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Applied Ergonomics 36 (2005) 575–583

APPLIED ERGONOMICS

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An ergonomic evaluation of manual Cleco plier designs: Effects of rubber grip, spring recoil, and worksurface angle

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Received 5 January 2004; accepted 27 January 2005

Abstract

The present study evaluated two design modifications (rubber grip and torsion spring) to the conventional manual Cleco pliers by electromyography (EMG), hand discomfort, and design satisfaction. This study also surveyed workers' satisfaction with selected design features of the pliers for ergonomic improvement. A two-way (plier design × worksurface angle) within-subject (nested within gender and hand size) design was employed. Eleven workers simulated the plier task in an adjustable workstation for different plier designs and worksurface angles (0°, 60°, and 90°). Lower EMG values were obtained for the pliers with rubber grip and at 60° of worksurface angle. EMG values varied significantly between the participants, but showed low correlations (Spearman's rank correlation = −0.27∼−0.58) with their work experience with the pliers. The hand discomfort and design satisfaction evaluations identified that the grip span (max = 14.0 cm) and grip force requirement (peak = 220.5 N) of the current pliers need ergonomic modification. The present study shows the needs of both the ergonomic design of a hand tool and the training of a proper work method to control work-related musculoskeletal disorders at the workplace.

Keywords: Manual Cleco pliers; Hand tool; Rubber grip; Spring recoil; Worksurface angle

1. Introduction

To operate manual Cleco pliers (Fig. 1), a common hand tool used in aircraft manufacturing, workers often use high grip forces along with non-neutral postures of the upper extremity. Made of forged steel and plated with nickel, the pliers consist of a pair of jaws and handles, crossed along the center of rotation. By using the pliers, a Cleco fastener is installed to hold aircraft skins and frames together temporarily; the head of the fastener, loaded with a stud and spring (spring *coefficient* = 771.3 N/cm and *displacement* = 0.6 cm), is secured in the jaws and then pressed for installation. For complete compression of the fastener head, at least 220.5 N of peak grip force (measured by a strain gauge in this study) must be applied to the plier handles. In addition to the high grip forces, awkward postures at the hand/wrist and shoulder (ulnar deviation and shoulder elevation) are often used for work at certain heights and angles of skins and frames (Kumar, 2001). Research has found that repetitive gripping with high forces and improper postures may significantly increase the risk of work-related musculoskeletal disorders at the upper extremity (Bernard, 1997).

To prevent upper extremity musculoskeletal injuries due to repetitive, prolonged use of Cleco pliers, ergonomic modification of the pliers is needed. The conventional pliers have been used at the workplace for more than 50 years without design improvement. Bevan (1996) lists problems of the conventional plier

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0003-6870/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.apergo.2005.01.014

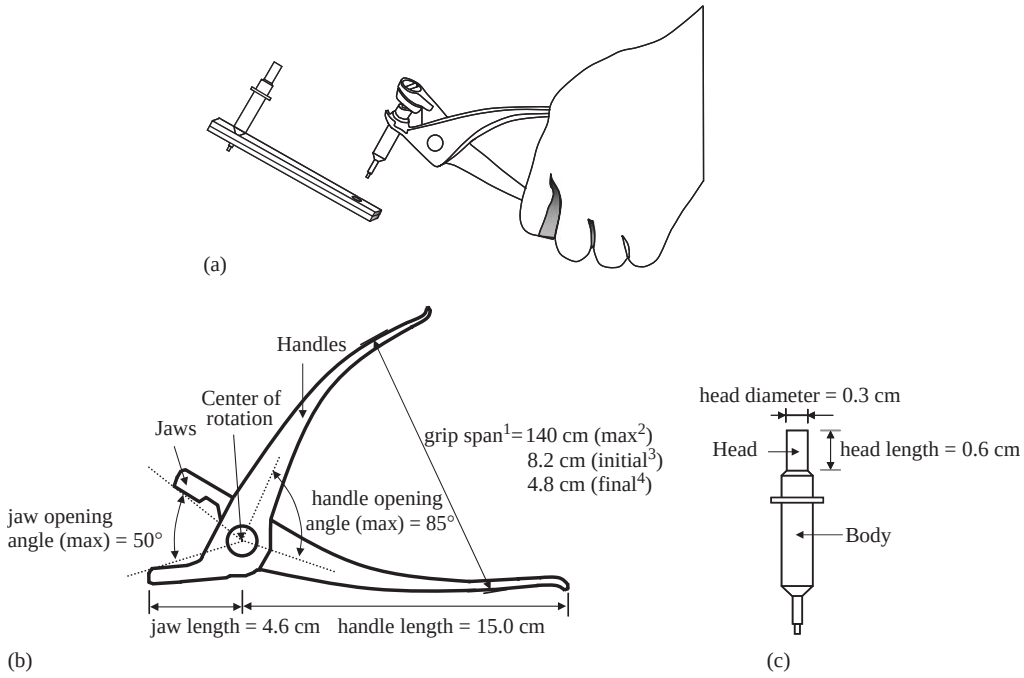

Fig. 1. Operation of manual Cleco pliers with a fasteners. [1]Outer distance between the handles at the position between the middle and ring fingers; [2]when the handles are completely open; [3]prior to force application to install a fastener; [4]when the fastener head is completely pressed down. (a) plier operation, (b) pliers and (c) fastner.

design, which include the handle opening being too wide, handle geometry causing deviated hand/wrist postures, and handle texture lacking sufficient friction. No follow-up study, however, has been conducted to examine the potential effects of ergonomic design changes for the pliers.

The goals of the present study were to: (1) evaluate the effectiveness of two design modifications (rubber grip and spring recoil) to the conventional pliers and (2) identify design features of the pliers requiring ergonomic modification. Three measures (EMG, hand discomfort, and design satisfaction) were employed to evaluate the two design additions and workers' satisfaction was surveyed for selected design features. Based on the ergonomic evaluation of the pliers, design recommendations were provided for manual Cleco pliers for better comfort, productivity, and health of the users at work.

2. Methods and materials

2.1. Participants

Workers were recruited at an aircraft manufacturing company by considering their work experience with Cleco pliers, health condition, and hand size. Workers having at least 1 year of experience with the pliers and no history of musculoskeletal injuries at the upper extremities were selected. Three hand-size groups (small: $\leqslant$33%ile; medium: 34–66%ile; and large: $\geqslant$67%ile) were defined for each gender based on the hand-breadth data (at the metacarpals) of the US population (Pheasant, 1996): for males, $<$8.8 cm for small, 8.8–9.2 cm for medium, and $>$9.2 cm for large; for females, $<$7.3 cm for small, 7.3–7.7 cm for medium, and $>$7.7 cm for large. The company allowed workers to participate in the study during their regular work hours.

Eleven workers (two participants for each of the three hand-size groups of each gender except the male large hand-size group) participated in the plier evaluation experiment. All the workers were 21 years of age or older (*mean* = 32, *SD* = 10.2, and *range* = 23−48). Their experience with manual Cleco pliers ranged from 1.5 to 10 years (*mean* = 4.5 and *SD* = 2.9).

2.2. Apparatus

A workstation adjustable in height and angle (Fig. 2) was constructed to simulate the Cleco plier task in a laboratory setting. At the workstation, the height (73.7–109.2 cm from the floor) and horizontal angle (0–120°) of worksurface and the horizontal distance (25.4–50.8 cm) of the foot location marker (from the workstation) can be controlled. The worksurface height and foot location adjustment ranges were determined to accommodate 95% US population (5%ile female to 95%ile male) in terms of stature for a standard work posture (20° of shoulder flexion, 40° of elbow flexion, and trunk and legs straight) during fastener installation/removal. The worksurface angle adjustment range was