International Journal of Industrial Ergonomics 39 (2009) 202–210

Contents lists available at ScienceDirect

International Journal of Industrial Ergonomics

journal homepage: www.elsevier.com/locate/ergon

Quantifying relationships between selected work-related risk factors and back pain: A systematic review of objective biomechanical measures and cost-related health outcomes

Nancy A. Nelson [a,*], Richard E. Hughes [a,b,1]

[a] White Pine Occupational Health Research, LLC, 2500 Brockman Blvd., Ann Arbor, MI 48104, United States
[b] Department of Orthopaedic Surgery, University of Michigan, 2019 BSRB, 109 Zina Pitcher Pl., Ann Arbor, MI 48109-2200, United States

ARTICLE INFO

Article history:
Received 14 November 2007
Received in revised form 9 May 2008
Accepted 19 June 2008
Available online 8 August 2008

Keywords:
Back pain
Epidemiology
Biomechanics
Ergonomics
Intervention

ABSTRACT

The objective of this investigation was to use published literature to demonstrate that specific changes in workplace biomechanical exposure levels can predict reductions in back injuries. A systematic literature review was conducted to identify epidemiologic studies which could be used to quantify relationships between several well-recognized biomechanical measures of back stress and economically relevant outcome measures. Eighteen publications, describing 15 research studies, which fulfilled search criteria were found. Quantitative associations were observed between back injuries and measures of spinal compression, lifting, lifting ratios, postures, and combinations thereof. Results were intended to provide safety practitioners with information that could be applied to their own work situations to estimate costs and benefits of ergonomic intervention strategies before they are implemented.

Relevance to industry: This investigation uses published literature to demonstrate that specific changes in workplace biomechanical exposure levels can predict reductions in back injuries. Results provide safety practitioners with information that can be applied to their own work situations to estimate costs and benefits of ergonomic intervention strategies before they are implemented.

1. Introduction

Low back pain is the most common reason for days away from work, according to U.S. Bureau of Labor Statistics data (Courtney and Webster, 1999). In 1994, for example, there were 490,094 low back sprains/strains/tears that resulted in at least one day away from work, with an incidence rate of 60.7 per 10,000 full-time workers. Data from Washington State's Department of Labor and Industries, a workers' compensation state fund insurer, demonstrated that non-traumatic soft-tissue musculoskeletal disorders of the back comprised 14.4% of all claims between 1992 and 2000, accounting for $1.5 billion in direct costs (Silverstein and Kalat, 2002). Authors have estimated that 37% of low back pain worldwide is attributable to occupation (Punnett et al., 2005). Clearly, these disorders represent a significant public health problem and economic burden to employers.

While work-related musculoskeletal disorders might be controlled by any number of means, in the absence of national ergonomics legislation, an alternative approach is to demonstrate the economic benefits that can come from investing in ergonomic interventions. Increasingly, health and safety practitioners are interested in implementing interventions, but are forced to demonstrate potential economic benefits before they are allowed to allocate resources to a project. Although case studies of profitable investments in ergonomics interventions do exist, they often have methodological limitations and are difficult for safety professionals to use in a direct manner. Many interventions do not examine health effects as outcomes, instead choosing to document only changes in environment, exposure, or process (van der Molen et al., 2005). Those epidemiology studies that do utilize health-related outcomes may use measures that vary in severity from pain symptom reports to disability and lost time (Cole et al., 2003). Many intervention effectiveness analyses have done little or no objective measurement of exposures related to injury reduction; for example, the many studies that have examined back belt effectiveness (van Poppel et al., 1997).

The objective of this investigation was to use published literature to demonstrate that specific changes in workplace biomechanical exposure levels can predict reductions in back injuries.

* Corresponding author. Tel.: 734 615 6410; fax: +1 734 332 6064.
E-mail addresses: nanphilco@aol.com (N.A. Nelson), rehughes@umich.edu (R.E. Hughes).
[1] Tel.: +1 734 474 2459.

0169-8141/$ – see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.ergon.2008.06.003

A systematic literature review was conducted to identify workplace epidemiologic studies which could be used to quantify relationships between several well-recognized biomechanical measures of back stress (related to lifting, spinal compression, and awkward postures) and economically relevant outcome measures (such as workers' compensation claims, sickness/accident claims, and the U.S. Department of Labor Occupational Safety and Health Administration (OSHA) log injury reports). It was hoped that this subset of the literature, that defined both exposures and outcomes in a specific and replicable manner, might provide safety practitioners with information that could be applied to their own work situations to estimate costs and benefits of intervention strategies before they are implemented. Sample calculations of cost reductions are carried out in another paper, using a mathematical model that incorporates both biomechanical and financial modeling techniques (Hughes and Nelson, submitted for publication).

2. Method

2.1. Literature search

A systematic literature review was undertaken to identify epidemiological publications that examined relationships between biomechanical risk factors and relevant back disorder outcomes in workplaces with significant exposure (as defined below). Criteria for exposure measures were that direct observation, videotaping, or instrumentation of study participants (or a sample thereof) must have been carried out, and/or that standard biomechanical methods, indices, or models must have been used to quantify postures, spinal compression, or lifting weight/frequency/duration. Vibration as a risk factor was not considered. The goal was to include studies that used objective, well-recognized, and readily available methods that could be duplicated by others in different workplace environments. The study must have expressed back outcomes using a definition that was easily linked to workplace costs of this disorder: workers' compensation claims, sickness/accident claims, OSHA log or other company-specific incident reports. Additional criteria included that the paper must have studied an occupational group in its usual work environment (experiments were excluded) and the study must have been conducted in an industrial, health care, construction or other work environment with potential for heavy exposure to physical back stressors (as described in Bernard, 1997; Gluck and Oleinick, 1998; National Research Council and Institute of Medicine, 2001; Silverstein et al., 2002). Office environment studies were excluded. It was anticipated that few articles would meet even the very broad criteria described above. For this reason, no additional criteria related to study quality were included.

A search of Medline and NIOSHtic-2 databases were conducted for years 1966 through June of 2007, using broad search criteria: for Medline, using the keyword "back", including all related subject headings and subheadings; for NIOSHtic-2, additional search criteria were imposed, adding keywords "epidemiology" or "biomechanics" or "ergonomics" to the above strategy. Eighty-nine professional journals were targeted, in the following categories: general medicine, epidemiology, biostatistics, public health, occupational/environmental health and medicine, industrial hygiene, biomechanics, ergonomics, orthopedic medicine, nursing, physical medicine and rehabilitation, rheumatology, and injury prevention. The journals "International Journal of Industrial Ergonomics", "Clinical Biomechanics" (pre-1999), and "Occupational Ergonomics" are not indexed by Medline and were searched via their individual websites. For the journal "Spine", search criteria were identical to those used for NIOSHtic-2. A complete list of targeted journals is available upon request. Abstracts were examined to identify potential papers of interest; additional papers were identified by examining references.

3. Results

A total of 7820 publications were identified in the literature search. Eighteen articles, describing 15 research studies, were found which fulfilled search criteria.

Outcome definitions were fairly homogeneous, including workers' compensation claims, OSHA log reporting, sickness/absence reports, lost work days, and various company-specific mechanisms for reporting back injuries, with the majority using company-specific reports (Table 1). The manner in which outcomes were expressed related to study designs, which included two case-control studies, 11 prospective (four of which were interventions), and two cross-sectional studies. Outcomes were generally expressed as rates; for four, Odds Ratios were utilized, one study expressed outcomes as relative risks, and one study used duration of sick leave related to back problems. Of the 18 total papers (describing the 15 studies), 16 addressed covariates in some manner: five used conventional multivariate biostatistical modeling approaches (Burdorf and Jansen, 2006; Hoogendoorn et al., 2002; Kerr et al., 2001; Norman et al., 1998; Punnett et al., 1991). Three papers used other multivariate statistical approaches (Marras et al., 1993; Marras et al., 1995; Marras et al., 2000); eight others addressed anthropomorphic and other variables (including gender, weight and height) via the exposure assessment method (those that used lifting indices and two- or three-dimensional biomechanical models to estimate spinal compression levels) (Garg and Owen, 1992; Herrin et al., 1986; Liles et al., 1984; Luijsterburg et al., 2005; Marras et al., 1999a; Sesek et al., 2003; Stuebbe et al., 2002; Wickstrom et al., 1993). Only two papers did not address covariates in relationships that were presented (Chaffin and Park, 1973; Ljungberg et al., 1989).

The study populations were largely industrial, including automobile, paperboard packaging, sheet metal and mixed industrial groups that did a significant amount of manual material handling work. Three studies included health care workers; another examined bricklayers. Measures used to determine low back disorder risk (referred to henceforth as "exposure measures") fell into four major categories: (1) compressive forces on the spine, (2) lifting frequency, mass, or duration, (3) lifting ratios or indices, and (4) measures of posture.

3.1. Compressive forces on the spine

Table 2 shows information from studies that utilized measures of compressive forces on the spine ($n = 6$). The six studies used various two- and three-dimensional biomechanical modeling systems to calculate forces (see Table 1). Study designs, exposure measures, and outcomes varied, although some direct comparisons can be made. Garg and Owen (1992) examined mean compressive spinal force at the L5/S1 disc, using a prospective study design. Lower rates for back injuries and lost or restricted work days were associated with lower compressive forces (Table 2). Using a similar prospective design, Herrin et al. (1986) found that peak compressive force at the L5/S1 disc varied by force category, with the highest back injury rate falling in the 1000–1500 lb. range. Lost or restricted work days followed a similar pattern. The two case-control studies presented mean peak spinal compressive force at the L5/S1 disc (Punnett et al., 1991) and L4/L5 disc (Kerr et al., 2001) for cases and controls; both showed higher compressive forces for cases. Stuebbe et al. (2002) found generally increasing back injury rates within increasing cumulative spinal compression. Kerr et al. also examined the relationship between higher cumulative lumbar disc compression (based on a cut-point