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The Impact of Lean Production and Related New Systems of Work Organization on Worker Health

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New systems of work organization, such as lean production and total quality management, have been introduced by employers throughout the industrialized world to improve productivity, quality, and profitability. However, few studies have examined the impact of such systems on occupational injuries or illnesses or on job characteristics related to job strain, which has been linked to hypertension and cardiovascular disease. The studies reviewed provide little evidence to support the hypothesis that lean production "empowers" auto workers. In fact, auto industry studies suggest that lean production creates intensified work pace and demands. Increases in decision authority and skill levels are modest or temporary, whereas decision latitude typically remains low. Thus, such work can be considered to have job strain. In jobs with ergonomic stressors, intensification of labor appears to lead to increases in musculoskeletal disorders. The evidence for adverse health effects remains inconclusive for related new work systems in other industries, such as modular manufacturing or patient-focused care.

Working men and women in industrialized countries have experienced substantial changes in job characteristics over the past generation. In Europe, surveys indicate increases in time constraints (i.e., workload demands) between 1977 and 1996 (European Foundation, 1997b). Similarly, in the United States, increases between 1977 and 1997 were reported for "working very fast" (from 55% to 68%) and "never enough time to get everything done on my job" (from 40% to 60%; Bond, Galinsky, & Swanberg, 1998). In Europe, in 1996, 23% of workers were working more than 45 hr/week (Walters, 1998). For U.S. workers, average weekly work hours (including nonpaid hours) increased by 3.5 to 47.1 hr from 1977 to 1997 (Bond et al., 1998). Somewhat increased job decision latitude was also reported in these surveys. In Europe, the proportion of workers reporting a measure of autonomy over their pace of work increased from 64% in 1991 to 72% in 1996 (Walters, 1998). In the United States, "freedom to decide what I do on my job" increased from 56% in 1977 to 74% in 1997, and "my job lets me use my skills and abilities" increased from 77% in 1977 to 92% in 1997 (Bond et al., 1998). However, at least in Europe, increases in autonomy were not sufficient to compensate for increased work intensity. The proportion of high-strain jobs in Europe increased from about 25% in 1991 to about 30% in 1996 (European Foundation, 1997b).

Paralleling these trends, new systems of work organization have been introduced by employers throughout the industrialized world to improve productivity, product quality, and profitability. Such efforts have taken a variety of forms and names, including lean production (i.e., Japanese production management; JPM), total quality management (TQM), team concept, cellular or modular manufacturing, reengineering, high-performance work organizations, and patient-focused care. Along with the human relations school and Scandinavian sociotechnical systems (STS), these new systems have been extolled as reforms of Taylorism and the traditional assembly-line approach to job design.

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There are reasons to be concerned about the way these systems may affect job characteristics, job stress, and health. Our own work (Cahill & Landsbergis, 1996; Landsbergis, Schnall, Schwartz, Warren, & Pickering, 1994; Schnall, Landsbergis, & Baker, 1994) and that of our colleagues (e.g., Johnson, Hall, & Theorell, 1989; Karasek & Theorell, 1990; Kristensen, 1996) provide evidence that job strain, that is, work combining high demands and low decision latitude (a combination of decision authority and skill variety), is a risk factor for hypertension and cardiovascular disease (CVD). (The terms *job decision latitude* and *job control* are often used interchangeably.) For example, in the Cornell Worksite Blood Pressure study, working men repeatedly exposed to job strain over 3 years have systolic blood pressures that are at least 10 mm Hg higher than men not exposed[1] (Schnall, Schwartz, Landsbergis, Warren, & Pickering, 1998).

Given the dramatic increases in workload demands reported recently in national surveys, one key question is to what extent is the implementation of lean production associated with increased workload demands, and therefore greater job strain? Karasek and Theorell (1990, p. 267) raised the other key question a decade ago in discussing experiments in work organization that might possibly create healthier jobs, for example, Quality of Work Life programs, Scandinavian STS, or JPM: "The unresolved question is the amount of control really afforded" to workers in lean production plants in the United States. In other words, do workers have greater or lesser job decision latitude, and therefore less or more job strain and risk of illness under lean production than under other systems?

Lean production is an "all-encompassing model" combining "diverse elements of Japanese production management" (Babson, 1995a, p. 6). Japanese engineers (first at Toyota) developed lean production by applying TQM concepts developed in the United States by W. Edwards Deming, Joseph Juran, and others. Lean production is an attempt to reduce impediments to the smooth flow of production through continuous improvement (*kaizen*) in productivity and quality, "just-in-time" (JIT) inventory systems (*kanban*), and elimination of "wasted" time and motion (*muda;* Applebaum & Batt, 1994). Small teams of hourly workers (Quality Circles; QCs) meet to solve quality and productivity problems.

Womack, Jones, and Roos (1990), in a classic text assessing lean production in auto manufacturing, argued that, in the best Japanese auto companies, by rotating jobs and sharing responsibilities, "multiskilled" workers can solve quality problems at their source and boost productivity. According to Womack et al. (1990) the "freedom to control one's work" (p. 14) replaces the "mind-numbing stress" (p. 101) of mass production. Armed with "the skills they need to control their environment," (p. 101) workers in a lean plant have the opportunity "to think actively, indeed proactively" (p. 99) to solve workplace problems. This "creative tension" (p. 102) makes work "humanly fulfilling" (p. 100). If such claims of increased worker skills and decision-making authority (the two components of job decision latitude in Karasek's job strain model) are true, then such programs could reduce job strain and stress-related illness. Lean workplaces are also considered to have a productivity advantage. (The continuing debate over productivity and quality under lean production and its Scandinavian alternatives [e.g., Adler, 1994; Adler & Cole, 1993, 1994; Berggren, 1992, 1994, 1995; Lowe, Delbridge, & Oliver, 1997] is outside the scope of this article.[2])

Applebaum and Batt (1994) identified typical features of lean production and compared them with STS and the U.S. human resources approach (see Table 1). Lean production provides for more job enlargement, cross-training, and problem-solving opportunities than traditional manufacturing job design. However, QCs are not "on-line" autonomous work teams, nor are they empowered to make managerial decisions (as are the autonomous work groups characteristic of STS). Lean production also leaves traditional hierarchy and the assembly line essentially unchanged (Applebaum & Batt, 1994;

[1] Job strain was determined by a self-report questionnaire in which employees answer 14 items about their job. Employees score high on demands if they report, for example, working very fast or very hard, and low on control (operationalized by 9 items on decision latitude) when they report, for example, having little say about how the job gets done and not learning new things.

[2] Some critics (e.g., M. Parker & Slaughter, 1994) have argued that the productivity advantage of lean companies has less to do with multiskilled workers, teams, or participation than with work intensification (through short work cycles, long hours, attendance control and labor flexibility, e.g., involuntary overtime), technical developments (e.g., simple designs, fewer parts, quick assemblies), and more outsourcing of work to low-wage, low job security (often non-union) suppliers. Suppliers manufacture a larger portion of each car among Japanese transplants than is common in North America or Europe (Berggren, Bjorkman, & Hollander, 1991). Large Japanese firms "rely strongly on small, highly paid core workforces which are supplemented by large peripheral workforces . . . often unqualified, low paid, predominantly female and lacking employment security" (Frohlich, 1997, p. 19).

Table 1
Some Common Models of New Work Systems

Variable	Lean production	Human resources	Sociotechnical systems
Origin	Japan	United States	England, Scandinavia
Worker teams	Supervised	No	Self-directed
Group decision making/ problem solving	Yes, through QCs	No	Yes
Cycle time	Short	Short	Long
Skills			
Vertical tasks	Just QC process	No	Yes
Horizontal tasks	Yes	Some	Yes
Knowledge depth	Trade off depth for greater breadth	Limited	Team characteristic, not individual
Autonomy	No	No	Yes
Jobs rotate	Yes	Some	Yes
Cross-training	High	Some	High
Worker participation	Consultative	Consultative	Substantive
	Off-line	Off-line	On-line
Unions	Company unions	Anti-union	Strong unions
Components	JIT, TQM, QC	QWL, EI	

Note. QC = quality circle; JIT = just-in-time; TQM = total quality management; QWL = quality of worklife; EI = employee involvement. From *The New American Workplace: Transforming Work Systems in the United States* (pp. 44–49), by E. Appelbaum and R. Blatt, 1994, Ithaca, NY: ILR Press. Copyright 1994 by Cornell University. Adapted with permission.

Babson, 1993, 1995a). Cycle time typically remains very short (often 1 min or less in auto assembly), and following highly standardized steps at narrowly defined tasks is mandatory (Berggren, Bjorkman, & Hollander, 1991; Bjorkman, 1996). Reliance is placed on industrial engineering, time studies, and predetermined standards to ensure maximum workloads, for example, working roughly 57 s out of 1 min versus 40–45 s in a traditional plant (Adler, Goldoftas, & Levine, 1997). JIT inventory systems remove the stock between operations that act as buffers in the system and "removes any 'free time' the worker may have previously enjoyed while the machine ran through its cycle" (Delbridge & Turnbull, 1992, p. 66), leading to "more strictures on a worker's time and action" (Klein, 1991). Rather, workers' personal time and flexibility become the buffers (Delbridge, Turnbull, & Wilkinson, 1995; Johnson, 1997; Lewchuk & Robertson, 1996).

Job characteristics, work hours, effects on family and leisure time, and occupational injuries and illnesses were not examined by Womack et al. (1990), who relied mainly on interviews with managers (Bjorkman, 1996).[3] Therefore, we focus on the critical but relatively neglected area of injuries and illnesses (primarily work-related musculoskeletal disorders [WRMDs], such as tendinitis and carpal tunnel syndrome) and on job characteristics related to job strain (i.e., job demands, control, and support).

The auto assembly line is the prototype of high job strain (low-control machine-paced work), and auto assembly jobs have also been the initial locus of recent efforts to change work organization. Thus, many studies of lean production, JIT, TQM, and related new systems are from this industry. However, lean work and other team-based methods are spreading throughout other sectors. A high proportion of U.S. manufacturing facilities (45%–57%) use some innovative work practice, such as job rotation, work teams, QCs, or TQM (Osterman, 1994). In Europe, current applications are positioned between the Scandinavian (STS) and the Toyota (lean) models with a tendency toward the Toyota model (European Foundation, 1997a; Frohlich, 1997).

Variants of lean production have been examined in the garment and health care industries in the United States. In the U.S. garment industry, the traditional (and still widely used) production process is the *bundle* system (Bailey, 1993; Berg, Appelbaum, Bailey, & Kalleberg, 1996). Inventories are stored in bundles of about 30 cut garment parts each. Operators perform one task, such as sewing a hem, on each piece in the bundle, which often takes only a few seconds (Bailey, 1993; Batt & Applebaum, 1995). The fragmented, repetitive work combined with piece rate leads to high rates of WRMDs (Brisson, Vinet, Vezina, & Gingras, 1989; Punnett, Robins, Wegman,

[3] In fact, "most recent research in strategic human resources and industrial relations focuses on the effects of participation on firm performance," not "outcomes for workers" (Batt & Applebaum, 1995, pp. 354–355).

& Keyserling, 1985; Schibye, Skov, Ekner, Christiansen, & Sjogaard, 1995). In a new work system—modular manufacturing—teams of multiskilled operators assemble an entire garment, with reduced supervision, and are involved in quality control, machine maintenance, and sometimes in setting and meeting group goals[4] (Bailey, 1993). Piece-rate wages are replaced by an hourly wage with a group bonus (Berg et al., 1996). However, modules do not appear to "alter the traditional sharp division between managers and production workers" (Bailey, 1993, p. 43).

In the U.S. health care industry, two recent forms of work restructuring are being studied. First, patient-focused care (PFC), based on TQM, uses cross-trained multiskilled teams, with fewer individual job categories, decentralized ancillary services, and computers to reduce case recording time. Registered nurses (RNs) manage teams, but fewer RNs are needed because lower paid, unlicensed generic health care workers undertake some direct care (T. Richardson, 1994; Sochalski, Aiken, & Fagin, 1997). Second, operations improvement seeks rapid cost savings by reducing the number of RNs and replacing them with nurses' aides (Greiner, 1995). These two new approaches are replacing an earlier system developed in 1970s known as primary nursing (Brannon, 1996), professional nurse practice models, or magnet hospitals, which featured RN autonomy and control over clinical practice and decentralized decision making (Aiken, Sloane, & Klocinski, 1997; Kramer & Schmalenberg, 1988; McClure, Poulin, Sovie, & Wandelt, 1983).

Thus, a careful assessment of the empirical literature on the impact of new work systems on job characteristics, injuries, and illnesses is critical in understanding the potentially major health effects of current employment and industrial trends not just in auto manufacturing but throughout industrialized economies.

Method

We conducted a search through Medline and PsycLit for all relevant studies published in English between 1976 and August 1998. Keywords for exposures included *lean production, total quality management, team concept, modular manufacturing, cellular manufacturing, high-performance work organizations, work restructuring, reengineering,* and *organizational efficiency.* Keywords for job characteristics outcomes included *workload, psychological demands, work pace, decision latitude, decision authority, job influence, job control, skill discretion, skill use, skills training, coworker support, supervisor support, staffing, job security,* and *job characteristics.* Keywords for health outcomes included *job stress, psychological stress, job satisfaction, cumulative trauma disorders, nerve compression syndromes,* and *sprains and strains.* We excluded studies that were designed to assess other outcomes of new work systems such as productivity, quality, labor relations, or organizational learning, as well as studies that have examined the effects of specific job design changes (piece rate, electronic performance monitoring) which are not part of a more comprehensive change in work organization or a team-based program.

We identified 38 studies, of which 13 were conducted in the auto industry, 13 in other manufacturing industries, 11 in the health care industry, and 1 in telecommunications (see Table 2). Of the 38 studies, 26 were conducted in the United States, 4 in Canada, 1 both in the United States and Canada, 6 in England, and 1 in Finland. Surveys were the most common study method ($n = 27$), including 15 follow-up surveys. There were nine case studies, and nine included injury record reviews. Five surveys in the United States and Canada were conducted by, or jointly with, labor unions. Of the 38 studies, 20 have been published in peer-reviewed journals; the studies' peer-review status is provided in Table 2 and later tables.

Results

Fatigue, Perceived Stress, and Tension in Auto Manufacturing

Surveys and case studies of Japanese-owned auto assembly plants in the United States and Canada have suggested high levels of perceived stress, fatigue, and tension (see Table 3). This has been attributed to fast work pace, long work hours, highly repetitive work, and few rest breaks. Among Canadian auto parts supplier workers, increases in job tension and fatigue over the past 2 years were significantly greater in lean than in traditional companies (Lewchuk & Robertson, 1996). At General Motors (GM) in Canada, where lean production was at an advanced stage, significantly more workers reported job tension and fatigue than at less lean companies such as Ford and Chrysler (Lewchuk, Roberts, McDonald, & Robertson, 1996; Lewchuk & Robertson, 1997).[5] British truck manufacturing employees reported significantly more work-related perceived stress after group production was

(text continues on page 116)

[4] Along with piece-rate wages, the bundle system promotes productivity; however, it complicates quality control and requires a large amount of inventory, roughly 15–20 days of work in progress. Modular manufacturing appears to improve quality, drastically reduces in-process inventory, reduces costs, and improves a firm's ability to quickly respond to retailer requests.

[5] Results for CAMI, the GM–Suzuki joint venture in Canada, tended to be intermediate between the lean GM and the more traditional Ford and Chrysler plants. However, it is difficult to interpret comparisons on the basis of the survey findings for CAMI because of the low response rate for CAMI workers (19%). Response rates for the other worksites were higher (i.e., GM: 24%, 67%, 74%, 85%; Chrysler: 48%, 68%, 76%; and Ford: 72%).

Table 2
Lean Production, Other New Work Systems, Job Characteristics, and Health Outcomes: Studies Reviewed

Authors and year	In peer-reviewed journal	Industry	Sample/worksite	Design/ method[a]	New work system	Outcome measure
			Automobile manufacturing			
Lewchuk and Robertson (1996)	Yes	Auto	1,670 employees of 16 Canadian auto parts suppliers	Survey	Lean	WRMD symptoms, fatigue, tension, workload, control, autonomy, skill
Canadian Auto Workers (1993); Lewchuk et al. (1996); Rinehart et al. (1995, 1997); Roberts (1995); Robertson et al. (1993)	No	Auto	100 CAMI (GM–Suzuki) employees, Ontario, Canada, surveyed four times in 20 months	Prospective survey; observations; interviews	Lean	Stress, workload, job rotation, participation/ influence, skills, training, team characteristics
Lewchuk and Robertson (1997)	Yes	Auto	2,424 Canadian employees of CAMI, GM, Chrysler, Ford	Survey; observation; interviews	Lean	WRMD symptoms, fatigue, tension, workload, control, job security, family life
Lewchuk et al. (1996)	No					
Rinehart et al. (1997)	No	Auto	CAMI, Ontario, Canada	Case study; rewrd review; prospective survey	Lean	WRMDs
Murphy and Olthius (1995)	No	Auto	Employees of Walker Exhaust, Ontario, Canada, surveyed twice in 21 months ($N = 332, 337$)	Cross-sectional surveys	Lean	Stress, safety, authority/influence, skill development, job satisfaction
Babson (1993, 1995b)	Yes	Auto	2,380 employees of Auto Alliance (Mazda–Ford), Michigan	Survey	Lean	Workload, authority, participation, skills training and use
Slaughter (1994)	No					
Reynolds (personal communication, 1996)	No					
Babson (1993, 1995b)	Yes	Auto	Auto Alliance (Mazda–Ford), Michigan	Case study; record review	Lean	WRMDs
Berggren et al. (1991); Fucini and Fucini (1990); Reynolds (personal communication, February 28, 1996)	No					
Berggren et al. (1991)	No	Auto	6 Japanese "transplants" in the United States and Canada	Case study	Lean	WRMDs, workpace, staffing, authority
Adler et al. (1997)	Yes	Auto	NUMMI (GM–Toyota), California	Case study; record review	Lean	WRMDs, training, job rotation, selection of team leaders
Adler (1995); Division (1993, 1994); Enos (personal communication, May 3, 1996); M. Parker and Slaughter (1994)	No					
Kaminski (1996b)	No	Auto	67 employees of Wayne Integrated Stamping & Assembly (Ford), Michigan (random sample)	Survey; interviews; record review	Teams; quality program	Job satisfaction, stress, control, CTDs

Table 2 *(continued)*

Authors and year	In peer-reviewed journal	Industry	Sample/worksite	Design/ method[a]	New work system	Outcome measure
			Automobile manufacturing			
Graham (1995)	No	Auto	Subaru–Isuzu, Indiana	Case study	Lean	WRMDs, stress, authority, participation
Wokutch (1992)	No	Auto	Jidosha, USA	Record review	Lean	Injuries and illnesses, CTDs
S. K. Parker et al. (1995)	No	Auto parts	35 British manufacturing employees, surveyed twice in 6 months	Prospective survey	TPS, JIT	Workload, autonomy, psychological strain
S. K. Parker and Sprigg (1998)	No	Auto	38 employees of a British truck manufacturing firm surveyed twice in 18 months	Prospective survey	Lean; assembly line	Job control, skill variety, problem-solving demands, job satisfaction, workload, work-related strain
			Other manufacturing industries			
Dean and Snell (1991)	Yes	Various	537 employees, 123 Pennsylvania companies	Survey	TQM, JIT	Task complexity, variety, interdependence
Fairris (1998)	No	Various	295 U.S. manufacturing companies	Survey; record review	QC, TQM, teams, rotation TQM	Lost workday injury rate, CTD change from 1986 to 1991
Wilkinson et al. (1997)	Yes	Various	8 facilities of 6 companies in Britian	Interviews		Job satisfaction
Mullarkey et al. (1995)	Yes	Electronics	56 British manufacturing employees, surveyed 4 times in 33 months	Prospective survey	TQM, JIT	Demands, control, coworker support, job satisfaction, psychological strain
Jackson and Martin (1996)	Yes	Electronics	44 British manufacturing employees, surveyed 2 times in 8 months	Prospective survey	JIT	Demands, production pressure, control, job satisfaction, psychological strain
Moye and Rosenthal (1996)	No	Electronics	72 employees of a large New Jersey firm (random sample)	Survey; interviews; record review	Teams, SPC, quality program	Supervision, influence, control, job satisfaction, work pace, stress, lost work days from injuries
Bertelli (1996)	No	Aerospace	80 employees of a large California firm (random sample)	Survey; interviews; record review	Teams, EI	Control, job satisfaction, injuries reported to OSHA
S. K. Parker et al. (1997)	Yes	Chemical	139 British chemical workers surveyed 2 times in 4 years	Prospective survey	Multiskilling quality improvement	Demands, control, participation, clarity, well-being, job satisfaction
C. Richardson (1995)	No	Steel	179 safety and health representatives of United Steelworkers of America	Survey	Teams, JIT, SPC, cells	Work pace, control, staffing, training, stress, overtime
Lim and Murphy (1996)	No	Manufacturing	5,199 employees of a Northeastern U.S. company	Survey	TQM	Job satisfaction, stress
Kaminski (1996a)	No	Lawn care products manufacturing	60 hourly employees of a Wisconsin firm (random sample)	Survey; interviews	Teams; quality program	Supervision, control, job satisfaction, stress
Batt and Applebaum (1995); Berg et al. (1996)	Yes	Garment	562 U.S. workers in 6 plants in 3 companies	Survey	Modular manufacturing	Job satisfaction, stress, autonomy, skills, variety, coworker support
Rooney et al. (1993)	No	Garment; warehouse	400 shoe and luggage manufacturing, 1,500 warehouse employees in Maine	Case study; record review	TQM; end piece-rate; job rotation; enlargement; ergonomics	Change in lost-time injuries, 1988–1992

(Table continues)

Table 2 *(continued)*

Authors and year	In peer-reviewed journal	Industry	Sample/worksite	Design/ method[a]	New work system	Outcome measure
			Telecommunications industry			
Batt and Applebaum (1995)	Yes	Telecom-munications	466 network craft and 322 customer service workers from 1 U.S. phone company	Survey	Self-managed teams	Job satisfaction, stress, autonomy, skills, variety, coworker support
			Health care industry			
Aiken et al. (1997)	Yes	Health care	1,956 nurses in 20 U.S. hospitals	Prospective survey; record review	Magnet hospitals	Needlesticks
Aiken and Fagin (1997); Kramer and Schmalenberg (1998)	Yes	Health care	U.S. hospital workers	Case study	Magnet hospitals	Job satisfaction, autonomy, skills, coworker support
Greiner (1995); T. Richardson (1994)	No	Health care	U.S. hospital workers	Case study	PFC	Authority, job satisfaction, stress, staffing
American Nurses Association (1995); Greiner (1995); Wunderlich et al. (1996)	No	Health care	U.S. hospital workers	Case study	Operations improvement	Job satisfaction, stress
Brett and Tonges (1990)	Yes	Health care	42 nurses on a Northeast U.S. hospital orthopedic unit followed for 8 months	Prospective survey	ProACT (similar to PFC)	Job satisfaction, workload
Moffitt et al. (1993)	Yes	Health care	59 staff of a Midwest U.S. hospital oncology unit followed for 11 months	Prospective survey	PFC	Job satisfaction
Peruzzi et al. (1995)	Yes	Health care	Staff of a Northeast U.S. hospital orthopedic and surgical units followed for 2 years	Prospective survey	Quality action team; cross-training unlicensed aides	Job satisfaction
Reisdorfer (1996)	Yes	Health care	Staff of a Midwest U.S. hospital followed for 1 year	Prospective survey	PFC	Job satisfaction
Jones et al. (1997)	Yes	Health care	65 staff of a Northeast U.S. hospital orthopedic unit followed for 1 year	Prospective survey	PFC	Job satisfaction
Kivimaki et al. (1997)	Yes	Health care	238 staff of surgical departments in 3 Helsinki area hospitals followed for 1 year	Prospective survey	TQM	Job satisfaction, participation in decision making, autonomy
Davidson et al. (1997)	Yes	Health care	736 Northeast U.S. hospital nurses followed for 1 year	Prospective survey	Downsizing; care teams; cross-trained support assistant	Job satisfaction

Note. WRMD = work-related musculoskeletal disorder; CAMI = Canadian Autobobile Manufacturing, Inc.; GM = General Motors; NUMMI = New United Motors Manufacturing, Inc.; CTD = cumulative trauma disorder; TPS = Toyota Production System, also referred to as Japanese management or lean production; JIT = just-in-time; TQM = total quality management; QC = quality circle; SPC = statistical process control; EI = employee involvement; OSHA = Occupational Safety and Health Administration; PFC = patient-focused care.

[a]All surveys were cross-sectional in design except where noted.

Table 3
Associations Between Lean Production in Auto Manufacturing and Health Outcomes

Authors and year	In peer-reviewed journal	Study sample	Work-related musculoskeletal disorders[a]	Fatigue, stress, tension
		Surveys, with comparison groups[b]		
Lewchuk and Robertson (1996)	Yes	16 Canadian auto parts suppliers	0	?+
Robertson et al. (1993), Rinehart et al. (1997)	No	CAMI (GM–Suzuki), Canada	?+	?+
Lewchuk and Robertson (1997)	Yes	CAMI, GM, Ford, Chrysler in Canada	?+	+
Murphy and Olthius (1995)	No	Walker Exhaust, Ontario, Canada		0
S. K. Parker and Sprigg (1998)	No	British truck manufacturer		+
S. K. Parker et al. (1995)	No	British auto parts company		+, 0[c]
		Case studies		
Rinehart et al. (1997)	No	CAMI (GM-Suzuki), Canada	+	
Berggren et al. (1991)	No	Auto Alliance (Mazda–Ford), Michigan	+	
Fucini and Fucini (1990), Berggren et al. (1991)	No	6 Japanese "transplants," United States, Canada	+	+
Adler et al. (1997), Division (1993, 1994)	Yes, No	NUMMI (GM–Toyota), California	+	
Graham (1995)	No	Subaru–Isuzu, Indiana	+	+
Wokutch (1992)	No	Jidosha, United States	+	

Note. Only primary references are listed. 0 = no association; ?+ = equivocal positive association; + = positive association; CAMI = Canadian Automobile Manufacturing, Inc.; GM = General Motors; NUMMI = New United Motors Manufacturing, Inc.

[a] In the Canadian surveys, these ratings are based on one question on "working in pain," or "how often does your job expose you to A. muscle fatigue and strains; B. repetitive strains. [b] For surveys with comparison groups, plus symbols refer to statistically significant findings. For case studies, plus symbols are based on the conclusions of the authors and/or the judgment of the current reviewers. [c] Positive association if lean production (Toyota Production System) introduced without worker participation; no association if worker participation.

replaced by a moving assembly line, along with components of lean production such as process simplification and standardization and relayout into cells (S. K. Parker & Sprigg, 1998). However, at a British auto parts company, increased stress was perceived only by employees who did not participate in the implementation of lean production (S. K. Parker, Myers, & Wall, 1995). At a Michigan assembly plant, where elements of lean production such as teams and a quality program were instituted jointly by labor and management, employees reported a slight decrease in perceived stress since the program began (Kaminski, 1996b).

Injuries in Auto Manufacturing

Several studies examined records of total injuries or musculoskeletal disorders in lean workplaces. At a Japanese-owned auto plant in the United States (Jidosha), following the start of full-speed production, injury and illness rates for 1988 were 44.4 (per 100 full-time employees), 66% higher than the rate for auto plants (Standard Industrial Classification [SIC] Code 3710) employing 100 or more workers (26.8; Wokutch, 1992, pp. 192–195). The 1988 cumulative trauma disorder (CTD) rate was 10.1 (per 100), over five times the industry average of 1.89. (CTD rates during this period, however, were greatly influenced by improved record keeping; Mirer, 1989.) At Mazda in Flat Rock, Michigan (now Auto-Alliance), in 1988 (the first year of full production), the lost workday "incident" rate was 3.7 per 100 workers, about 50% higher than the average (2.4) of other auto plants in Michigan. CTD rates were about double a comparable Michigan assembly plant (Fucini & Fucini, 1990, pp. 175–179). According to Graham (1995, pp. 77, 86), at Subaru–Isuzu, an outbreak of hand and wrist injuries occurred after production officially began and line speed increased. At GM in Canada, 67% of workers reported working in pain at least half the days in the last month, a proportion significantly greater than other companies surveyed (Lewchuk et al., 1996; Lewchuk & Robertson, 1997).

In 1993, at New United Motors Manufacturing, Inc. (NUMMI), a GM–Toyota joint venture, the California Occupational Safety and Health Administration (CalOSHA) cited the company for ergonomic hazards. According to CalOSHA, "Serious employee injuries due to repetitive stress, as well as employee symptoms of impending stress, have increased alarmingly. Complaints of symptoms to [supervisors] frequently did not lead to adequate correction of the problem" (Division, 1993, p. 2). CalOSHA cited examples in which equipment to make a job easier and safer went unused because it was slower than doing the job with muscle power alone. CalOSHA also charged NUMMI with ignoring ergonomic hazards through a no-rotation policy: "no rotation between jobs until employees achieved a high standard of excellence and expertise on their new 'primary' job" (Division, 1993, p. 3; Division, 1994). According to Adler et al.'s (1997) case study, job rotation had been suspended in August 1992 to provide employees time to learn new jobs during a model changeover, but by summer 1993 rotation had not yet been fully restored. Because the previous major model changeover (in 1989) had produced a similar rise in CTDs, but these were not prevented in 1993, union–management relations became strained. Owing to greater attention paid to ergonomics by labor and management, a new truck launch in 1995 included job rotation, 20 new hires, managers' evaluation tied to safety results, and fewer injuries (Adler et al., 1997).

Adler et al. (1997, pp. 420, 435) also suggested that contributing to the problem was a climate that encouraged working in pain. For example, the United Auto Workers (UAW) ergonomics representative at NUMMI stated that workers "do not come to the Medical Department with their concerns because they are being harassed by members of supervision" (M. Parker & Slaughter, 1994, p. 86). Similarly, Fucini and Fucini (1990, p. 182) reported that injured workers at Mazda had been ridiculed by managers and told they were "faking it" and that injuries were not "work related." Berggren et al. (1991, p. 55), in their study of Japanese-owned auto plants in North America, also reported lack of early treatment because of peer pressure to "work in pain" and not report injuries, and the denial of work relatedness by management (e.g., "there are weak and there are strong people").

In contrast, the Wayne, Michigan, auto plant operating teams under a Ford–UAW contract have seen declines in CTDs since 1990 (Kaminski, 1996b). Because of a new bargaining unit, equipment, and work process, it is difficult to compare CTD rates between team concept and traditional management. However, managers, workers, and union leaders attributed the reduction in injury rates to job rotation and use of better ergonomic equipment (Kaminski, 1996b; Landsbergis, Adler, et al., 1998). The Ford–UAW national ergonomics program may have also contributed to the decline in CTDs. Two other case studies of team concept programs jointly implemented by management and labor (Bertelli,

1996; Moye & Rosenthal, 1996) also report reductions in injury rates; however, few details are provided.

Finally, a study combining data from a 1992 national business survey and changes in three-digit SIC code injury rates between 1986 and 1991 (Fairris, 1998) found inconsistent results. QCs were associated with increases, but work teams were associated with decreases in CTDs. TQM was associated with increased injuries, but not with CTDs.

Job Characteristics in Auto Manufacturing

Canadian and U.S. studies of lean production in auto manufacturing provide information on the job characteristics that constitute job strain (see Table 4). Job demands were often reported to be elevated. Auto parts workers in lean companies reported significantly heavier workloads and "too few people" than those in traditional companies (Lewchuk & Robertson, 1996). Significantly more GM workers reported "work too fast," "too few people to do work," "work as fast as you can at least half the time so you do not fall behind," and increases in workload over the past 2 years than workers at other Canadian auto companies (Lewchuk et al., 1996; Lewchuk & Robertson, 1997). At Mazda, 73% reported "I will likely be injured or worn out before I retire" (Babson, 1993). However, British manufacturing employees reported significantly fewer problem-solving demands after introduction of a moving assembly line (S. K. Parker & Sprigg, 1998), and British auto parts employees reported slightly less workload if they participated in the implementation of a lean system, but a significant increase in workload if they did not participate (S. K. Parker et al., 1995).

Low or decreasing decision authority was also reported in many cases. At CAMI in Canada, while 51% of employees reported at Survey 1 being "actively involved in making decisions at work," 1.5 years later at Survey 4 this proportion fell to 33%. The role of teams in providing a place for "influence over the job" similarly fell from 79% to 45%. During early startup periods, "participation" and job rotation were practiced, but during production, dissatisfaction rose. At Survey 4, 60% reported that teams "get us all to pressure one another" compared with only 19% at Survey 1 (Robertson et al., 1993). At Walker Exhaust in Ontario, Canada, in 1992, workers in Japanese-style production teams reported slightly more decision-making authority than workers in traditional jobs. Two years later, however, the new jobs had become more like traditional jobs. There was less teamwork and less responsibility for workers than before, and team leaders had been eliminated (Murphy & Olthius, 1995).

A significantly greater proportion of Canadian GM workers reported low control and autonomy than Ford or Chrysler workers (Lewchuk & Robertson, 1997). British employees reported significantly less job control after the moving assembly line and elements of lean production were introduced (S. K. Parker & Sprigg, 1998). At Mazda, each worker was required to follow a Program Work Sheet (PWS), which describes the job cycle in minute detail and which cannot be altered without supervisory approval. Seventy-three percent of workers reported that their PWS had been changed without their consultation at least several times, changes that 67% reported "made my job harder." As a result, 48% wanted team leaders elected, whereas only 16% preferred the "present system" (Babson, 1993).

The promise of producing highly trained, multiskilled workers was also challenged by the survey data. At CAMI, the proportion of workers who felt that "as a result of training, I'm no more skilled since all the jobs are about the same" rose from 53% at Survey 1 to 72% at Survey 4 (Robertson et al., 1993, p. 26). At Mazda, 89% of respondents said that "the actual training I have received is fair or poor." Only 6% reported it as excellent (Babson, 1993). British truck manufacturing employees reported a decrease in skill variety and use (S. K. Parker & Sprigg, 1998). In the 1992 survey, Walker Exhaust employees in Japanese-style teams reported greater opportunities for skills training than other workers. However, the follow-up survey indicated that training opportunities had declined, and these jobs had become similar to traditional jobs. Nonetheless, many workers continued to see these jobs positively, as "better" than other manufacturing jobs on "satisfaction, work pace and health and safety" (Murphy & Olthius, 1995, p. 102).

At the Wayne, Michigan, auto plant, 71% of workers report having benefited from the team concept (Kaminski, 1996b; Landsbergis, Adler, et al., 1998). Workers had input into the design of the new system before it was put in place, team leaders were elected, teams could schedule personal and vacation time, the union monitored overtime and seniority rights, and the new system was written into contract language and ratified overwhelmingly (Kaminski, 1996b). In one area, workers have more control and discretion and are able to stockpile their product (contrary to JIT principles). Managers and union leaders agreed "this is not a lean production plant" (Kaminski in Landsbergis, Adler, et al., 1998).

Table 4
Associations Between Lean Production in Auto Manufacturing and Job Characteristics

Authors and year	In peer-reviewed journal	Study sample	High job demands	Low decision authority	Poor skill development
		Surveys, with comparison groups[a]			
Lewchuk and Robertson (1996)	Yes	16 Canadian auto parts suppliers	+	?+	0
Robertson et al. (1993)	No	CAMI (GM–Suzuki), Canada	?+	+	+
Lewchuk and Robertson (1997)	Yes	CAMI, GM, Ford, Chrysler in Canada	+	+	
Murphy and Olthius (1995)	No	Walker Exhaust, Ontario		0	0
S. K. Parker and Sprigg (1998)	No	British truck manufacturer	−	+	+
S. K. Parker et al. (1995)	No	British auto parts company	+, ?−[b]	0	
		Case studies, or surveys without comparison groups[c]			
Babson (1993, 1995b)	Yes	Auto Alliance (Mazda–Ford), Michigan	+	+	+
Berggren et al. (1991)	No	6 Japanese "transplants," United States, Canada	+		
Graham (1995)	No	Subaru–Isuzu, Indiana	+	+	

Note. Only primary references are listed. + = positive association; ?+ = equivocal positive association; 0 = no association; − = inverse association; ?− = equivocal inverse association; CAMI = Canadian Automobile Manufacturing, Inc.; GM = General Motors.

[a] For surveys with comparison groups, plus and minus symbols refer to statistically significant findings. [b] Increase in workload if Toyota Production System introduced without worker participation; inverse association if worker participation. [c] For case studies, or surveys without comparison groups, plus and minus symbols are based on the conclusions of the authors and/or the judgment of the current reviewers.

Other Manufacturing Industries

Elements of lean production, such as multiskilled worker teams, quality programs, and JIT, have been introduced in other manufacturing industries. Such new work systems in other U.S. industries are associated with high perceived stress levels and higher job demands, but associations were null or mixed in the British samples (see Table 5). One group of British electronics workers changing to JIT (Mullarkey, Jackson, & Parker, 1995) showed an increase in job satisfaction and team-timing control and a slight decrease in demands, whereas another sample (Jackson & Martin, 1996) reported a decrease in job satisfaction and timing control and an increase in production pressure. Workers in a British chemical company undergoing downsizing and reporting increased demands showed a 4-year increase in job satisfaction and no change in psychological strain, apparently owing to increases in control and participation (S. K. Parker, Chmiel, & Wall, 1997).

Three U.S. case studies examined team concept programs introduced in a joint labor–management setting (Bertelli, 1996; Kaminski, 1996a; Moye & Rosenthal, 1996). Over 75% of workers agreed that the union should work with management to further develop these "transformations"; however, more workers reported an *increase* in perceived stress than a decrease (Kaminski, Bertell, Moye, & Yudken, 1996).

In the study of garment manufacturing, modular workers reported greater skill use but also reported increased perceived stress and no difference in job satisfaction compared with bundle workers (Berg et al., 1996). Worker teams or job redesign (more task identity and significance) were significantly associated with satisfaction; however, increased workload–stress was associated with reduced satisfaction, thus, no net gain in satisfaction for modular workers (Batt & Applebaum, 1995). It remains to be seen what effect modular production has on injury or illness risk.

Among shoe and luggage manufacturing and warehouse and distribution workers of a large company, CTDs were increasing in the late 1980s as a result of piece-rate pay, "gain sharing," and increased specialization and repetition (Rooney, Morency, & Herrick, 1993). A number of work organization changes were implemented in 1989, reducing lost-time injuries by over 70% between 1988 and 1992. The various changes, labeled "TQM," included job enlargement, job rotation, increased decision making, task variety, elimination of most piece-rate pay systems, worker teams, ergonomics training, "light-duty" jobs, and medical management of CTDs. Thus, it is difficult to determine which of the new work systems or practices contributed most to injury reduction.

A survey of union representatives (C. Richardson, 1995) indicated that many workplaces in the U.S. steel industry had instituted new work systems, including JIT, teams, cells, International Organization for Standardization [ISO] 9000, kaizen, and statistical process control (SPC). A majority of respondents also reported increased pace of work, inadequate staffing levels, more overtime, increasing stress, and inadequate training.[6]

Telecommunications Industry

One study (Batt & Applebaum, 1995) examined the impact of self-managed teams on unionized installation and repair crews (network craft) and in customer services. There was little impact of the new work system on customer service workers. However, network craft workers reported significantly more job satisfaction, autonomy, coworker support, days of training, and advancement opportunities in comparison with workers in traditionally managed (but highly skilled) craft jobs. For this group, job satisfaction was significantly associated with on-line participation (e.g., greater autonomy) but not with off-line participation (e.g., QWL, TQM, and problem-solving teams).

Health Care Industry

Case studies of patient-focused care (PFC) experiments (see Table 5), which have used elements of lean production such as TQM and multiskilled teams, have suggested improved job satisfaction provided that staffing levels remain reasonable (Greiner, 1995; T. Richardson, 1994). However, RNs often report more stress and less time available to spend with patients. Less skilled employees tend to report more job satisfaction because of their "enhanced" roles and greater decision-making authority, but also dissatisfaction with pay (Greiner, 1995). The *operations improvement* restructuring model involves minimal multiskilling, team-care delivery, or decentralization, but rather replacement of RNs by aides, and has

[6] Similarly, nearly half of British union safety representatives surveyed identified new management techniques as a main cause of workplace stress, a much higher proportion than for other causes such as long hours, layoffs, harassment, or shiftwork (O'Neill, 1996).

Table 5
Associations Between New Work Systems in Industries Other Than Auto Manufacturing, Strain, Satisfaction, and Job Characteristics

Industry/authors and year	In peer-reviewed journal	Sample	New work system	Psychological strain, stress	Job satisfaction	Skills training	Low decision authority/ control	Workpace/ demands
			Surveys, with comparison groups[a]					
Other manufacturing industries								
Dean and Snell (1991)	Yes	123 Pennsylvania companies	TQM, JIT, AMT			0		
Mullarkey et al. (1995)	Yes	British electronics employees	TQM	0	0		−	+
			JIT	0	+		0 (individual) − (collective)	?−
Jackson and Martin (1996)	Yes	British electronics employees	JIT	0	−		?+	?+
S. K. Parker et al. (1997)	Yes	British chemical workers	Multiskilling, quality improvement (context: downsizing)	0	+		−	+
Lim and Murphy (1996)	No	U.S. manufacturing workers	TQM	−	0			
Batt and Applebaum (1995); Berg et al. (1996)	Yes	U.S. garment workers	Modular manufacturing	+	0	+	−	+
Telecommunications industry								
Batt and Applebaum (1995)	Yes	U.S. telecommunications workers	Self-managed teams					
			Network craft	?+	+	?+	−	
			Customer service	0	0	0	−	
			Case studies, or surveys without comparison groups					
Other manufacturing industries								
Wilkinson et al. (1997)	Yes	British industrial workers	TQM		+		−	+
Moye and Rosenthal (1996)	No	U.S. electronics workers	Teams, SPC, quality improvement	+	?+		?+	+
Bertelli (1996)	No	U.S. aerospace workers	Teams, quality program	+	?+		?+	+
Kaminski (1996a)	No	U.S. lawn care products manufacturing	Teams, quality program	+	+		?+	
C. Richardson (1995)	No	U.S. steelworker union representatives	JIT, SPC, teams, cells, kaizen	+			?+	+
Health care industry								
T. Richardson (1994)	No	U.S. hospital workers	PFC					
Greiner (1995)	No		RNs	?+[b]	?+[b]	0	?+	+
			Aides	?+[b]	+[b]	+	?−	+
American Nurses Association (1995); Greiner (1995); Wunderlich et al. (1996)	No	U.S. hospital workers	Operations improvement	?+	−	0	?+	+

Table 5 *(continued)*

Industry/authors and year	In peer-reviewed journal	Sample	New work system	Psychological strain, stress	Job satisfaction	Skills training	Low decision authority/ control	Workpace/ demands
Aiken and Fagin (1997); Aiken et al. (1997); Kramer and Schmalenberg (1988)	Yes	U.S. nurses	Magnet hospitals	0	+	+	−	0
			Surveys, with comparison groups[a]					
Brett and Tonges (1990)	Yes	U.S. hospital nurses	ProACT (similar to PFC)					
			RNs		0			?+
			LPNs		0			?+
Moffitt et al. (1993)	Yes	U.S. hospital nurses	PFC		+			
Peruzzi et al. (1995)	Yes	U.S. hospital nurses	Quality action team (similar to PFC)		?+			
Reisdorfer (1996)	Yes	U.S. hospital nurses	PFC		?+			
Jones et al. (1997)	Yes	U.S. hospital workers	PFC					
			Nurses		0			
			Support staff		?−			
Kivimaki et al. (1997)	Yes	Finnish hospital workers	TQM		0		0	
Davidson et al. (1997)	Yes	U.S. hospital nurses	Care teams; cross-trained assistants; downsizing context		−			

Note. Only primary references are listed.
0 = no association; − = inverse association; + = positive association; ?− = equivocal inverse association; ?+ = equivocal positive association.
TQM = total quality management; JIT = just-in-time; AMT = advanced manufacturing technology; SPC = statistical process control; PFC = patient-focused care; RNs = registered nurses; LPNs = licensed practical nurses.
[a] For surveys with comparison groups, plus and minus symbols refer to statistically significant findings. For case studies, or surveys without comparison groups, plus and minus symbols are based on the conclusions of the authors and/or the judgment of the current reviewers. [b] If staffing levels remain reasonable.

resulted in greater employee dissatisfaction (Greiner, 1995). The few surveys that have been conducted of PFC and related experiments (see Table 5) provide inconclusive evidence of their impact on employee health, primarily because of their small sample size, inadequate assessment of actual changes in job characteristics, and nearly sole reliance on job satisfaction as the employee outcome measure. Other studies have suggested an association between downsizing and understaffing and stress among RNs (American Nurses Association, 1995), occupational injuries (Shogren & Calkins, 1997), and back injuries among aides in nursing homes (Service Employees, 1995; Wunderlich, Sloan, & Davis, 1996).

In auto manufacturing, lean production was touted as a solution to the serious product quality and human resource problems created by the traditional assembly-line approach to job design (Taylorism). In contrast, the newer health care restructuring programs are replacing an earlier model (the professional nurse practice model or magnet hospitals), which has been associated with high job satisfaction, adequate staffing, social support, clinical career ladders, a high degree of nurse autonomy, responsibility and control over clinical practice, lower staff turnover, superior clinical outcomes[7] (Aiken & Fagin, 1997; Aiken et al., 1997; Kramer & Schmalenberg, 1998; McClure et al., 1983), and reduced risk of needlestick injuries (Aiken et al., 1997). The new systems are also being adopted in Canada, Europe, and other countries despite little empirical evidence as to their effectiveness or their safety (Aiken & Fagin, 1997).

Discussion

The studies reviewed provide little evidence to support the hypothesis that auto manufacturing workers are empowered under lean production. In fact, recent surveys tend to confirm earlier case studies which suggested that lean production in auto manufacturing creates intensified work pace and demands. Increases in decision authority and skill are very modest or temporary, and decision latitude remains low. Thus, such work can be considered to have job strain. In jobs with physical ergonomic stressors (such as manufacturing), intensification of labor may lead to increased rates of musculoskeletal disorders. The exceptions to these general conclusions tend to appear in groups of workers who participated in the implementation of new work systems, or in which worker influence was secured through a collective bargaining agreement. The evidence for health effects remains inconclusive for related new work systems in other industries such as modular manufacturing or PFC.

If increased work pace and limited autonomy (job strain) are common effects of lean production, then the expansion of lean work principles (e.g., an understaffed, flexible labor force; little job security; and overtime) throughout the workforce could produce dramatic increases in the incidence of hypertension and CVD. If increased rates of WRMDs are associated with lean production, then WRMDs, with a shorter latency period than hypertension or CVD, may be considered the "canary in the mine"—a warning of increased future chronic illness.

Our review suggests that any comparison of the costs and benefits (e.g., productivity, quality, and efficiency) of lean production and related new work systems should incorporate the costs of chronic illnesses, such as WRMDs, hypertension, and CVD. If illness costs are greater under lean systems, and if lean companies are held responsible for the social costs of such illnesses, then there will be an economic incentive to moderate the stressful features of lean production.

Limitations

Our conclusions are limited by the few well-designed studies available. Most relied on self-reported survey data or official injury and illness records, both of which are subject to reporting bias. Nearly half of the studies have not been published in peer-reviewed journals. None examined hypertension or CVD. Also, most major surveys of employees of lean auto companies have been conducted in cooperation with labor unions. Although this raises the potential of bias, it is also a contrast to earlier studies (e.g., Womack et al., 1990), which relied almost exclusively on interviews with managers and did not address work environment issues. Few studies of non-union workplaces are available. For example, "no physiological or ergonomic research of relevance has been allowed access to lean production worksites in Japan" (Bjorkman, 1996, p. 115).

Because of the many variants of new work systems, and their differing labor–management context, greater efforts are needed to describe the actual work

[7] Hospital nurse staffing levels and higher nursing skill mix (a higher proportion of RNs) have consistently been found to be significant correlates of lower inpatient mortality (Sochalski, Aiken, & Fagin, 1997). For example, magnet hospitals (i.e., the professional nurse practice model) have lower mortality rates for Medicare patients (Aiken, Smith, & Lake, 1994).

reform (and its health impact) rather than simply relying on labels. For example, an "idealised model of TQM is difficult to find in practice" (Wilkinson, Godfrey, & Marchington, 1997, p. 805). Other interventions, "some related to TQM and some not, are increasingly being herded under the TQM banner" (Hackman & Wageman, 1995, p. 338).

It is also possible that survey scales developed to measure job strain may not be able to capture what is particularly stressful about lean production. Many current job content instruments were developed to examine the characteristics of Taylorism, in which there was little teamwork or worker participation. Without understanding and measuring the organizational context of decision making and group activities, current instruments may overestimate the level of control and social support employees actually have in lean firms (Nishiyama & Johnson, 1997).

Union or Worker Response to Lean Production

In unionized facilities, where most studies of lean production have been conducted, it was nearly impossible to study a "pure" form of lean production. Often, the new work system led to a reaction from workers and unions. Such responses have included a 5-week strike in 1992 at CAMI (Canadian Auto Workers); a 2-hr strike at NUMMI in 1994 (UAW); a strike threat at Mazda in 1991 (UAW); OSHA inspections and settlements at GM, Ford, and Chrysler in 1989–1990 and at NUMMI between 1992 and 1994 (UAW); surveys to document conditions; and collective bargaining (Adler et al., 1997; Babson, 1993; J. Enos, personal communication, May 3, 1996; Lund, 1994; M. Parker & Slaughter, 1994; D. Reynolds, personal communication, February 28, 1996; Rinehart, Huxley, & Robertson, 1995; Robertson et al., 1993; Slaughter, 1994; Swoboda, 1990). These efforts altered lean production to some extent—through moderating work demands (more staff as well as control over line speed and job standards), increasing latitude (electing team leaders, ability to transfer, joint committees), ergonomics programs, and less arbitrary access to training (see the Appendix).[8]

In some cases, joint labor–management implementation of team programs (Kaminski, 1996b) appears to have resulted in improved working conditions. Such programs, often called *high-performance work organizations,* have been established to both increase business competitiveness and "sustain good jobs" within the protection of a collective bargaining agreement (Turner, 1996, p. 1). These need to be further evaluated for their impacts on job characteristics and on health.

A Research Agenda

Many research questions remain, which require answers from prospective and comparative studies. We need to know the impact of lean production and related new work systems on the following.

1. *Health.* This includes the use of standardized diagnostic criteria to assess musculoskeletal disorders, hypertension, and heart disease.

2. *Skill development and use.* Is the content of skills training technical, basic skills, critical thinking, or standardized company-specific procedures (Jacobs, 1995)? Skill development by definition requires a process (e.g., a negotiated process) that allows employees access to training, adequate training, and more highly skilled jobs. Does increased outsourcing lead to reduced opportunities for workers to move into skilled trades jobs (Richardson, 1993)?

3. *Coworker support and solidarity.* Is coworker support, solidarity, and group autonomy increased or decreased under lean production and related systems such as TQM? Informal work groups in traditional production helped control work pace and kept knowledge on the shop floor (Johnson, 1989, 1997). One expressed purpose of JIT and TQM is to bring work group knowledge under management control. In addition, to what extent is peer pressure used to increase work pace, reduce support, deny injuries, and delay medical treatment?

4. *Union strength.* In Wayne, Michigan, 72% of workers reported that the union's bargaining power had been strengthened after implementation of team concept (Kaminski, 1996b), whereas at three other U.S. team concept programs (Bertelli, 1996; Kaminski, 1996a; Moye & Rosenthal, 1996), a majority felt that the union was weaker after the transformation (Kaminski et al., 1996). Similarly, in a British study, management in several industrial facilities stated that TQM was, in part, a way to "marginalize the unions." In another facility, however, introducing TQM involved a closer relationship with the unions

[8] The Japanese Auto Workers union has also campaigned for shorter work hours, a reexamination of the JIT system, the integration of segmented and routine jobs, and the redesign of production jobs to make them more available to older and to female workers (Berggren, 1992, p. 252). In the United States, nurses have negotiated the process and timing of hospital restructuring and have protested nurse layoffs (American Nurses Association, 1995; Brannon, 1996; Greiner, 1995; T. Richardson, 1994; Wunderlich, Sloan, & Davis, 1996).

(Wilkinson et al., 1997). At NUMMI, a more militant union leadership was elected in 1994 in response to many members' "desire for a more assertive union" (Adler et al., 1997, p. 420).

5. *Health in non-union workplaces,* especially low-wage supplier or contractor firms. By 1990, 39% of all North American auto industry employment was non-union, 76% outside the Big 3 (Babson, 1995a). Lean companies place greater demands on suppliers to deliver JIT and meet strict quality standards. If unions tend to modify the most stressful features of lean production, are conditions worse at non-union U.S. workplaces or those in developing countries? In general, studies that show improved job characteristics among survivors of downsized companies need to consider the job characteristics (and income) of former employees now working elsewhere (as shown by Ostry, Marion, Demers, & Hertzman, 1998).

6. *Workforces that are older and not highly selected.* Older workers appear to be at greater risk for hypertension and heart disease if exposed to job strain (Landsbergis, Schnall, Warren, Pickering, & Schwartz, 1998; Schnall et al., 1994). In most Japanese transplants in the United States, extensive screening of applicants (1%–3% chosen) leads to a workforce that is "young, strong, intelligent, good-mannered, highly motivated and prepared to cooperate" (Berggren et al., 1991, p. 4).[9] Transplants often provide pay and benefits far above the prevailing wage and job security in largely rural areas. To what extent might this motivate workers to underreport complaints or injuries?

Another important research issue is the time period of the impact of lean methods. For example, CAMI and Mazda employees felt initially satisfied with their participation in planning production. However, once the system was operating, they felt betrayed by speed-up, injuries, and limited participation. After union or worker resistance, are more stressful aspects of the new system modified?

We also need better health and job characteristics data on alternatives to lean production. For example, the Scandinavian STS autonomous work group model provides greater latitude and longer cycle time than traditional assembly lines or lean production, and thus appears to be more conducive to employee health, prospects for personal growth, assumption of responsibility, opportunity to use one's skills, and reduction in physical strains and injuries (Berggren, 1992). Thus, we need to test the hypothesis proposed by Womack (1996), a proponent of lean production, that longer cycle times are not necessarily preferred by workers. Melin, Lundberg, Soderlund, and Granqvist (in press) demonstrated that workers in such a flexible STS organization do not show increases in systolic blood pressure, heart rate, and adrenaline during their work shift as do workers on a traditional assembly line. In addition, catecholamines return to baseline more rapidly after work in the flexible organization.

The unionized Saturn auto facility in Tennessee combines lean production elements of *kaizen* and TQM, the Scandinavian semiautonomous work team approach, and a comprehensive ergonomics program (LaBar, 1994). In some areas, cycle time is about 10 min. Worker teams have more latitude at Saturn to run their work areas than at Mazda or NUMMI (Bluestone & Bluestone, 1992). Recently, however, there has been conflict over the scope of teams' latitude and over shiftwork (Labor Notes, 1995). Unfortunately, neither injury and illness data nor job characteristics survey data are available to evaluate what appears to be the United States' nearest approximation to the sociotechnical approach.

Are there elements of lean production (e.g., cooperation with suppliers, statistical quality control, and multiskilled teams) that can be adopted for efficiency and quality, while also expanding worker job security, skills, and authority and positively affecting health? Are there elements that may be more harmful to workers (e.g., JIT, according to Parker, in Landsbergis, Adler, et al., 1998)?[10] Adler et al. (1997, p. 434) suggested that lean production can increase injuries if implemented poorly, but if "management makes health and safety a priority," features of the lean system can be used to improve ergonomics. Both "the Swedish and the lean production models permit 'variants' and 'hybrids' " (Adler, 1994, p. 1368). For example, at ABB (in Sweden), team building, multiskilling, job rotation, and process organization, along with ending line production and restricting monotonous work tasks to two consecutive hours, "seems closer" to STS "than to lean production" (Bjorkman, 1996, p. 116). However, Womack et al. (1990) took a fundamentalist approach and portrayed the Japanese model as indivisible, under no circumstances to be divided, modified, or combined with other solutions (Berggren et al., 1991, p. 55).

[9] In Japan's Takaota Toyota plant, the workforce is all male and much younger than at NUMMI. After age 30–35 years, workers are promoted to team leader and moved to slower paced off-line work or to slower paced suppliers (Adler et al., 1997).

[10] Parker and Wall (1998) argued that the particular effects of new work system will depend on various factors, such as the type of technology, the way the initiative is implemented, and the particular choices about work roles that managers make.

More research is also needed on the effect of related new work systems, such as TQM, on models of occupational health interventions and worker participation. For example, ergonomists have begun to espouse the strategies of TQM and teams. "Ergonomics and the quality movement both advocate the same organizational mechanism for implementation of change, the small workforce-dominated team," but there have been "relatively few evaluations" of this approach (Drury, 1997, pp. 251–256). New work systems might reduce CTDs by causing "a more variable exposure" and "increased investment in the work force" (Winkel & Westgaard, 1996, p. 75). However, some ergonomists have warned of the dangers of this approach. "The rather rigid guidelines of quality standards (e.g., ISO-9000 series) certainly imply adherence to a single written procedure" (Drury, 1997, p. 259). "Undue productivity demands may cause undue biomechanical and psychosocial exposures" (Winkel & Westgaard, 1996, p. 75).

TQM's approach to improving system performance is to empower employees by expanding their horizontal control (influence over and responsibility for the immediate job and work group levels) while simultaneously expanding management's vertical control over the total production system (Johnson, 1997; Schurman, 1996, p. 377). TQM keeps "authority centralized" (Hackman & Wageman, 1995, p. 337).[11] In contrast, participatory action research (Israel, Schurman, & House, 1989) views multiple stakeholder interests as legitimate and seeks to create governance structures and processes that allow the responsible participation of multiple stakeholder groups (Schurman, 1996).

The distinction between forms of empowerment and participation is evident in studies of *participatory ergonomics*—a collection of techniques and approaches to problem solving (Kuorinka, 1997). For example, some programs, using QC–TQM-type teams, without union involvement, have achieved limited success, in part because issues of staffing and assembly-line speed were beyond the scope of the teams' authority (Bohr, Evanoff, & Wolf, 1997; Moore & Garg, 1997a, 1997b).[12] Other programs have used joint labor–management committees to gather ideas from coworkers, and such committees appear to have greater authority to influence staffing or equipment purchasing (Loisel, et al., 1997; Loisel, et al., 1994; Moore, 1994; "Preventing CTDs," 1993). Therefore, although many interventions may use the label *participatory ergonomics,* more research is needed to test the hypothesis that on-line or substantive participation (e.g., shared authority, self-managed teams, and redesigned job characteristics) may produce better worker health than off-line or consultative participation (e.g., QC, TQM, and maintenance of centralized authority).

Finally, to what extent are lean production and related new systems of work organization optional or essential components of current lean economic trends? Many employers have incorporated aspects of lean production such as downsizing (American Management Association, 1997), outsourcing to low-wage suppliers, 24-hr operations (alternate work schedules), compressed work weeks (e.g., four 10-hr days or three 12-hr days), and workforce flexibility (e.g., mandatory overtime with little advance notice). In 1997, 29% of U.S. workers reported that it is somewhat or very likely that they will lose their jobs in the next couple of years, an increase from 15% in 1977 (Bond et al., 1998). Between 1985 and 1993, the proportion of nonagricultural, salaried U.S. workers who worked more than 48 hr per week grew 30%, to over 21 million (Rones, Ilg, & Gardner, 1997). The average U.S. married-couple family worked 247 more hours in 1996 than in 1989 (Mishel & Bernstein, 1998). Such economic trends may help to explain increases in time constraints and workload demands reported in European and U.S. surveys over the past 20 years (Bond et al., 1998; European Foundation, 1997b). Are these trends leading to a reduction in the prevalence of low strain and passive jobs in Karasek's model—a "shrinkage of the quadrants" resulting in a predominance of active and high-strain jobs in the economy?

To what extent are lean economic trends increasing illness risk? In Japan, a 1982 case study found *karoshi* deaths (death from overwork) associated with long working hours (an average of 60 hr per week), shift work, and irregular work schedules (Nishiyama & Johnson, 1997). To what extent are increased work demands (versus better reporting) responsible for the dramatic increase in the injury and illness rate among auto assemblers (SIC Code 3711) from 5.7 per 100 in 1985 to 33.2 per 100 in 1994 (Bureau of Labor Statistics, 1998)? Excessive overtime may increase stress, fatigue, family problems (Cooper, 1996), hypertension (Hayashi, Kobayashi, Yamaoko, &

[11] W. Edwards Deming and Joseph Juran were "quite circumspect about the nature of employee involvement under TQM" (Wilkinson, Godfrey, & Marchington, 1997).

[12] During the 1980s, the meatpacking industry, in response to global competition, had "rationalized" production—increased line speed, introduced machine pacing, and fragmented jobs (Novek, Yassi, & Spiegel, 1990)—which led to dramatic increases in injuries (National Institute for Occupational Safety and Health, 1994, pp. 5–6).

Yano, 1996), and heart disease (Breslow & Buell, 1960; Falger & Schouten, 1992; Tüchsen, 1993; Uehata, 1991). Downsizing has been associated with increased rates of fatal occupational injuries in the United States (D. Richardson & Loomis, 1997), absenteeism, and musculoskeletal disorders in Finland, especially among older workers (Vahtera, Kivimaki, & Pentti, 1997), and significant increases in minor psychiatric disorders, blood pressure, and weight among English male government employees (Ferrie, Shipley, Marmot, Stansfeld, & Smith, 1998). A major commitment of resources to studying these issues at the employer, national, and international levels is essential for a better understanding of the major social and economic factors contributing to worker health in the next century.

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Appendix

Modification of Lean Production in Auto Manufacturing Through Union Efforts

Improved staffing through a temporary assignment pool of workers to fill in for absent or injured workers. (Undermines one purpose of teams: peer pressure to discourage absenteeism and encourage working while injured.)
Fairer access to training
Increased transfers between departments
Joint committees on health and safety, ergonomics, and training
The right to elect or recall team leaders
Team leaders' duties in contract
Increasing workloads owing to absenteeism is forbidden
Temporary assignments offered to workers on the basis of seniority
Some limits on line speeds and workloads
No alternative work schedule of four 10-hr days (NUMMI in 1994)
Ergonomics programs
Job analysis, worksite evaluations
Engineering controls, task rotation, rest periods
Review models before production
Better medical management
Reduce line speed
No reprisals for reporting injuries

Note. From Adler et al. (1997); Babson (1993, 1995b); Enos (personal communication, May 3, 1996); Lewchuk et al. (1996); Lund (1994); M. Parker and Slaughter (1994); Reynolds (personal communication, 1996); Rinehart et al. (1995); Robertson et al. (1993); Slaughter (1994). NUMMI = New United Motors Manufacturing, Inc. (a GM–Toyota joint venture).

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