RELATIONSHIP BETWEEN COMPUTER VISION ESTIMATED TRUNK KINEMATICS AND WORK-RELATED LOW-BACK PAIN

Runyu L. Greene[1], Ming-Lun Lu[2], Yu Hen Hu[1] and Robert G. Radwin[1]

[1] University of Wisconsin-Madison, Madison, WI, USA
[2] National Institute for Occupational Safety and Health, Cincinnati, OH, USA

The association between trunk kinematics (e.g. trunk flexion angle; lateral and twisting velocity) and low-back pain (LBP) in manual materials handling activities has been recognized in numerous studies (Marras et al., 1993; Lavender et al., 2003). A computer vision algorithm developed by our laboratory detects moving subjects from the background, identifies lifting instances and locations by spatial and temporal features of the object, and creates a rectangular bounding box tightly around the subject. Previous work demonstrated the application of this algorithm for predicting lifting postures (Greene et al., 2019a) and estimating trunk kinematics (Greene et al., 2019b). The goal of the current research is to explore using these algorithms for evaluating trunk kinematics and their association with self-reported LBP and task measures defined by the revised NIOSH lifting equation (RNLE) (Waters et al., 1993).

A diverse database of videos, exposure data, and health outcomes for 2581 lifting and lowering tasks, performed by 217 workers were used from a prospective study of LBP (Lu et al, 2014; Ferguson et al., 2019). The videos were coded by trained analysts to represent the range of the elements (lifts and lowers) within a task. Each task was simulated in the laboratory using a motion capture system (Lu et al., 2014). At baseline and follow-ups, health outcomes were measured using the standardized Nordic Musculoskeletal Questionnaire, and aggregated as distinct lifting tasks. The percentage of LBP cases for each task was calculated by the equation: %LBP = (Number of new cases per task)/(Number of workers performing the task). A semi-automated video analysis approach was adopted for measuring task parameters. For each element in a selected lift, consecutive frames for 300 ms to 1000 ms before and after the lifting or lowering instance were analyzed to obtain the following task parameters: (a) bounding box height and width, (b) load location, speed, and acceleration, and (c) calibration benchmarks. The trunk angle in each frame was estimated using the method described by Greene et al. (2019b) to measure the angular speed and acceleration of the trunk using the bounding box dimensions and the change in trunk angle between frames of the video.

The 32 lifts performed by 7 subjects, encompassing 9 distinct tasks, were analyzed. The % LBP for 150 workers who performed the 9 tasks was calculated. The correlation between trunk kinematics and two risk measures from the RNLE, frequency independent lifting index (FILI), single task lifting index (STLI), and the %LBP were calculated. Average acceleration, maximum speed, and maximum acceleration of the trunk showed high correlation to the % LBP (0.67, 0.76, and 0.77, respectively), and average angle and maximum angle of the trunk had relatively high correlation to FILI (0.66 and 0.79, respectively) and to STLI (0.66 and 0.74, respectively). Incorporating these kinematics variables into current lifting assessment methods may increase the sensitivity of risk identification. This novel approach demonstrated a feasible way for using computer vision to measure kinematic variables without applying direct measuring devices.

Acknowledgements: This study was funded, in part, by a grant from the National Institute for Occupational Safety and Health (NIOSH/CDC) R01OH011024 (Radwin), NIOSH/CDC contract 5D30118P01249 (Radwin), and a pilot training grant from the NIOSH-funded MCOHS-ERC Pilot Research Training Program OH008434 (Greene). The authors would like to thank the Menekse Barim, Marie Hayden and Dwight Werren from NIOSH for assisting in data collection and analysis.

Disclaimer: The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention.

Ferguson, S. A., Merryweather, A., Thiese, M. S., Hegmann, K. T., Lu, M. L., Kapellusch, J. M., & Marras, W. S. (2019). Prevalence of low back pain, seeking medical care, and lost time due to low back pain among manual material handling workers in the United States. BMC musculoskeletal disorders, 20(1), 243.

Greene, R. L., Hu, Y. H., Difranco, N., Wang, X., Lu, M. L., Bao, S., ... & Radwin, R. G. (2019a). Predicting Sagittal Plane Lifting Postures from Image Bounding Box Dimensions. Human factors, 61(1), 64-77.

Greene, R. L., Lu, M. L., Barim, M. S., Wang, X., Hayden, M., Hen Hu, Y., & Radwin, R. G. (2019b). Estimating Trunk Angles During Lifting Using Computer Vision Bounding Boxes. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting (Vol. 63, No. 1, pp. 1128-1129). Sage CA: Los Angeles, CA: SAGE Publications.

Lavender, S. A., Andersson, G. B., Schipplein, O. D., & Fuentes, H. J. (2003). The effects of initial lifting height, load magnitude, and lifting speed on the peak dynamic L5/S1 moments. Int. J. Industrial Ergonomics, 31(1), 51-59.

Lu, M. L., Waters, T. R., Krieg, E., & Werren, D. (2014). Efficacy of the revised NIOSH lifting equation to predict risk of low-back pain associated with manual lifting: a one-year prospective study. Human factors, 56(1), 73-85.

Marras, W. S., Lavender, S. A., Leurgans, S. E., Rajulu, S. L., Allread, S. W. G., Fathallah, F. A., & Ferguson, S. A. (1993). The role of dynamic three-dimensional trunk motion in occupationally-related. Spine, 18(5), 617-628.Patrizi, A., Pennestrì, E., & Valentini, P. P. (2016). Comparison between low-cost marker-less and high-end marker-based motion capture systems for the computer-aided assessment of working ergonomics. Ergonomics, 59(1), 155-162.

Waters, T. R., Putz-Anderson, V., Garg, A., & Fine, L. J. (1993). Revised NIOSH equation for the design and evaluation of manual lifting tasks. Ergonomics, 36(7), 749-776.