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Consequences of Car Driving on Foot and Ankle Mobility and Reflexes

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Abstract

Car driving could induce fatigue and an altered sensorimotor control of foot muscles. Also, the use of a cruise controller (CC) or an adaptive cruise controller (ACC) could delay the brake reaction time when an emergency braking response is needed. The literature brings very few information on fatigue of the leg muscles during prolonged car driving and no data was found on any lengthened brake reaction time in CC/ACC condition. We recently showed that 1 hour driving at constant speed (120 or 60 km/hour) induced fatigue of the tibialis anterior (TA) muscle. TA fatigue was associated with a reduced myotatic reflex, a situation which reduced the sensorimotor control of muscles maintaining the foot on the accelerator pedal. Driving in CC/ACC condition increased the amplitude of leg displacement during emergency braking and markedly lengthened the brake reaction time, increasing the braking distance. The brake reaction time increased with age in the CC/ACC condition. Thus, car driving modifies the sensorimotor control of foot muscles and the use of new tools to control the speed of a motor vehicle significantly lengthens the brake reaction time. This could result from an increased amplitude of leg motion and/or an age-related decrease in reflex control.

Keywords: Foot muscles; Car driving; Brake reaction time

Introduction

Car driving could be the source of foot and ankle problems. First, fatigue of the leg muscles participating to the driving task could occur during prolonged driving for occupational activities. The plantar flexor muscles (gastrocnemius and soleus muscles) play a key role to adjusting the force exerted by the foot on the accelerator pedal. In addition, the dorsiflexor muscles (tibialis anterior or TA, and tibialis posterior muscles) maintain the foot position on the accelerator pedal. Second, the braking reaction behaviour to an oncoming car collision could be affected when using a cruise controller (CC) or an adaptive cruise controller (ACC). In these two driving conditions, the right foot stays on the floor of the vehicle and is not in the close proximity of the braking pedal. When an emergency braking response is needed in a CC/ACC condition one could suppose that the amplitude of the leg displacement should increase and this could delay the brake reaction time.

Systematic Review

Very few data are found on the occurrence of leg muscle fatigue during prolonged car driving. Some studies have shown that prolonged (1hour) simulated driving on the trapezius, deltoid, and vertebral muscles [1-4] but not on the leg muscles. In a recent study [5], we measured before and after a 1 hour driving trials at 120 km/hour or 60 km/hour the maximal plantar flexion and foot inversion forces, and the electromyographic (EMG) activities of gastrocnemius medialis (GM) and tibialis anterior (TA) muscles. We only studied male subjects (mean age: 42+4 y) who were free of foot pain and had no antecedent of trauma or surgery of the feet and legs. Their driving experience was superior to ten years. The participants were not randomized.

The sensorimotor control of these leg muscles was studied through the recordings of the tonic vibratory response (TVR) and the Hoffman reflex (H reflex) which respectively explored the myotatic and overall sensorimotor reflexes, and also using the EMG power spectrum analysis, which allowed to approach the recruitment strategy of motor units during fatiguing tasks. The computation of the ratio between the high (H) to low (L) EMG energies (H/L ratio) gives an indication on the changes in the motor unit recruitment during sustained fatiguing contraction. It is well documented that preceding the peripheral muscle fatigue there are a reduced recruitment of high-frequency, highly fatigable motor units [6] to delay the occurrence of the falling force. Any TVR reduction in the leg muscles during driving could alter their sensorimotor control with the consequence of a lengthened brake reaction time. A homemade apparatus was built using auto parts including a driver's seat, a wheel, a steering column, brake and accelerator pedals. The subject was asked to maintain at 20N the force exerted on the accelerator pedal. This force value is measured when driving a Volkswagen Golf car at 120 km/hour. In subjects driving in control condition with the accelerator pedal, we reported that the H/L ratio decreased in TA after 30 min of driving whereas the same H/L changes inconstantly occurred in GM muscle. After the driving session had stopped, the maximal foot inversion force significantly decreased (-19%) while the plantar flexion force did not vary. Simultaneously, the TVR amplitude decreased in TA muscle but no H reflex changes were noted. These observations suggest that driving at constant elevated speed reduced the reflex control of the TA muscle. The neuromuscular changes were modest or absent in the GM muscle, explaining the absence of an altered braking response.

The brake reaction time involves several mechanisms, including the displacement of the leg to the brake pedal as well as the sensorimotor control of the leg's extensor muscles with the participation of both their central command and peripheral reflexes. The braking reaction behaviour to an oncoming car collision, including the measurement of brake reaction time (BRT) and muscle activation of the lower extremity muscles at the collision moment, has been well documented when using the accelerator pedal (Control condition) [7-12]. Some of these studies [9,11,12] clearly showed that the time to collision at brake application was significantly higher in females [12] and old subjects [9]. Also, Loeb et al. [11] showed strong differences between the experienced and novice drivers in the brake pressure applied. On the other hand, the literature brings very few data on the braking response to collision when using a cruise controller (CC) or an adaptive cruise controller (ACC). One study [13] has examined the capacity of the driver to brake pulses in ACC condition but no comparative data were reported in the absence of ACC. Some studies report that ACC results in an improved situation of awareness compared to manual driving, the ACC driver attending more to the roadway [14,15]. However, others [16] have shown that delayed driver reactions occurred in critical situations when driving with the CC or ACC. In a recent study [17], we measured the emergency braking response in Control and CC/ACC condition in the same individuals than in our previous study [5]. The analysis of the braking response consisted in measurements of the brake reaction time (BRT), the delay to produce the peak braking force (PBD), the total emergency braking response (BRT+PBD), and the peak braking force (PBF). These measurements were associated with recordings of the electromyograms of leg and thigh muscles. The Tonic Vibratory Response (TVR) and the Hoffman reflex (HR) were recorded in leg muscles. Compared to Control, the CC/ACC Condition did not modify PBF, TVR amplitude, and HR latency but markedly delayed BRT and PBD. In the CC/ACC condition, the sum of BRT and PBD values (total braking latency) was 164+34 ms. This corresponded to a substantial increase in the braking distance (5.5 m) compared to Control. The increased braking distance was reduced (2.7 m) but remained already significant when driving at 60 km/hour. We concluded that driving in the CC/ACC condition significantly delays the active emergency braking response to vehicle collision. The higher amplitude of leg motion and/or the age-related changes in motor control may be responsible for to the delayed braking response in CC/ACC condition.

Conclusion

As a summary, foot and ankle mobility in driving and emergency braking conditions has been well documented in literature and several factors influencing the braking efficiency were identified, such as gender, experience or age of drivers. It was more recently proposed that braking assistance systems such as CC or ACC should also be considered as having a significant effect on ankle mobility and muscle activation. Practitioners should pay attention to the occurrence of muscle fatigue during prolonged car driving and also to an increased braking distance in the CC/ACC condition.

References

1. Durkin JL, Harvey A, Hughson RL, Callaghan JP (2006) The effects of lumbar massage on muscle fatigue, muscle oxygenation, low back discomfort, and driver performance during prolonged driving. Ergonomics 49: 28-44.
2. Hostens I, Ramon H (2005). Assessment of muscle fatigue in low level monotonous task performance during car driving. J Electromyogr Kinesiol 15: 266-274.
3. Kolic, M, Taboun SM (2002) Combining psychophysical measures of discomfort and electromyography for the evaluation of a new automotive seating concept. Int J Occup Saf Ergon 8: 483-496.
4. Sheridan TB, Meyer JE, Roy SH, Decker KS, Yanagishima T, et al. (1991) Physiological and psychological evaluations of driver fatigue during long term driving. SAE International (Society of Automotive Engineers), International Congress & Exposition.
5. Jammes Y, Behr M, Weber JP, Berdah S (2016) Consequences of simulated car driving at constant high speed on the sensorimotor control of leg muscles and the braking response. Clin Physiol Funct Imaging. 36: 249-256.
6. Bigland-Ritchie B, Dawson NJ, Johansson R, Lippold OCJ (1986) Reflex origin for the slowing of motoneurone firing rates in the fatigue of human voluntary contractions. J Physiol 379: 451-459.
7. Gao Z, Li C, Hu H, Zhao H, Chen C, et al. (2015) Experimental study of young male driver's responses to vehicle collision using EMG of lower extremity. Biomed Mater Eng. 26: 563-573.
8. Behr M, Poumarat G, Serre T, Arnoux PJ, Thollon L, et al. (2010) Posture and muscular behaviour in emergency braking: An experimental approach. Accid Anal Prev 42: 797-801.
9. Bélanger A, Gagnon S, Stinchcombe A (2015) Crash avoidance in response to challenging driving events: the role of age, serialization, and driving simulator platform. Accid Anal Prev 82: 199-212.
10. Engström J, Aust ML, Viström M (2010) Effects of working memory load and repeated scenario exposure on emergency braking performance. Hum Factors 52: 551-559.
11. Loeb HS, Kandadai VK, McDonald CC, Winston K (2015) Emergency braking in adults ts versus novice teen drivers: response to simulated driving events. Transp Res Rec 2516: 8-14.
12. Montgomery J, Kusano KD, Gabler HC (2014) Age and gender differences in time to collision at braking from the 100-car naturalistic driving study. Traffic Inj Prev 15: 15-20.
13. Lee JD, McGehee DV, Brown TL, Nakamoto J (2007) Driver sensitivity to brake pulse duration and magnitude. Ergonomics 50: 828-836.
14. Stanton NA, Young MS (2005) Driver behaviour with adaptive cruise control. Ergonomics. 48: 1294-1313.
15. De Winter JCF, Happee R, Martens MH, Stanton NA (2014) Effects of adaptive cruise control and highly automated driving on workload and situation awareness: A review of the empirical evidence. Trans Res Part F: Traffic Psyc Behav 27: 196-217.
16. Vollrath M, Schleicher S, Gelau C (2011) The influence of cruise control and adaptive cruise control on driving behavior–A driving simulator study. Accid Anal Prev 43: 1134-1139.
17. Jammes Y, Behr M, Llari M, Bonicel S, Weber JP, et al. (2017) Emergency braking is affected by the use of cruise control. Traffic Inj Prev 24: 1-6.