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Ergonomics and comfort in lawn mower handle positioning: An evaluation of handle geometry

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ABSTRACT

Hand operation accompanied with any combination of large forces, awkward positions and repetition may lead to upper limb injury or illness and may be exacerbated by vibration. Commercial lawn mowers expose operators to these factors during actuation of hand controls and therefore may be a health concern. A nontraditional lawn mower control system may decrease upper limb illnesses and injuries through more neutral hand and body positioning. This study compared maximum grip strength in twelve different orientations (3 grip spans and 4 positions) and evaluated self-described comfortable handle positions. The results displayed force differences between nontraditional (X) and both vertical (V) and pistol (P) positions ($p < 0.0001$) and among the different grip spans ($p < 0.0001$). Based on these results, recommended designs should incorporate a tilt between 45 and 70°, handle rotations between 48 and 78°, and reduced force requirements or decreased grip spans to improve user health and comfort.

1. Introduction

Repetitive high grip force exertions have been related to fatigue, discomfort, and injury to the hand and wrist. It has been shown that factors such as force, exertion angle and grip span greatly affect comfort and maximum exertion (Shivers et al., 2002). Manual hand actuation may seem trivial; however, in combination with high forces, non-neutral positions, and/or high multiple repetitions, along with exacerbation from vibration, musculoskeletal disorders (MSDs) become a very serious risk (Garg and Kapellusch, 2011; Ma et al., 2009; Adamo et al., 2002). More specifically, work-related musculoskeletal disorders (WRMDs) have been an area of great concern in the industrialized world (Bernard, 1997). Not only can these conditions cause discomfort or pain to the user but they can result in lost time and profit for the employer. Discomfort and fatigue are often considered predictors or early warning symptoms for WRMDs (Garg and Kapellusch, 2011; Ma et al., 2009). It has been shown that factors such as force, exertion angle and grip span greatly affect comfort as well as maximum exertion (Shivers et al., 2002). Similarly, wrist posture in the flexion/extension plane (Hallbeck and McMullin, 1993) and the radial ulnar deviation plane (Lamoreaux and Hoffer, 1995) can alter potential maximum grip forces. If maximum exertion is decreased, the amount of force comfortably generated may proportionately decrease. Therefore, it is crucial that steps are taken to minimize fatigue by reducing the ratio of high maximum exertion to lower required force and through designs that ensure user comfort (Kong et al., 2011; Kuijt-Evers et al., 2004). Investigation into the effect of work piece orientation and hand tool interface is important for the evaluation of hand tool utilization and in the designing of a work environment (Lin and McGorry, 2009; McGorry and Lin, 2007). Through these investigations, designers should be able to reduce user fatigue and discomfort.

Designers often strive for a neutral wrist position (Estill and Kroemer, 1998; Drury et al., 1985). One study by Gustafsson and Hagberg reported that a neutral wrist position during computer mouse work resulted in less productivity and lower perceived comfort (2002). This investigation indicated that comfort is dependent on more than just a neutral wrist position and that the activity at hand may dictate a different position that is more comfortable and therefore preferred. For example, the height of the work space may alter wrist angles for individuals of different heights. Investigations in the garment industry on discomfort in the upper extremities of workers reported that a simple adjustment in seat height through adjustable chairs could not only reduce pain in the upper extremity but it could decrease occurrences of non-neutral positioning of both the right elbow and wrist (Herbert

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et al., 2001). Handle grip spans have also been shown to affect both comfort and grip strength and researchers found the most comfortable grip spans lie between 50 and 55 mm (Lee et al., 2009). These examples describe the different factors that affect the comfort and maximum forces. Garg and Kapellusch stated that even gripping that occurs on and off over a period of time should not meet or exceed 17% of a user's maximum voluntary contraction (MVC) (2011).

Commercial lawn care employees, which we will refer to as landscapers, spend a major portion of their day operating lawn mowers. Commercial mowers used by professional landscaping companies often subject the users to hours of awkward grip forces five days a week for the duration of the mowing season. Many mowing sites are filled with numerous landscaping obstacles, varying terrain, and tight spaces. Therefore, companies provide walk-behind machines in order to give the employee more precision and control. Walking behind a mower is slower than riding on stand-on or seated mowers. Therefore an attachment, known as a sulky, allows the operator to ride behind the mower increasing the speed without sacrificing maneuverability. The attachment is designed with one or two wheels, a platform for standing, and a simple hitch which attaches to the walk-behind machine. The sulky allows the operator to run the lawn mower at a higher speed than walking; however, it also slightly confines the position of the operator.

Although the lawn care industry has improved the efficiency of the employee's work, there remain some areas of improvement for user health and comfort. One of these areas is in the handle control systems. There have been several research papers covering the correlation of hand size, wrist angle, and grip span on grip strength; these studies however are not sufficient for the factors that affect the professional mowing system in this study. Most of these studies have been conducted on hand dynamometers (Edgren et al., 2004; Sancho-Bru et al., 2003; DiMartino et al., 2004; Fiebert et al., 1998; Pazderka et al., 1996; Hansen and Hallbeck, 1996; Ramakrishnan et al., 1994; Ayoub and Lo Presti, 1971). Previous studies have explored specific hand tools and their ergonomic design specifications (Kuijt-Evers et al., 2004). However, none have been aimed at lawn mowing hand controls or similar tasks. Traditionally, these machines have been designed with the focus on the mechanics and not the operator. For example, the lawn mowers are designed to move quickly for faster task completion, but the resultant vibration experienced by the operator is not ideal (Thrailkill et al., 2013). Without the user-centered design focus, the operator works in non-neutral body postures, which are uncomfortable and could lead to WRMDs.

Since lawn mowing employees spend large amounts of time performing these repetitive tasks, it is crucial that measures are taken to reduce discomfort and minimize fatigue during operation in order to prevent WRMDs. A local manufacturing company contracted the researchers for an ergonomic analysis of their current commercial lawn mower handle geometry. This handle geometry was very different than traditional commercial lawnmower. Based on a search of other commercially available lawn mowers, the common control systems are currently a straight bar or a pistol position (Fig. 5). The manufacturing company specifically cited pistol position as their main competitor. Since the pistol position is the most similar to the nontraditional control system (NCS), this research aimed to determine a significant postural and comfort differential between the systems. There is no formal ergonomic comparison of handle geometries. The lawn mower under investigation allows landscapers to set a speed and release the control bar to accelerate. By engaging the control bar, the landscaper can brake (by engaging both control bars on the right and left), turn left (by engaging the left control bar), turn right (by engaging the right control bar), or reverse (by engaging the control bar past the neutral zone). The neutral zone is 6.3 mm and full speed acceleration is 9.0 mm. Two different forces are required while operating the nontraditional handle system. Based on the drivetrain of the mower the manufacturing company measured the required grip force to be about 88 N for engaging the handles (squeezing). In order to release the handles in a controlled manner, the manufacturing company measured the required force to be about 44 N of force.

The purpose of this study was to evaluate different conditions under which a commercial lawn mower may provide optimal comfort, help promote neutral wrists and incorporate injury prevention through ergonomic handle geometry. This study specifically aimed to evaluate the physical requirements and ergonomic geometry of the commercially available NCS position of the local manufacturer compared to a commonly used pistol-grip position and a completely vertical position in order to better understand the strength capacity required in job performance and highlight areas in this field that may require attention and future innovation. This was pursued through the evaluation of maximum grip forces in various handle configurations and an investigation of chosen comfortable handle positioning. The goal of this study was to evaluate the ergonomics and comfort of the nontraditional lawn mower handle geometry based on the postures and physical force required to operate the machine. The hypothesis of this research group is that the nontraditional handle will provide better user conditions than other commercially available geometries due to a relatively neutral user posture during operation.

2. Materials and methods

2.1. Force

The study on grip force compared four different handle geometries along with three different grip spans. The handle geometries were chosen based on the NCS (X), the commonly used pistol position (P), an average comfortable position (C) which was measured in the comfort study later in this text, and a vertical position (V) that potentially allowed for more neutral wrist angles.

2.1.1. Participants

Following IRB approval, participants were recruited and consented. For this grip force study, 72 participants were recruited ranging from 19 to 54 years of age from the population of students the University of Nebraska-Lincoln (63) and employees of the contracting manufacturing company (9). The manufacturing company employees increased our age range and had experience with lawn mowers. Of the participants, 46 were male, and 26 were female. These participants voluntarily completed the study and each individual was informed that his/her standing at the company or the university would not be affected by his/her willingness to participate, and told that they could withdraw at any time.

2.1.2. Stationary handle mock-up

Instrumentation used for the force and comfort studies included a mock-up apparatus that simulated lawnmower handle bars as seen in Fig. 1. This stationary simulation device could be adjusted to various heights, grip spans, handle angles, handle spreads, and tilt (Figs. 3–5). This mockup (Fig. 1) was made of a camera tripod with a bracket mounted at the center of a horizontal piece of steel that allowed the handles to slide in order to achieve a desired handle spread. The handles rotated to the various angles with a pin rotation using a wingnut. The camera tripod allowed the angle and the height of the handle to adjust for maximum comfort. The two handle grips were made of PVC pipes and covered by the rubber