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An EMG-based model to estimate lumbar muscle forces and spinal loads during complex, high-effort tasks: Development and application to residential construction using prefabricated walls

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ABSTRACT

Residential building construction is moving toward more industrialized construction methods (e.g., use of prefabricated wall or "panels"), yet remains one of highest risk sectors for work-related musculoskeletal disorders. The centralized design process inherent in the use of wall panels offers the potential for proactive control of musculoskeletal risks, consistent with the prevention-through-design (or PtD) philosophy. As part of an ongoing effort to incorporate ergonomics into panel design, estimates of low back loading and injury risk were needed over a range of tasks performed during panelized construction. Here, a free-dynamic, three-dimensional, electromyography-based model was developed to provide such estimates, which was a modification of an earlier, relatively coarser model. Specific modifications included a more detailed representation of lumbar muscle anatomy and contraction dynamics, high-pass filtering of electromyograms to better represent muscle activation levels, and an enhanced calibration procedure through which five model parameters are specified on an individual basis and used to estimate lumbar muscle forces. With these enhancements, the predictive ability of the model was assessed over a wide range of simulated panel erection tasks. Predicted model parameters corresponded well with values reported earlier. Reasonable levels of correspondence were found between measured and predicted lumbosacral moments, though predictive ability varied between tasks and rotation planes.

Relevance to industry: Wall panels are representative of the current trend toward increasing use of industrialized methods in residential construction. Model-based estimates can be used as part of a larger project to facilitate proactive design of residential construction using panelized walls in order to reduce musculoskeletal exposures and spine injury risks.

1. Introduction

Work-related injuries and illnesses pose a continuing threat to the health and well-being of U.S. construction workers and to the productivity of construction firms. Our emphasis here is on residential construction, a large economic activity requiring over 1 million workers in 2006 (Mullins, 2006), and which is projected to grow by ~20% in the approaching decade (BLS, 2008c). Residential construction has been recognized as among those sectors having a relatively high prevalence of work-related injuries and illnesses (BLS, 2008a,b; Schoonover et al., 2010), with injury rates likely higher than those reported in centralized databases (Lipscomb et al., 2003a). In this sector, overexertion injuries are the 2nd largest source of direct costs, and more than half of these injuries result from postural and unexpected loads (Lipscomb et al., 2003a,b). Modern residential construction can be viewed as a craft-based enterprise driven by a centralized design process, but this design is detached from the actual construction process on site (e.g., method of assembly) and often takes little or no account of the ergonomic impacts on workers (Wakefield et al., 2001; O'Brien and Beliveau, 2002). Modern construction, and to some extent residential construction, is also moving toward increasing prefabrication, one example of which is the use of panels (panelized walls) that are increasingly being adopted by residential U.S. production builders (Wakefield et al., 2001).

Panels are designed by a central designer based on several criteria (e.g., preferred and maximal lengths), are built in a manufacturing facility, and are then erected by workers on site.

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