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Effects of Right Lower Limb Orthopedic Immobilization on Braking Function: An On-The-Road Experimental Study With Healthy Volunteers

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ABSTRACT

Little is known about how immobilization of the right lower limb might affect driving. The purpose of the present study was to evaluate the effect of 2 types of immobilization on the emergency braking time of healthy subjects during actual driving conditions. The emergency braking times of 14 healthy volunteers were assessed in a closed circuit under 3 conditions: wearing running shoes, wearing an Aircast Walker®, or wearing a walking cast on their right lower limb. An instrumented car was used to measure the emergency braking times during braking tests with and without a distractor. The foot movement times were significantly increased with both immobilization devices compared with the running shoe ($p < .01$). The median total braking time with the running shoe during emergency braking without a distractor was 0.452 (interquartile range, 25th to 75th [IQR], 0.413 to 0.472) second. The results obtained with the Aircast Walker® or the walking cast were significantly longer ($p < .01$), at 0.480 (IQR, 0.431 to 0.537) second and 0.512 (IQR, 0.451 to 0.535) second, respectively. When a distractor was added, the total braking time with the running shoe, Aircast Walker®, and walking cast was 0.489 (IQR, 0.429 to 0.575), 0.516 (IQR, 0.459 to 0.586), and 0.510 (IQR, 0.469 to 0.570) second, respectively, with no statistically significant differences among these 3 conditions. Wearing an immobilization device on the right lower limb minimally lengthens the emergency braking time in healthy drivers under actual driving conditions. Clinicians must nonetheless exercise caution when advising a driver wearing an orthopedic immobilization, because driving a motor vehicle is a complex psychomotor task that goes well beyond the emergency braking time.

Patients frequently ask their physicians whether they can drive a car while wearing an orthopedic immobilization device. Studies to date on this subject have mainly focused on retrospective surveys. Analysis of surveys provided to orthopedic patients have shown that 15% to 50% of patients admitted driving while wearing a cast (1,2). An analysis of data from physicians, insurance companies, and police department surveys added more complexity to the subject (1–5). Most insurance companies relegate the decision of whether a patient can safely drive or not with an immobilization device to the physician. In making this determination, physicians must therefore rely on their own clinical judgment, because practically no applicable guidelines are available (6). For example, the UK's Driver and Vehicle Licensing Agency has issued no recommendation related to driving with a limb temporarily immobilized, and the online resource states "If you have broken a limb you do not need to tell the DVLA [UK's Driver and Vehicle Licensing Agency] about it" (7). The situation is similar in the

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United States, with the driver's handbooks for California, Florida, and Texas making no reference to this situation (8–10).

Moreover, a series of studies have focused on resuming driving after orthopedic surgery involving the lower limb, such as hip (11–13) and knee (14–19) replacement, anterior cruciate ligament reconstruction (20,21), knee arthroscopy (22), operative fracture fixation (23,24), ankle arthrodesis (25), and first metatarsal osteotomy (26). In all these studies, the effect of surgery was assessed by determining the emergency braking reaction time using a driving simulator during the postoperative period. However, only 3 studies have attempted to quantify the effect of wearing an orthopedic immobilization device on a lower limb. Our group was the first to assess the braking force and emergency braking time of 48 healthy subjects with and without immobilization of the right lower limb (27). In that study, we reported an increase in the braking reaction time of not more than 41 ms with subjects wearing an orthopedic immobilization device (27). This increase was deemed small and was not found to significantly alter the subjects' driving ability. Our findings differed from the findings of Orr et al (28) and Waton et al (29), who reported a slightly longer increase in the emergency braking time of healthy subjects wearing a right lower limb immobilization device, and these investigators advised against driving with any type of plaster cast or brace on the right lower extremity. Although valuable, these studies' conclusions remain limited, because the evaluations were performed uniquely on a driving simulator, not during actual driving conditions.

To our knowledge, no experimental study has attempted to determine the effects that wearing an orthopedic immobilization device on the right lower limb could have on driving performance under real conditions. Thus, making recommendations is a genuine issue. To address this, and to validate the ideas presented in our study with the driving simulator, we report a study that assessed the effect of 2 types of immobilization on the emergency braking time of healthy subjects driving under actual road conditions.

Materials and Methods

To be eligible for the present study, the participants, adults aged 25 to 60 years, must have undergone an assessment on the simulator in our previous study (27) and agreed to being contacted for a subsequent study. The additional inclusion criteria for the participants were possession of a valid driver's license; ≥5 years of driving experience; and the use of only the right foot for accelerating and braking. The exclusion criteria were a history of drug or alcohol abuse; the use of psychotropic medication; sleep disorders; psychiatric illness; central nervous system disorders; vision loss or another uncorrected vision disorder; cardiovascular disease; cerebrovascular disease; peripheral vascular disease; metabolic disorders; kidney disease; musculoskeletal impairment; and motion sickness. All participants provided informed written consent before taking part in the study. The human research ethics committee of our institution approved the research protocol (project no. 08-060, approved November 24, 2008), and the procedures followed were in accordance with the Declaration of Helsinki. In addition, the study was registered in a public trials registry (ClinicalTrials.gov, Bethesda, MD; US National Library of Medicine; available at: http://clinicaltrials.gov/show/NCT01171287; identifier, NCT01171287).

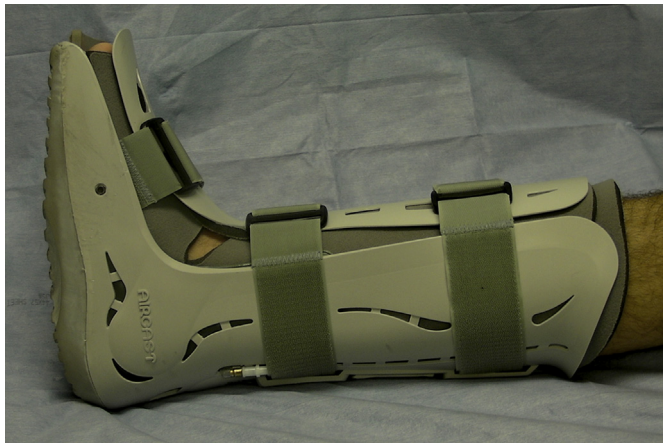

Fig. 2. Aircast Walker®.

The data for the present study were collected in October 2008. After obtaining municipal authorization, a closed-circuit track was established on a 2-lane straight section of road approximately 500 m in length (Fig. 1). The vehicle used was a 4-door Nissan Sentra™ XE 2001 (Nissan Canada, Mississauga, Ontario, Canada) with automatic transmission. This vehicle, leased from a driving school, was equipped with an emergency brake on the passenger's side. A certified driving instructor rode on the passenger's side to stop the car in the case of an emergency. Load cells (LAU220; Futek Advanced Sensor Technology, Irvine, CA) were added to the vehicle's accelerator and brake pedals to record the pedal movement and applied force at all times. The load cells were connected to signal amplifiers (SGCM-401; Intertechnology, Don Mills, Ontario, Canada) and then to an acquisition card (NI USB-6009; National Instruments, Austin, TX) for frequency sampling at 2000 Hz. The signal light, comprised of 31 red light-emitting diodes, was also connected to the acquisition card. The light was installed on the dashboard just above the steering wheel so the drivers would not have to shift their eyes from the road to see it. The acquisition card was connected to an HP® Compaq NC6220 laptop computer (Hewlett-Packard, Palo Alto, CA). In addition to the acquisition card, the laptop was equipped with a global positioning system device (WAN-213 GPS receiver; Holux Technology, Hsinchu, Taiwan) to record the vehicle speed at a sampling frequency of 1 Hz.

The present study used a pre–post experimental device in which each participant was his own control. Participant emergency braking time was assessed under 3 randomized conditions: while wearing their normal running shoes; with the right lower limb immobilized in a foam pneumatic walker (Aircast Walker®; DJO, Vista, CA); and with the right lower limb immobilized in a walking cast. The Aircast Walker® (Fig. 2) was adjusted by inflating the air cells to achieve satisfactory ankle immobilization. The walking cast (Fig. 3) was made of a synthetic flexible material (Delta-Cast Conformable; BSN Medical, Leuven, Belgium). A nonslip sole (Cast Boot; Darco, Huntington, WV) was adjusted to the foot length and then applied under the cast. For both conditions, once the ankle was immobilized, the participant was required to walk a distance of 50 m to ensure comfort and become familiar with wearing the immobilization device.

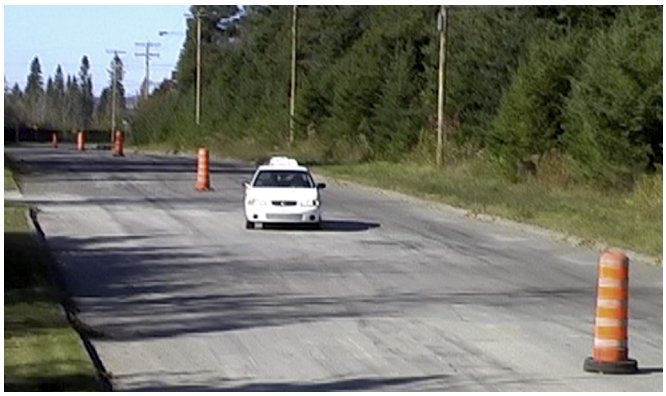

Fig. 1. Closed-circuit track.

Fig. 3. Walking cast. A nonskid sole (not shown) was also applied to the walking cast.