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Field Quantification of Physical Exposures of Police Officers in Vehicle Operation

Colin D. McKinnon
Jack P. Callaghan
Clark R. Dickerson

Faculty of Applied Health Sciences, University of Waterloo, Waterloo, ON, Canada

*Mobile police officers perform many of their daily duties in their vehicles. Combined workspace inflexibility and prolonged driving create potential musculoskeletal injury risks. Limited research exists that quantitatively describes postural and load exposures associated with mobile police work. The purpose of this study was to characterize officer activity during a typical workday and identify opportunities for ergonomic intervention. Digital video of traffic officers (*N *= 10) was used to classify postures according to work activity. Cumulative time in 10 activities was calculated, and a time-history of driver activity documented. Most (55.5 ± 13.4%) time was out of the vehicle, and 22.3 ± 10.5% was spent in single-arm driving. On-paper documentation and mobile data terminal use were identified as in-car activities that may benefit from targeted interventions. The primary contribution of this study is characterization of daily mobile police activity and the identification of possible intervention strategies to mitigate physical exposure levels.*

police officers   driving   activity characterization   mobile data terminal

1. INTRODUCTION

Emergency services and crisis intervention personnel, including law enforcement, experience higher physical demands compared to persons in more sedentary occupations [1]. In all aspects of police work, ranging from physical criminal restraint to automotive pursuit to legal documentation, officers are exposed to physical stressors which may put them at risk for musculoskeletal pain or injury. Mobile police officers, particularly in the traffic division, experience not only acute stressors in emergency response situations, but also cumulative physical exposures with prolonged occupational driving. These mobile police officers experience documented musculoskeletal and performance issues [2, 3] with substantial levels of perceived discomfort associated with in-vehicle demands [4]. Occupational driving itself demonstrably increases the risk of developing musculoskeletal disorders [5], and these generic concerns extend to the mobile police population.

Investigations into the occupational stressors specific to the police community are scarce. Very few studies document the physical exposures [6] and the muscular disorders [3, 7] that officers experience. Conclusive quantitative geometrical and biomechanical evidence of physical stressors have not yet emerged from such studies, but subjective officer questionnaire and survey responses clearly indicate prevalence of pain and discomfort specific to the mobile police population [3, 7]. Greater levels of low back, shoulder, hand, and wrist problems occur with increased exposure to occupational driving, specifically within mobile officers [7]. Despite these previous research efforts, modern advances in technology throw into question the current suitability of conclusions regarding design of patrol car interiors.

Correspondence and requests for offprints should be sent to Clark R. Dickerson, Department of Kinesiology, Faculty of Applied Health Sciences, University of Waterloo, Waterloo, ON, Canada N2L 3G1. E-mail: <cdickers@healthy.uwaterloo.ca>.

Introduction of modern mobile data terminal (MDT) systems has given officers means for rapid, secure access to comprehensive information [8], however, postural and cumulative loading complications may arise with the modified working postures that come with this improved availability of information and work efficiency. The introduction of MDT systems has affected not only communication abilities, but modified the interactions that officers have with in-car equipment and durations of communications-based activities. To create a strong, visible police presence in the community and to deter visible crime, traffic division officers are often encouraged to complete nearly all their daily duties within the cab of the police vehicle. In addition to physical constraints imposed by MDT systems, cruiser design and layout flexibility is inhibited by environmental constraints including a steering wheel with limited range of motion, a rear separation cage used to secure detainees, and multiple pieces of required on-person equipment, which are typically secured with a bulky duty belt. Performing nearly all daily duties within this confined workspace likely exacerbates the postural exposures associated with occupational driving and potentially introduces additional concerns that could increase the prevalence of musculoskeletal disorders.

Speculation exists regarding the influence of these factors on the working and seated postures of officers while they perform duties in the mobile environment, however, no research has rigorously quantified the postural and load exposures that relate to this constrained workspace. Given the lack of relevant research, it is difficult to justify specific interventions to improve the working situation.

The economic importance of addressing musculoskeletal disorders and contributing risk factors is well defined. On average, there are 449 compensation claims per year across Canada for low back musculoskeletal injury [9] and ~1400 lost time claims in the USA [10]. Based on Workplace Safety and Insurance Board data, the average direct compensation cost of Ontario claims for police officers was 100 177 CAD[1] [11]. The issue of seating and MDT placement is a topic of concern for police fleet operations [9, 10, 11].

The purpose of this study was to characterize the daily activities of traffic division officers. Identification and concurrent quantification of physical exposures will direct improved police cruiser design conclusions that will improve workplace safety and reduce the injury-based financial burden of this population.

2. METHODS

Mobile police officers were recorded using an in-vehicle digital video collection system for complete shifts and whole-body postures were matched to identify and characterize the most common driver activities during a typical working day.

2.1. Subjects

Ten traffic division officers volunteered for this study. Participants were in good general physical health and provided written informed participatory and video consent.

2.2. In-Vehicle Video System

A digital video collection system, including a laptop computer (Figure 1a) was secured in a custom protective housing on the floor of the passenger side of a standard Ford Crown Victoria police cruiser. A 3.6-mm, 0.1-lux bullet camera (Defender Security, USA) was mounted on the passenger side of the roll cage, ~10° posterior to the driver's seated frontal plane (Figure 1b). Digital video was captured at 20 Hz using a USB device (Sunplus SPC506A Video Capture; Bronzepoint Security Products, USA) and Windows Movie Maker collection software. Audio collection was disabled for all trials.

[1] 100 177 CAD ≈ 100 000 USD ≈ 75 000 EUR

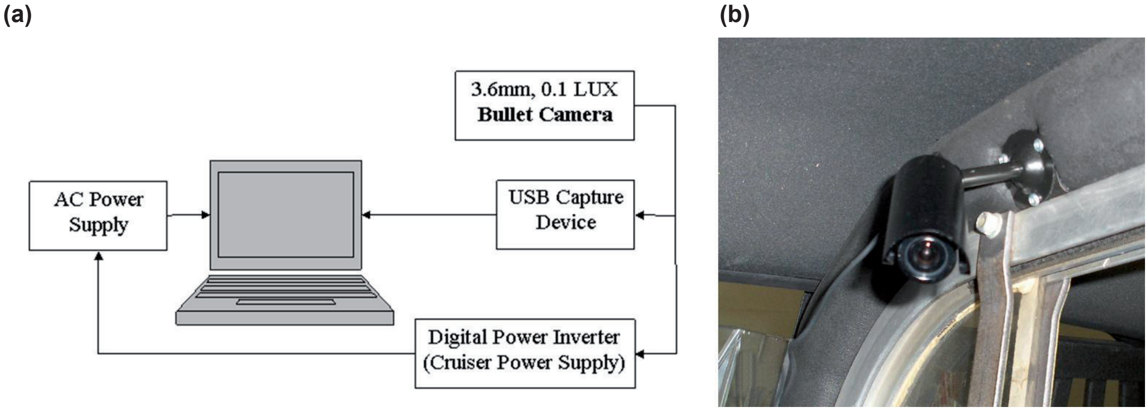

Figure 1. In-car video collection system (a) components and layout, and (b) camera placement on the passenger-side roll cage of police cruiser.

2.3. Experimental Protocol

Continuous digital video was captured for single occupant police cruiser daytime shifts ranging in duration from 5.5 to 9.5 h. Start time ranged between 6:30 and 8:00 and end time between 15:30 and 18:30. The authors initiated video collection equipment prior to shift commencement and were not present in the vehicle during the shifts recorded. Officers were instructed to perform their daily task set as they normally would. Video was pre-screened to identify the most common driver activities and yielded 10 possible driver activities (Table 1). Video collections (.wmv) were down sampled from 20 to 1 Hz. This process minimized file size and processing duration while maintaining video integrity and capture of whole-body activity details.

TABLE 1. Identified Common Driver Activities

Activity	Description
1	right-handed MDT use
2	two-handed MDT use
3	two-handed driving
4	on-paper documentation
5	left-handed driving (right upper limb relaxed)
6	forward right arm reach
7	lateral right arm reach
8	traffic observation
9	vehicle entry/exit
10	out of vehicle

Notes. MDT (mobile data terminal) use is interaction with the in-car laptop system.

2.4. Data Analysis

Each video collection was analyzed using the REACT (Regional Enforcement Activity Characterization Tool) custom software tool developed at the University of Waterloo using Matlab R2008a (Mathworks, USA). Videos were loaded into the REACT graphical user interface (Figure 2) and officers were activity posture matched for each frame of digital video. Video frames were matched to one of the 10 predetermined driver activities. The total number of frames for each of the activities yielded cumulative time spent in each activity, which was reported in seconds. These totals were used to calculate group means and standard deviations for percentage time in each activity for the entire collection, percentage of in-car time in each activity (excluding time outside of vehicle), and percentage of time in each activity after initial vehicle entry.

Activity analysis produced a time-history of driver activities that defines the order, frequency, and duration of each activity throughout the collection (Figure 3). Time-history data was analyzed with custom software developed in Matlab R2008a. Duration of each group of consecutive video frames in activity 1 (right-handed MDT use) and 2 (two-handed MDT use) was determined and mean keyboard typing task duration was calculated.

Figure 2. Regional Enforcement Activity Characterization Tool (REACT) graphical user interface for officer activity selection. Officer activity postures consider the entire body matched to one of the 10 postures shown for each frame of digital video.

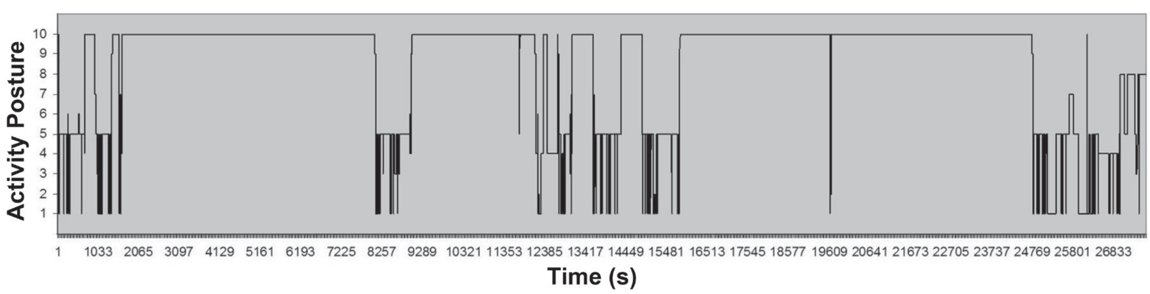

Figure 3. Sample time-history of police officer activities. *Notes*. Activity numerical values represent the postures indicated in Table 1. Full shift duration ranged from 5.5 to 9.5 h.

3. RESULTS

Percentage of time spent in each of the identified activities for the full video collection, for activity in vehicle (out of vehicle activity omitted), and for activity after initial entry of the officer in the vehicle are presented in Tables 2–4, respectively. Over the entire collection, the longest time spent in any one activity was 55.5 ± 13.4% out of the vehicle (Table 2). Time out of the vehicle occurs for various reasons, including roadside interaction due to traffic violations, attendance

TABLE 2. Mean (*SD*) Percentage Time in Each of the 10 Identified Common Activities (*n* = 10). Activities Are Ranked According to Descending Mean Time

Activity	Mean Time (%)	*SD* (%)	Rank
Officer out of vehicle	55.5	13.4	1
Left-handed driving (right hand relaxed)	22.3	10.5	2
On-paper documentation	9.38	7.52	3
Right-handed MDT use	4.57	2.00	4
Two-handed driving	3.95	3.00	5
Vehicle entry/exit	1.28	0.49	6
Two-handed MDT use	1.23	1.06	7
Relaxed/traffic watch	0.65	1.19	8
Right arm lateral reach	0.61	0.33	9
Right arm forward reach	0.53	0.36	10

Notes. MDT—mobile data terminal.

TABLE 3. Mean (*SD*) Percentage Time in Each Activity for In-Vehicle Activities (*n* = 10). Time Out of Vehicle is Omitted. Activities Are Ranked According to Descending Mean Time

Activity	Mean Time (%)	*SD* (%)	Rank
Left-handed driving (right hand relaxed)	50.3	15.7	1
On-paper documentation	20.8	16.5	2
Right-handed MDT use	10.3	3.99	3
Two-handed driving	8.98	6.54	4
Vehicle entry/exit	3.09	1.29	5
Two-handed MDT use	2.78	1.81	6
Right arm lateral reach	1.49	0.81	7
Relaxed/traffic watch	1.20	2.08	8
Right arm forward reach	1.12	0.60	9

Notes. MDT—mobile data terminal.

TABLE 4. Mean (*SD*) Percentage Time of Activity After Initial Vehicle Entry in Each of the 10 Identified Common Activity Postures (*n* = 10). Activities Are Ranked According to Descending Mean Time

Activity	Mean Time (%)	*SD* (%)	Rank
Officer out of vehicle	50.4	16.7	1
Left-handed driving (right hand relaxed)	24.7	11.6	2
On-paper documentation	10.4	8.64	3
Right-handed MDT use	5.01	2.14	4
Two-handed driving	4.57	3.78	5
Vehicle entry/exit	1.41	0.51	6
Two-handed MDT use	1.36	1.15	7
Relaxed/traffic watch	0.81	1.56	8
Right arm lateral reach	0.68	0.38	9
Right arm forward reach	0.58	0.38	10

Notes. MDT—mobile data terminal.

at municipal court meetings, equipment retrieval from the trunk, and meal breaks. The highest mean percentage time spent in an in-car activity was 50.3 ± 15.7% of in-car time spent driving with the left arm (Table 3).

On-paper documentation and MDT use represented the most time of in-car, nondriving activities. Completion of various paper-based logs on paper (on-paper documentation) consumed 20.8 ± 16.5% of the in-vehicle time. MDT use (combined one- and two-handed) represented over 13.08% of time activities performed by officers (Table 4).

Slight variations existed for interparticipant individual joint postures, but whole-body activities consistently fit into one of the 10 activities created in the REACT software tool. All frames from all officers were successfully classified within this rubric.

4. DISCUSSION AND CONCLUSIONS

Using this digital video collection method of activity characterization, the typical daily task set was quantitatively and explicitly described for a sample of mobile police officers. Two distinct work environments were identified for these officers: in- and out-of-vehicle. Out-of-vehicle activities encompassed more than half of the daily activities (Table 2), identifying them as having potential for intervention to reduce the prevalence of musculoskeletal symptoms among this population. However, due to the highly variable nature of these activities, and legal and logistical difficulty in documenting them, this study focused on in-vehicle activities. The data generated in this study provides a rigorously ranked quantification of percentage time spent in various in-vehicle activities that was previously unavailable for modern mobile police operations. Due to the absence of high load activities performed in the vehicle, cumulative postural activity exposures were chosen as a method to identify possible aspects of the work activity or workplace that would be most beneficial to address with design modifications.

In-car activities are further divisible into driving and nondriving activities. Onset of low back pain or discomfort has previously been identified for occupational driving activities in general [2, 13], as well as for the flexed lumbar postures associated with such activities [14, 15]. The level of this discomfort is directly related to the amount of occupational driving exposure [13]. In this current investigation, single-handed (left arm) driving (Figure 4a) made up 50.3 ± 15.7% of the in-vehicle activities performed by the officers on a time basis (Table 3). As driving is a functionally necessary component of this occupation, as well as many others, limited potential modifications to the environment unique to this population seem pragmatic. Further, as much work continues to be done on reducing spinal loading through automotive seating investigations [16, 17, 18] the focus of this study was on possible intervention in this specific population with nondriving, in-vehicle activities and equipment interfaces.

High exposures to nondriving, or peripheral, police activities present additional risk to mobile officers. Postural adaptations to driving task layout changes are accomplished primarily by changes in limb posture, whereas torso posture remains largely unaffected [19]. Thus, officers are exposed to repetitive or static upper limb loads which may lead to musculoskeletal impairment [20]. In general, extended upper limb exposures or flexed and abducted postures

Figure 4. Sample images of driver activities for (a) left-handed driving, (b) on-paper documentation, and (c) two-handed mobile data terminal use.

in these peripheral tasks increase cumulative shoulder moments [21]. Increased muscular loads associated with these moment increases may induce local muscular fatigue and increase the risk of upper limb problems [22].

On-paper documentation (Figure 4b) and MDT use (Figure 4c) emerged as the best apparent candidates for attempted mobile police environment interventions, based on cumulative exposures. Despite improvements in communication that accompany modern MDTs, officers are still required to complete various daily logs on paper. Completing various forms of paperwork consumes ~20% of the time spent working in the vehicle. There is no fixed location or standard method for completing this documentation in the vehicle. As a result, officers use different strategies and individualized joint postures to complete this task.

MDT use is another area of concern as it represented over 13% of in-car time activities performed by officers (combined one- and two-handed use). The MDT as currently configured has minimal adjustability, and thus its location and orientation are not easily repositioned to reduce upper limb and low back loading associated with the arm extension and trunk axial twisting its use requires. These specific problems are not common to all police fleets, but not unique to fleet observed in this study. Supportive devices are available to minimize such problems, but are not designed to function in the mobile environment [23]. Large swing arm or "boom" mounts and removable MDT mounting solutions have been implemented in unique applications, but have not motivated fleet-wide adaptations [24]. Given the significant investment required to outfit a police fleet with modern MDT systems compared to the cost of mounting hardware, it may be worth upgrading current mounting solutions [23].

High standard deviations for mean time in an activity existed for each of the less frequently performed activities. Due to the relatively small sample size ($n = 10$) and the homogeneous nature of mobile police work, the activity set performed by an officer varied both day-to-day and from officer-to-officer. For many of the activities, there are no set performance methods or defined techniques. Relaxed/traffic watch ($0.65 \pm 1.19\%$) varied based on patrol style: some officers preferred to be constantly moving in their vehicle, while others frequently stopped to assess traffic situations. Two officers preferred the latter style, which inflated the standard deviation value.

This study effectively characterized mobile police activity and identified possible opportunities for ergonomic interventions. This robust activity characterization is an important first effort in moving towards creating improved automotive interior designs that address the set of unique challenges facing mobile police. Based on percentage of time in various in-vehicle activities, the ultimate goal is to develop and implement targeted, evidence-based workspace design changes that effectively reduce physical data entry time (on-paper documentation and MDT use) and reduce the associated risks. Potential structural and technological modifications may include voice operated systems, which eliminate most physical interactions with the system, single-cage police cruisers which allow posterior seat movement for MDT use directly in front of the driver, and wireless handheld devices which eliminate the need for a fixed system. A change from a single unit (screen and keyboard) to split systems with a dash mounted display and a separate keyboard that will allow greater adjustability and range of positions appears to potential solution given the currently available technology. Such changes must be evaluated from both ergonomic, performance and safety stances, as they must both maintain officer proficiency and safety while removing or mitigating physical risks.

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