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Original Research

# The Effects of Hip and Spine Orthoses on Braking Parameters: A Simulated Study With Healthy Subjects

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**Abstract**

**Background:** Although a person's fitness to drive has gained more attention over the past few years, investigations have focused mainly on postsurgical (eg, hip arthroplasty) driving performance. Few data are available on how orthoses affect the ability to perform an emergency stop.
**Objective:** To determine whether common lumbar and hip orthoses impair driving performance by increasing brake response time and weakening brake force (BF).
**Design:** Crossover repeated measures design.
**Setting:** University hospital.
**Participants:** A crossover, repeated-measures design was used to test 30 healthy volunteers with and without each of the orthoses in random order.
**Methods:** A custom-made simulator was created from a car cabin fitted with measurement equipment to record braking parameters under realistic spatial constraints.
**Main Outcome Measurements:** Reaction time (RT), foot transfer time (FTT) (these 2 together: brake response time), and maximum BF.
**Results:** Although spine orthoses lead to statistically significant increases in RT (Vertebradyn-Strong, $P = .002$; Horizon 637 LSO, $P = .32$; and SofTec Dorso, $P = .013$), this effect was not observed in hip orthoses, where instead FTT was prolonged (DynaCox and Hohmann-like orthosis, $P < .001$). BF was not significantly altered in any of the orthoses.
**Conclusions:** This study demonstrates that hip and spine orthoses lead to impaired driving performance. Depending on the type of immobilization, this effect mostly increases RT or FTT, lengthening total stopping distances by up to half a meter at 100 km/h. However, in the absence of an underlying pathological condition in individuals with orthoses, their braking performance should be sufficient to continue driving.

## Introduction

The ability to drive a motor vehicle is an essential component of individual independence that characterizes our modern culture and is a key element for community integration [1]. In many countries, ensuring fitness to drive ultimately is considered the responsibility of the driver [2-4]. Nonetheless, patients with conditions that partly immobilize the right lower limb or that cause spinal problems, leading to reduced individual mobility, often seek advice from their treating orthopedic specialist as to whether they are able to drive. When giving recommendations to patients, however, specialists should exercise caution regarding the precise wording because potential liabilities may arise from such advice [4,5]. To date, scientific evidence is scarce regarding patients' fitness to drive, especially concerning the use of orthoses. Studies are therefore needed to provide solid scientific data upon which to base such recommendations.

Safe participation in road traffic requires various abilities, and different approaches exist to assess fitness to drive. One key element is the ability to halt the car within a short total stopping distance; this comprises reaction distance (the distance covered by the car until the beginning of deceleration) and braking distance (covered during deceleration) (see Table 1).

Whereas drivers have little impact on braking distance other than the force applied to the brake pedal


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**Table 1**
Components of total brake response time*

| Reaction Time | Movement Time | Device Response Time |
|---|---|---|
| Sensation<br>Perception/recognition<br>Situational awareness<br>Response selection<br>Programming | Lift the foot off the accelerator pedal and transfer it to the brake (*foot transfer time*)<br>Depress the pedal (*brake pedal traveling time*) | Time it takes the device to engage once activated |

Total stopping distance = reaction distance + braking distance. Reaction distance = total brake response time × speed of the vehicle.
* Data from Green [6]; reprinted from Hofmann et al [15].

(brake force [BF]), reaction distance is dependent directly on the individual performance of the driver. The time it takes the driver from receipt of the brake signal until complete depression of the brake pedal is called total brake response time (TBRT), which can be further subdivided into the following categories: reaction time (RT), movement time (MT) (consisting of foot transfer time [FTT] and brake pedal traveling time [BPTT]), and device response time [6,7]. (For further details regarding the components of each parameter, see Table 1.) TBRT without BPTT is called "brake response time" (BRT) and frequently has been used in the scientific literature to evaluate braking performance.

Although there is no generally accepted clear limit for TBRT, suggested values by different road authorities range from only 700 milliseconds [2,8] to 1500 milliseconds [9]. These recommendations need to be considered under the premises for which they apply: the experimental conditions of the simulator, its spatial constraints, the ergonomics of the equipment, the strength and urgency of the signal, driver age, level of fatigue, etc [4,10-14]. A key element is the factor of expectancy. When the driver is anticipating the signal, a much faster reaction (circa 700 milliseconds) is observed than when the driver is reacting to an unexpected event (circa 1500 milliseconds) [6,7]. For the specific, controlled experimental setup used in this study, we established a reference value for BRT in healthy subjects of 600 milliseconds [15].

Several studies have analyzed the effect of orthopedic surgery on braking performance [16], but only limited literature exists regarding the influence of immobilization of the lower limb on fitness to drive. The studies that have been published, however, have almost exclusively analyzed immobilization of the ankle and knee [5,17-19]. There is one study that investigated the effect of cervical spine immobilization [20] on normal driving, without, however, testing emergency situations. To our knowledge, no literature is available concerning the influence of hip or lumbar spine orthoses on braking performance.

In this study, the braking performance of young healthy volunteers wearing different hip and spine orthoses was recorded and compared with measurements of the same group without orthoses. We used an original car cabin to test driving ability under realistic spatial constraints. We recorded not only BRT with its components RT and FTT, but also the maximum BF on the brake pedal.

The aim of this study was to simply measure the influence of the orthoses themselves, without analyzing the effect of pathologic conditions that lead to patients wearing hip or spine orthoses. From the previous findings of ankle and knee immobilization [5,17-19], we expected orthoses that immobilize the hip or spine also to diminish braking performance. We hypothesized that although both types of orthoses would affect RT, hip orthoses also would increase FTT and decrease BF. Moreover, we thought it would be interesting to investigate not only the extent to which this effect is of statistical significance but also its clinical relevance.

## Methods

### *Participants*

Healthy volunteers, most of whom were students at the University of Tübingen, were asked to participate in the study. Inclusion criteria were a valid driver's license and age between 18 and 40 years; female and male participants were counterbalanced. Exclusion criteria were previous surgery of the ankle, knee, hip, or spine; known cardiovascular disease; a musculoskeletal or neurologic condition requiring medical treatment; a medical history of psychiatric disease or addiction; regular drug intake (with the exception of the contraceptive pill in women); and pregnancy.

Full departmental, institutional, and ethical committee approval by the University of Tübingen, Germany (chairperson Prof. D. Luft) was obtained before commencement of the study (project number: 527/2013BO1; date of final approval: November 27, 2013). Written informed consent was received from all subjects before participation in the study.

### *Tested Orthoses*

The hip orthoses used in this study were the soft hip belt Coxa-Hit (Sporlastic, Nürtingen, Germany), which