A COMPARISON BETWEEN ELECTROMYOGRAPHY (EMG) AND INCLINOMETER PREDICTED SPINAL COMPRESSION

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Biomechanical modeling methods used to quantify spinal compression have traditionally been complex, time-consuming, and costly. The objective of this study was to compare spinal compression estimates calculated from postural data collected with the Virtual Corset™ inclinometer (VC) to those calculated from erector spinae electromyography (EMG). Data collected in a large field study of the risk factors for low back injury in five heavy industries in British Columbia was used for analysis. VC and EMG data were collected simultaneously on 117 full work shifts. Compression normalized EMG and VC estimated spinal compression was time-synchronized and analyzed in parallel for comparison. Full-shift means, medians and 90th percentiles of spinal compression correlations were 0.71, 0.61 and 0.69 respectively ($p<0.01$, $N = 117$). VC may provide a relative ranking of compression between subjects, but requires correction factors for absolute estimates. This may open alternatives for assessing low back exposures in large field studies.

Key words: spinal compression, electromyography (EMG), occupational exposure assessment

UNE COMPARAISON ENTRE L'ÉLECTROMYOGRAPHIE (EMG) ET L'INCLINOMÈTRE AFIN DE PRÉDIRE LA COMPRESSION RACHIDIENNE

Les méthodes de modélisation biomécaniques utilisées pour quantifier la compression rachidienne étaient traditionnellement complexes, chronophages et coûteuses. L'objectif de la présente étude était de comparer les estimations de la compression rachidienne calculées à partir de données sur la posture recueillies grâce à l'inclinomètre appelé Virtual Corset^{MC} (VC) à celles qui ont été calculées à partir de l'électromyographie (EMG) du bas du dos. Les données recueillies dans une vaste étude sur le terrain à propos des facteurs de risque de blessure au bas du dos, menée dans cinq industries lourdes de la Colombie-Britannique, ont été utilisées aux fins d'analyse. Les données du VC et de l'EMG ont été recueillies simultanément au cours de 117 quarts de travail complets. La compression rachidienne estimée à l'aide d'une EMG normalisée de la compression et d'un VC était synchronisée dans le temps et analysée en parallèle aux fins de comparaison. Les corrélations entre les moyennes, les médianes et les 90^{e} percentiles de la compression rachidienne dans les quarts de travail complets étaient respectivement de 0,71, 0,61 et 0,69 ($p<0.01$, $N = 117$). Le VC peut fournir une hiérarchisation relative de la compression entre les sujets, mais des facteurs de correction sont requis pour les estimations en valeurs absolues. Cela peut ouvrir la porte à d'autres façons d'évaluer les expositions à la compression rachidienne dans les vastes études sur le terrain.

Mots clés : compression rachidienne, électromyographie (EMG), évaluation de l'exposition professionnelle

INTRODUCTION

Back injuries are among the most common workplace injuries and have been a prevalent and expensive problem in British Columbia (BC) (WorkSafeBC, 2005). Studies suggest that awkward postures, manual materials handling and the resulting compression forces are leading risk factors for the onset of low back disorders (Waters et al., 1993). In order to reduce the occurance of back injuries, it is essential for researchers and ergonomists to have a better understanding of the work exposures that increase the risk of injury (Burdorf, 1992). Methods to quantify or represent the patterns and time history of postures, forces, and spinal compression in occupational settings are essential for proper work environment assessments (Wickstrom et al., 1996). Unfortunately, methods for estimating maximal (peak) compression loads and cumulative loads accrued over the course of a full work shift have traditionally been complex, time-consuming, and costly, limiting large-scale and field-based studies. However, epidemiological studies require exposure data on large numbers of individuals in order to observe relationships and to be representative. Traditional quantitative methods have involved video-based motion analysis over short durations (i.e., minutes) followed by laborious biomechanical modeling of spinal compression. Portable electromyography (EMG) of the erector spinae muscles has been used to collect longer durations of data by measuring electrical muscle activity. Video-based analysis and EMG are labour-intensive and capital-intensive, as well as requiring substantial set-up and calibration, which limits their utility in the work place. Cumbersome measurement techniques limit sample size as well as hinder the ability to identify risk factors and intervene to prevent back injuries. Inexpensive direct measurement instruments such as the Virtual Corset™ (VC) inclinometer may be more feasible for collecting data on a large number of individuals, and have the additional benefit of being accessible and feasible for use outside of research by ergonomists or other occupational health and safety professionals practicing in industry.

An effective exposure assessment method should include several qualities to make it easily accessible for researchers and ergonomic professionals. Such qualities include: direct measurement, real-world feasibility in industrial settings, instrumentation that minimizes work interruption, ease of use, full-shift analysis, and low cost (Trask et al., 2007). The purpose of this study is to evaluate the above mentioned qualities in an inclinometer posture measurement device called the "Virtual Corset™" (VC), a novel measurement approach to estimate spinal compression. Here we report the initial steps in this process. Although the VC does not account for external hand loads, recent lab work has shown that spinal compression is more related to posture than hand loads (Hoozemans et al., 2006). We compared spinal compression estimates calculated from VC data to spinal compression estimates calculated from erector spinae EMG (based on compression-normalized EMG) (CNEMG) (Potvin et al., 1996; Mientjes et al., 1999).

METHODS

Participants

This study is a component of a larger occupational field study of the risk factors for low back injury in five heavy industries in BC: transportation, wood products, construction, warehousing, and forestry. A random sample of 53 working participants with accepted back injury claims in the year 2001 and 73 of their co-workers who volunteered to participate were included in the study for a total of 126 participants. All employers were contacted and consented to data collection at their worksites. Seventy-seven percent of the participant population was sampled on two measurement days resulting in a total of 223 measurement days (Trask et al., 2006). For this study 117 measurement days having both EMG and VC data were selected for analysis.

Data Collection

EMG was measured using a portable data collection system (ME3000, Mega Electronics, Finland) with disposable Ag-AgCl electrodes (Blue Sensor N-00-S, Ambu, Denmark). Electrodes were placed over the erector spinae at approximately the level of L4/L5. Signals were collected at 1000 Hz and filtered with an 8-500 Hz band pass filter (Trask et al., 2006). The VC inclinometer (VC-323, Microstrain, Inc., Williston, VT) was used to measure posture in two dimensions relative to gravity (flexion/extension and lateral bending) at a rate of 7.6 Hz. This pager-sized data logger was mounted to the trunk at approximately the T6 spinous process. Any postural offsets associated with the position of the VC were corrected via an upright calibration stance (Trask et al., 2006).

Estimating Spinal Compression

Three phasic signals in the EMG and VC were created by calibration exercises performed at the start and end of each shift, allowing EMG and VC data to be aligned in the same time domain for analysis. For CNEMG, a linear compression calibration equation was developed using a series of pre-shift static efforts with the trunk at 0^o, 45°, and 60^o of flexion with and without an 11.4-kg load; the Y-intercept was an estimate of compression of an unloaded spine. The calibration allowed shift-long EMG measures to be expressed as Newtons (N) of spinal compression as published previously (Potvin et al., 1996; Mientjes et al. 1999; Village et al., 2005; and Wells et al., 1997). A quasi-dynamic link-segment model (Ergowatch 4D WATBAK, University of Waterloo, Canada) was used to estimate spinal compression. Spinal compression was estimated with the VC data using similar methods; a regression of spinal compression by postural angle was developed under the assumption that they were linearly related. The time-synchronized EMG and VC data was analyzed in parallel to calculate estimates of spinal compression for comparison of the two methods. There is further detail regarding signal processing and estimation of spinal compression in Trask et al. (2006).

Statistical Analysis

Pearson r correlation coefficients were used to examine the relationship between average CNEMG (N) and VC predicted compression (N) for each of three summary measures calculated for the work shifts monitored: the mean, median and 90^{th} percentile. Paired *t*-tests were then used to compare the differences between EMG and VC predicted compressions for each of the three metrics (the mean, median and 90^{th} percentiles). The absolute and percent differences were calculated to show the magnitude of discrepancy between EMG and VC estimates of compression.

RESULTS

A total of 117 measurement days were analyzed. The average age, height and weight of the participants were 42 years, 177 cm and 83 kg respectively. All but 5% were male.

Pearson correlations for the full-shift means, medians and 90^{th} percentiles of spinal compression using the two data collection methods in each industry are presented in Table 1.

Table 1. Correlation Results for Predicted VC Compression (N) and EMG Compression (N) by Industry Group (p-value<0.001 unless otherwise indicated, i.e., * = p< 0.05 level))

	Mean	**Median**	**90th%ile**
All Industries (N=117)	0.71	0.61	0.69
Construction (N=22)	0.48*	0.50*	0.41*
Transportation (N=29)	0.77	0.67	0.70
Forestry (N=26)	0.60	0.51	0.56
Warehouse (N=16)	0.72	0.61*	0.81
Wood Products (N=24)	0.83	0.72	0.85

Paired *t*-tests showed that there were systematic and statistically significant differences between VC- and EMG-estimated compression, with the VC giving higher full-shift compression estimations as shown in Table 2.

Table 2. Paired *t*-test Results for Predicted EMG Compression (N) minus VC Compression (N) by Industry Group

	Mean		**Median**		**90th%ile**	
	Mean Difference (N)	p-value	Mean Difference (N)	p-value	Mean Difference (N)	p-value
All Industries (N=117)	-559	0	-392	0	-1343	0
Construction (N=22)	-567	0.002	-252	0.073	-1810	0
Transportation (N=29)	-444	0.002	-291	0.007	-1069	0.003
Forestry (N=26)	-845	0.003	-721	0.005	-1966	0.001
Warehouse (N=16)	-373	0.059	-343	0.071	-654	0.042
Wood Products (N=24)	-502	0.003	-316	0.046	-1032	0.014

As shown in Figure 1, the greatest magnitude of absolute difference between EMG and VC predicted spinal compression was for the 90th percentile metric.

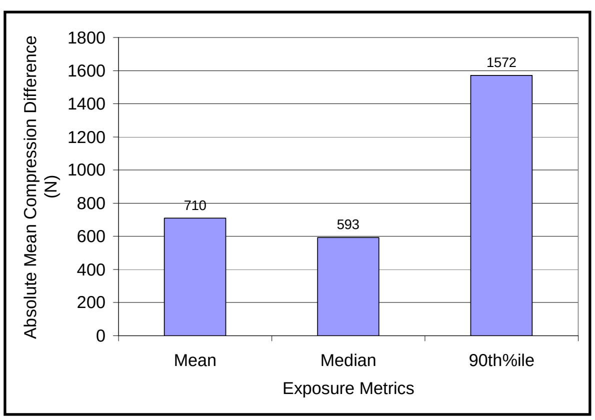

Figure 1. Mean Absolute Difference between VC and EMG predicted compression for the 3 summary metrics

Figure 2 shows the percent difference for each exposure metric, where once again the greatest difference is the 90th percentile with 59%.

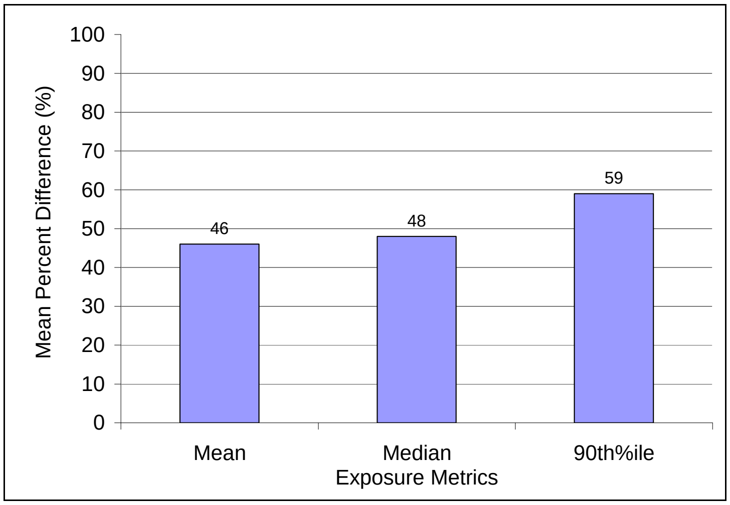

Figure 2. Mean Percent Difference Between VC and EMG predicted compression

DISCUSSION

Overall, VC and EMG predicted spinal compressions are significantly correlated. It is interesting to note that across all exposure metrics, the wood products industry consistently produced the strongest correlation, while the construction industry was consistently the weakest. Although the data is stratified by industry, these do not represent homogenous exposure groups due to considerable variability within each industry (Trask et al., 2006).

Estimation of spinal compression from postural data excludes the effect of external loading such as manual materials handling (MMH). However, a laboratory-based study of simulated work tasks has shown that a large proportion of spinal compression is directly related to trunk flexion (Hoozemans et al., 2006). Given that the VC only measures posture we expect that VC and EMG predictions of spinal compression to match when trunk flexion is the primary contributor to compression, and that it would underestimate compression when there are large amounts of MMH. Surprisingly, the paired *t*-test results clearly show that the VC generally overestimates compression when compared to the EMG predictions. This systematic difference shows that although VC compression may provide a means to determine relative rankings of compression between subjects, absolute estimates of compression would require additional modeling and correction factors to be applied.

There is a linear relationship between muscle activity and muscle force as products of posture and load lifted (Kumar et al., 1996). Therefore, linear calibration is applicable for EMG estimates but not necessarily for VC estimates as shown by the large absolute and percent differences presented in this study. Future work will further explore these relationships and will involve devising non-linear calibration techniques, based on biomechanical principles, for trunk posture and spinal compression to allow use of the VC data. Future work will also investigate job-based and task-based characteristics, such as the relative amounts of lifting and bending, as determinants for the suitability of this exposure assessment method. The goal is to have a tool that will be accessible, feasible, and useful to industrial ergonomists and hygienists for use in evaluating job demands, prioritizing jobs for intervention, and determining the effectiveness of the implemented interventions. Even a rough estimate of the loads generated during tasks should be adequate for identifying problems and developing solutions (Schultz et al., 1981), and it is expected that subsequent iterations of this method will meet this need.

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