

Lean production and work-related musculoskeletal disorders: overviews of international and Swedish studies

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Abstract. This paper aimed at summarizing the knowledge of the relationship between Lean and work related musculoskeletal disorders (WMSD), and WMSD risk factors, in manufacturing companies. Literature search processes identified 23 publications studying this, in scientific journals. Eight included measurements of WMSD; three were mostly negative, two showed mixed results, one showed no results and two were mostly positive. Eighteen publications included measurements of WMSD risk factors; seven showed mostly negative results, eight showed mixed results, two showed mostly positive results and one was inconclusive. Three literature reviews were identified, which studied this question; two were mostly negative, while the third was inconclusive. Also, 12 publications of grey literature studying Lean and WMSD risk factors in Swedish organizations were identified; nine showed mixed results, two showed mostly positive results and one showed mostly negative results. Due to the varying quality and study design of the publications, together with the few identified studies, it is difficult to compare them. The context and the implementation also likely affect the results. The general conclusion was that a Lean implementation may increase the risk of WMSD and risk factors for WMSD, if it is not accompanied with an ergonomic intervention.

Keywords: WMSD, working conditions, manufacturing

1. Introduction

Lean Production is currently the dominating rationalization concept in the manufacturing industry in Sweden[1-2]. Due to the fast spread of Lean, it is important to study the effects of Lean on work related musculoskeletal disorders (WMSD) and potential risk factors for WMSD, especially since assembly workers in general has a high risk of developing WMSD.

The Swedish context is of special interest for this study, due to the socio-technical tradition that has been influential in the Scandinavian countries, together with a strong union presence and legislation regarding work conditions[2]. These factors likely affect how Swedish companies work with Lean and how the concept affects the employees[3].

1.1. Lean production

Lean Production as a management concept was introduced to a wider public through the book *The Machine that Changed the World*[4]. The concept was not new; earlier publications existed, but through this book, the concept received a large impact[5].

There is no unified definition of Lean[6] and different researchers focus on different aspects of the concept. However, techniques which are often included in Lean's operationalization are small-sized batches (Just in Time-production), 5S/housekeeping, waste reduction (*muda*), production balancing (*jidoka*), *kanban*, standardization, reduction of set-up times and continuous improvements[6].

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1.2. Aim of the study

The aim of the study was to create an overview of the scientific knowledge concerning the relationship between Lean Production (and similar production system designs) and WMSD/risk factors for WMSD. The focus was on manufacturing companies.

A separate search was also made, with the aim of studying how Swedish organizations' work with Lean affects employees.

2. Method

Literature searches were performed in *Ergonomics Abstract*, *Pubmed* and *Business Source Elite*¹. The identified publications references lists were used to find more publications. The search was limited to English and Swedish publications, published after 1980. Conceptual and theoretical papers have been excluded. Studies from non-manufacturing contexts or studies which only focused on specific Lean tools were excluded from the results. Also, studies of Total Quality Management/TQM were excluded, since TQM and Lean are significantly different[6]. However, studies of the Toyota Production System/TPS, Just in Time-philosophy and JiT-manufacturing were included in the results, due to the similarities between TPS and Lean, and since JiT was determined to be an often reoccurring part of Lean.

No excluding definition of Lean has been used during the search process, due to the lack of a unifying definition of the concept. Neither has any means of measuring level of Lean implementation been used, for the same reasons. In order to determine which risk factors that affect mechanical exposure, and consequently, increases the risk for WMSD, Westgaard and Winkel's definition was used[7].

No quality measurement model has been use to assess and rank the identified publications in the search, depending on such factors as study design, etc.

During the search, three literature reviews[7-9] were also identified, which studied directly or indirectly the relationship between Lean and employee effects. Other researchers have also contributed with publications of significance for this overview, which were not identified by the search engines or included in the reference lists of the identified publications.

Since no publications in scientific journals were detected, which studied the relationship between WMSD and Lean in the Swedish manufacturing in-

dustry, the choice was made to expand the search to grey literature (conference publications, consultant and union reports, student thesis and dissertations, etc.). This decision was based on Eklund et al.'s[10] argumentation to use the best knowledge available.

3. Results

The search process resulted in 23 publications in scientific journals (not including the publications describing Swedish organizations work with Lean). These are presented in table 1. The few identified papers, together with the differences between the studies, meant that no meta-analysis was possible. The included studies were of varying quality and the Lean interventions were seldom described in detail, making comparisons difficult.

Of the identified publications, eight included measurements regarding WMSD; three showed mostly negative results, two showed mixed results, one showed positive results and two showed no differences between Lean and non-Lean companies. 18 of the found publications studied relevant risk factors for WMSD. Of these, seven showed mostly negative results, eight showed mixed results, two showed positive results and one showed inconclusive results.

Three literature reviews were identified, which studied the relationship between Lean and employee effects[7-9]. Two of these showed mostly negative views of Lean's effects on employee, while one gave an inconclusive view.

The search for publications describing the relationship between Lean and employee effects in Swedish companies resulted in 12 publications (mostly grey literature). Of these, nine showed mixed results, two showed mostly positive results and one showed mostly negative results. Only one publication contained measurements of WMSD frequencies, comparing Lean to non-Lean companies; it showed an increased risk for WMSD in Lean companies, especially for women. However, one of the found publications contained results from non-manufacturing organizations.

When comparing included positive and negative employee results in the Swedish and non-Swedish publications, the ratio between them in the Swedish studies were more even; in the non-Swedish studies, the negative results were more common.

¹ Used search words are available on request.

4. Discussion

Given the small number of studies, together with their varying quality and study design, and often insufficient descriptions of the Lean interventions, there is not enough basis to make decisive conclusions regarding the connection between Lean and WMSD. However, tentative conclusions were made regarding emerging *tendencies* in the found publications.

The results shows a tendency for increasing the risk of WMSD, when Lean is implemented, especially if the implementation is not accompanied by an ergonomic intervention program, focused on addressing issues such as reducing monotony and repetitiveness of work.

When it comes to risk factors for WMSD, the results shows that Lean appears to have a tendency to lead to increased work pace, workload, work intensification and stress. However, Lean often, though not always, seem to create positive effects for the employees as well. Consequently, this seems to be in line with Berggren's[11] conclusion, that Lean means worker smarter *and* harder, not just smarter.

The results from the publications describing employee effects from Swedish companies also shows mixed results, though with a majority of positive effects, at least concerning risk factors for WMSD. However, the grey nature of the studies, together with the low number of publications, means that conclusions from them should be tentative, at best. There is little direct information concerning WMSD, meaning that no conclusions are merited from the publications.

The tendency towards more positive results from Lean, could possibly be explained by the Swedish socio-technical context[3] and a high level of employee participation in the companies' Lean implementations. Also, Saurin and Ferreira's[12] argumentation, that a Lean system which is not fully in place allows for more worker autonomy, which could reduce some of the negative aspects of the Lean, could apply here. The reason is because many of the studied Swedish companies have only implemented some aspects of Lean.

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Lastly, we need to keep in mind, as Hasle et al.[8] and Landsbergis et al.'s[9] argue, the importance of how the implementation and context affects the employee results from Lean. Consequently, it is difficult to assess how much of the results that are caused by these factors. Based on this, we argue that it is important to monitor the Lean implementation effects on the employees, in order to reduce problems and capture positive effects.

5. Conclusions

While Lean can lead to both positive and negative effects for employees, there is insufficient amount of studies, and they are of varying quality and study design, to make decisive conclusions. Nevertheless, negative results are more frequently reported in the non-Swedish studies, when compared to the grey literature describing studies in Swedish organizations. Thus, it is merited to *tentatively* conclude that without active ergonomic interventions, the introduction of Lean in a manufacturing setting can create an increased risk for work-related musculoskeletal disorders, though the risk of this in Swedish companies might be lower. However, future research is needed to better understand the relationship between Lean Production and WMSD, both in Swedish and non-Swedish organizations.

6. Limitations

The result of the literature searches does not pretense to be covering all existing publications of Lean and WMSD, especially not psychological risk factors.

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Table 1

Identified studies describing found relationship between Lean and WMSD, and between Lean and risk factors for WMSD.

(+) = high, increasing; (+?) = weak positive connection; (-) = decreasing, low; (-?) = weak negative connection; (+/-) = both increasing and decreasing; (0) = no effect/no connection. The studies are presented in chronological order, starting with the most recent ones.

Author, year, industry, study design, studied change	Effects on WMSD & health	Effects on risk factors for WMSD
Saurin & Ferreira 2009[12] Manufacturing of harvesters, Brazil, interviews, questionnaires, feedback meeting, no control group, several Lean tools implemented since 2001.	Pain/discomfort at a moderate level; unchanged by Lean (0).	Increased work pace/load (+) Decreased time for brakes (-) Increased pressure from superiors to achieve goals; still, the employees were fairly satisfied with the relationship with the managers (+) General working conditions had improved (+) Moderately stressed, which had increased from Lean (+) Improved autonomy (+)
Womack et al. 2009[13] Car manufacturing, USA. Comparison between 56 work stations in a Lean & traditional factory.	The Lean factory had reduced the number of injuries by 19% between 2000-2006 (-).	Repetitive work increased (+) Lower use of force (-) No difference in work postures (0) In both factories, 60% of the work was classified as having risk for hand related problems; no significant differences between the two factories.
Brown & O'Rourke 2007[14] Shoe manufacturing, China. Case study: 27 questionnaires & focus groups (20 persons), no control group. Lean was introduced approximately 1 year ago; used tools was JiT, reduced inventories, etc.		Increased pressure on the production (+) Increased individual stress (+) Almost all of the respondents reported that the work conditions had improved during the recent year. (+) Stress was related to worry of not reaching set goals, unrealistic goal setting, too high work pace, too much work, unfair supervisor
Conti et al. 2006[15] Manufacturing, UK, 1391 questionnaires, assessed level of Lean (1-5) for 10 Lean tools & tested 21 hypothesis related to stress.		Reversed u-shaped connection between stress and level of Lean implementation: low level of Lean, increased stress, while reduced stress at high level of implementation of Lean(+/-) The stress is increased by work intensification, overtime, doing the work for personnel missing for sick leave, lack of tools, ergonomic difficulties and shame for defect products; stress was reduced through participation, teamwork and support in the work situation.
Mehri 2005[16] Car manufacturing, Japan, former employee of studied company. 75 interviews.		Perceived work load was high (+)
Brenner et al. 2004[17] Fairis & Brenner 2001 [18] Industrial setting, statistics from BLS, combined with investigation of the occurrence of TQM, JiT, teams and Quality Circles.	Correlation between cumulative trauma disorders/CTD and Quality Circles/QC, and between CTDS & JiT (+); worse	

	when JiT & QC was combined (+). No connection between CTD & TQM, & between CTD & team. (0)	
Schouten & Benders 2004 [19] Bike assembly, Holland Observations and 63 employee questionnaires, used tools were JiT, quality control, TPM, standardization, 5S, andon, kaizen and reduced inventories.	<i>Workers:</i> Few problems with health/ physical reactions (-)	<i>Workers:</i> Autonomy limited (-) Support from supervisors or other departments had decreased (-) High dissatisfaction with work content (-) Short work cycles (-) Overview of work limited (-) Need for resting high (+) Satisfactory means to solve problems in work, due to support from workers (+) Work satisfaction limited (-) <i>Supervisors:</i> Better working conditions, when compared to workers (+)
Seppälä & Klemola 2004 [20] Manufacturing companies, Finland. Cross-sectional study, 525 questionnaires, 4 companies, introduced Lean tools were JiT, "pull" production, etc.		Increased perceived work pace (+) Increased perceived work control (+) Increased stress for the white-collar workers (+)
Parker 2003 [21] Automotive manufacturer, UK. 368 questionnaires, 3 years after Lean was implemented. Control group used. Introduced Lean tools: assembly lines, Lean-teams, process development teams, standardization, reduced inventories, "pull-production", manufacturability. The assemblers in the assembly line were not included in the Lean teams.		Work related depression increased with assembly lines and standardization (+) Reduced confidence to own ability to perform a broader role, such as making suggestions for improvements (-) Worker involvement in the workplace was reduced (-) Participation was unchanged for those participating in Lean-teams (0), while it increased for the employees in the technical support group (+) No changes in workload or work related worry for lean team (0); increased for assembly lines (+). Reduced participation in the work process and usage of skills, and reduced autonomy, were contributing factors for negative effects from Lean.
Andersen-Connolly et al. 2002 [22] Manufacturing, USA. Longitudinal questionnaire study (1997 & 1999), 1244 questionnaires. Studying effects from restructuring, outsourcing, reduced inventories, simplified processes & cross-functional teams.		<i>Employees:</i> Reduced health related to work intensity, competence and teamwork (-). Improved health related to autonomy (+) <i>Management:</i> Reduced health related to work intensity and autonomy (-). Improved health related to teamwork and work skill (+).
Bruno & Jordan 2002 [23] Car manufacturing (Chrysler), USA. Longitudinal study (1989 & 1997). Lean tools implemented: quality circles, teamwork, kaizen and andon.		The perceived work environment and job satisfaction was reduced (-) Most of the employees felt that quality circles & teamwork gave very little (0). However, difficult to assess if the changes are caused by Lean or other factors, such as distrust of the management or failed expectations on the work.
Lewchuk & Robertson 2001 [24] Lewchuk & Robertson 1997 [25] Car manufacturing companies, Canada. Comparing 4 companies of differing level of Lean implementation. Highest level had GM & CAMI; lowest had Ford & Chrysler. 2424 questionnaire.	Working with pain, exposure to muscular fatigue & WMSD (+?)	Perceived work pace higher at GM (+) Highest perceived work load at GM (+) Possibility of varying work rhythm and talking during the work was lowest at GM, highest at CAMI (+/-) Difficulty of finding replacement for bathroom brakes were approximately the same (0)
Jackson & Mullarkey 2000 [26] Garment manufacture. Comparing normal production line & cell manufacturing.		Job satisfaction unchanged (0) Work related effort unchanged (0)
Leclerc et al. 1998 [27]	Odds ratio 2,24	

Assorted manufacturing companies, France. Cross-sectional study of JiT-production, with reference group	for developing CTD in companies working with JiT (+).	
Adler et al. 1997 [28] Car manufacturing (NUMMI), USA. Longitudinal case study, investigating the ergonomic situation during launches of new car models in 1993 and 1995.	High frequency of reported injuries during launch of car model (+). Injuries reduced after ergonomic intervention program (-).	
Lewchuk & Robertson 1996 [29] 16 suppliers to car manufacturing companies, Canada. 2 Lean companies, 4 companies who had initiated Lean, 8 traditional companies & 2 explorative companies. 1670 questionnaires	Working with pain similar in Lean & traditional companies (0). Working with pain lower at companies initiating Lean (-)	Perceived work load higher, and the perceived increase was higher, when comparing the Lean companies to the traditional companies (+) Perceived work load and uncomfortable working postures was lower in companies initiating Lean compared to traditional companies; the perceived increase in work load was also lower (-) Uncomfortable work postures, fatigue after work and tension during work was similar in Lean & traditional companies (0); however, the perceived increase of fatigue after work and tension during work was higher in the Lean company (+)
Jackson & Martin 1996 [30] Electronics manufacturing, UK Comparison between JiT assembly line (small batches, job rotation, simplified processes, pull production, inspection of own work) & traditional non-JiT line. 44 questionnaires before & after.		Work load higher with JiT (+) Work satisfaction decreased with JiT (-) Psychological stress unchanged (0) Chance of influencing work pace and which order in which job task are done in the work process decreased with JiT (-)
Nielsen 1996 [31] 6 manufacturing companies, 1 in process industry, Denmark Studied production systems inspired by Japanese management (sporadic implementation of JiT, other Lean tools in parts of the factories). Interviews with persons from all levels of companies, observations from 3 companies, 150 questionnaires from 4 companies		Few or no changes in competence requirements (0) Integration of quality control in the normal job design was perceived as creating better job satisfaction (+) No changes in worker autonomy, though in one company, the autonomy increased since workers could see the production planning one month ahead, instead of only 1-2 weeks (0) Physical work load unchanged (0) The general conclusion was that those jobs who had the best working conditions from the start perceived some improvements (+), while it was unchanged in the jobs with repetitive and unqualified jobs (0). The results and basis for the conclusions were not clearly presented in the paper.
Stewart & Garrahan 1995 [32] Car manufacturers, USA & UK 4 factories; 140 questionnaires. Used tools: teamwork, continuous improvements, etc.		Physical fatigue from work increased (+) Mental fatigue from work increased (+) Job satisfaction unchanged, or slight decrease (0/-)
Mullarkey et al. 1995 [33] Electronics manufacturing, UK Prospective study of JiT & TQM.		Stress showed no connection to JiT (0) Work satisfaction increased with JiT (+) Work pace/demands had a weak reversed connection with JiT (-?)
Babson 1993 [34] Car manufacturing (Mazda & Ford), USA. Case study, 2380 questionnaires 3 years after Lean implemented. No control group.		Perceived work demands increased (+) Perceived work control decreased (-) A high proportion of the respondents believed that they would be injured/worn out before pension, with the current work intensity (+)

Table 2

Identified studies describing the relationship between Lean and risk factors for WMSD in Swedish companies. (+) = high, increasing; (+?) = weak positive connection; (-) = decreasing, low; (-?) = weak negative connection; (+/-) = both increasing and decreasing; (0) = no effect/no connection. The studies are presented in chronological order, starting with the most recent ones.

Author, year, type of publication, study design, studied change	Effects on WMSD & health	Effects on risk factors for WMSD
Berglund 2010 [35] Dissertation. Qualitative study, 3 companies working with Lean.		Increased job satisfaction, through employee involvement in work with continuous improvements (CI) and problem solving (PS) (+) Reduced job satisfaction, due to increased control and steering of the work (-) Reduced cycle times (-)

<p>Brännmark 2010[36] Conference paper. Qualitative & quantitative study (41 interviews, 82 questionnaires), 8 companies. Lean tools: value stream mapping, standardization, 5S, improvement groups & set-up time reduction.</p>		<p>Improved working environment (+) Increased stress (+)</p>
<p>Oudhuis & Olsson 2010[37] Conference paper. Qualitative case study of large company implementing Lean.</p>		<p>Improved work environment (+) Increased job satisfaction, through employee involvement in CI & PS (+) Increased stress due to more monotonous and stressful work (+) Reduced cycle times (-) Reduced job satisfaction, due to standardization making work more boring (-) Increased workload, due to increased demands for working overtime (+) The positive effects of Lean only affect a portion of the employees.</p>
<p>Andersson & Liljenvald 2009[38] Student thesis. Questionnaire study of common elements in manufacturing companies' Lean work.</p>		<p>Increased job satisfaction, through increased group autonomy and employee empowerment, is common aspects in Swedish medium sized manufacturing companies work with Lean (+?)</p>
<p>Pettersen 2008[39] Conference paper. Qualitative study, 2 companies implementing Lean. Lean-tools: daily steering, visualization & 5S.</p>		<p>Improved work environment (+) Improved job satisfaction, due to improved communication between departments (+)</p>
<p>Eklund & Berglund 2007[40] Conference paper. Qualitative study, 2 companies implementing Lean (one turbine manufacturer & one lift truck manufacturer).</p>		<p>Improved working environment (+) Lowered workload, due to slower and more even work pace (+) Increased job satisfaction, through employee involvement in CI & PS (+) Increased stress, caused by more monotonous work, assembly lines and increased work pace (+) Reduced job satisfaction, due reduced contacts with other employees (-) Reduced cycle times (-) Increased workload, due to demands to work more overtime and to work in shift, not just day time (+)</p>
<p>Berglund 2007[41] Student thesis. Qualitative study of company implementing Lean.</p>		<p>Improved working environment (+) Reduced workload, due to slower and more even work pace (-) Increased job satisfaction, through employee involvement in CI & PS (+) Reduced job satisfaction from increased control, steering and standardization (-)</p>
<p>Börnfelt 2006[1] Dissertation. Qualitative study of 3 companies' Lean work.</p>		<p>Increased job satisfaction, through employee involvement in CI & PS (+) Increased job demands, due to competition between work groups and "shame" techniques, and the employees are expected to monitor each other (+)</p>
<p>Berglund 2006[42] Consultant report. Interviews with managers from 22 companies working with Lean, plus work place studies in 5 companies.</p>		<p>Reduced heavy lifting and improved work postures (-) Employees can take shorter breaks when needed (+) Work pace is slow and leveled (-) Increased job satisfaction, through employee involvement in CI & PS (+) Two of the five studied work places were assess as needing improvements in work postures, increased work variation and reductions of heavy lifting.</p>
<p>IF Metall 2003[43] Union report. Questionnaire study (17 000 respondents) of Lean's impact on working conditions.</p>	<p>WMSD frequency higher for employees in Lean companies; highest risk for women(+)</p>	<p>Increased workload, due to insufficient staffing (-) Reduced cycle times (-) Increased perceived stress by over 70% of respondents (+) The positive effects of Lean only affect a portion of the employees.</p>
<p>Härenstam et al. 2000[44] Book chapter. Mixed qualitative & quantitative study, 72 organizations & 210 respondents. Comparing the effects on work conditions in Lean & non-Lean organizations.</p>		<p>Work postures increasing the risk of WSMD was higher (+) Increased workload (+) Increased stress, due to increased number of indirect obstacles in the work (+) Less negative effects, compared to non-Lean organizations, on influence and stimulation in the work situation (-) The negative effects are especially negative for women.</p>
<p>Nilsson 1996[45] Peer review article. Discusses Lean & how it affects white-collar workers in Sweden</p>		<p>White-collar workers: Broader work duties (+) Increased workload, due to understaffing (+)</p>