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Feasibility of force platform based roadside drowsiness screening – A pilot study

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ABSTRACT

Previous research on driver drowsiness detection has focused on developing in-car systems that continuously monitor the driver while driving and warn him/her when drowsiness compromises safety. In occupational settings a simple test of postural control has showed sensitivity to work shift induced fatigue in drivers. Whether the test is feasible for surveillance purposes in roadside settings is unknown. The present research sought to evaluate the feasibility of using a force platform test of postural control as a breathalyzer-like drowsiness-test at the roadside.

Seventy-one commercial drivers stopped by at our measurement sites and volunteered to participate in the study. We tested postural control with a computerized force platform, on which the drivers stood eyes open while it sampled body center-of-pressure excursions at 33 Hz for 30 s and scored postural control as the area of the 95% confidence ellipse enclosing the excursions. The drivers also completed the Karolinska Sleepiness Scale (KSS) and we recorded each driver's wake up time, time on task, and time of testing.

Five of the seventy-one drivers exhibited significantly poorer postural control than their peers ($P = 0.03$). The wake up times and times on task for these five drivers indicated that they were on a night shift schedule or had a long time on task. Furthermore, their postural control and KSS scores correlated ($r = -0.88$, $P = 0.04$), whereas the scores did not correlate for their peers ($r = 0.10$, $P = 0.48$).

These results indicate that the force platform test identified drivers, whose impairment in postural control was drowsiness-related. Specifically, the test identified the few drivers in this roadside sample whose wake- and work histories resembled a night shift schedule. In this kind of roadside setting, with a demographically heterogeneous group and interindividual differences in people's responses to drowsiness, it suggests that the method, further developed, may provide a drowsiness test for roadside surveillance.

1. Introduction

Drowsy driving is a main factor in traffic accidents (*e.g.* NHTSA, 2009; NTSB, 1999). For instance, in the U.S., as many as 28% of polled private drivers and 47% of polled long-haul truck drivers admit to having nodded off at the wheel at least once (McCartt et al., 2000; NSF, 2009). Falling asleep while driving causes at least 100,000 crashes annually in the US; 40,000 lead to nonfatal injuries, and over 1500 result in fatal injuries (Royal, 2002). In Finland, as many as 20% of polled long-haul truck drivers admit to having nodded off at the wheel at least twice (Häkkänen and Summala, 2000). Falling asleep while driving is believed to cause at least 10% of all fatal traffic accidents in this country (VALT, 2006). In light of these unsettling statistics, researchers and policymakers have long recognized the need for a breathalyzer-like drowsiness-test to tackle drowsy driving with police surveillance (Maggie's Law, 2003; Philip and Åkerstedt, 2006; Radun, 2009). Still, there is no breathalyzer-like drowsiness-test to aid such surveillance (Radun, 2009).

Much effort has gone into developing systems that continuously monitor the driver while driving and warn him/her when drowsiness compromises safety. Such systems typically rely on monitoring eye movements, microsleep episodes, and driving performance (Golz et al., 2011; Stephan et al., 2006), using either a single method or several methods in combination (Vadeby et al., 2010). Whether these technologies truly serve a preventive purpose in terms of whether a driver who receives a warning actually

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reacts to it in an appropriate manner remains unclear (Anund and Kircher, 2009). Importantly, these *in-car monitors serve the concerned citizen*, but are ill-suited for *police surveillance, which calls for a breathalyzer-like test*.

Current drowsiness-tests that are administered in occupational settings generally rely on questionnaires or psychomotor vigilance tests (Balkin et al., 2004; Dijk et al., 2001). Questionnaires that rate the subjective feeling of drowsiness are fast to administer (Balkin et al., 2004) and sensitive to acute and partial sleep loss (Balkin et al., 2004; Van Dongen et al., 2003). However, they are insensitive to chronic sleep loss, which implies that people are largely unaware of the cumulative deficits in performance that chronic sleep loss causes (Van Dongen et al., 2003). The objective 10-min psychomotor vigilance test (PVT) is sensitive to acute, partial, and chronic sleep loss (Balkin et al., 2004; Van Dongen et al., 2003). However, administering a 10-min PVT while surveying drivers may be unacceptably time consuming whereas the shorter 5-, 3-, and 1.5-min test versions are less sensitive to sleep loss (Basner et al., 2011; Roach et al., 2006). This may explain why the PVT has not yet become the breathalyzer-like drowsiness-test for surveillance purposes.

Recent studies imply that quantifying postural control with a force platform may provide a base for a breathalyzer-like drowsiness-test. The rationale is that the force platform test is sensitive to factors regulating drowsiness. The ability to maintain posture, whether sitting, standing, or walking, is important for everyday functioning. The cerebellum and brainstem control posture by continuously integrating sensory influx from the vestibular-, proprioceptic-, and visual systems, and by executing muscular control (Mumenthaler and Mattle, 2004). Clinicians evaluate postural control with a computerized force platform, on which the patient stands while the platform samples the body center of pressure excursions and quantifies the postural sway: poor postural control causes large postural sway (Era et al., 2006). While impaired postural control generally is attributed to aging (Era et al., 2006; Prieto et al., 1996), recent research suggests that postural control also exhibits circadian and homeostatic mechanisms and that the force platform test is sensitive to these factors (Forsman and Hæggström, 2012). In *laboratory settings*, postural control decreases during sustained wakefulness (Avni et al., 2006; Bougard et al., 2011; Forsman et al., 2007a; Smith et al., 2012) while also displaying circadian rhythmicity (Forsman et al., 2007b; Patel et al., 2008; Sargent et al., 2012) and sleep inertia (Forsman et al., 2013) in young participants. Moreover, studies with elderly participants show similar results (Jorgensen et al., 2012; Robillard et al., 2011). In *field settings*, postural control has showed sensitivity to work shift induced fatigue in medical doctors (Kohen-Raz et al., 1996; Sato et al., 1995) and in commercial drivers (Albuquerque et al., 2011). The latter study implies that the force platform test could be valid also in the driving domain. Another rationale to use postural control as a drowsiness-marker is that the 30-s test version is fast to administer (Forsman et al., 2007c). As noted above, posturographic research has successfully detected the factors that regulate drowsiness. However, these studies have (1) enrolled participants strictly controlled with respect to their demographics, health, sleep- and work histories, and (2) focused on analyzing repeated measurements designs. It is therefore unclear how the force platform test performs if the participants have different sleep- and work histories and if only one measurement per person is available, as is often the case in a surveillance situation. This could, in principle, partly be assessed by pruning a repeated measurements protocol, but to our knowledge it has not been done.

The aim of this study was to examine whether the force platform test potentially could serve as a breathalyzer-like drowsiness-test for surveillance purposes at the roadside. The driver takes the test only once while not driving rather than undergoing continuous monitoring while driving. To do this we set up roadside measurement sites and tested drivers who volunteered to take a 30-s force platform test and to complete the Karolinska Sleepiness Scale (*KSS*; Åkerstedt and Gillberg, 1990). We also recorded their work and sleep history. The roadside sampling provides a bench-mark for what performance the force platform test could at least achieve in a "worst-case scenario", because the inter-individual differences in people's responses to drowsiness are expected to be considerable (*e.g.* Fig. 1 in Forsman et al., 2007a; Van Dongen et al., 2004) and therefore confound the correlation between the drivers' drowsiness and postural control. In the analysis we focus on the relation between the drivers' wake/work histories and postural control, but we also determine correlation between the drivers' *KSS* and postural control. Taking drowsiness-screening to the roadside is a gargantuan task, but we believe that carrying out the most realistic protocol available to us is important for assessing the feasibility of the proposed test. This approach helps us in our work to develop a technique that identifies drivers, whose decrements in postural control are drowsiness-related.

Table 1
Study schedule and volunteers during week 46.

Time of testing	Drivers[a] (count)	Age (mean ± SD, range)	Vehicle
Fri 18:00 to Sat 06:00	26	39 ± 13 (22–60)	Truck
Sat 18:00 to Sat 24:00	4	43 ± 5 (37–49)	Bus
Sun 01:00 to Sun 22:00	41	44 ± 13 (19–60)	Taxi
	71	42 ± 13 (19–60)	

[a] All were men, except for three drivers tested on Sunday.

2. Methods

2.1. Participants

We approached Finnish goods- and public transportation companies as well as taxi companies in Helsinki. With their approval we set up the equipment in their localities and tested all drivers who volunteered during week 46. Before inclusion in the study we obtained verbal informed consent from the volunteers. Anonymity (*i.e.*, verbal consent) was important to ensure the driver that he/she could not be identified at any point during or after the study. One exclusion criterion from the study was age over 60, because balance decline accelerates with increasing age (Era et al., 2006). Other exclusion criteria were current or diagnosed leg- or back disorders. Seventy-six drivers volunteered and 71 were included (Table 1).

2.2. Protocol

This experimental field study relied on drivers stopping by at one of the three measurement sites, equipped for the test, to participate at their convenience (Table 1). Previous studies of driving performance have shown that drowsiness affects performance variables during the night shift but not during the day shift (Forsman et al., 2013). Therefore, we kept the measurement sites open during the night (Table 1) to permit drivers working during the night to participate. Upon inclusion in the study the drivers completed the Karolinska Sleepiness Scale (described below). We asked about their last wake-up time (*i.e.*, their current time awake) and their current time on task (*i.e.*, for how many hours they had been driving before they stopped at the test site). We recorded the time of day of testing and tested their postural control (described below).