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Grasping an object at floor-level: Is movement strategy a matter of age?

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ABSTRACT

Bending down to pick things up off the floor is something that we do every day. This multisegment task can be done in a considerable number of postural configurations because of the large number of degrees of freedom to be controlled when executing it. In this study where volunteers performed a repetitive bending task, multi-segment kinematic analysis allowed us to identify seven different bending strategies. Most operators used more than one bending strategy, but no particular strategy-type was found to be specific for a specific age group. However, the number of strategies used by an operator decreased with increasing age. It therefore appears that this factor influences the variability of the strategies used when repeatedly executing a movement involving the lower limbs to collect small objects from floor-level. This decrease in movement variability in senior operators may contribute to their increased risk of developing musculoskeletal disorders.

1. Introduction

Picking objects up off the floor is an action that we perform every day. Adult humans are familiar with this movement and no longer need to learn it. However, this multisegment task can take a considerable number of postural configurations as there are a large number of degrees of freedom to control when executing it. The action of squatting has been the subject of a large number of studies aiming to determine the biomechanical constraints on the lumbar region during transport of heavy loads (Anderson and Chaffin, 1986; Van Dieën et al., 1999; Sheppard, 2012). Three types of lifting techniques have often been compared: the squat, the semi-squat, and the stoop (Burgess-Limerick and Abernethy, 1997; Van Dieën et al., 1999; Straker, 2003). Several studies have compared the respective benefits and advantages of these different techniques, and various factors have been found to promote use of one or the other. Some of these factors are linked to the object carried – such as its weight (Hoozemans et al., 2008), how cumbersome it is, the height from which it must be collected and that at which it must be deposited (Burgess-Limerick et al., 2001), the speed of transfer (Lin et al., 1999) or its trajectory (de Looze et al., 1998) – while others correspond to the functional capacities of the carrier – such as their gender (Lindbeck and Kjellberg, 2001; Plamondon et al., 2014b; Sheppard et al., 2016) or age (Van Dieën et al., 1994), the muscles solicited (Trafimow et al., 1993), the physiological cost (Kumar 1984), the oxygen consumption during the exercise (Hagen and Harms-Ringdahl, 1994) or how much experience the carrier has with transporting heavy loads (Plamondon et al., 2010, 2014a). This last point illustrates how expertise causes carriers to adapt their posture depending on the context, as determined by the object (weight, dimensions, fragility) or the trajectory to be covered between the initial point and the destination.

In these previous studies, the expertise which determines how the carrier moves appears to be closely linked to the characteristics of the object to be transported. But what variations in movement would be observed if the external constraints such as the volume of the object, or its weight, were no longer the main constraints for the task? In this type of situation, internal constraints, directly linked to the subject such as age (which could influence their functional capacities), appear to be one of the most significant factors determining the variability of the final movement (Gaudez et al., 2016). These constraints take on even greater importance in the current socio-economic context where older workers remain at work for longer. With advancing age, changes to muscle properties can combine with a worker's capacity to repeat a physically demanding movement, such as collecting objects from the floor (Duchateau et al., 2006; Gibo et al., 2013). The capacity to repeat this movement will be all the more hampered when a rapid work pace is added to age-related constraints (Gilles et al., 2017). Nevertheless, numerous elements remain to be modulated when performing the movement. For example, the trajectories of the limbs are involved, the speed of execution and any obstacles that must be avoided have to be considered (Rosenbaum et al., 2001). Planning a movement also involves a conscious decision to grasp an object with the aim of doing something with it. This aspect gives sense to the movement (Bril and et Goasdoué, 2009; Bril, 2015). To study and analyse motor variability, it

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is important to provide the means to give sense to a movement when planning it. It was with this objective in mind that the task analysed in this study was designed. The task involves collecting parts stored at floor-level, for their assembly with another part on a mounting table.

A previous paper presented results from classical movement analysis performed on the same task (Gilles et al., 2017). This exhaustive analysis of the data provided us with an extensive range of information through which we could understand the physiological limitations involved in performing a task requiring squatting. These limitations were determined by the age of the person executing the task and/or the pace of the work. However, examining the different joints independently makes it difficult to understand the overall posture adopted when performing a task. Thus, a certain number of questions relating to the segmentary strategy implemented when collecting the parts could not be solved by this method. Indeed, the disparity of results obtained during the first analysis suggested the existence of intra-subject postural variability, but also of inter-subject postural variability determined by internal factors, such as age, or external factors, such as pace. In this paper, we hypothesize that the disparity of results observed might be due to a series of co-existing strategies.

The objective of the work described in this paper was to perform a multisegment analysis to better identify the postural strategies adopted during the task requiring collection of objects placed at floor-level. With respect to these strategies, the questions were twofold: First, is there a dominant strategy characteristic of each age group? Second, does the same person use more than one strategy? And, if more than one strategy is identified, what is level of variability in these strategies? Is this level of variability influenced by age or the pace of work?

2. Methods

2.1. Participants

Sixty-three right-handed men voluntarily participated in this experiment. Volunteers were recruited based on two main selection criteria. First, subjects had to be in one of the three following age-groups: junior (J) from 30 to 35 years old, median (M) from 45 to 50 years old, or senior (S) 60–65 years old. The characteristics of subjects in each of these age-groups are presented in Table 1. In addition, all subjects had to have worked or still be working in what is considered a “physically demanding” job to ensure relatively homogeneous evolving functional capacities. Volunteers were recruited either through temporary employment agency or through advertisements published in local newspapers. Participants' functional capacities were assessed before the experiment based on tests of flexibility, 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. All subjects gave their free and informed consent for participation in this study, the protocol for which was approved by the ethics committee for biomedical research at our Institute.

Table 1
Characteristics of the subjects in the different age-groups. Values are expressed as mean (range). Differences in body mass and height were not significant. The body mass index for the Junior group was significantly different from that for the Senior group (ANOVA $p = 0.038$).

Characteristic	Junior	Median	Senior
Number of subjets	20	20	23
Age (years)	32.6	47.1	61.8
	(30–35)	(45–50)	(60–65)
Body mass (kg)	74.9	78.8	81.2
	(53–103)	(60–110)	(62–106)
Height (m)	1.77	1.75	1.74
	(1.55–1.87)	(1.63–1.91)	(1.65-1.88)
Body Mass Index	23.9	25.6	26.9
	(19.7–34.5)	(20.6–34.6)	(21.0–35.5)

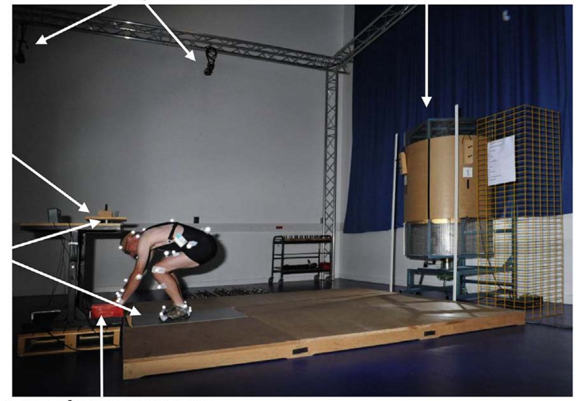

Fig. 1. Experimental set-up used during the assembly task. Participants started near the table. They had to go to the distributor to collect a base part. Then, they had to go back to the work station where they had to fetch component parts stored under the table. All parts were assembled together on the assembly table. Upon completion of the assembly, participants had to place it on the distributor/collector and immediately start a new assembly cycle. This paper only deals with the part of the assembly where subjects collected the component parts stored under the table.

2.2. Procedure

Subjects were asked to perform an assembly task in conditions similar to those encountered at an assembly-line workstation. The height of the workstation was adapted to the size of each subject. The task involved several successive actions executed in a cyclic and repetitive manner at a defined work pace. A single assembly cycle involved collecting an assembly base from a distributor/collector of parts, moving between the distributor and the workstation, collecting parts stored at floor-level under the assembly table, assembly of the parts with the base on the worktable, and finally, once all parts had been assembled, return to the distributor/collector (Fig. 1). In this paper, analysis focused on the action of collection of the parts, one handle (200 g) and two nuts (7 g each), stored under the workstation. No recommendations were made on how to proceed when collecting the parts stored at floor-level. The only obligation was that, during each assembly round, the precise number of parts required should be collected, rather than amassing a reserve for subsequent assembly tasks.

The repeated assembly cycles, which included collection of spare parts from the floor-level reserve, were performed during two work sessions, each of which lasted 20 min. For each of these sessions, a different work pace was imposed by the base distributor. Subjects had access to real-time visual information on their progress with respect to the prescribed work pace. The pace was either comfortable, corresponding to 25 s per assembly cycle, i.e., a total of 49 assemblies, or rapid, at 20 s per assembly cycle, i.e., 60 assembly cycles to be completed. The order in which sessions were completed was randomised, but as many subjects from each age-group started by one or other of the paces. The pace was monitored continuously throughout the work session. A verbal reminder of the requirement to maintain the pace was given to subjects if they slowed down.

2.3. Apparatus

The postures adopted during repeated assembly cycles involving collection of parts from floor-level, were video recorded throughout the experimental sessions.

3D modelling of each assembly cycles was computed with Motion Inspector® software. Modelling was based on three superimposed models: i) an anthropometric model using 67 anthropometric measurements for each subject (Hanavan, 1964); ii) an inverse dynamic