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A better way of fitting clips? A comparative study with respect to physical workload

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ABSTRACT

The clip fitting task is a frequently encountered assembly operation in the car industry. It can cause upper limb pain. During task laboratory simulations, upper limb muscular activity and external force were compared for 4 clip fitting methods: with the bare hand, with an unpowered tool commonly used at a company and with unpowered and powered prototype tools. None of the 4 fitting methods studied induced a lower overall workload than the other three. Muscle activity was lower at the dominant limb when using the unpowered tools and at the non-dominant limb with the bare hand or with the powered tool. Fitting clips with the bare hand required a higher external force than fitting with the three tools. Evaluation of physical workload was different depending on whether external force or muscle activity results were considered. Measuring external force only, as recommended in several standards, is insufficient for evaluating physical workload.

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1. Introduction

The current trend, in manufacturing industries, of seeking productivity gains combined with a high level of quality has resulted in a willingness on the part of designers to ensure an uniformity in the ways in which operators work (Gold et al., 2009; Parent-Thirion et al., 2007; Neumann et al., 2006; Domkin et al., 2005; Chassaing, 2004; Andersen et al., 2003; Neumann et al., 2002). Workstation designers define a single succession of postures and movements to be performed by the operator, without offering any alternative. Assembly lines are no exceptions to this rule. Such lines are made up of series of workstations on which tasks are performed in succession and repeatedly (Carnahan et al., 2001). Many of these tasks are performed manually, with the bare hand or using a tool, powered or unpowered (Byström et al., 1995). In view of the repetitiveness of the movements, of the level of force required to perform an action, of extreme joint amplitudes and/or of activity maintained for long periods, neck and upper limb pain or indeed musculoskeletal disorders occur frequently in the workers performing such tasks (Ferguson et al., 2013, 2012; Jansen et al., 2012; Xu et al., 2012; Spallek et al., 2010; Nordander et al., 2009; Landau et al., 2008; Buckle and Devereux, 2002; Silverstein et al., 2002; Sluiter et al., 2001; Fransson-Hall et al., 1995). In ergonomics, workplace exposure to such physical workload is often evaluated by measuring muscular activity, which has been correlated with pain or musculoskeletal disorder symptoms (Ferguson et al., 2012; Porter et al., 2010; Bao et al., 2009; Ostensvik et al., 2009; Southard et al., 2007). Conversely, designers mostly use standards as a basis for evaluating physical workload, such standards recommending assessment of external force or posture (CEN 1005-4, 2004; CEN 1005-3, 2002; CEN 894-3, 2008).

One of the tasks that are frequent in automotive assembly processes is insert fitting. The inserts are small components of different shapes, made of metal, plastic or composite material. They are referred to by various names including clips, staples, nuts, rings or bushings. They are used to secure two parts together, for example a glove compartment and a dashboard. This task can be performed manually or in automated manner. As in other assembly tasks, automation is considered in order to reduce musculoskeletal disorders related to manual fitting. However, investment in automated machinery is costly and requires considerable expertise (Andrews et al., 2008). Usually, it is not considered to be cost-effective in view of the lifespan of such a part and of alterations that are often performed half way through its life. Therefore, insert fitting is generally performed manually, with or without a tool.

An ergonomic investigation conducted at an automotive supplier specialized in designing and producing dashboards preceded

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this study (Gaudez, 2008a, 2008b). The request from that company involved objectifying physical workload exerted during the insert fitting operation, which was a source of neck and upper limb pain or of musculoskeletal disorders. In that company, the insert fitting operation was combined with other operations such as deflashing, visual quality inspection, and packaging of the dashboards. The company had developed an unpowered tool. Its aim was to reduce the physical workload during the insert fitting operation. But it was observed that, when fitting the particular variety of clip-type inserts, most of the operators performed the operation with the bare hand despite the fact that the workstation working procedure recommended fitting them with the tool. In that company, the operators suffering from upper limb pain fitted the clips sometimes with their bare hand and sometimes with the tool. Operators changing their working practices depending on their physical conditions, such as depending on whether they feel tired or in pain, has already been observed during work activities (Derosier et al., 2008). Those operators explained that alternating the two fitting methods allowed them to vary their movements and reduced the physical workload on different parts of the body. In addition, many operators found that the tool was too heavy and that its handle was too large, cold, hard, and slippery when sweaty.

This laboratory study simulated the clip fitting activity. Its aim was to use muscular activity and external force measurements to evaluate the physical workload on the neck and upper limbs. Four different insert fitting methods were analyzed: two used in the company, namely bare hand and unpowered tool, as well as two prototype tools, one unpowered and one powered. The first objective of this study was to determine whether any one of these four methods generated lower physical workload than the other ones, thereby demonstrating its benefit to the musculoskeletal health of workers. The second was to compare the results of muscular activity measurements with the results of external force measurements.

This laboratory study supplemented the initial ergonomic investigation. Indeed, this simulation offered the advantage of isolating the insert fitting operation and thus of satisfying the initial request of the automotive supplier. It also allowed the use of prototype tools and techniques that were difficult to apply out in the company such as measuring resultant force, which would have required the workstation to be transformed.

2. Method

2.1. Subjects

Eleven right-handed male volunteers took part in the experiment. Those subjects did not work in the company in which the ergonomic investigation had been conducted, due to economic and social difficulties present at the time of the laboratory study and to the distance between the company and INRS (National Research and Safety Institute), where the laboratory was located. The volunteers were professionally experienced in performing precision assembly work.

The 11 subjects had not suffered from any musculoskeletal pain during the month preceding the experiment. Their average age was 27 years (ranging from 19 to 60 years), their average height was 178 cm (ranging from 171 to 191 cm), their average weight was 77 kg (ranging from 57 to 111 kg) and their body mass index was 19 (ranging from 19 to 37). The subjects gave their informed consent to the experiments, which were approved by the local ethics committee.

2.2. Test bench

An experimental test bench was used to simulate the clip fitting task. The shape, dimensions, and material of the clip supports were identical to those making up a dashboard in the company. Ten clip supports were fixed to a rule (Fig. 1). The clips were purchased from the same manufacturer as the one used by the automotive supplier. The supports were inclined such that the subjects inserted the clips forward and downward at a 45° angle in the sagittal plane. This inclination of the supports was frequently to be found on the dashboards. The rule was fixed to an elevating table simulating the height-adjustable workstations of the company. The table height was adjusted to the anthropometry of each subject. It was set at 90% of the elbow-to-floor height of the subject, corresponding to working in a standing position requiring average normal vision and precision (CEN ISO 14738, 2008).

2.3. Task

Standing and facing the rule, each subject fitted clips to each support using four different methods: with the bare hand, with an unpowered tool commonly used at the company, with an unpowered prototype tool, and with a powered prototype tool (Fig. 1). The prototype tools were developed at INRS with the help of the company's methods department that worked with the operators.

The unpowered tool commonly used at the company was circular in cross-section and cylindrical in longitudinal section. Its length was 120 mm, its diameter was 32 mm and its weight was 200 g. It had a magnetic cavity at its end that was preformed to match the geometrical shape of the clip for subsequent positioning on the support. The clip was held by magnetization in that cavity. An unpowered prototype tool featuring merely a modified handle was therefore developed from that commonly used tool. Various studies bear witness to the importance of the ergonomics of the handle of the hand tool in terms of performance, comfort, and physical stress for the operator (Harih and Dolšak, 2014a, 2014b; Ng and Saptari, 2014; Garneau and Parkinson, 2012; Eksioglu, 2004). Its handle had a shape that was circular in cross-section and conical in longitudinal section. That shape appeared to be optimum for hand tools requiring handling with precision or with force (Kong et al., 2008; Dong et al., 2007). Its length was 115 mm. Its largest diameter was 36 mm and its smallest diameter was 20 mm. The diameter of the handle splayed to 25 mm in the vicinity of the cavity to form a guard and was made of slightly rough, hard plastic in order to prevent the fingers and hand from slipping, and the handle from feeling cold. This prototype tool weighed 130 g. The cavity located at the tool tip was identical to that on the tool commonly used at the company. The magnetic force of the cavity was identical for both tools. The subjects were told to hold the unpowered tools with a full hand grip in their dominant hand with the thumb directed towards the cavity to ensure consistency between subjects. That way of holding the tool was the one that was observed most frequently during the ergonomic investigation. The powered prototype tool was developed from a pneumatic stapler, whose nose and loading magazine were modified. Its loading magazine contained 10 clips. Urged by a spring, the clip went into place automatically in the cavity of the tool. The handle extended at right angles and was held in the dominant hand, with the forearm extended in alignment with the hand. The handle was 140 mm long, oval (40 mm × 30 mm) in cross-section and cylindrical in longitudinal section. A trigger that was 45 mm long, was actuated by the index finger and the middle finger of the dominant hand. It weighed 970 g and was sheathed in slightly rough plastic. The tool tip featured the same cavity as that of both of the unpowered tools and a position mark was added to the cavity so as to make it

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