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A Critical Review of a Pivotal Scientific Contribution: Liles and Associates 24 Years Later

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Objective: This review evaluates (in retrospect) the contribution of Liles and associates (1984) to the causality debate of the work relatedness of low back pain. **Background:** Often it takes years to appreciate the role of a paper with respect to the body of literature as a whole. **Method:** Although many papers appear remarkable when they are first published, the real value of a contribution often can be appreciated by considering how the paper "fills in the pieces of the puzzle" over time. This paper examines how the Liles paper influenced low back pain causality efforts after its introduction. **Results:** This analysis indicates that Liles and associates contributed to the science of low back disorder causality by (a) advancing the idea of quantitative measures used for field studies, (b) identifying a dose-response relationship for low back pain, and (c) recognizing the influence of a system of work and nonwork influences related to low back pain development. **Conclusion:** The Liles contribution to *Human Factors* has proven to play a pivotal role in our understanding of how low back pain is influenced by work exposure. **Application:** The concepts introduced here can help future efforts associated with understanding musculoskeletal disorder causality and work.

INTRODUCTION

Low back pain continues to be a problem that affects a large number of workers and affects the financial status of many organizations as well as individuals. Nearly two thirds of adults will suffer from low back pain at some point during their lives (Deyo & Weinstein, 2001). Nationally, health care expenditures for those suffering from low back pain are approaching $100 billion annually (Luo, Pietrobon, Sun, Liu, & Hey, 2004). Because the stakes are so high, low back pain is a problem that has attracted much attention. Historically, it has been generally accepted that low back pain can be a result of work exposure (Andersson, 1981; Chaffin, 1974, 1981; Frank, Pulcins, Kerr, Shannon, & Stansfeld, 1995; Kelsey, 1975a; Magora, 1970; Nachemson, 1975; Snook, 1978). Yet, Deyo (1998) has observed that even with less heavy labor, more automation, and improved diagnostic imaging and surgical and nonsurgical therapy work, disability caused by back pain has steadily risen. Others claim that back pain is a natural part of life and has little relationship to the work task (Hadler, Tait, & Chibnall, 2007).

Given that humans are complex and exposed to numerous potential risk factors that cannot be controlled during scientific studies, a definitive answer regarding the work relatedness of low back pain remains elusive. Although many firmly believe that work exposure can lead to low back pain, variability among people and the inability (and impracticality) to study work exposure via the medical "gold standard" – the randomized controlled trial experimental design – have left the door open to politicization of the causality issue. Furthermore, the controversy over the introduction of federal ergonomics standards has promoted more intense political debate. These developments have further clouded the issue of work causality and low back pain.

This backdrop has resulted in several objective efforts to assess the causality issue. The National Institute for Occupational Safety and

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Health (NIOSH) reviewed the epidemiological evidence for the work relatedness of low back pain in 1997 (Bernard, 1997). In addition, the U.S. Congress contracted with the National Academies to perform two independent reviews of the scientific evidence related to work and musculoskeletal disorders (including low back pain). These efforts took a broader approach that integrated the epidemiologic, biomechanical, psychological, and physiological evidence in their interpretation of the literature. The first effort was coordinated through the National Research Council (NRC), which convened a group of 10 scientists to evaluate the science and reported its findings in 1999 (NRC, 1999). The second effort consisted of a joint study between the National Research Council and the Institute of Medicine that expanded the investigational group to 19 scientists and physicians and reported its findings in 2001 (NRC, 2001). All three of these reports identified a causal relationship and relied on the pivotal work of Liles, Deivanayagam, Ayoub, and Mahajan (1984) that was published in *Human Factors.*

One of the reasons that the article by Liles et al. (1984) has played an important role in the interpretation of the body of knowledge is that this study was able to document work exposure through job observation and measurement. Most of the field studies prior to this time (Kelsey, 1975b; Magora, 1972; Undeutsch et al., 1982; Videman et al., 1984) had based their work exposure assessments on self-reports or job titles. These studies were limited by a lack of sensitive and quantitative work exposure measures. The article by Liles and associates was not the first field study to establish the work relatedness between physical work exposure measures and low back pain. Chaffin and Park (1973) reported similar field-based findings a decade earlier. However, the article by Liles and associates was unique in that it was able to establish a nonlinear dose-response relationship and exposure threshold above which low back disorder incidence, severity, and costs increase dramatically. In addition, this was the first epidemiologically oriented paper published in *Human Factors.*

ORIGINAL STUDY SUMMARY

The original goal of the study by Liles et al. (1984) was to validate the use of the Job Severity Index (JSI) as a tool for the control of manual materials-handling injury in the workplace. The JSI was a technique developed by these authors as a measure of worker stress associated with particular lifting tasks. The concept behind the JSI was to predict worker capacity through regression equations based on worker anthropometry and psychophysically determined strength. The workers' capacity is then compared with task exposures described as a function of task origin and destination (relative to the worker anthropometry), the amount of weight lifted, the distance of the object being lifted from the spine, and exposure time and lift frequency. The summation of the task weight exposures relative to worker capacities in the JSI was intended to represent the worker relative stress.

The JSI concept was tested with a relatively large group of workers who performed primarily materials-handling tasks, defined as those in which more than 4.53 kg was lifted at least 25 times a day. JSIs were calculated for 453 workers employed in 101 jobs within 28 companies. Health effects were determined through "comprehensive injury profiles" developed for each worker and consisted of reported or recorded lifting injuries to the back. Company personnel files, insurance records, and supervisor interviews were used to assess history of injury for each worker until the job changed, typically from 1 month to more than 2 years.

The analyses classified JSIs into 10 equal categories, and a dose-response relationship with injury was identified. Liles et al. (1984) identified an "injury threshold" for a JSI of 1.5. The results indicated that injury rates increased dramatically for workers exposed to JSIs above 1.5. The authors also identified a 60:1 difference for low back disorder costs for those working in jobs with JSIs above 1.5 compared with those working in jobs with JSIs below 1.5.

Study limitations consisted of no reporting of response rates or subject inclusion criteria, no adjustment for confounders, and a lack of statistical analyses. Study strengths consisted of a design that allowed for observed exposures to previous injury onset and an objective assessment of exposure.

CONTRIBUTIONS TO THE SCIENCE

Many aspects of the article by Liles et al. (1984), in hindsight, can be considered valuable contributions to the causality argument and either have

become accepted concepts or supported the model that work contributes to low back pain. First, this article and the effort by Chaffin and Park (1973) were the first field studies of low back pain to more specifically document work exposure through quantifiable biomechanically relevant measures. After the study by Liles et al. was published, quantification of work exposure in field environments became much more acceptable and common. One analysis has demonstrated that when physical work exposure can be quantified, a stronger relationship with low back pain can be established (NRC, 2001). These types of quantitative field exposure measures paved the way for more sophisticated field exposure measures that were able to build on these concepts (Marras et al., 1993). Thus, this is one of the early studies that was able to demonstrate the value of work exposure quantification.

Second, the study by Liles et al. (1984) also was able to demonstrate that a nonlinear dose-response relationship was present with work exposure. Not only is this finding important for epidemiological acceptance, but the dose-response relationship is also important from a biomechanical perspective in that it validates the load-tolerance relationship, which has become the underpinning of biomechanical and epidemiological logic.

Related to this concept, the Liles et al. (1984) article identified the concept that a risk threshold exists, above which risk significantly increases. This is certainly consistent with much of the contemporary view of low back pain initiation.

Third, although not recognized at the time, the study by Liles et al. (1984) demonstrated what later was recognized as a J-shaped relationship between work exposure and low back pain risk. The concept of the J-curve was introduced by Videman years later (Videman, Nurminen, & Troup, 1990). This concept suggested that the greatest level of spine pathology was associated with those exposed to high workloads, and the lowest level of pathology was associated with those exposed to moderate levels of work exposure. Sedentary or very low work exposure resulted in moderate elevation in low back pain risk compared with moderate exposure. The data reported by Liles and associates also demonstrate such a trend.

Finally, the article by Liles et al. (1984), along with the contribution by Chaffin and Park (1973), was able to stress the importance of considering the individual's capacity relative to the work demands. The JSI index was a measure of this relationship. Most previous studies did not consider the individual's tolerance for exposure. However, this study demonstrated the importance of considering the individual along with the work. This concept has become the hallmark of back rehabilitation and return-to-work efforts. In addition, this concept has played an important role in viewing the body of literature in perspective. Although the political debate regarding the work relatedness of low back pain has resulted in an all-or-nothing argument, scholarly assessments of the literature (NRC, 1999, 2001) have concluded that low back pain risk is a result of a mixture of personal factors (age, strength, genetics, conditioning, etc.), psychosocial factors (job control, pacing, etc.), and work exposure factors. The approach by Liles et al. in considering two of these categories was consistent with this interactive risk factor view of causality.

Collectively, these points show that 24 years later, the approach associated with the study by Liles et al. (1984) was appropriate, and many of the findings support the foundation for contemporary thinking about low back pain causality.

INFLUENCES

One measure of the value and influence of a scientific contribution is the citation history related to the paper. A citation search of the article by Liles et al. (1984) indicates that this study has been cited by a very impressive list of musculoskeletal researchers. As mentioned earlier, this study has been referenced by NIOSH as well as the two National Academies studies. However, the citation search has revealed that many of the prominent researchers in musculoskeletal disorders throughout the world have included this study as part of their considerations of work causality. This list consists of many eminent researchers, including Drs. Era Viikari-Junura, Laura Punnett, Waldemar Karwowski, H.-R. Guo, and Rob Radwin, to name just a few.

A Web search of references to this study that goes beyond journal articles indicates numerous and widespread hits. The Web sites quoting this paper indicate a spectrum of references: low back pain research, ergonomics studies, safety forums, and rehabilitation programs. Hence, this study has been able to influence the thinking and practices of many associated with low back pain control and treatment.

CONCLUSIONS

We have seen that the article by Liles et al. (1984) can indeed be considered a pivotal paper and a good example of valuable research efforts published within *Human Factors.* This article is an excellent example of the value of scholarly publishing. It is not uncommon that the parts of a paper that contribute the most to future thinking are not the topic of the paper but the unintended contributions. For example, the value of this paper has little to do, specifically, with the JSI validation, which was the objective of the study. However, the "concepts," both recognized and unrecognized, associated with this paper at the time of publication have played a role in the thinking of those researchers who have studied work causality for more than two decades after this paper was published. We can all thank Liles and colleagues for the role their work has played in the evolution of the low back causality science as well as for the role this study has played in the evolution of biomechanical and ergonomics thinking.

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