**Occupational epidemiology: six guiding principles for future studies of physical work load and its effects on health and performance**

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1. **Previous epidemiologic studies of biomechanical exposures at work**

Associations between physical workloads (biomechanical exposures) and musculoskeletal disorders (MSD’s) have been investigated extensively; numerous longitudinal cohort and case-control studies have demonstrated the effect of exposures such as manual handling and awkward postures on MSDs in the neck, shoulder, arm, and back. Several reviews of these associations conclude, however, that the scientific evidence is insufficient, one major reason being that exposures were measured using instruments that deliver uncertain and, in some cases, biased data (e.g. Palmer and Smedley 2007; Wai et al. 2010). Moreover, exposure at baseline has often been treated as representative for the entire follow-up period. Thus, important questions remain unanswered concerning the temporal patterns of exposure and their associations with MSD outcomes.

A newer topic, if less well-studied, is the potentially positive effect of reduced sitting at work on cardiometabolic risks (van Uffelen et al. 2010). This illustrates that biomechanical exposure can even be beneficial to sustained health, well-being and performance. The apparent paradox underscores the importance of not assuming a linear, monotonic association of biomechanical exposures with occupationally relevant outcomes.

In light of these and related issues, the present paper offers six guiding principles for future longitudinal studies of the effects of biomechanical exposures at work.

2. **Guiding principles for studies of biomechanical exposures at work**

2.1 **Principle 1. Collect exposure data repeatedly and analyse them fully**

For any individual, exposure may vary considerably, both within and between days close in time, and across the course of working life. Within-subject exposure variability likely leads to biased exposure-outcome relationships (e.g. Burdorf 1995), and the effects of, e.g. fluctuating work tasks or permanently changed working conditions can only be accommodated by recurring exposure recordings. Thus, we encourage repeated collection of relevant exposure data, if possible even retrospectively (Svendsen et al. 2004). Repeated exposure data are especially needed in studies that explicitly seek to investigate concurrent temporal relationships between exposure(s) and outcome(s). Moreover, the effects of varying exposure patterns should be examined explicitly and exposure-outcome associations should not be assumed to be linear.

2.2 **Principle 2. Include metrics describing exposure variation**

In spite of a general consensus that the time-pattern, or variation, of biomechanical exposures is an important determinant of health, well-being and performance (Mathiassen 2006), very few longitudinal studies include data on exposure variation and analyses of their predictive validity. Methods are available for
expressing temporal exposure properties (e.g. Chastin and Granat 2010; Straker et al. 2014; Toomingas et al. 2012), and they all require access to considerable amounts of data, collected for extended periods of time. Thus, we encourage measurement of exposure using direct measurement techniques that can be used continuously for prolonged periods (e.g. Skotte et al. 2014), or modelling based on ‘cheap’ predictors (van der Beek et al. 2013) where these are feasible and can be shown not to suffer from excessive measurement error.

2.3 Principle 3. Collect data describing health status repeatedly

Individual health and well-being fluctuates across time, and an understanding of transitions between different states is needed to fully understand effects of biomechanical exposures. For instance, some exposures may explain the incidence of early MSD symptoms, while others may determine whether a chronic condition will develop. In order to disentangle such transitions and their determinants, we encourage repeated recordings of outcomes, for instance using electronic media (Jespersen et al. 2012).

2.4 Principle 4. Include outcomes related to function and performance

The potential of ergonomics to contribute to organisational development by understanding human and organisational performance was emphasized in a recent IEA position paper (Dul et al. 2012). We encourage future studies to include measures of human capacity and performance, both at and outside work, in order to enhance knowledge on determinants of these outcomes and on their relationships with health and well-being.

2.5 Principle 5. Examine interactions between relevant exposures

Interactions between exposures will be identified only if they are explicitly addressed in the statistical models for data analysis. We therefore encourage modelling associations between exposures and outcomes beyond the standard approaches of assuming different exposures to be statistically independent or controlling for potential confounding. We particularly emphasize the need for a better understanding of interactions between biomechanical and psychosocial exposures. Complex temporal relationships between different exposures, and their eventual effect on relevant outcomes, can only be disentangled with comprehensive data, collected with appropriate timing and analysed according to explicit hypotheses about these relationships.

2.6 Principle 6. Examine effect modification

Associations between exposure(s) and outcome(s) may also differ between groups defined by age, physical capacity, disease status, socioeconomic condition, and gender. Emphasizing the need to understand the problems and potentials of particular groups in modern occupational life, we encourage using appropriate statistical procedures for determining the modifying effects of these factors.

3. Future epidemiologic studies of biomechanical exposures at work

In this paper, we identified six guiding principles which would enable occupational epidemiology to better understand the role of biomechanical exposure time patterns in determining health, well-being and performance, recognizing the fluctuating nature of musculoskeletal and other outcomes. We believe that following the proposed guiding principles to the extent possible, of course on top of standard good epidemiologic practice (Rothman et al. 2012), can considerably improve the ability of epidemiologic studies to support the determination of health-promoting patterns of exertion and the design of effective interventions, both for preventing disorders and for promoting health and performance.
References


