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Evaluation of upper body kinematics and muscle activity during milking attachment task

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ABSTRACT

The objective of the study was to evaluate the effects of udder height on upper body kinematics and muscle activity during a simulated attachment task in a parallel parlor set up, and the effects of udder access method (back or side) on the task biomechanics. Twenty males performed the task under conditions that simulated three udder heights and two udder access methods. The muscular load and kinematics during the task confirmed that milking is a physically demanding task. Trunk flexion angle increased with decreasing udder height, and the erector spinae activation was higher when the udder was below shoulder height compared to at or above. Compared to accessing the udder from side of the cow (herringbone parlor style), accessing from behind (Parallel parlor style) was associated with lower trunk flexion, greater shoulder horizontal adduction, lower shoulder elevation, and greater anterior deltoid activation. Milking in herringbone parlor style and with the udder at or above shoulder level may help reduce strain on the trunk/neck.

1. Introduction

Dairy production in the US has steadily moved toward large-herd milking operations due to the lower production cost (Reinemann, 2002). The shift toward a large-herd model has led to increased physical demand and potentially increased risk of work-related musculoskeletal symptoms (MSS) among milking parlor workers. The estimated prevalence of work-related MSS among dairy milkers is as high as 76% (Douphrate et al., 2012, 2014a; Kolstrup, 2012; Dairy Workers, 2014; Douphrate et al., 2013), with shoulder and neck being the most commonly affected areas. It is said that 40–47% of milkers report having shoulder symptoms and 32–47% report having neck symptoms in the past 12 months (Douphrate et al., 2014a; Kolstrup, 2012; Nonnenmann et al., 2008). Long work-hours and biomechanics of milking tasks have been associated with a high prevalence of reported shoulder and neck MSS among milkers (Douphrate et al., 2014b).

In modern milking parlors, cows stand on a raised platform, at a higher level than workers who operate in a milking pit, which enables the workers to perform milking tasks while maintaining a relatively upright posture. Milking routine consists of six tasks; pre-dipping of teats for sanitization, stripping, wiping, milking unit attachment and detachment, and post-dipping of teats for sanitization. Many milkers perform the routine throughout 8–12 h shifts, six days a week for almost 50 weeks per year (Douphrate et al., 2012). Of the six tasks, the attachment task, which requires milkers to reach under the udder to secure a cluster (i.e. device to milk the cow), results in the highest activation level of the arm and forearm muscles, and is regarded as among the most physically demanding (Douphrate et al., 2014a, 2016; Pinzke et al., 2001).

The biomechanics of the attachment task has only been described in two previous studies. The first study was conducted in 1986, when stanchion system milking was still being utilized, and milkers operated on the same floor as the cow and had to squat/kneel to perform milking tasks (Arborelius et al., 1986). The second study was conducted more recently by (Jakob et al. 2012). The study examined the effects of udder height on upper body kinematics and muscle activity among professional milkers. This study demonstrated that milking a cow with its udder at the milker's shoulder

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height is ideal in minimizing deltoid and upper trapezius muscle activity level (Jakob et al., 2012).

The data collection in the study by Jakob et al. (2012) was conducted in a set up called herringbone parlors where cows are positioned at 30–45° angle to the pit, and thus milkers access udders from side of the cow. Because of better cost and space efficiency, however, herringbone parlors are being gradually replaced by the parallel parlors where the cows are positioned perpendicular to the pit, and thus milkers access the udders through cow's hind legs. This design requires the milkers to access udders through a narrower space by keeping their elbows close together and making other biomechanical adjustments. However, no study has described upper body kinematics of milking in parallel parlors (Douphrate et al., 2012). Therefore, it is unknown how the difference in body positioning associated with different parlor design influences milkers' motion and muscle activity.

The objective of the study was to expand on the work conducted by Jakob et al. (2012) to better understand the biomechanics of milking unit attachment task. Specifically, we evaluated the effects of udder height on upper body kinematics and muscle activity during a simulated attachment task in a parallel parlor set up, and the effects of udder access method (back or side), as dictated by the parlor design, on the task biomechanics.

2. Material and methods

2.1. Participants

Data collection took place at the Applied Biomechanics Research Laboratory at the University of Texas at San Antonio. Twenty healthy males (age: 22.2 ± 1.9 years, hand dominance: R/L = 16/4, height: 172.8 ± 5.2 cm, mass: 75.0 ± 8.4 kg, acromion-grip length: 79.0 ± 3.2 cm) agreed to participate in the study. Only males were recruited since approximately 90% of dairy milkers are males (Baker and Chappelle, 2012; Roman-Muniz et al., 2006). No participants had prior experience with cow milking. All participants provided a written informed consent approved by the University of Texas at San Antonio prior to participating in the study.

2.2. Instrumentation

A video-based motion capture system (Vicon Inc., Centennial, CO) with eight T10s cameras was used to capture kinematics at a sampling rate of 100 Hz. Electrical muscle activity of the upper and lower trapezius, neck extensor, erector spinae, and anterior deltoid of the dominant upper extremity was sampled via surface electromyography (EMG) with a differential amplifier (BTS Bioengineering, FreeEMG 300, Brooklyn, NY). The system has an input impedance of 1Gohm, common mode rejection rate greater than 110 dB, and signal-to-noise ratio of 70 db. Muscle activity data were collected at a sampling rate of 1000 Hz. The kinematic data and the EMG data were synchronized electronically.

A custom-made simulated udder was constructed for the study (Fig. 1). A PVC pipe with a circular base at the bottom, representing a cow udder, was built into a support frame. The height of the base was adjustable, so that the udder could be moved up or down to the participant's shoulder height and 15 cm above or below the shoulder height. A milking unit is attached to a cow's udder, and vacuum pressure enables the harvesting of milk. Magnets were secured to the end of each milking unit teat cup and the base of the simulated udder. Magnetic attraction enabled the attachment of milking unit to the udder. When simulating milking in a parallel parlor design, in which the participants accessed the udder from behind the cow (through the hind legs), two vertical strings were positioned 32 cm apart and 17 cm in front of the udder, based on field-based data from previous studies. Participants were asked to access the udder without touching the strings, which represented cow's hind legs. The strings were removed when simulating milking in a herringbone parlor, in which the participants accessed the udder from the side of the cow.

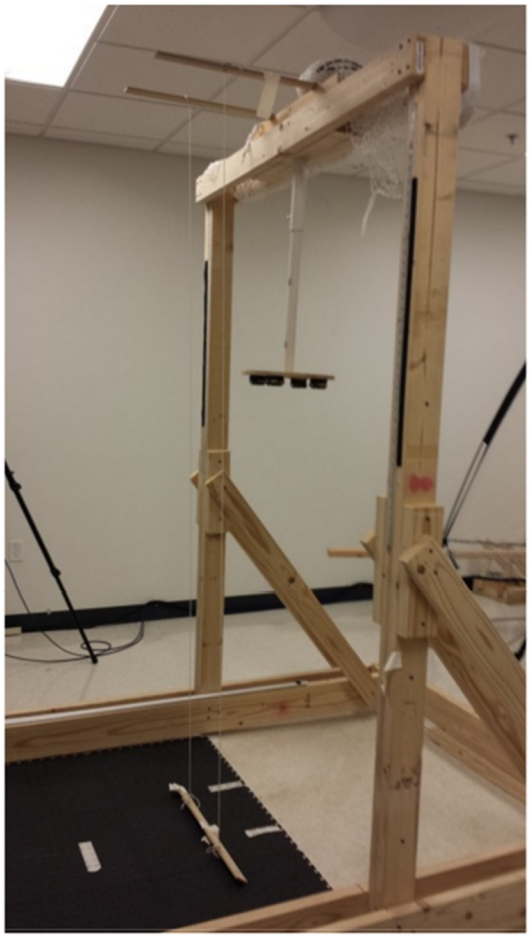

Fig. 1. Custom made Udder.

2.3. Procedures

After informed consent, participants proceeded to practice the milking unit attachment task (Fig. 2). The attachment task began with the participant standing in front of the udder holding the milking unit with both hands. On the investigator's cue, the participant moved the milking unit towards the udder, and attached the back two arms of the cluster to the back two teats followed by the front two arms to the front two teats. This is a common technique used by male workers, since their hands are larger compared to females, which allows them to hold all four teat-cups at once. Although hand-dimension was not measured, none of the participants had trouble holding the cluster. Once the milking unit was attached to the udder, the participant brought his arms back to his side. The participants practiced this task with the udder at their shoulder height for approximately 4–5 min until they were comfortable with the task and were able to repeat the task fluidly and consistently without hesitation or pausing. The investigator explained and demonstrated the tasks before the participants practiced, and provided feedback and correction during practice.