

The Effect of Variable Lower Extremity Immobilization Devices on Brake Response Driving Outcomes



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Statement of Purpose and Literature Review

Immobilization devices such as surgical shoes and CAM walkers are commonly prescribed by foot and ankle surgeons for a variety of lower extremity pathologies and during the post-operative period, but have the potential to affect a patient's ability to maintain a safe level of control over the accelerator and brake pedals while operating an automobile.

Tremblay et al. found a significant delay in healthy volunteers' brake response times when driving in walking casts and Aircast walkers, but were reluctant to draw any definitive conclusions about this delay's potentially deleterious effect on driving safety [1]. Other investigators have published meaningful data for healthy and post-operative subjects comparing other driving outcomes measures including reaction times, applied pedal forces, and thinking times [2, 3, 4]. However, we are unaware of any investigation of driving outcomes in a surgical shoe nor any investigation studying a measure of inaccurate brake responses when the accelerator and brake pedals are depressed simultaneously. This is despite the fact that "pedal misapplication" has been identified as a major contributing factor for many automobile accidents [5].

The objective of this investigation was to assess three driving outcomes (mean emergency brake response time, frequency of abnormally delayed braking responses, and frequency of inaccurate brake responses) in a group of healthy participants under three variable footwear conditions (regular shoe gear, surgical shoe, and CAM walker).

Methodology

Following approval by our Institutional Review Board (Temple University Hospital Protocol# 23148), the emergency braking outcomes of twenty-five healthy volunteers were assessed with a computerized driving simulator (Stationary Simple Reaction Timer, Vericom Computers, Inc., Rogers, MN; Figure 1) under three variable test conditions: shoe (defined as control) vs. surgical shoe (Figure 2) vs. CAM walker (Figure 3). The simulator consists of a laptop computer, steering wheel, accelerator, and brake pedal.

Participants were able to adjust their seat position to ensure proper alignment and comfort, instructed on the use of the system, given a demonstration, and had an opportunity to practice multiple trial runs prior to initiation of the experiment. Participants were first asked to depress the accelerator pedal to achieve constant speed as a driving scene was displayed on the monitor. Then, at random intervals within a 10-second period, the software flashed a series of red lights on the screen which alerted the participants to release the accelerator and depress the brake pedal as fast as possible. The primary outcome measure of this investigation was considered the mean brake response time, defined as the time between red light activation and initiation of the brake pedal. Participants performed ten trial runs in each of the three footwear models, with elimination of the fastest and slowest time prior to data analysis.

Consistent with various clinical literature and governmental standards, we defined a normal brake response time cut-off as < 0.70 seconds [6-8]. Observed brake response times at or above this value were recorded as "abnormally delayed." We also defined an "inaccurate" response as inadvertent simultaneous depression of both the accelerator and brake pedal. To our knowledge, this represents a unique outcome measure in the driving safety literature.

Descriptive statistics were calculated and included the mean, standard deviation, range, and frequency. For our primary outcome measure of mean brake response time, we utilized a paired *t* test to compare control and experimental group values. For our secondary outcome measures of frequency of abnormally slow brake response and frequency of inaccurate brake responses, we used the Fischer's exact test.

Results

Descriptive Statistics:

Control Group (Participant in their regular shoe gear; $n = 200$ trials):

The mean brake response time of participants in their regular shoe gear was 0.575 ± 0.063 seconds ranging from 0.45 to 0.74 seconds. Five (2.5%) of 200 trials were defined as "abnormally delayed," while 4 (2.0%) of 200 trials were defined as "inaccurate."

Experimental Group #1 (Participant in a surgical shoe; $n = 200$ trials):

The mean brake response time of participants in the surgical shoe was 0.611 ± 0.099 seconds ranging from 0.45 to 1.13 seconds. Thirty-seven (18.5%) of 200 trials were defined as "abnormally delayed," while 8 (4.0%) of 200 trials were defined as "inaccurate."

Experimental Group #2 (Participant in a CAM walker; $n = 200$ trials):

The mean brake response time of participants in the CAM walker was 0.736 ± 0.129 seconds ranging from 0.46 to 1.14 seconds. One hundred eleven (55.5%) of 200 trials were defined as "abnormally delayed," while 36 (18.0%) of 200 trials were defined as "inaccurate."

Comparative Statistics:

Mean Brake Response Time:

Both the surgical shoe (0.611 vs. 0.575 seconds; $p < 0.001$) and the CAM walker (0.736 vs. 0.575 seconds; $p < 0.001$) demonstrated statistically slower mean brake response times in comparison to the control shoe gear.

Frequency of Abnormally Delayed Brake Responses:

Both the surgical shoe (18.5% vs. 2.5%; $p < 0.001$) and the CAM walker (55.5% vs. 2.5%; $p < 0.001$) demonstrated statistically more frequent abnormally delayed brake responses in comparison to the control shoe gear.

Frequency of Inaccurate Brake Responses:

The CAM walker (18.0% vs. 2.0%; $p < 0.001$) demonstrated statistically more frequent inaccurate brake responses in comparison to the control shoe gear, while the surgical shoe (4.0% vs. 2.0%; $p = 0.3808$) did not demonstrate a difference.

Table 1. Comparative Statistics

	Mean Brake Response Time	Frequency of Abnormally Slow Brake Responses	Frequency of Inaccurate Brake Responses
Regular Shoe Vs. Surgical Shoe	0.575 vs. 0.611 seconds, $p < 0.001^*$	5 (2.50%) vs. 37 (18.50%), $p < 0.001^*$	4 (2.0%) vs. 8 (4.0%), $p = 0.3808$
Regular Shoe Vs. CAM Walker	0.575 vs. 0.736 seconds, $p < 0.001^*$	5 (2.50%) vs. 111 (55.50%), $p < 0.001^*$	4 (2.0%) vs. 36 (18.0%), $p < 0.001^*$
Surgical Shoe Vs. CAM Walker	0.611 vs. 0.736 seconds, $p < 0.001^*$	37 (18.50%) vs. 111 (55.50%), $p < 0.001^*$	8 (4.0%) vs. 36 (18.0%), $p < 0.001^*$



Figure 1: Investigation Outcome Measures

The primary outcome measure of this investigation was mean brake response time as assessed with a computerized driving simulator. Secondary outcome measures included frequency of "abnormally delayed" brake responses (defined as ≥ 0.70 seconds) and frequency of "inaccurate" brake responses (defined as incidental simultaneous depression of the both the accelerator and brake pedals; this represents a unique outcome measure within the driving safety literature).



Figure 2 and 3: Investigation Variables

Participants were tested under three variable testing conditions. The control condition was defined as the participant wearing their regular shoe gear. The first experimental variable was the participant wearing an appropriately sized surgical shoe, while the second experimental variable was the participant wearing an appropriately sized CAM walker. Ten emergency brake responses were recorded for each test condition, with elimination of the fastest and slowest trial prior to data analysis.

Discussion

The results of this investigation provide foot and ankle surgeons with a better understanding on how to appropriately advise their patients who have been prescribed a lower extremity immobilization device on whether or not they can safely operate an automobile.

Compared to their regular shoe gear, the participants demonstrated significantly slower mean brake response times and more frequent "abnormally slow" brake responses while wearing the surgical shoe and the CAM walker. In fact, the frequency of the CAM walker trials that were considered to be "abnormally delayed" outnumbered the amount of safe response trials at 111 to 89. These represent two common forms of immobilization device prescribed by foot and ankle surgeons both in the post-operative recovery process and in the treatment of other acute and chronic foot and ankle pathologies.

We have also introduced a new outcome measure of "inaccurate" brake responses defined as inadvertent simultaneous depression of both the accelerator and brake pedals. This outcome may be particularly applicable as it speaks to a common cause of automobile accidents [5]. **We found that these "inaccurate" responses occurred significantly more frequently while in the CAM walker compared to regular shoe gear and the surgical shoe.**

Although this investigation only included healthy participants without acute or chronic foot and ankle pathology, these results may be additionally relevant to this population as several investigations have demonstrated that any limb pain is associated with negative effects of driving parameters [6, 7, 9, 10].

It is our hope that this data is utilized by foot and ankle surgeons in the education and consent of their patients with respect to the post-operative recovery process following surgical intervention, and is used in the development of future studies examining the effect of podiatric pathologies and intervention on automobile driving function.

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We would like to acknowledge our faculty advisor (Dr. Andrew J. Meyr, DPM FACFAS) and Laura E. Sansosti, DPM (Temple University Hospital Podiatric Surgical Resident) for their advisory role with this project and presentation.