The effect of combining physical and cognitive loads on motor variability in a standardised repetitive precision task

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1. Introduction

Lack of variation has been suggested to be an important cause of musculoskeletal disorders caused by occupations involving mainly repetitive tasks (Mathiassen 2006). Jobs with low cycle-to-cycle variability may be particularly disposed to fatigue, and eventually pain (Mathiassen et al. 2003, Madeleine 2010, Srinivasan and Mathiassen 2012). Examples of such occupations include short-cycle assembly work, repetitive lifting tasks (Granata et al. 1999, van Dieen et al. 2001), carpentry work (Hammarskjold et al. 1990) and meat cutting (Madeleine et al. 2008).

In this context, motor variability is the naturally occuring variability in movements and/or muscle activities between successive repeats of a task which are intended to be identical in performance. Motor variability has recently received increased attention from occupational biomechanics researchers because of its association with important variables in working life, such as pain, fatigue and skill acquisition; recently reviewed by Srinivasan and Mathiassen (2012). One critical area of research identified by this review is to understand which factors in work design systematically affect motor variability, among factors such as work pace, precision, workstation design and concurrent cognitive loads.

This study focuses on the effect of combining physical and cognitive loads on arm movement kinematics and variability in repetitive precision work. While several studies have shown mental tasks to induce increased muscle activity when added on top of a physical task (Lundberg et al. 1994, Birch et al. 2000, Finsen et al. 2001, Leyman et al. 2004, Au and Keir 2007, Wang et al. 2011), other studies, however, indicate that a superimposed mental task may have no effects on muscle activity during physical work (Blangsted et al. 2004), or even decrease it (Mehta and Agnew 2011, Mehta et al. 2012). The effects of combining physical and mental demands have been suggested to depend on the muscle group engaged in the physical task as well as the required load level (Mehta et al. 2012).

However, the effect of occupationally relevant combinations of physical and cognitive loads on motor control (specifically on movement kinematics and cycle-to-cycle variability) is still an open question. This study compares a task with realistic concurrent physical and cognitive loads to a reference task with the same physical load without the added cognitive component.

2. Methods

A laboratory-based simulation of repetitive precision work was developed using a ‘pipetting’ task paradigm, in which water was repeatedly transferred from one tube to another, with a cycle time of 2.8s. Thirty-five healthy female subjects, with prior experience in pipetting, and aged 20-45 years, performed this task. In each task condition, the subjects repeatedly transferred liquid from a big pickup tube to eight specific target tubes set in a 10x10 tube-array, 20 times in a randomized order (1 session = 20 repeats x 8 tubes = 160 cycles). A metronome was used to set the pace of the task. In the reference condition (“Phy”, fig 1), the pipetting sequence was indicated using lights mounted below each tube, to indicate which tube to transfer liquid to. In the concurrent physical and cognitive task condition (“Phy+Cog”, fig 1), instead of visual clues identifying the target tubes, the subjects received on a computer screen in front of them a ‘tube number’ comprised of row and column numbers indicating which tube to transfer liquid to. 3D arm-hand movement kinematics were recorded, and used to compute the average and cycle-to-cycle variabilities of range of motion, peak velocity, average velocity, time to peak velocity and area under the movement curve of shoulder elevation and elbow flexion (more details on work-task setup, data recording and computation of motor variability indices can be found in (Srinivasan et al. 2015)).

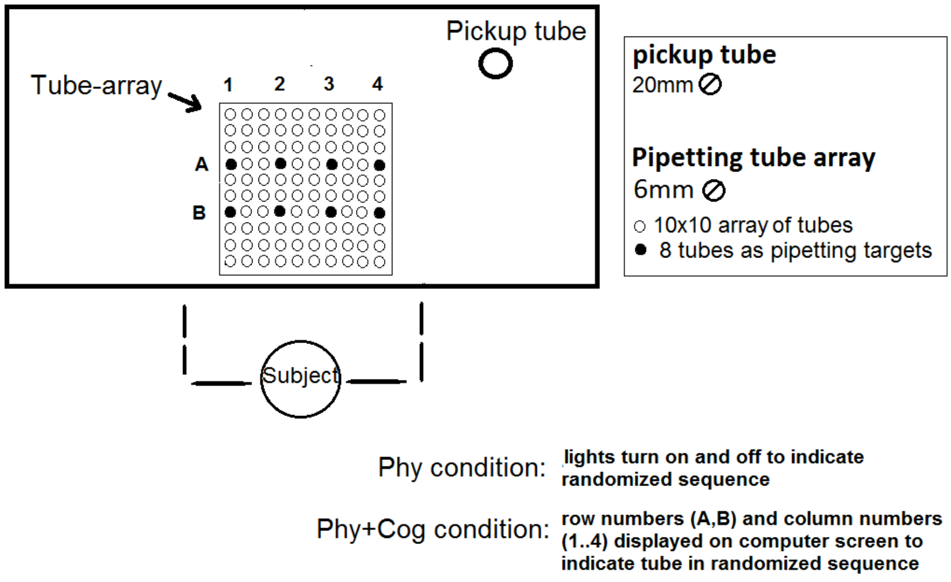
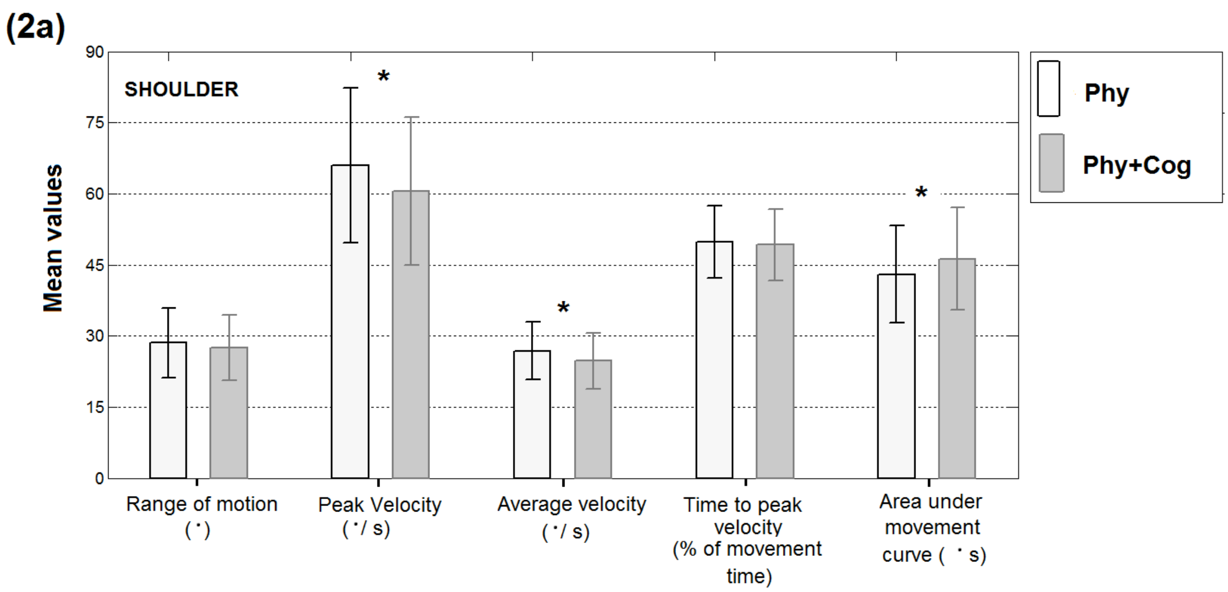


Figure 1. Experimental task setup.

3. Results

Mean values and cycle-to-cycle variabilities of kinematics properties of shoulder elevation are shown in figure 2. Figure 2(a) illustrates that the mean values of peak and average velocities across all cycles were significantly lower, and area under the movement curve was higher in 'Phy+Cog' condition when compared to the reference 'Phy' condition. As shown in figure 2(b), none of the cycle-to-cycle variabilities of shoulder kinematics properties were, however, significantly different between the two pipetting conditions. The same results were found for mean values and cycle-to-cycle variabilities of elbow flexion kinematics also (figures not shown).



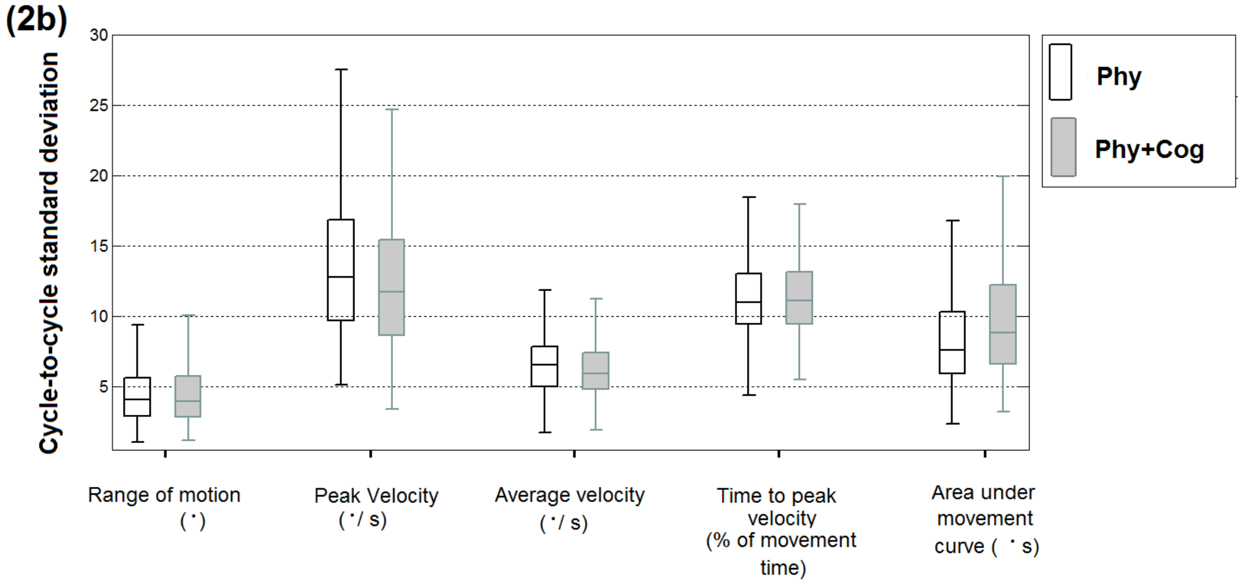


Figure 2. Shoulder elevation kinematics in repeated pipetting with (Phy+Cog) and without (Phy) an added cognitive load. (a) Mean values across cycles; (b) cycle-to-cycle variabilities (standard deviations).

4. Discussion

This study suggests that in temporally constrained tasks such as paced repetitive precision work, performed by experienced subjects, movements in a task with concurrent physical and cognitive demands are slower than those in a task with only physical demands (lower velocities and higher area under movement curve in 'Phy+Cog' than 'Phy'). However, movement kinematics were no more variable in the task with concurrent cognitive demands than the reference physical task. Thus, from this point of view, adding a cognitive demand to a repetitive task will not have any effects on exposure variation.

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