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Motor adaptation capacity as a function of age in carrying out a repetitive assembly task at imposed work paces

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ABSTRACT

The working population is getting older. Workers must adapt to changing conditions to respond to the efforts required by the tasks they have to perform. In this laboratory-based study, we investigated the capacities of motor adaptation as a function of age and work pace. Two phases were identified in the task performed: a collection phase, involving dominant use of the lower limbs; and an assembly phase, involving bi-manual motor skills. Results showed that senior workers were mainly limited during the collection phase, whereas they had less difficulty completing the assembly phase. However, senior workers did increase the vertical force applied while assembling parts, whatever the work pace. In younger and middle-aged subjects, vertical force was increased only for the faster pace. Older workers could adapt to perform repetitive tasks under different time constraints, but adaptation required greater effort than for younger workers. These results point towards a higher risk of developing musculoskeletal disorders among seniors.

1. Introduction

As in most European countries, the working population in France is ageing. Two facts have led older workers to remain at work for longer. First, the current sociodemographic situation shows that the segment of population between 55 and 65 years of age is growing due to the high birth rate from 1945 to 1974. And second, reforms to public policies related to funding for retirement pensions have postponed the age of retirement (DARES, 2011).

However, a person's health status, including physiological and psychological systems, changes as age progresses (Seitsamo and Klockars, 1997; Kowalski-Trakofler et al., 2005). For example, in terms of functional capacities, the knee extensors have been observed to lose strength in seniors and tendon extensive properties is known to decrease with age (Kubo et al., 2007; Viitasalo et al., 1985). Older employees also produce less muscular force than younger ones (Mathiowetz et al., 1985; De Zwart et al., 1995; Broersen et al., 1996; Reilly et al., 1997; Ilmarinen, 1997, 2001; Robertson and Tracy, 1998; Ilmarinen, 2001; Macaluso and De Vito, 2004). These differences could be due to several factors: sarcopenia, changes in excitation-contraction coupling, modifications to the tendons and bones, and changes in nerve control (Macaluso and De Vito, 2004; Narici and Muffulli, 2010). These changes in force production with age nonetheless depend on the group of muscles analysed. Thus, the strength of the lower limbs appears to be more affected by age than that of the upper limbs (Viitasalo et al., 1985; Lynch et al., 1999; Narici and Muffulli, 2010). This difference is linked to preferential atrophy of the lower limb muscles (Doherty, 2003; Janssen et al., 2000; Macaluso and De Vito, 2004; Narici and Muffulli, 2010). In the long-term, this atrophy may cause older people to adopt a sedentary lifestyle. The upper limbs are more preserved as a great proportion of daily manual activities involves these muscle groups (Kornatz et al., 2005; Narici and Muffulli, 2010).

These physiological data illustrate older workers the potential embrittlement. It can explain why they are more likely to develop musculoskeletal disorders than younger workers (Kim et al., 2010). In addition, although most older employees still seem fit enough to continue their work, the fact that they require longer to recover after working and sustained effort cannot be ignored (Kiss et al., 2008; Cote et al., 2014). Moreover, the burden of years of work can be seen in how functional capacities evolve. Indeed, several studies have shown a strong correlation between the increase in age-related mobility problems and deterioration of hip and knee

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joints due to occupational exposure (Maetzel et al., 1997; Rossignol et al., 2005; Werner et al., 2011). This general trend for fragility in older workers must nonetheless be moderated by the itinerary of the individual concerned. This life course brings into play many independent factors such as lifestyle, education, practicing physical exercises, socioeconomic status, stress, and so on.

However, age is not the only factor that should be taken into account when analysing work-related efforts. For example, it is just as important to evaluate whether the physical demands required by the workplace do not exceed the employee's physical capacities (Okunribidoa et al., 2011). The influence of the physical load, in combination or not with age-related effects, may be revealed by the employee's motor adaptation capacities when performing tasks. This adaptation therefore requires a modification of the motor resultant represented by voluntary movement. Indeed, a number of questions must be solved by the central nervous system to compute a voluntary movement. The movement should appropriately meet the expected goal and the context in which it must be accomplished. The notion of internal models emerged as a possible system to mimic the hypothetical paths that the brain uses to determine and produce the appropriate move (Wolpert et al., 1998). Two types of internal model can be distinguished: the inverse model calculates the appropriate command to put the body into the desired articular configuration; and the forward model, which predicts the body's reactions to the command given via a system of efferent copies of motor commands (Miall and Wolpert, 1996; Wolpert and Kawato, 1998; Todorov, 2004). The decision to perform a movement is made based on a compromise between the cost and the risk after taking in a large amount of both internal and external sensorial and cognitive information (Wolpert and Landy, 2012).

When performing work on an assembly line, the motor adaptation required to correctly complete a task is continually present. Performing a repetitive movement to meet production objectives despite the environmental hazards at the moment of execution represents an additional constraint for all workers (Kilbom, 1994). However, the time constraint often involved in repetitive work becomes particularly penalising for older employees (Derriennic et al., 1990; Moliné, 2003; Volkoff et al., 2010). Xu et al. (2014) also observed that female workers of different ages were capable of working at a set pace with no difference in timing of hand movements. These authors assumed that older participants had to work closer to their physical limits. Indeed, compared to younger workers, older workers showed more effort in adaptation to maintain the same motion strategies in response to muscle fatigue (Qin et al., 2014a, 2014b). Moreover, time constraints can limit intra-individual variability in the motor responses observed, even for spatially and temporally constraining tasks (Madeleine et al., 2003; Mathiassen et al., 2003, Möller et al., 2004; Madeleine et al., 2008; Dempsey et al., 2010). Nevertheless, this variability could be beneficial in protecting the health of ageing workers.

In this paper, we present the results of a controlled laboratory study in which three groups of subjects of different ages performed a standardised task at two predetermined paces. The objective was to assess the effect of age on the motor adaptation capacities of employees to a repetitive work performed at two different imposed paces. Two kinds of adaptation were analysed during the repetitive task performed. One focused more on adaptations to whole-body movement, whereas the other focused more on adaptations to upper limb movements. Our hypothesis was that older workers can adapt, but that adaptations become more difficult when pace increases. Moreover, the difficulty adapting should be more apparent for whole-body movement than for upper limb movement.

2. Method

2.1. Participants

Sixty-five right-handed men voluntarily agreed to participate in the experiment. Subjects were recruited based on two criteria. First, the subjects had to fall into one of the following three age groups: junior (J), 30–35 years old; middle-aged (M), 45–50 years old, and senior (S), 60–65 years old. The characteristics of the three age groups are presented in Table 1. Secondly, all subjects had to have worked or be still working in what is considered a “physically demanding” job to ensure homogenous evolution of functional capacities. All participants provided a complete description of their work activities throughout their professional lives. In all cases, during a large part of their careers, they either had to carry loads, or work in awkward postures performing construction or carpentry work, or working in a mechanical workshop. Participants were recruited either through a temporary employment agency or responded to small ads published in local papers. Participant's functional capacities were assessed before the experiment through flexibility tests, dexterity (based on the Purdue pegboard test (Desrosiers et al., 1995)), speed of upper limb movement, and analysis of the muscular force of the upper and lower limbs. At the end of the assessment, subjects were familiarised with the task they would have to perform during the experiment by completing 10 assemblies as fast as possible. All subjects gave their free and informed consent for participation in this study, the protocol for which was approved by the Consultative Committee for the Protection of Subjects in Biomedical Research (institutional ethics committee).

2.2. Procedure

Subjects were asked to perform a repetitive mounting task during two 20 min work sessions, at two different work paces. The conditions in which the mounting was performed were similar to those found on an assembly line. Three activity phases were identified in each mounting cycle (Fig. 1a):

1 A moving phase: this phase involving movement from the base part dispenser to the assembly station work at the beginning of the mounting cycle, and from the assembly station to the dispenser at the end of the cycle.
2 A collecting phase: during this phase component parts – a handle and two nuts – were collected. Parts were stored under the assembly table. This phase was a motor task involving more predominantly the lower limbs.
3 An assembly phase: during this phase a handle was fixed to a base by screwing two nuts onto two threaded rods (Fig. 1b). This phase was performed on the assembly table. It corresponded to a motor task mainly involving the upper limbs.

Table 1
Mean (range) characteristics for the three subject groups.

Subject characteristics	Junior	Middle-aged	Senior
Number of subjects	20	22	23
Age (years)	32.6 (30–35)	47.1 (45–50)	61.8 (60–65)
Body Mass (kg)	74.9 (53–103)	78.1 (60–110)	81.2 (62–106)
Height (m)	1.77 (1.55–1.87)	1.74 (1.63–1.91)	1.74 (1.65–1.88)
Body Mass Index	23.91 (22.06–29.45)	29.39 (22.58–30.15)	29.82 (22.77–29.99)