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Re-thinking floor mat design from an ergonomics perspective: Can a two-part mat system reduce biomechanical loads during normal mat handling tasks?

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ABSTRACT

Floor mats are commonplace in commercial buildings, particularly in entry ways. These mats are routinely handled by delivery personnel as the mats are picked up for cleaning and clean mats are deployed. A new two-part mat design, which eliminates the need to move the rubber base during mat change operations, was hypothesized to reduce the physical demands on delivery personnel. Electromyographic data from back and shoulder muscles and spinal kinematics were obtained as 12 volunteers simulated mat selection, mat deployment, and mat pick-up tasks. Other factors considered in this study included mat size, pick-up method, and mat textile orientation during deployment. Results indicated that the two-part design reduced muscle activation levels across all tasks. Biomechanical benefits were also found when the mats were picked-up using a kick-fold as opposed to hand-fold method and when mats were deployed with the textile component rolled towards the inside of the roll.

1. Introduction

Many commercial buildings use floor mats in entryways and corridors to reduce slip and fall risks and to maintain cleanliness. Delivery drivers routinely visit commercial sites to replace soiled mats with those that have been cleaned. This requires them to select mats from within a warehouse, pick up the soiled mats from within customer facilities, and deploy clean mats. According to the Bureau of Labor Statistics (BLS), in 2015 there were 10,470 overexertion injuries among light truck and delivery service drivers. Nearly 3400 of those injuries were related to lifting and lowering. In this same population, there were 5340 back and 2520 shoulder injuries in 2015.

Although highly variable, a typical delivery driver may exchange 80–100 mats per day, in addition to other supplies, such as shop towels and uniforms. Mats are handled multiple times in this delivery process. It begins with delivery preparation, wherein drivers lift clean, rolled mats off a storage cart in the company's distribution center and load them into a delivery truck. Upon arrival at a delivery site, drivers first remove soiled mats, by folding them to contain any dirt or debris on the carpet textile. These are then lifted from the floor and either placed in a cart or carried directly back to the delivery truck. Then, drivers deploy clean mats in the same locations as the mats they had previously removed. Fig. 1 shows a delivery driver performing these tasks. The soiled mats are returned to the cleaning and distribution center after drivers complete their deliveries, where they are cleaned and placed back into inventory. Delivery drivers are exposed to a variety of musculoskeletal risk exposures, such as lifting, lowering, and repetitive movements. However, we could not find any mention of this occupation or the specific work tasks they perform in the literature.

A novel, convertible flooring concept was developed that involved a two-part mat, in which a textile top can be separated for servicing from a stable base. This concept is believed to provide many potential benefits, including: efficiency (less cost to launder and transport); stability (eliminating repeated laundering of the base reduces handling, lays flatter, and becomes less of a slip/trip/fall hazard); ergonomics (less weight to handle, deploy, and launder); modularity (more-adaptable to end-customer specifications); and aesthetics (ability to make more-attractive mat).

This study focuses on the potential ergonomic benefits of this convertible flooring design. The two-part system requires only the handling

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Fig. 1. Work postures observed as a deliverydriver deploys a 0.9 m x 1.5 m mat (top row), deploys a 0.9 m x 3.0 m mat(bottom left), picks up a mat using the kick-fold method (bottom middle), andselects mats for delivery (bottom right).

and cleaning of the textile component and not its base. This might possibly reduce the biomechanical loads required to select mats at the distribution center, pick up soiled mats, and deploy clean mats. Additionally, the biomechanical loads on the back and shoulders are also anticipated to be affected by other task specific factors, such as the size of the mats, the textile orientation when rolled, and the specific method used to pick up the mats. Common mat sizes are 0.9 m × 1.5 m and 0.9 m × 3.0 m, with the longer mats being heavier and more difficult both to deploy and pick-up. With a kick-folding method, the delivery driver is in an upright posture until the mat is consolidated in a pile, at which point it is pick up with a short lifting motion. When using the hand-folding method, drivers are in a sustained flexed trunk posture as they move forward to gather up the mat in preparation for lifting it off the floor. The textile orientation, whether the textile is rolled on the inside and the rubber is on the outside or vice versa, affects how much of the mat needs to unroll during deployment before the mat contacts the floor. Thus, these task factors may interact with the mat design and alter the potential biomechanical benefit that may be achieved using the two-part mat system.

The primary objective of this study was to evaluate potential biomechanical benefits of handling this novel two-part mat design compared with conventional floor mats, as a function of key tasks performed with them by delivery drivers. As described above, the biomechanical loads experienced during mat pick-up are likely to be affected by the size of the mat and the method used to roll the mat (folding by hand versus kick-folding). Mat deployment is likely affected by mat size and how the mat is rolled (textile in versus textile out). Therefore, biomechanical loads are hypothesized to be reduced when: 1) The novel two-part floor mat design is selected, picked up, and deployed; 2) A kick-folding method is used versus a hand-folding method during mat pick-up; 3) The deployed mats has been rolled with the textile material facing inward (textile-in) versus when they are rolled with the textile surface facing outward (textile-out); and 4) Smaller mats versus larger mats are handled.

2. Method

2.1. Participants

Twelve subjects, seven males and five females, participated in the study. Their average age, height, and weight was 22 years (range 20–30 years), 175 cm (range 155–193 cm), and 73 kg (range 55–101 kg), respectively. None of the participants were involved in an occupation that required repeated manual material handling work. Exclusion criteria during subject selection included significant back, leg, or shoulder pain in the past year, back surgery, or limited clinical conditions.

2.2. Experimental design

In this within-subject experimental design, participants performed three mat-handling tasks: mat selection, mat pick-up, and mat deployment. The independent variables are depicted in Fig. 2. These were: mat design (conventional vs. two-part); pick-up method (kick-fold vs. fold); textile orientation during deployment (textile-in vs. textile-out); and mat size (small vs. large). Table 1 shows the relevant dimensions of the four mats used in this study. The textile components of the small and large two-part mats were about 25–33 percent lighter than their conventional mat counterparts, respectively. For the mat selection task, only the effect of mat design (conventional vs two-part system) was investigated using the large mat size. In the mat pick-up task, the effects of mat design, pick-up method, and mat size were investigated. In the mat deployment task, the effects of mat design, textile orientation, and mat size were investigated. Participants repeated each condition three times.

The dependent measures were comprised of surface electromyographic (EMG) responses and trunk kinematic measures. The EMG data were obtained from the left and right erector spinae (ERS-L, ERS-R) and anterior deltoid (DEL-L, DEL-R) muscles, at a frequency of 2000 Hz, using a wireless surface EMG system (Trigno by Delsys). Additional Trigno sensors, attached to each lower leg, were sampled for the accelerometer signal which were used to indicate the starting point in mat