Comparing motor variability between experienced workers and novices

[1] Alireza Sedighi, [1] Sunwook Kim and [1] Maury A. Nussbaum

[1] Virginia Tech, Blacksburg, VA, USA
email: sedighia@vt.edu

INTRODUCTION

Work musculoskeletal disorders (WMSDs) remain among the most prevalent occupational pathologies in industrialized countries [1], and existing evidence indicates that repetitive motions are an important risk factor. "Internal variation" offers a potential method for reducing or preventing WMSDs and which can be achieved by focusing on motor variability (MV). MV refers to variations in kinetic or kinematic aspects of a movement pattern and muscle activity, and suitable levels may help to reduce the risk and/or symptoms of WMSDs [2].

Our long-term goal is to use MV as a means to develop useful tools for providing occupational guidelines, and ultimately to help decrease injury risks. Previous work indicates that experienced workers use more stable motor control strategies compared with novices [3]. However, little evidence exists that has formally characterized MV differences associated with experience. Understanding variations in the movement of experienced workers may be one useful approach toward the noted guidelines. Thus, the goal of this research was to quantify how MV differs between experienced workers and novices.

METHODS

We analyzed data obtained in a prior study [4], in which experienced workers and novices performed repetitive symmetric and asymmetric lowering/lifting tasks. Six experienced workers (25.9±5.9 years) and six novices (26.0±5.3) were involved in the noted study, with five males and one female in each group. Each participant performed 20 repetitions of lowering and lifting a box, in both symmetric and 60° asymmetric conditions. Boxes were set to 10% of individual body mass. The lifting/lowering rate was 10 cycles per minute, which was controlled by a metronome. Participants were asked to hold the box continuously, with a fixed position of the feet, and to use a free-style lifting technique. Segmental kinematics and the box trajectory were tracked using a 7-camera optical motion capture system.

To investigate MV in the lifting task, variation in the center-of-mass (COM) trajectory was considered, since in a similar task (i.e., sit-to-stand) the whole-body COM has been suggested as a parameter under CNS control. We used the goal-equivalent manifold (GEM) approach to quantify trial-to-trial MV. Given that the simulated lifting task was time constrained (paced), a consistent performance time was considered as the main goal in the GEM analysis. Expanding upon the method described by Dingwell et al. [5], the variability in each cycle can be calculated in the GEM direction (δt_T) and the direction perpendicular to it (δt_P), as:

$$\begin{bmatrix} \delta t_T \\ \delta t_P \end{bmatrix} = \frac{1}{\sqrt{1+T_n}} \begin{bmatrix} 1 & T_n \\ -T_n & 1 \end{bmatrix} \begin{bmatrix} V_n - V^* \\ X_n - X^* \end{bmatrix}$$

where X_n and V_n are the normalized path and velocity of the COM, respectively; (X^*,V^*) is a preferred operating point, which is the closest point on the GEM to the mean of (X_n,V_n); and $T_n=X_n/V_n$. To study the variation structure, we computed the SD of δt_T and δt_P. SDs of the relative variability (i.e., $\delta t_T/ \delta t_P$) of novices and experienced workers were also calculated, to determine which group had more flexible movement patterns [6].

Separate mixed-factor analyses of variance (ANOVAs) were used to assess the effects of the level of experience (LE) and lifting symmetry (LS) on the GEM-related variables: $\sigma(\delta t_T)$, $\sigma(\delta t_P)$ and $\sigma(\delta t_T)/ \sigma(\delta t_P)$. Simple effect tests were used to explore significant interaction effects. Model assumptions were verified, and p values < 0.05 were considered statistically significant.

RESULTS AND DISCUSSION

There were significant EL × LS interaction effects on $\sigma(\delta t_T)$, $\sigma(\delta t_P)$, and $\sigma(\delta t_T)/\sigma(\delta t_P)$ (p values = 0.013, 0.006, and 0.003, respectively), and neither of the main effects were significant for these three measures. In the asymmetric condition, MV of experienced workers in the GEM direction was significantly (p=0.0033) higher than novices (Figure 1 top). Novices had significantly (p=0.0085) lower $\sigma(\delta t_P)$ in the symmetric vs. asymmetric conditions (Figure 1 middle), suggesting less control over their COM in the former. In the symmetric condition, experienced workers had significantly (p=0.0036) lower $\sigma(\delta t_T)/\sigma(\delta t_P)$, suggesting a reduced set of effective solutions compared with novices. In contrast, movement variations among experience workers were slightly higher in the asymmetric condition (Figure 1 bottom). Based on $\sigma(\delta t_T)/\sigma(\delta t_P)$, the motor control strategies utilized by novices significantly differed between the two lifting conditions (p=0.005).

Both groups appeared to regulate movements of their COM to maintain the GEM goal function, since $\sigma(\delta t_T) > 1$ and $\sigma(\delta t_P) < 1$ [5]. Experienced workers had a lower $\sigma(\delta t_T)/\sigma(\delta t_P)$ in the symmetric lifting condition, suggesting that their movements were more constrained [6]. Lee and Nussbaum [3] found that experienced workers were more stable in the symmetric condition, based on higher Lyapunov exponents. Together, these two results indicate that experienced workers may constrain their movements to increase stability. These earlier authors [4] also found that peak kinetics were lower among novices in the symmetric condition, which may confirm that higher relative variability leads to safer behavioral strategies. Task asymmetry was also reported to increase stability among novices but decrease stability among experienced workers [3], which is consistent with our results. In the asymmetric task, novices exerted more control of their COM to maintain task timing, and they used more constrained patterns. Since asymmetry increased task difficulty, a consistent strategy likely could not be used. On the other hand, the experienced workers increased their flexibility [increased $\sigma(\delta t_T)/\sigma(\delta t_P)$], and which may help to decrease the risk of injury. Considering the current and previous findings together, we conclude that the central nervous system may adopt stable patterns rather than flexible movements with work experience or with increased task difficulty.

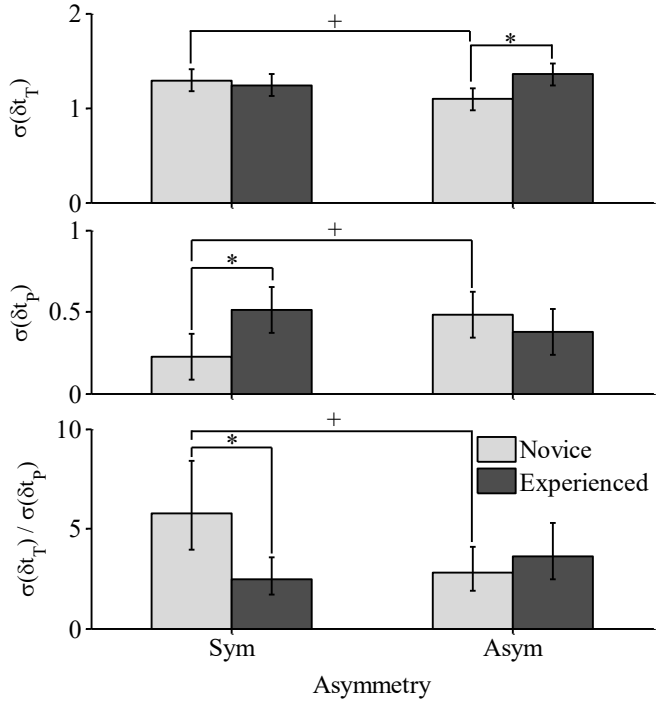

Figure 1: GEM result for symmetric (Sym) and asymmetric (Aysm) repetitive lifting tasks. *Top*: variability in the GEM direction. *Middle*: variability in the direction perpendicular to the GEM. *Bottom*: relative variability. * indicates a significant difference between groups within a symmetry condition, + indicates difference between conditions for a given group, and error bars indicate 95% confidence intervals.

REFERENCES

1. da Costa, B.R. et al. *Am J Ind Med,* **53**, 285-323, 2010.
2. Srinivasan, D. et al. *Clin Biomech,* **27**, 172-184, 2012.
3. Lee, J. & Nussbaum, M.A. *J Biomech,* **46**, 1211-1215, 2013.
4. Lee, J. & Nussbaum, M.A. *Ergonomics* **55**, 1535-1547, 2012.
5. Dingwell, J.B. et al. *Plos Comput., Biol.***6** e.1000856, 2010.
6. Folstein, M.F. et al. *Plos one,* **7**, e41306, 2012.