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International Journal of Industrial Ergonomics 30 (2002) 149–161

International Journal of
Industrial
Ergonomics

www.elsevier.com/locate/ergon

Ergonomic design and evaluation of wire-tying hand tools

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Received 22 October 2001; accepted 5 February 2002

Abstract

Unnatural postures and repetitive forceful exertion have been identified as risk factors for hand/wrist injury problems. These factors may be reduced via design/redesign of the power or non-power hand tool used. Examples of handle design are common in the literature. Hand tool mechanisms designed to reduce the risk factors have seldom been studied. In this study, the development and design of three wire-tying hand tools is introduced. The new designs, together with the traditionally used pliers, were evaluated in simulated wire-tying tasks in the laboratory. Results from these experiments showed that EMG(%MVC) of the flexor digitorum superficialis and the flexor carpi ulnaris of the right forearm may be significantly reduced when using the new designs compared to pliers. The number of unnatural postures, including flexion, extension, radial deviation, and ulnar deviation were all significantly decreased when using the new designs. The subjective responses of the subjects, including exertion level, ease of use, and muscular discomfort all favored the new designs, as compared to the pliers.

Relevance to industry

Hand tool design is essential in reducing the ergonomic risk factors for hand/wrist problems. The focus has been on handle design in the past. In this paper, examples for reducing the unnatural postures and muscular effort via the mechanism design of a wire-tying hand tool is introduced and discussed.

Keywords: Cumulative trauma disorders; Ergonomic risk factors; Hand tool design; Wire-tying task

1. Introduction

Upper extremity cumulative trauma disorders (CTDs) have been associated with work activity in a variety of tasks. Awkward postures were recognized as key ergonomic risk factors for CTDs in the literature (Armstrong et al., 1986; Putz-Anderson, 1988; Muggleton et al., 1999). Schoenmarklin et al. (1994) confirmed the view that flexion and extension might cause hand problems. Armstrong and Chaffin (1979) found that flexion and extension of the wrist were associated with the high incidence of carpal tunnel syndrome in sewing machine operators. Radial and ulnar deviations have also been implicated in carpal tunnel syndrome (Tanaka et al., 1995). Masear et al. (1986) associated extreme wrist motion, particular flexion and ulnar deviation with carpal tunnel syndrome problems in the meat-cutting industry. In addition to carpal tunnel syndrome, other problems such as De Quervain's disease and lateral

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0169-8141/02/$ - see front matter
PII: S0169-8141(02)00097-5

epicondylistis have also been associated with radial and ulnar wrist deviations (Armstrong, 1996; Dimberg, 1987). In studying muscular symptoms in automobile assembly workers, Hägg et al. (1997) concluded that an ulnar deviated hand posture occurred more frequently than other unnatural hand postures and was the key risk factor for hand symptoms.

In addition to awkward postures, excessive muscular force and high rates of manual repetition were also noted as risk factors (Silverstein et al., 1986; Moore and Garg, 1994). Electromyography (EMG) has been the major quantitative measure of muscular effort in studying cumulative trauma disorders. EMG in percent of maximal voluntary contraction (%MVC) has been used for comparing the major variables (Moore and Garg, 1994; Lee and Jiang, 1999). The rate of repetition may be measured by cycle time. If the cycle time is less than 30 s or more than 50% of the cycle time involved in performing the same kind of manual operation, involves high repetitive motion (Putz-Anderson, 1988).

Ergonomic risk factors were usually found when hand tools were being used. Hand tool design/redesign of was therefore an essential issue in the reduction of hand/wrist discomfort and injuries (Putz-Anderson, 1988; Cobb et al., 1996; Killough and Crumption, 1996; Muggleton et al., 1999; Lee and Jiang, 1999).

In a survey conducted by the Institute for Occupational Safety & Health of the ROC (IOSH, 1998), 531 construction workers in northern Taiwan were interviewed concerning their experience with musculoskeletal symptoms. Aches in the upper extremity, next to low back pain, were reported as the second most common problems. Aches in the upper extremity were found to be associated with extensive use of hand tools and/or awkward working postures. Seventy four percent of the interviewers reported that they used hand tools to accomplish their task. Among them, 57% reported that they experienced aches in the upper extremity in the past 12 months.

Pliers are one of the most commonly used non-power hand tools by construction workers (IOSH, 1997). Pliers are normally used in cutting wires and tying components together. Iron wire is used in tying plastic pipe, plywood forms, and iron before concrete is poured. When tying wire, threads must be clamped and twisted. Wire clamping is accomplished using pliers via power grasp of the hand. Wire twisting could not be finished without the repetition of awkward hand/wrist postures, such as flexion, extension and ulnar deviation of the wrist together with supination and pronation of the arm. Unclamping wires require the worker to exert pressure against the metal handle to open the jaws using the fourth and fifth fingers. A large number of wire-tying tasks might need to be accomplished in 1 day by a single iron or pipeline worker. The wrist motion repetitions for the wire-tying task are high. In order to reduce the unnatural postures of the wrist, a bent plier handle was introduced to reduce wrist deviation (Tichauer, 1966; Emanual et al., 1980; Schoenmarklin and Marras, 1989). Tichauer (1976) validated that the use of bent-handled pliers was effective in reducing tenosynovitis, epicondylitis, and carpal tunnel irritation symptoms. The idea of bent handles ($19 \pm 5^{\circ}$) for all tools and sports equipment was even patented in the US by John Bennett (Emanual et al., 1980). In fact, unnatural postures of the hand/wrist can also be reduced via tool mechanism design. This idea has seldom been discussed in the literature.

Fig. 1. Pliers and wire-tying hook.