descriptive Statistics for Full Covariate Sample and Seven Clusters (cont.)

	Cluster Work-ST Work-Ter	: D- rm	Cluster: W STD-Wor STD-Wor	ork- 'k- rk	Cluster: Worl Work-STD-Wo Work-STD-Wo Work	k-STD- rk-STD- rk-STD-	Cluster: Worl Work-ST Work-STD-	k-STD- D- Work
Personal Characteristics	Mean/Percent	SD	Mean/Percent	SD	Mean/Percent	SD	Mean/Percent	SD
Age	52.8	11.9	55.1	10.5	53.6	8.4	54.8	9.8
Male	77		83		72		79	
Ethnicity								
White	24		82		83		80	
Black	13		10		11		12	
Other	11		8		6		8	
Job characteristics								
Unionized	59		69		81		73	
Tenure, yrs	12.9	9.3	16.6	8.9	18.4	8.0	16.8	8.7
Wages (W2, 2012 dollars)	40,532	18,968	42,002	16,433	41,472	13,501	42,036	14,860
Smelter plant	37		46		45		44	
Hourly worker	82		90		97		94	
Health (no. of inpatient and ou	tpatient visits)							
Risk score	1.12	1.80	1.14	1.49	1.35	1.52	1.25	1.34
Asthma	0.53	3.48	0.64	2.69	1.37	5.61	0.88	5.02
Arthritis	1.88	4.43	2.76	5.28	6.02	8.49	3.68	6.19
Depression	0.28	1.34	0.37	1.61	0.86	2.49	0.52	1.96
Diabetes	1.69	6.51	2.59	8.28	3.64	10.23	3.03	9.81
Ischemic heart disease	0.78	3.40	1.31	4.65	1.95	6.05	1.66	5.35
Hypertension	3.16	6.42	4.44	7.71	5.79	8.88	5.04	8.47
Musculoskeletal	0.75	1.44	1.12	1.91	2.37	2.95	1.54	2.34
Ν	3,093		2,867		1,043		2,298	

Three of the clusters involve regular work followed by one or two periods of short-term disability; these are combined in the "Short STD" group. Together, these workers represent 22% of the sample. The mean age of workers in these clusters is approximately 2 years older than those in the "Regular Work" clusters; years of tenure are fairly similar. "Disruptive Work" and make up 22% of the sample. These workers are, on average, older (*F*-statistic = 118.19, P < 0.001) and have shorter tenure with the company (*F*-statistic = 462, P < 0.001), suggesting that these workers may have started work at older ages. They have worse health than in any other cluster, as measured by both the number of outpatient and inpatient hospitalizations for a variety of chronic diseases and by the composite risk score measure of health (*F*-statistics = 140, P < 0.001).

Two clusters are characterized by three or more periods of short-term work disruptions; these are grouped together as

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	Full Sample		Type: Regular Work		Type: Some STD		Type: Disruptive Work		Type: Long-Term Disability	
	Mean/Percent	SD	Mean/Percent	SD	Mean/Percent	SD	Mean/Percent	SD	Mean/Percent	SD
Personal characteris	stics									
Age	52.6	12.0	51.50	12.74	53.21	11.70	54.77	9.91	55.3	9.34
Male	82		83		81		80		81	
Ethnicity										
White	80		80		79		82		75	
Black	10		9		11		11		19	
Other	10		11		10		7		6	
Job characteristics										
Unionized	51		40		58		70		28	
Tenure, yrs	13.4	9.3	11.8	9.2	14.0	9.1	16.8	8.7	12.3	7.7
Wages (W2)	42,440	21,706	42,911	24,720	41,838	19,104	41,895	15,450	40,520	19,758
Smelter plant	39		37		41		45		42	
Hourly worker	75		65		82		92		64	
Health (no. inpatier	nt and outpatient v	visits)								
Risk score	1.00	1.29	0.87	0.96	1.07	1.58	1.24	1.57	1.64	2.78
Asthma	0.46	2.83	0.29	1.89	0.49	2.94	0.85	4.20	0.79	2.81
Arthritis	1.83	4.47	1.04	3.17	1.82	4.09	3.73	6.46	4.30	7.19
Depression	0.26	1.32	0.16	1.00	0.26	1.20	0.52	1.92	.55	1.59
Diabetes	1.75	6.72	1.27	5.54	1.72	6.24	2.92	9.15	2.74	8.04
Heart disease	0.74	3.53	0.37	2.25	0.83	3.81	1.55	5.21	1.54	6.30
Hypertension	3.18	6.54	2.40	5.47	3.34	6.57	4.91	8.28	4.46	8.32
Musculoskeletal	0.69	1.55	0.33	0.94	0.72	1.41	1.52	2.34	1.82	2.51
Ν	28,843		15,438		6,232		6,474		699	

<b>TABLE 2.</b> Descriptive statistics for run covariate sample and rifee cluster droupings	TABLE 2.	Descriptive	Statistics for	r Full Covariate	Sample and	Three Cluster	Groupings
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Finally, the last cluster consists of all workers that ever spend some time on the long-term disability, which constitutes 1.65% of the sample. Workers in the "Ever LTD" cluster are, on average, older and have shorter tenures at the firm. Perhaps not surprisingly, their baseline health, as measured by risk score, is worse than in any other group and counts of inpatient and outpatient visits for all diseases is higher.

# Demographic and Employment-Related Correlates of Cluster Membership

Multinomial regression predicting group membership reveals a number of significant patterns related to employee demographics, health conditions, and work characteristics (see Table 3). Sex is significantly associated with membership: being female increases the risk of inclusion in both the "Short STD" and "Disruptive Work" groups significantly<sup>1</sup> (P < 0.001 for both), but not for the risk being in the LTD cluster.

There are a number of reasons, short of initial selection into the workforce, why women in this cohort have more than twice the likelihood of entering into disruptive work as men. Women work different jobs than men. These jobs may be either more physically demanding than the jobs men are working or, perhaps, have higher levels of exposure to total particulate matter. We test this explanation in a number of ways. First, given extant literature on gender segregation across occupations,<sup>33,34</sup> we explore the distribution of women and men in jobs based on their job grade, a rough approximation for the prestige of job (jobs with higher job grades are more likely to be salaried and/or managerial). Results can be found in the supplemental materials. We observe very little difference in the job distribution of men and women at the company based on job grade. Second, we examine the distribution of sex by total particulate matter (Supplemental Materials, Figure 4, http://links.lww.com/ JOM/A638). Here we do observe sizeable differences between men and women: women have much higher representation in low-TPM-exposure jobs at both the start of their tenure at the firm and cumulatively. As such, the sex effect we observe does not appear to be related to women being disproportionally exposed to particulate matter. Finally, we ask whether women, despite being in lower-TPM-exposure jobs, may be disproportionally susceptible to TPM exposure (Supplemental Material, Table 2, http://links.lww.com/ JOM/A638). Again, we find little evidence of this. Interaction effects in the multinomial models between sex and total particulate matter exposure are not statistically significant.

## Health-Related Correlates of Cluster Membership

The number of inpatient and outpatient hospitalization visits for heart disease, hypertension, and musculoskeletal conditions are all associated with significantly lower odds of membership in the "Regular Work" clusters. Health appears to be particularly strongly associated with work trajectories in the "Disruptive Work" group, as well as the likelihood of ending up in LTD (P < 0.0001 for both). A one standard deviation in risk score increases the odds of inclusion in the "Disruptive Work" group by more than 40%. Inpatient and outpatient visits for arthritis, heart disease, hypertension, asthma, and depression all increase the risk of inclusion in this category, and musculoskeletal disease is, by far, the leading health condition associated with likelihood of disruptive work trajectories (P < 0.0001).

## Job-Related Correlates of Cluster Membership

We also explore job characteristics and job exposures in these models. Salaried employees are more likely to fall into one of the three clusters (ie, Short STD, Disruptive Work, Ever LTD) that are not Regular Work (P < 0.0001, P < 0.0001, P < 0.008, respectively). Exposure to cumulative total particulate matter increases the odds of inclusion in both "Short STD" and "Disruptive Work" (with highest odds for the latter). Of particular importance,

<sup>&</sup>lt;sup>1</sup> Pregnancy leaves and family leave are excluded from the definitions of our STD classification, so it is unlikely that pregnancy is the reasons for the observed sex effect.



**FIGURE 2.** Sequence distribution plot for the entire sample (N = 49,595) for the seven original clusters aggregated into three groups. Sequence distribution plots can be read as the relative proportion (of 100%) of the sample (y-axis) in a particular state at a particular date (x-axis).

cumulative exposure to TPM is strongly associated with work disruption: workers in the top quartile of cumulative exposure are 2.5 times more likely to have disruptive work trajectories. Figure 3 displays the predictive margins for the work-disability clusters for quartiles of particulate matter exposure. These associations also hold for work exposures at the beginning of employee's work trajectories. Workers who start their tenure at the company in jobs in the top quartile of environmental exposure are 1.5 times as likely to end up experiencing a disruptive work trajectory (P < 0.001) and 1.3 times more likely to end up with at least some short-term disability (P < 0.001).

We also observe a positive effect of wages, as measured by baseline W2 reports, on likelihood of falling into any of the groups defined by disability events. There are a number of mechanisms that may underlie this effect. One possibility is that those exposed to higher TPM receive higher wages. We see an interaction between first year annual wages and total annual and cumulative TPM exposure, suggesting that there may be some direct or indirect "hazard pay" in which workers who are differentially compensated accordingly (Supplemental Materials, Table 2, http://links.lww.com /JOM/A638).

Results for the group of workers in the "Ever LTD" show a number of distinct patterns. Although there is no association with



**FIGURE 3.** Marginal predicted probability of being in regular work by cumulative TPM exposure quantile (relative to "Short STD" or "Disruptive Work").

	(2)	(3)	(4)
Variables	Some STD	<b>Disruptive Work</b>	LTD
Age (January 2012)	0.986*** (0.00286)	0.961*** (0.00299)	0.993 (0.0106)
Female	1.250*** (0.0921)	2.037*** (0.148)	1.345 (0.381)
Race/ethnicity (baseline = white)			
Black	1.094 (0.0869)	1.073 (0.0882)	2.163***(0.573)
Other	1.008 (0.0805)	0.947 (0.0816)	0.936 (0.333)
Job characteristics			
Tenure, yrs	1.038*** (0.00540)	1.072*** (0.00556)	0.970* (0.0163)
W2 (log)	1.108*** (0.0198)	1.206*** (0.0278)	1.094* (0.0531)
Smelter	0.952 (0.0530)	0.999 (0.0564)	0.401*** (0.112)
Hourly	1.015 (0.107)	1.239* (0.146)	0.129*** (0.0312)
Health characteristics			
Health risk score (baseline)	1.211**** (0.0544)	1.329*** (0.0663)	$1.280^{***}$ (0.0889)
Asthma	1.009 (0.0125)	1.031** (0.0124)	1.030 (0.0212)
Arthritis	1.032*** (0.0109)	1.084*** (0.0123)	1.097*** (0.0166)
Depression	1.045 (0.0282)	1.129*** (0.0326)	1.139*** (0.0443)
Diabetes	0.996 (0.00350)	1.008** (0.00337)	1.012 (0.00826)
Ischemic heart disease	1.050*** (0.00947)	1.085*** (0.00959)	$1.092^{***}$ (0.0225)
Musculoskeletal disease	1.319*** (0.0348)	1.548*** (0.0412)	1.699*** (0.0613)
Occupational exposure (particulate matter 2	.5)		
Quantile 2	1.454*** (0.103)	1.864*** (0.143)	1.360 (0.363)
Quantile 3	1.521*** (0.116)	2.146*** (0.173)	1.608 (0.484)
Quantile 4	1.474*** (0.128)	1.988*** (0.180)	0.675 (0.296)
Constant	0.0762*** (0.0227)	0.0183*** (0.00626)	0.0327*** (0.0292)
Observations	28,843	28,843	28,843

#### TABLE 3. Results from Multinomial Logistic Model: Relative Risk Ratios Relative to Regular Work Type

race/ethnicity in the STD clusters, being Black is strongly associated with a higher probability of using long-term disability insurance (P < 0.001). In addition, the strong gender effect that is observed in the other clusters does not hold in the LTD group. Moreover, we observed stronger relationships to job characteristics, including a statistically significant higher risk to being an hourly working and a much lower risk of being in the LTD group for workers who work in smelters relative to fabrication. Disease patterns remain similar; there are positive associations with arthritis, heart disease, depression, and, especially, musculoskeletal disease.

## DISCUSSION

In this article, we characterize working trajectories over an extended period of time for a large sample of American workers. To do so, we used administrative data to track monthly working states for active workers over an 18-year period, including regular work, disability episodes, leaves of absences, and terminations. Using these data, we first used sequence and cluster analysis to characterize long-term trajectories of work and disability and to group workers according to their patterns of work experience. We then used multinomial logistic regression models to examine demographic, health, and job-related characteristics that were associated with membership into particular work trajectories.

Our analysis produces a number of findings that should be of interest to those studying occupational health. In our data, workers can be categorized into a small number of work trajectories. Although the majority of workers in this sample have stable working patterns, others exhibit patterns of work characterized by disruptions that may be detrimental to job performance and productivity.

Membership in these trajectories is predicted by a number of different individual and job characteristics. Some demographic and health characteristics appear particularly salient. Notably, women are more likely to experience workforce disruptions than men, though they are at no higher risk of long-term disability. Given that these workers are involved in manufacturing, women at the firm may be select in a number of observable and unobservable ways. Little is known about women working in manual labor and these results point to the importance of further exploration into this special population.

There are also important gradients related to health characteristics and chronic disease. Musculoskeletal disease is the leading health condition associated with likelihood of disruptive work trajectories. A particular highlight is the finding that depression increases the likelihood of being in the "Disruptive Work" and "Ever LTD" groups. Depression is often overlooked as a potential driver of job disruption relative to other chronic disease, though evidence does point to its importance in labor market participation and worker productivity.<sup>35</sup>

Perhaps the most striking result is the strong association between increased exposure to particulate matter and the likelihood of a disruptive work trajectory. Exposure to high levels of TPM has been shown to be associated with a number of deleterious health conditions, including ischemic heart disease<sup>36</sup> and other cardiovascular diseases, impaired lung function,<sup>37</sup> and mortality.<sup>38,39</sup> Here we provide evidence that such exposure may have important employment implications as well.

We acknowledge a number of limitations. The primary limitation has to do with the nature of our sample: workers at the firm are not a nationally representative group. Although this does limit the generalizability of our findings, the workforce is also like the American public on a number of key dimensions.<sup>33</sup> Second, the methods employed here allow us to describe overall trajectories of employment and disability, but do not allow us to pinpoint dynamic changes that may precipitate or facilitate specific disability spells, nor do they account for the timing or duration of the spells. Subsequent analyses will pursue such possibilities.

P < 0.0

Workforce disruptions are costly events for both employers, in terms of productivity, and employees, in terms of both health and financial well-being. Among workers, these disruptions are not random events and there are clear signs that both intervention and further study could help to increase worker health. Further reductions to TPM seem likely to result in a healthier workforce. More research is needed to understand why women are experiencing higher rates of disruptive work than men. Given the high costs of disruptive work, the evidence presented here offers opportunities for improved understanding of why workers end up in poor health and what workplaces can do to mitigate it.

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