Applied Ergonomics 58 (2017) 482–490

Contents lists available at ScienceDirect

Applied Ergonomics

journal homepage: www.elsevier.com/locate/apergo

Effects of milking unit design on upper extremity muscle activity during attachment among U.S. large-herd parlor workers

David I. Douphrate [a, *], David Gimeno Ruiz de Porras [a], Matthew W. Nonnenmann [b], Robert Hagevoort [c], Stephen J. Reynolds [d], Anabel Rodriguez [a], Nathan B. Fethke [b]

[a] The University of Texas Health Science Center at Houston, School of Public Health, San Antonio Regional Campus, TX, USA
[b] University of Iowa, College of Public Health, Iowa City, IA, USA
[c] New Mexico State University, Dairy Extension, Clovis, NM, USA
[d] Colorado State University, Environmental and Radiological Health Sciences, Ft. Collins, CO, USA

ARTICLE INFO

Article history:
Received 4 February 2016
Received in revised form
6 August 2016
Accepted 8 August 2016

Keywords:
Dairy
Electromyography
Milking unit
Equipment

ABSTRACT

Background: Large-herd dairy parlor workers experience a high prevalence of musculoskeletal symptoms in the upper extremity. The purpose of this study was to evaluate the effect of milking unit design on upper extremity muscle activity during milking unit attachment.
Methods: Upper extremity muscle activity was recorded among U.S. large-herd parlor workers (n=11) using surface electromyography. Participants performed several milking unit attachment cycles with each of six milking unit designs. Muscle activity levels were then compared between unit designs.
Results: Mean muscle activity levels (in %MVE) across milking units ranged from 6.8 to 8.2 for the upper trapezius, 8.2 to 10.3 for the anterior deltoid, 13.8 to 17.2 for the forearm flexors, and 9.9 to 12.4 for the forearm extensors. Pairwise comparisons between milking units did not reveal statistically significant differences in muscle activity levels across milking unit designs. However, a general pattern of higher muscle activity was observed with specific milking units. Milking unit weight, milk tube spread, and teat cup shape may explain differences in muscle activity levels.
Conclusions: Milking unit design may influence muscle activity levels among parlor workers. Small reductions in muscle activity associated with milking unit design have the potential to delay the onset of fatigue or development of musculoskeletal health outcomes among parlor workers.

1. Introduction

1.1. U.S. dairy profile

Dairy production in the U.S. has rapidly progressed toward a large-herd model due to associated economies of scale (Reinemann, 2001). In 2012, there were 46,000 dairy operations in the U.S. (USDA, 2012), down from 72,500 in 2002 (37% decrease). Concurrently, milk production and herd sizes have increased. In 2012, 63% of milk produced in the US came from large-herd operations (>500 head) (USDA NASS, 2013), compared with only 37% in 2002 (USDA NASS, 2004). Operations with 2000 head or more accounted for 35% of milk production in 2012 (USDA NASS, 2013), up from just 15% in 2002 (USDA NASS, 2004). The relatively recent shift towards large-herd dairy production may lead to an increased risk of work-related musculoskeletal disorders (MSD) among parlor workers due to task specialization and greater work demands. As herd sizes increase, the need for effective health and safety intervention research in the U.S. dairy industry will also increase (Douphrate et al., 2009a).

About 79% of U.S. milk production is on farms employing immigrant workers (Adcock et al., 2015). Previous studies have reported that Hispanic labor on U.S. dairies is common [e.g., 50% in New York (Maloney, 2002), 85–89% in Colorado (Reynolds et al., 2009; Roman-Muniz et al., 2006), 92% in Vermont (Baker and Chappelle, 2012), and 94% in California (Eastman et al., 2012)]. Prior research by the authors suggests that 97% of U.S. large-herd parlor workers are Hispanic, with the majority (89%) being male (Douphrate et al., 2014). Hispanic immigrant men, particularly those with limited English skills, who work on farms that have been found to have significantly high rates of fatal and non-fatal injuries

* Corresponding author. University of Texas, School of Public Health, San Antonio Regional Campus, 7411 John Smith Drive, Suite 1100, San Antonio, TX 78229, USA.
E-mail address: david.i.douphrate@uth.tmc.edu (D.I. Douphrate).

http://dx.doi.org/10.1016/j.apergo.2016.08.008
0003-6870/

(Dávila et al., 2011).

Dairy workers have the second highest prevalence of injuries among U.S. farm workers (Boyle et al., 1997; Crawford et al., 1998; NIOSH, 1993) Pinzke (2003) reported over 83% of dairy workers experience musculoskeletal symptoms (MSS). Additionally, Karttunen and Rautiainen (2011) reported a decline in working ability in 39% of dairy farmers caused by musculoskeletal disorders. Despite increased mechanization with parlor milking, musculoskeletal health outcomes are prevalent among parlor workers. Tuure and Alasuutari (2009) reported one out of three parlor workers were affected by problems in the upper extremity. Kolstrup et al. (2006) reported 86% of Swedish dairy workers reported some kind of MSD which was most prevalent in the upper extremity (52%). Other Swedish dairy farm studies reported prevalences of shoulder and hand/wrist MSS exceeding 50% (Pinzke, 2003; Stal et al., 1996). A recent study involving Hispanic, large-herd parlor workers in the U.S. revealed 76% experienced work-related MSS in at least one body part, and the highest prevalence was in the upper extremity (55%) (Douphrate et al., 2014). Dairy workers file 8.6 workers' compensation claims per 200,000 work hours (Douphrate et al., 2006), higher than the national injury rate (6.2 per 200,000 h) (BLS, 2004). The largest percentage (35%) of injury claims involves the upper extremity, and nearly 50% of injuries occur in the milking parlor (Douphrate et al., 2009b).

1.2. Milking routine

The milking routine includes five primary tasks: 1) teat dip with a cup for sanitization; 2) teat strip to stimulate milk flow; 3) teat wipe; 4) milking unit attachment (Fig. 1); 5) automatic detachment of milking unit after milking; and 6) post-dip of teats for sanitization. Milking unit attachment to the udder has been identified as among the most physically strenuous tasks of the milking routine (Douphrate et al., 2014).

A milking unit consists of a number of parts: claw, teat cups, liners, and tubing. Together the claw, teat cups and liners constitute a milking unit (Fig. 2). Milking unit designs differ based on shape of milking claw and component materials. Studies have reported milking units can weigh more than 3.0 kg (Schick, 2000; Stål et al., 2003). Techniques for attaching the milking unit include either holding the claw with one hand and attaching teat cups with the other hand (Fig. 3a), or using each hand to attach two teat cups simultaneously (Fig. 3b). The attachment process involves a forward reach into a confined area between the hind legs of the cow.

Repetitive work and non-neutral postures have been reported as risk factors associated with having MSD among parlor workers (Kolstrup et al., 2006). Increased automation of the milking process requires forceful arm and hand motions (Stål et al., 2000), and attachment of the milking unit has been reported as the most strenuous task because of repeated lifting and attaching of milking units (Pinzke et al., 2001b). Shoulder to udder reach distance has been reported to contribute to a lever action up to 9.0 N m contributing to high muscle load during unit attachment (Jakob et al., 2007). Douphrate et al. (2014) reported 32% of large-herd parlor workers perceived milking unit attachment to be the most strenuous. These findings were in line with other studies that identified milking unit attachment to be among the most demanding milking task (Jakob et al., 2012; Stål et al., 1996, 2003).

1.3. Study objective

Milking parlor productivity and efficiency involves a triad of interactions between the cow, milking equipment and environment, and worker. Worker performance has the potential to have a profound influence on milk production, cow health and parlor productivity. Within each milking parlor, worker milking routine consistency is paramount. Inconsistent or improper milking routine can prolong or reduce cow milk let-down, increase milking time, adversely affect teat health, and decrease optimization of milk harvest volume. Human error, lack of training, fatigue, or discomfort can contribute to milking process drift and a reduction in milking consistency. To date, research emphasis has been placed on the cow or milking equipment and their effects on milk production. Little attention has been placed on the worker, and his/her interaction with the cow, equipment or his/her working environment.

Fig. 1. Milking unit attachment.

An ongoing five-year investigation has involved the estimation of physical exposures (i.e. muscle forces, posture, motion) among U.S. large-herd parlor workers using direct-measurement technologies, as well as the evaluation of effectiveness of targeted interventions to reduce these exposures. One task-specific intervention strategy could be focused on the reduction of muscular burden associated with milking unit attachment task. Lighter milking units or alternative unit shapes have the potential to reduce upper extremity muscular burden. The purpose of this study was to evaluate the effects of milking unit design on upper extremity muscle activity during milking unit attachment among large-herd parlor workers. Our evaluation included two prototype milking unit designs which were lighter in weight and non-

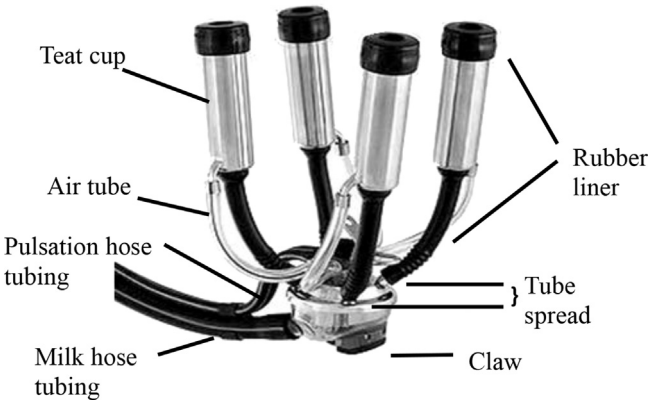

Fig. 2. Milking unit components.