



Analysis of physical demands during bulk bag closing and sealing



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ABSTRACT

Several tools are sold and recommended for closing and sealing flexible intermediate bulk containers (bulk bags) which are used to transport product that has been mined and processed. However, there is limited information on the risks, physical demands, or the benefits of using one tool over another. The purpose of this study was to evaluate the physical demands involved with two closing methods and several sealing tools in order to provide recommendations for selecting tools to reduce exposure to risk factors for work-related musculoskeletal disorders. In this study, twelve participants completed bag closing and sealing tasks using two different closing methods and eight sealing tools on two types of bulk bags. Physical demands and performance were evaluated using muscle activity, perceived exertion, subjective ratings of use, and time. Results indicate that using the “flowering” method to close bags required on average 32% less muscle activity, 30% less perceived exertion, 42% less time, and was preferred by participants compared to using the “snaking” method. For sealing, there was no single method significantly better across all measures; however, using a pneumatic cable tie gun consistently had the lowest muscle activity and perceived exertion ratings. The pneumatic cable tie gun did require approximately 33% more time to seal the bag compared to methods without a tool, but the amount of time to seal the bag was comparable to using other tools. Further, sealing a spout bulk bag required on average 13% less muscle activity, 18% less perceived exertion, 35% less time, and was preferred by participants compared to sealing a duffel bulk bag. The current results suggest that closing the spout bag using the flowering method and sealing the bag using the pneumatic cable tie gun that is installed with a tool balancer is ergonomically advantageous. Our findings can help organizations select methods and tools that pose the lowest physical demands when closing and sealing bulk bags.

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1. Introduction

The prevalence of work-related musculoskeletal disorders (WMSDs) of the upper extremity is increasing (Houvet and Obert, 2013). Injuries associated with the upper extremities and trunk accounted for over 50% of all nonfatal mining injuries in 2010 (Smith, 2013). Repetitive motion cases are among the top 10 leading causes of occupational injury, and direct costs associated with these injuries are estimated to be almost \$2 billion per year (Liberty Mutual Research Institute for Safety, 2014). Flexible intermediate bulk containers (hereafter referred to as bulk bags) are commonly used by mines to store and transport materials, and the processes of closing and sealing bulk bags rely heavily on the upper extremities. Overexertion was common (23%) among operators of bag filling stations and the injuries typically affected the upper extremity,

with finger (50%) and hand (10%) injuries being the most common (Mine Safety and Health Administration, 2004–2008). Further, these tasks can require awkward postures and repetitive motions, which can contribute to WMSDs (Gallagher and Heberger, 2013; Houvet and Obert, 2013). Despite the associated risk factors, methods used to close and seal bulk bags have not been evaluated from an ergonomics standpoint.

Bulk bags are closed by gathering the bag material together and sealed by securing the material using either a string, plastic cable/zip ties, or metal wire ties (heavy duty coated metal twist ties with loops at the end to aid coiling). Often, bags are fabricated with a built-in string that can be used to seal the bags, but many tools are sold and recommended for sealing bags when cable/zip and wire ties are used. Strings are generally tied by hand (e.g., in a knot or bow), cable ties can be secured either by hand or with several types of cable tie guns (e.g., trigger gun or pneumatic gun), and wire ties are twisted closed with the use of a mechanical device.

Though there has been limited research on the types of tools

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used to seal bags, risk factors such as awkward postures, forceful exertions, and repetition have been shown to be associated with the occurrence of WMSDs (Armstrong et al., 1993; Gallagher and Heberger, 2013). A series of two studies evaluated methods of closing wire ties (Li, 2002, 2003) and compared the traditional use of pliers to twist wires to various alternative methods, including a non-powered wire tying hook and a novel wire tying hand tool, as well as several attachments for a powered screwdriver. These studies found reduced forearm muscle activity and deviated postures and increased subjective ratings with the alternative methods, which required less repetitive motions and awkward postures of the hand and wrist. Another study compared the use of plastic cable ties and wire ties during two different construction tasks (Gangakhedkar et al., 2011). Finding indicated reduced muscle activity and reduced time when using cable ties versus wire ties, likely because of the requirement to twist wire ties compared to cable ties that do not need to be twisted closed. To the authors' knowledge, no other studies have specifically evaluated tools available to seal bulk bags.

The purpose of this study was to evaluate the physical demands associated with several observed methods of bulk bag closing and sealing in order to provide guidance on selecting methods to reduce exposure to risk factors for WMSDs. Performance and physical demands were quantified using task completion time, muscle activity, subjective exertion ratings, and subjective assessments of the closing and sealing methods. Bag closing and sealing were evaluated separately in two experiments, each of which was performed in a controlled laboratory setting.

2. Materials and methods

2.1. Participants

Twelve participants (8 male, 4 female) were recruited using convenience sampling and all completed the study. Mean (standard deviation) age, stature, and body mass were 41.9 (8.6) years, 180 (7) cm, and 81.8 (11.2) kg for males, and 31 (4.8) years, 170 (6) cm, and 61.8 (5.0) kg for females. Participants were all right-hand dominant, self-reported having no recent history of musculoskeletal injury, and completed an informed consent procedure approved by the NIOSH Institutional Review Board.

2.2. Experimental design and equipment

Two experiments were conducted independently to evaluate bag closing and sealing. Each experiment used a full-factorial repeated measures design.

2.2.1. Experiment 1: bag closing

The first experiment evaluated bag closing, and participants completed four conditions with two levels of bag type (duffle and spout; Fig. 1) and two levels of closing method (snaking and flowering; Fig. 2). The bags were made of woven polypropylene, mounted from the four corners, rested on the ground and stuffed with empty boxes to simulate being full of material, as they would commonly be at bagging operations (Fig. 1). Material in the bag did not interfere with the closing and sealing tasks studied. Spout and



Fig. 1. Type of bags used; drawing of duffel (left), lab setup of duffel and spout, and drawing of spout (right).



Fig. 2. Bag closing methods; snaking (left), flowering (right).

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