Ergonomic Analysis of Three Tarping Systems for Flatbed Transport Trailers

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Introduction

Loads transported on flatbed trailers must often be covered with large tarps or other covering systems to protect them from the elements. Manual tarping requires drivers to lift the tarps, lay the tarps out, pull the tarps, attach straps, and climb on loads and trailers. Tarping and untarping loads on flatbed trailers creates concerns related to falls as well as the high physical demands on the body, especially the back and shoulders as the tarps are heavy and awkward to distribute and secure to cover loads. Musculoskeletal disorders (MSDs) are cause for concern when tarping loads and include shoulder and back injuries from pulling tarps, manual handling of tarps, and injuries from tarping, and are a significant occupational health and safety issue [1, 2].

There are various methods available to cover loads on flatbed trailers, including manual tarping, rack and tarp kits, sliders, roll-ups tarps, curtain side tarps and automatic tarping machines. Each of these methods has different strengths and limitations. The tarping system used typically depends on load configuration. The most common tarping method continues to be manual tarping because it is most versatile. Regardless of the type of tarping system used, loads must be secured with straps. The strapping task also has some inherent hazards but is not included in this study as it is required for all tarping methods.

As part of a larger researcher-workplace collaborative project on the prevention for MSDs in the transportation sector, an ergonomic change team at a flatbed trucking company identified tarping as a job that required further investigation to reduce risks. A study was conducted to compare manual tarping and untarping to two alternative tarping methods, rack and tarp kit and sliders tarping system. The demands of the three different tarping systems were evaluated through a study which consisted of ten truck drivers covering the load on the flatbed trailer using the three different tarping systems. Multiple measures were used to characterize the three tarping systems, including required forces measured with a digital force gauge, injury risk which was assessed by peak, average and cumulative loads and muscle activity of the wrist, lower back and upper trapezius, heart rate, exposure to fall hazards, and drivers' preference based on demand and injury risk reduction.

Description of Tarping Methods and Required Forces

Manual tarping

To manually tarp a load on a flatbed trailer the driver must first retrieve the tarp which is often stored at the front headboard of the trailer and secured with a strap. A winch bar is used to loosen the straps which are securing the folded tarps, and then the straps are thrown over the trailer and wound up. The weight of the tarp depends on the tarp fabric and size. The flatbed trailer with a full load can be covered with either two large tarps, which are 7.3 m x 10.7 m in dimension, each weighing approximately 60 kg, or three small tarps, which are 7.3 m x 7.3 m in dimension, each weighing about 44 kg.

The tarps must be put on top of the load. Where possible, instead of manually lifting the tarp, drivers use a forklift at the site to put it onto the top of the load. The driver must climb onto the trailer and onto the top of the load to untie and unfold the tarp. Then the tarp must be spread over the top of the load by tossing the folded sections of the tarp over the sides of the load and trailer and by pulling the tarp to straighten it (Figure 1a). The forces to pull the tarp and open it ranged from 98 – 196 N. When performing this task, the driver is bent over with their hands below their knees. Unfolding the tarp on top of the load is often performed by lifting the part of the tarp and tossing it to the side. These forces exceed the upper limit lateral force guideline of 97 N [3]. The forces to pull the tarp across the load to straighten it ranged from 205 – 343 N. These forces also occur when the driver is bent over with hands below knees and therefore exceed the maximum pull strength for 248 N (for females) at a

vertical height of 33 cm [3]. While unfolding and straightening the tarp, the driver must walk across the tarp on top of the load, which can be up to four meters high. After the tarps are spread out, the end of the tarps must be tucked around the front and rear of the load and then secured with bungees and ropes. Then the remaining sides of the tarps are folded under and secured with bungees and ropes attached to the rub rail. Folding and tucking in the edges of the tarp and securing the tarp is critical so that the wind does not catch the tarp and rip it while driving. Throughout the process of unfolding and securing the tarps, the driver has to repeatedly climb on and off the load and trailer.

When the driver delivers the loaded trailer to the destination, the load must be untarped. First all the ropes and bungees must be unsecured. Then the tarps are pulled off the load, which requires a pull force that ranged from 284 – 402 N, and occurs using two hands around elbow height (Figure 1b). This force exceeds the published strength capabilities for both males and females pulling at 81 cm high, 322 and 185 N respectively [3]. Once the tarps have been pulled off the load, they must be straightened out by pulling them on the ground which requires 324 N of force. This force exceeds the published strength capabilities for females pulling at 33 cm high, 248 N [3]. Folding the tarp is generally performed with one hand lifting up and pulling across the body. This requires 88 – 137 N of force which exceeds the force guideline of 59 N for one handed lift [4] and also the 67 N guideline of lateral push/pull [3]. The driver then folds the tarp, as if folding a large tent, and then rolls it up. Ropes and bungees are used to secure the tarp in a tightly folded bundle. The tarps must then be secured back on the trailer, which is often done by dragging the tarp to the trailer and then lifting it onto the trailer. Tarping or untarping a load takes 30 minutes or more.

Overall, many of the elements of manual tarping and untarping require forces that exceed published strength capabilities. Manually tarping results in high back loads that pose an increased risk of low back pain for many workers [5, 6, 7], severe awkward back postures, which is another risk factor for back disorders [8], high levels of back muscle activity, and high shoulder loads. It is important to note that the demands during manual tarping would be even greater if the larger, heavier tarps were used or during adverse weather conditions.

Figure 1 a: Manual Tarp

Figure 1 b: Manual Untarp

Tarping and untarping using a Rack-and-tarp kit

A rack and tarp kit, also known as a side kit, is a system of panels and arc-shaped hoops that create a frame for the tarp to go over. When a load is either picked up or delivered, the rack and tarp kit must first be untarped and then retarped. To untarp a rack and tarp kit, the driver must untie all the ropes and bungees on the outside of the trailer that secure the tarp. Then the driver has to lift out the rear panel and climb into the trailer to push the tarp over the hoops from one side of the trailer to the other. This takes approximately 100 N of force. After pushing the tarp to one side, the hoops are lifted out from the side that the tarp was untied from (Figure 2), and then the hoops are pushed over to the other side where the tarp is hanging. Next the side panels and poles are lifted out of the trailer and temporarily set along the ends of the trailer. Removing the panels during the untarp phase requires a force in the upward direction between the bars, which ranges from 49 – 98 N and is performed with two hands at approximately 150 cm. The upper range of this force exceeds the strength

capabilities of two handed pulling up at shoulder height (78.5 N) [3]. After the panels and poles are removed from the one side of the trailer, the load can be put on the trailer or taken off. The driver has to walk around and up and over any product on the trailer.

To retarp a rack and tarp kit, the driver inserts the poles and panels into the slots along the side edge of the trailer. Retarping the system requires the panels to be inserted between the bars, which requires a two handed push force ranging from 49 -98 N. These forces to push down are within the two handed push down strength capabilities at shoulder height (196 N) [3]. Then the hoops are inserted back into the tops of the poles, and the tarp is pulled back across the hoops. The tarp is pulled across at multiple sections, until the slack is removed. Pushing or pulling the tarp across the hoops takes 78 – 196 N of force with hands at a vertical height of 130 – 198 cm. This element is performed using either one hand, two hands, or with one hand pulling on the tarp and the other lower down pulling on the rope. These forces exceed the strength capabilities for standing overhead one handed pulling (132 N) and pushing (136 N) [9]. In addition, the upper range of these forces exceeds the two handed strength capabilities of 169 N at a vertical height of 188 cm [3]. Then the driver climbs down from the trailer, pulls the tarp tight, and ties the ropes along the rub rails. If the tarp is not fitted around the panels and corners correctly, the driver has to climb back onto the trailer to fix the tarp. Finally the bungees around the tarp are secured to the rub rails.

Overall, the rack and tarp kit method results in high back and shoulders loads and high back and shoulder muscle activity. These high loads are attributed to the high forces to pull overhead and severe awkward shoulder postures. The severe shoulder flexion is expected for this method because the vertical height working range for the rack and tarp system is from 122 to 198 cm. Severe shoulder flexion is associated with shoulder disorders and this risk increases the longer the duration of exposure [8].

Figure 2: Rack and Tarp Kit

Tarping and untarping using Sliders

A sliders tarping system consists of a tarp attached to a frame and rail system that is dedicated to that flatbed trailer. When a load is either picked up or delivered, the sliders system must be untarped and then retarped. This system is operated from the ground. To untarp the sliders system, a driver disconnects the buckles connecting the flaps at the back of the trailer, opens up the back flaps, and pulls apart the Velcro at the bottom of the back flap. Then the driver obtains a long handle crank from the slots under the trailer, connects it into the bottom of the back flap, and then uses it to roll up the back flap until it is over the top of the slider trailer. Once the back flap is rolled over the top, the handle end of the long crank is attached with the corner flap. A small handle crank is then used to disengage the rear inner braces. The driver then pushes the slider open towards the headboard. The main forces for the sliders method was pushing or pulling the tarp system open or closed and these forces ranged from 107 – 235 N. Typically one hand is used to push or pull the slider system at a vertical hand height of approximately 140 cm. The forces in the upper range exceed the strength capabilities for one-handed maximum horizontal pull force with dominant hand, 147 N for males and 98 N for females [4] as well as the one-handed horizontal female pull strength capabilities of 61 N [10]. If the slider tarp gets jammed in the rails,

due to a poorly maintained system or due to ice and snow, the driver may have to go back and forth to both sides of the trailer to push the slider from both sides of the trailer. Next a winch bar is obtained and used to unwind the ratchet locking mechanisms at each of the front corners. Then the front slats are disengaged and the slider is pushed towards the rear of the trailer. To retarp a slider tarping system, the untarping sequence is retraced (Figure 3). Overall this system prevents the driver from having to climb on the trailer and reduces tarping and untarping time to approximately 10 minutes (if no difficulties are encountered).

Although the slider method initially appeared easier, it also resulted in high peak back loads and peak muscle activity. This is mainly due to the asymmetrical high forces required to pull or push the slider. Participants were required to pull or push the unit with one hand and as a result this torque increased spinal compression and low back activity. This method, however, required less time and resulted in lower cumulative exposure.

Figure 3: Slider Tarp

Comparison of Tarping Methods

Strength Capabilities

All three tarping methods had job elements which exceed published strength capabilities and force guidelines. Some tarping tasks may limit the number of workers who are able to perform the job and may increase risk of injury. Overall, the forces during manual tarping and untarping were the highest and exceeded strength capabilities much more than rack and tarp and sliders. Feedback from the company indicated that they are trying to widen their pool of drivers but their current hiring is limited by the high strength demands of the tasks.

Risk of Musculoskeletal Disorder

Manual tarping and untarping results in the greatest back exposure based on the greater amount of time with high back loads, greater duration of time in severe back flexion, greater cumulative back loads, and higher back muscle activity. This greater amount of back flexion is expected for this method as the vertical working range for tarping a load on a flatbed trailer is from ground level to approximately 160 cm, depending on the load size and techniques used, whereas the other two methods do not typically require work below 100 cm. Overall, the manual tarping method has the greatest risk of back injury due to higher forces, the peak and cumulative loading, and the time in awkward back postures. In addition, there was also high loading on the upper extremity during manual tarping and untarping.

The rack and tarp kit method involved more overheard work as represented by the time in severe shoulder flexion for right and left shoulders. This greater shoulder flexion was consistent with the greater trapezius activation during this tarping method. Thus, the rack and tarp method results in greater risk of shoulder injury.

Even though the slider method had peak loads which were not significantly lower than the other tarping methods, this method required less time and resulted in lower cumulative exposure, including less time exerting

forces, less time in awkward shoulder and back postures, and lower cumulative back and shoulder loads. Thus, the sliders method results in the lowest risk of injury.

Workload (heart rate)

Based on the heart rate values, all three tarping methods are demanding jobs. The average heart rate of all three tarping methods was in the "high workload" category. In addition, the heart rates during the tarping methods ranged from 81.3% to 95.8% (average 93%) percent of the participants' age-predicted maximum heart rate. Based on the heart rate results, the sliders method is preferred because it resulted in a lower average heart rate, lower percentage of maximum predicted heart rate and less time in the high workload or greater.

Working at heights

Tarping a load using a standard tarp and rack and tarp kit requires drivers to climb on the trailer and load, whereas the sliders tarping method minimizes or eliminates the need to climb on the load and flatbed trailer. Working from the trailer or on top of the load, poses inherent safety risks as there is risk of falls from elevation which is increased due to slippery, uneven surfaces and trip hazards.

Injuries from falls from trailers and getting on and off the trailer is a prominent concern in the transportation sector [11, 12] as a standard flatbed trailer is 122 – 137 cm off the ground [13] and the load can be up to 4 meters high. A study that analyzed injury claims of the fall from trucks as recorded in the database of the Ontario Workplace Safety and Insurance Board (WSIB) for the year 1997 identified 352 claims which involved a fall that occurred from a truck, trailer or the cargo, and the costs associated with the 352 claims were over 5 million dollars [12]. Of these cases, 50 percent were falls from the back or side of the trailer. In Ontario, the industrial regulations, O. Reg. 851 s. 85 requires fall protection for any worker working at heights three meters or greater. In the United States, OSHA regulations require fall protection for workers over 1.83 meters. Flatbed truck drivers who tarp loads are frequently required to climb on the trailer and load. Drivers often climb on the load without adequate fall protection as the site or customer often does not have a fall arrest system provided for tarping or the different trailer and load geometry do not permit it [14]. Additionally, workers are very susceptible to environmental conditions while completing these tasks because weather, such as wind, rain, cold and snow, plays a huge role in increasing the difficulty of the job.

Getting onto a standard flatbed trailer is difficult, and it poses a hazard because the trailer has few, if any, handholds, inadequate steps, and slippery surfaces. Although the use of three-point contact during climbing is advocated in the transportation industry training, it is often not possible when climbing on flatbed trailers or loads due to lack of adequate handholds and steps. Getting onto the flatbed trailer is often done by climbing on the Interstate Commerce Commission (ICC) bar, which is not an adequate step as it was designed to prevent vehicles from going under the trailer in a rear-end collision [13], or from around the headboard, or over a tire. Similarly, getting onto the load is also difficult and has inherent hazards since the load typically does not have any handholds or steps and may be uneven and slippery.

Whereas, getting off the load and trailer is often achieved by drivers jumping down because it is the quickest means to get down and there is no method incorporated to safely get off using three-point contact. In this tarping study, the participants jumped off the trailer to the ground 58% of the time and jumped off the load down to the trailer 75% of the time. This concern is also apparent for exiting truck cabs as drivers tend to jump from the first or second of step of the tractor [15, 16]. Jumping from elevated surfaces creates high impact forces which transfer high loads to the joints and also increases the potential of slips and falls immediately after landing. Jumping from the cab seat level has been reported to produce impact forces averaging 6 times the subject's body weight, and as high as 12 times [16]. These high forces create risk of injury to the bones and joints, and this risk of injury increases as people age, become deconditioned, and lose muscle mass, strength, flexibility, and bone density [15]. A study that examined injury reports from a voluntary incident reporting system spanning over two dozen U.S. trucking companies reported that 27% of the 3053 cases reported were due to slips and falls and 9% of those cases were from entering or exiting vehicle beds of trucks, trailers or semi-trailers [11].

Summary

Based on this study, manual tarping results in greater physical demands and safety risks than the other alternate systems and thus the two alternate tarping methods are to be preferred where feasible. Perhaps surprisingly, the peak and average loads did not differ much between methods; most benefits were seen in the time that forces were exerted. Rack and tarp kit method was preferred over manual tarp because it has lower loading compared to manual tarping except for duration time in severe shoulder flexion. The slider method was preferred overall as it minimizes or eliminates the need to climb on the load thus reducing fall hazard exposure, demands with climbing on the load and loading from jumping is eliminated. It also has lower physiological workload with lower average heart rate, lower percent of maximum heart rate, less time in high workload, takes less time to complete, less time exerting forces, less back and shoulder loads, less time in severe back flexion and bilateral shoulder flexion and is impacted less by windy and inclement weather. Thus, the slider method was found to minimize demands, heart rate and safety concerns and was preferred by drivers.

These findings were consistent with the drivers' feedback. All participants preferred the two alternative tarping methods over manual tarping. Three quarters of the drivers preferred sliders and the rest preferred rack and tarp kit. Some drivers stated that manual tarping should be eliminated. Others had feedback to improve the job by making lighter and more durable tarps. The drivers reported that the sliders were easier, less time consuming, less physically demanding and had less risk of injury.

The alternate methods offer a wide range of benefits including reduced physical demands, reduced exposure to fall hazards as well as improved productivity due to the shorter times, but with the disadvantage of being less versatile.

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