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Quantifying Grip Strength Requirements While Riding Freight Cars During Slack Action Events—A Preliminary Investigation

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Abstract: Riding freight cars is still a task performed by railroad conductors and brakemen during what are called "shove" movements. The way freight cars connect and move also produces "slack action," which are perturbations in the train's movement primarily in the longitudinal or for-aft direction. This study aims to demonstrate and quantify the grip force requirements necessary to ride freight cars during controlled, repeated shove train movements that generate "slack action." Using Tekscan™ hand force measurement equipment, real-time hand forces were measured while holding and riding a freight car, repeatedly, through slack action events. Four glove types and two weather conditions were studied. Peak measured grip force during slack action events were approximately double average grip force measures during freight car riding—across glove and weather conditions tested. The Ninja Ice™ glove performed best requiring approximately half the grip force to maintain grip than the standard leather glove. Wet glove conditions doubled grip force under steady state riding, while wet glove conditions, on average, more than tripled peak grip forces during slack action events. We found it is feasible to measure grip strength requirements under controlled freight car slack action movements. Measured grip strength requirements may provide insight on the biomechanical demands of riding freight cars during slack action events.

Keywords: Grip Strength, Slack Action, Railroad

1. Introduction

Since the 1800s, railroad conductors and brakemen have ridden on freight car ladders during train movements as necessary. Today, the most common occurrence of holding and riding freight car ladders occurs when the conductor serves as the engineer's lookout while moving a cut of cars from one location to another, a practice known as "protecting the shove."

Freight cars are connected to each other by a coupler mechanism and drawbar, which is connected to the freight car's draft gear. The draft gear acts as a shock absorber by allowing the drawbar to slide in the fore-aft direction, effectively compressing or rebounding depending on the forces acting upon it. "Buff" forces cause the drawbar to be compressed while "Draft" forces cause the drawbar to be extended. Changes in the movement of the train that cause the draft gear to compress or extend, can create a sudden acceleration or deceleration of the freight car, known as "slack action." The peak accelerations tend to occur when the movement of the drawbar tops or bottoms out.

Slack action events have been reported to contribute to incidents involving the conductor losing his/her grip and falling from the freight car. This research endeavors to determine the grip strength required to maintain one's handhold on a freight car during typical slack action events. Moreover, this research aims to assess the effects of glove type and weather conditions (wet or dry).

2. Methods

In part one of this study (Fleming et al. 2019), we assess the accelerations associated with a limited number of "shove" train movements. At the same time, in this study, we assess the grip force needs to hold onto the freight car. A 10G triaxial accelerometer was used to quantify the typical range of accelerations that a freight car is subjected to during typical yard operations. Using Tekscan™ hand force measurement equipment, real-time hand forces were measured while holding and riding a freight car throughout the range of measured accelerations. Real-time grip force data was collected synchronously with acceleration data and one video camera view of the subject rider from above the riding position.

The independent variables tested where glove type (Ninja Ice™, Nitrile, Leather, and Leather with a vented back), and weather conditions (dry, wet—rain). The freight car type was fixed—what is called a hopper car. The hopper car was shoved and pulled along the same track, repeatedly, 77 times.

Figure 1 shows the Tekscan™ force sensors for the hand, glued to a thin cotton glove, which held the sensors in place relative to the digits of the hand. There are 69 sensors distributed over 18 circuits, as shown on the left side of Figure 1. The right side of Figure 1 shows the "circuit board" for the sensors. A protective thin cotton glove was placed over the force sensors to keep the sensors protected and from moving when inserted into the leather, nitrile, and Ninja Ice™ gloves.

Figure 1. Tekscan palm-side hand force sensors assembled to thin cotton glove on the left; the rest of the "circuit board" on the right

The gross grip force was measured by the Tekscan system for each hand. Grip force was calibrated before each shove train movement using a grip dynamometer. The Tekscan system and the tri-axial accelerometer measured data at 50 HZ.

The average grip force measured for each condition was recorded and assessed using a repeated measures analysis of variance model. The peak grip force, which occurred at the peak perturbation during the shove train movement was also recorded. One subject was used for the testing. The subject was a 56-year-old man weighing 225 pounds with a height of 74

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inches. The study focused on the forces exerted by the leading hand, since the method of riding was fixed, whereby the subject used the trailing arm and hand in a “chicken wing” posture to wrap around the ladder.

3. Results

Figure 2 shows an example plot of the grip force traces for the left and right hands as a function of time alongside photos, from video capture, showing the associated method of holding onto the freight car—the “chicken wing method.”

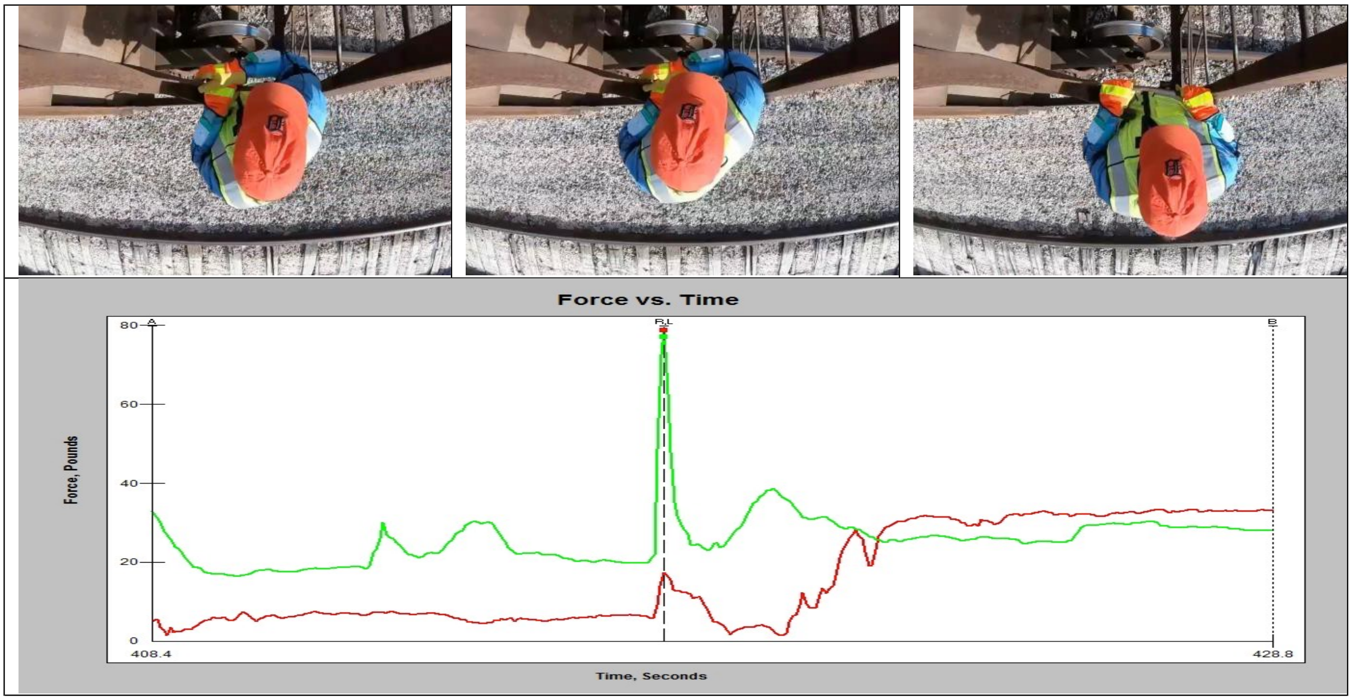

Figure 2. Overhead video – posture during first 10 seconds, at 10 seconds, and after 10 seconds (top left, middle, and right). The left (green) and right (red) hand forces are shown over a 20-second span (bottom).

A repeated measures, unbalanced, Analysis of Variance (ANOVA) was used to assess the main effects of glove type and weather and the interaction effect between glove type and weather for the leading hand grip force. The analysis found that glove type and weather had significant effects on peak and average leading hand grip forces ($p<0.05$). Figure 3 shows the glove type effect for peak hand forces. Figure 4 shows the weather effect for peak hand forces. The Nija Ice™ glove performed best registering the lowest peak and average forces among the glove types. Moreover, dry conditions had the lowest peak and average forces. However, the difference between peak and average forces was greatest under wet conditions, 50.9 v 24.7 pounds. Under dry conditions, the difference between peak and average forces was 16.3 v 12.9 pounds. The interaction between glove type (Nija Ice™ and leather being the only gloves tested under wet and dry conditions) and weather conditions was not significantly different. The vented leather gloves and nitrile gloves were only tested in dry conditions, hence the possible explanation of the difference between the two types of leather gloves.

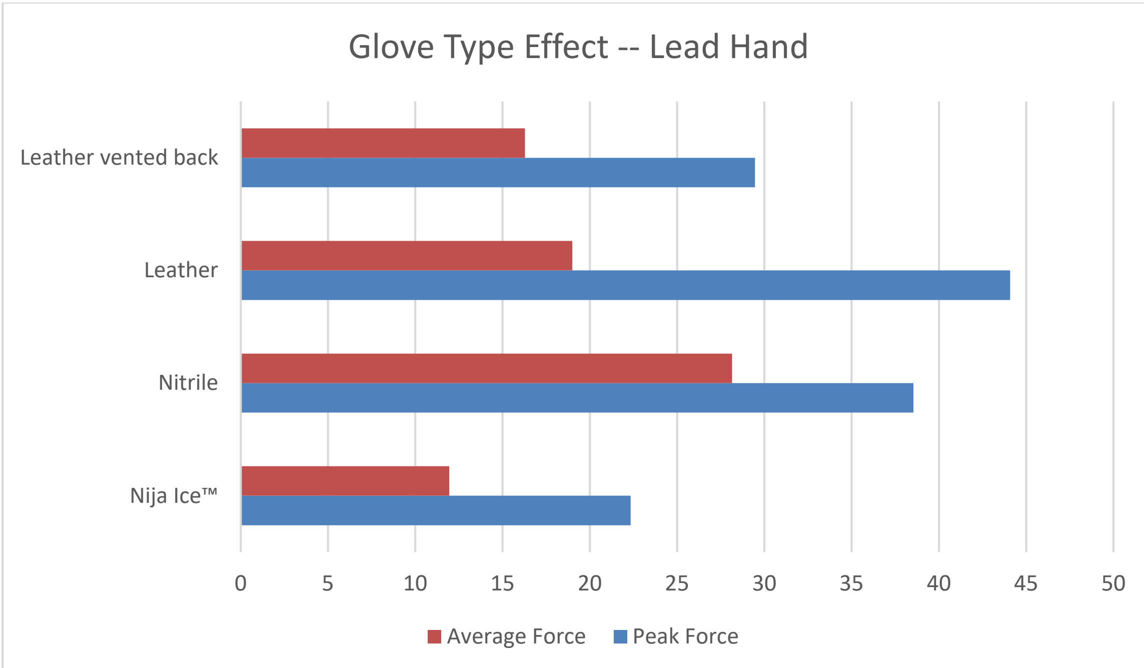

Figure 3. Glove type effect—peak hand and average hand forces

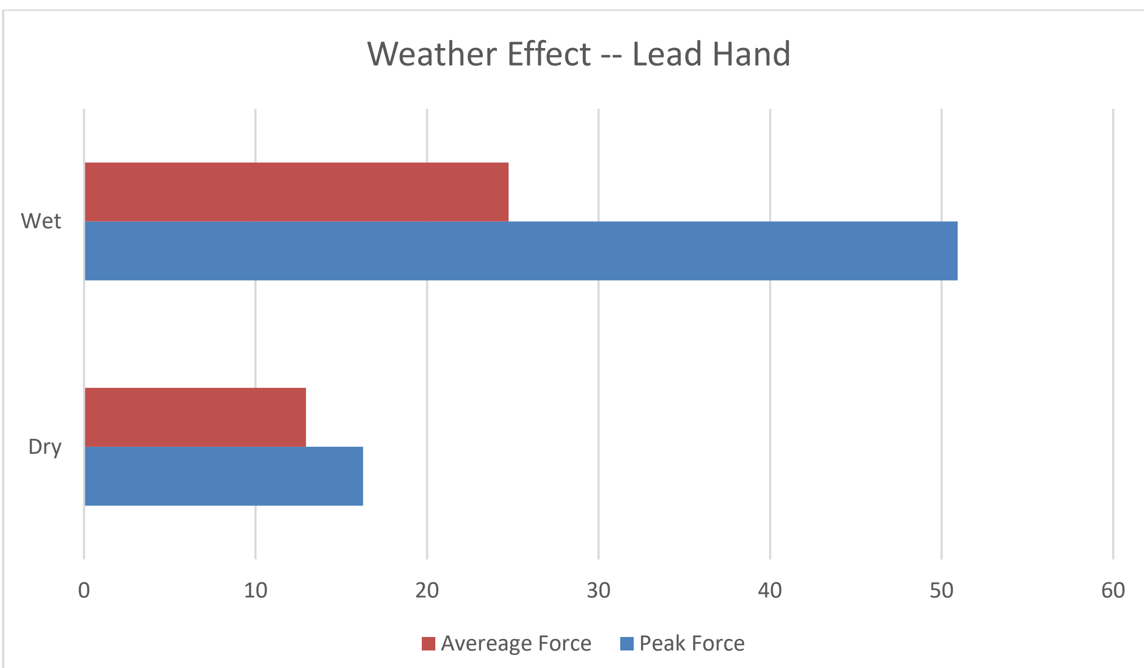

Figure 4. Weather effect—peak and average hand forces

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4. Discussion

Glove type and weather conditions both affected grip force performance for average and peak grip forces. The Ninja Ice™ glove performed best, requiring the least grip force (peak and average) among the gloves tested, including under wet conditions. And weather conditions significantly affected grip force performance for average and peak grip forces. Dry conditions required significantly lower grip forces (peak and average) as compared to wet conditions. Peak grip force needs, under wet conditions, where 3 times greater than average grip force needs, showing that the effect of slack action is greatest upon grip force needs when weather conditions are wet.

This preliminary investigation demonstrates that grip force, both peak and average, can be measured during freight car riding tasks. The data presented here is the first known grip force data collected for this task. Previous efforts have relied on the use of a force gauge to estimate grip forces—under very narrow conditions (Page et al. 2016). Moreover, the findings from this controlled study suggest testing under real-world conditions may prove fruitful in assessing the effects of gloves and helping to determine what glove characteristics are best in reducing grip strength needs during riding and slack action events.

The data collected and reported here may assist with biomechanical modeling of slack action events along with general riding conditions. Such analysis, in conjunction with real world temporal data, may allow for the assessment of muscle fatigue and determine the clinical grip strength needed to perform the task studied here.

5. References

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