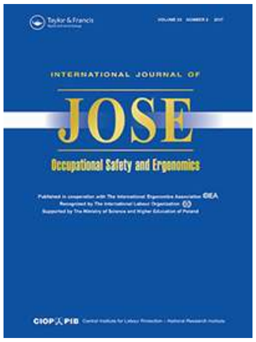

International Journal of Occupational Safety and Ergonomics

ISSN: 1080-3548 (Print) 2376-9130 (Online) Journal homepage: http://www.tandfonline.com/loi/tose20

An ergonomic evaluation of city police officers: an analysis of perceived discomfort within patrol duties

Michelle Cardoso, Michelle Girouard, Jack P. Callaghan & Wayne J. Albert

To cite this article: Michelle Cardoso, Michelle Girouard, Jack P. Callaghan & Wayne J. Albert (2017) An ergonomic evaluation of city police officers: an analysis of perceived discomfort within patrol duties, International Journal of Occupational Safety and Ergonomics, 23:2, 175-184, DOI: 10.1080/10803548.2016.1249728

To link to this article: https://doi.org/10.1080/10803548.2016.1249728

Accepted author version posted online: 20 Oct 2016.
Published online: 28 Nov 2016.

International Journal of Occupational Safety and Ergonomics (JOSE), 2017
Vol. 23, No. 2, 175–184, http://dx.doi.org/10.1080/10803548.2016.1249728

An ergonomic evaluation of city police officers: an analysis of perceived discomfort within patrol duties

Michelle Cardoso[a], Michelle Girouard[a], Jack P. Callaghan [b] and Wayne J. Albert[a]*

[a]*Faculty of Kinesiology, University of New Brunswick, Canada;* [b]*School of Kinesiology and Health Studies, University of Waterloo, Canada*

The purpose of this study was to assess the perceived discomfort of patrol officers related to equipment and vehicle design and whether there were discomfort differences between day and night shifts. A total of 16 participants were recruited (10 males, 6 females) from a local police force to participate for one full day shift and one full night shift. A series of questionnaires were administered to acquire information regarding comfort with specific car features and occupational gear, body part discomfort and health and lifestyle. The discomfort questionnaires were administered three times during each shift to monitor discomfort progression within a shift. Although there were no significant discomfort differences reported between the day and night shifts, perceived discomfort was identified for specific equipment, vehicle design and vehicle configuration, within each 12-h shift.

Keywords: perceived discomfort; ergonomics; police officers; vehicle design

1. Introduction

Many researchers have now linked prolonged occupational driving to musculoskeletal injuries and lower back pain [1–8]. Approximately 25% of police officers are considered prolonged drivers, driving at least 25,000 km/year, of which about 18% reported experiencing lower back pain either 'often' or 'always' when driving [5,9]. Some police officers spend up to 12 h/day driving while wearing occupational gear (i.e., duty belt, Kevlar vest). The police cruiser cabs, associated seating and workstation configurations have limited adjustability, which inhibits officers from setting the seat to accommodate their specific anthropometric measurements. Comfort is also subjective, and the seat configuration officers find comfortable may not necessarily be the best for long-term driving or prolonged sitting. Unfortunately, there are a limited number of studies that have observed officers on the job. While simulations in a laboratory setting are very useful, the results are often not generalizable, because they do not account for accompanying job stressors, additional occupational situations and the demands of a real shift. Most studies that have used driving simulators were limited to 2.5 h or less of simulated driving [1,10–12], which again does not represent the reality of a typical shift.

One of the few field studies conducted on police officers found that lumbar support and the duty belt were among the features causing the most discomfort, especially in the lower back [9]. One limitation of Donnelly et al.'s study was that while they did observe the officers during a full shift, they did not differentiate between day and night shifts. Without knowledge of the differences between shifts, it is difficult to provide recommendations for a more ergonomic work environment. The purpose of this field study was to evaluate the subjective response of officers towards their health and discomfort related to their shift and vehicle and duty belt configuration. It was hypothesized that discomfort values would be greater during the night shift in comparison with the day shift.

2. Methods

2.1. *Participant recruitment and information*

At the time of the study, the Fredericton, NB, Canada, City Police force had 113 sworn officers, of which only 25 were female. The study was promoted through email and general information sessions held before each platoon's briefing. Ten male and six female general city patrol officers were recruited for the study. Prior to the field collection, officers were provided information on the study and an opportunity to ask questions as per research ethics board requirements. Once consent forms were signed, information regarding the officers' age, gender, height, waist circumference, sitting height and mass were recorded.

2.2. *Experimental design*

Each participant had a researcher sit in the passenger seat to monitor the ergonomic concerns of performing in vehicle

*Corresponding author. Email: walbert@unb.ca

tasks for a full day and night shift. All officers drove either a Ford Crown Victoria or a Ford Interceptor. Three questionnaires were used in this study to gather subjective information regarding: (a) specific car features and occupational gear; (b) body part discomfort; and (c) health and lifestyle information. Discomfort was monitored through questionnaires at the beginning, middle and end of the officer's 12-h shift. Because of the variability in work demand, the mid-shift questionnaire was administered as close to the 6th hour of the shift as possible.

2.2.1. *Seat features and occupational demands questionnaire*

The seat features and occupational demands questionnaire (SFODQ) focused on determining which aspects of the police cruiser, as well as occupational equipment and tasks, were perceived as causing discomfort. This questionnaire was adapted from the automotive seating discomfort questionnaire (ASDQ) [13], which was originally designed for measuring discomfort associated with car seat features or components. According to Smith et al. [13] the ASDQ questionnaire is a repeatable and reliable method to measure discomfort associated with automotive seating. The repeatability and reliability of the ASDQ was validated by running a mixed repeated-measures analysis of variance on three major interactions (gender, seat position and day of the session) in which significance was found. The ASDQ is a universal method that provides adequate detail and consistent subscales on the occupant's perceived discomfort towards specific areas of the seat [13]. The questionnaire is not biased towards gender or age, it simply measures the sensitivity of the interaction between the person and the vehicle seat [13,14]. The questionnaire was found to provide significant levels of reliability and consistency ($p < 0.5$). A between-questionnaire comparison revealed significantly correlated subject responses ($r^2 = 0.715$). Donnelly et al. [9] revised the questionnaire by adding questions specific to police fleet vehicles and the associated in-vehicle working environment. There are questions specific to the car seat, occupational gear worn (i.e., duty belt) and the occupational tasks performed in the cruiser. The discomfort rating scale is based on a 100-mm visual analog scale (VAS), where 0 mm = *no discomfort* and 100 mm = *extreme discomfort*. The SFODQ questionnaire was administered at the beginning (T1), middle (time = 6 h, T6) and end (time = 12 h, T12) of each shift.

2.2.2. *Body part discomfort questionnaire*

The body part discomfort questionnaire (BPDQ) was also administered at the beginning, middle and end of the shift in conjunction with the SFODQ to monitor potential discomfort progression. The BPDQ is a 100-mm VAS with anchors at 0 mm = *no discomfort* and 100 mm = *the worst discomfort imaginable*. The following body locations were assessed: neck and right and left measures for the shoulder, upper, middle and lower back, side of trunk, upper pelvis, sacrum, buttocks, upper and lower thigh and side of (upper) leg. The BPDQ questionnaire was a slightly modified version of the questionnaire designed and used by Mergl [15. Since Donnelley et al.'s publication, the identical BPDQ was successfully used and validated [12,16].

2.2.3. *Health and lifestyle questionnaire*

The health and lifestyle (H&L) questionnaire was administered once. The information contained in the H&L questionnaire pertained to health, fitness levels, stress and other personal and occupational factors that may be influencing their discomfort. The questionnaire's reliability has been assessed in previous research [17,18] and resulted in an average correlation for all items on a test–retest reliability study of 0.89. Cronbach's α statistics, appropriate for certain questionnaire items, ranged from 0.79 to 0.82 [17].

2.3. *Duty belt configuration*

Officers are taught a basic configuration on how the duty belt should be set up; however, they are allowed to customize depending on their physical size and personal preference. Not all duty belt items (i.e., baton, handcuffs, pepper spray) are required at all times; what items are included is left to personal preference. Prior to the start of the shift, snapshots of their duty belt were taken using a digital camera to capture individual item configuration. Location and number of items on the duty belt were quantified by subdividing the number of items placed in the front, back, right and left side of the duty belt. The participants were weighed with and without their occupational gear. The mass, location and number of items on the duty belt and the mass of the vest were recorded. Because of the nature of field work, duty belt information for one male participant could not be recorded.

2.4. *Statistical analysis*

Statistical analyses were performed using SPSS version 20.

2.4.1. *Participant information*

Participant information (i.e., age, mass, anthropometrics) was summarized using descriptive statistics (group means and standard deviations).

2.4.1.1. Seat features and occupational demands questionnaire. The scores from the SFODQ questionnaire were only used as a guide to see which features the officers rated as causing the most discomfort, and therefore descriptive statistics (mean and standard deviation) were computed. The data were then rank-ordered, determining which features were perceived as causing the most discomfort.

2.4.1.2. Body part discomfort questionnaire. Mauchly's test of sphericity was used with a Greenhouse–Geisser adjustment when the sphericity assumption was rejected. However, histogram plots of outcome variables revealed that skewness in the normal distribution that could not be corrected using traditional transformation methods. As such, a non-parametric approach using a Kruskal–Wallis test was used. The independent variable was time (with three levels: T1, T6, T12), and the dependent variables were the mean discomfort scores for each body part.

2.4.1.3. Officer anthropometrics, duty belt configuration and lower back pain. In order to determine whether officer anthropometric characteristics had an effect on duty belt configuration (i.e., the number of items on the duty belt as well as how the items are placed relative to the torso) and weight. A Pearson product moment coefficient of correlation was conducted with mass of the duty belt, body mass index and incidence of lower back pain as the variables.

2.4.1.4. Health and lifestyle questionnaire. Descriptive statistics were used to summarize the officers' health, fitness levels, stress, length of employment status and length of injuries (neck and lower back). A Pearson product moment coefficient of correlation was then executed to measure the relationship between the length of time working in the police force and pain (neck and lower back).

3. Results

3.1. Participant information

Table 1 presents a summary of participant information and anthropometrics. On average, the vest and duty belt combine for an additional 7.18 ± 1.56 kg that is predominantly carried around the officer's mid-section and waist (Figure 1).

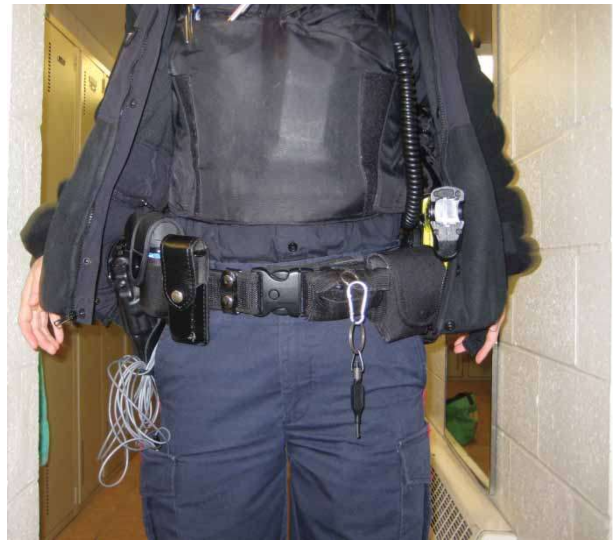

Figure 1. Front of duty belt and vest on an officer.

The mass of the duty belt was invariably dependent on the number of items included by the officer. The number of items worn ranged between 5 and 14; but on average the officers wore a total of 9 items on the duty belt. In terms of specific location, 3 ± 2 items were carried on the front of their duty belt, 2 ± 2 on the back, 2 ± 1 on the right side and 3 ± 1 on the left side, respectively. Individual duty belt information as well as waist circumference and body mass index are reported in Table 2.

There was a significant positive correlation between the number of items on the duty belt and body mass index with $r = 0.705$ ($df = 12$; $p = 0.005$). However, there was no significant correlation between the mass of the duty belt and waist circumference ($r(12) = 0.378$, $p = 0.183$). A significant positive correlation ($r(12) = 0.754, p = 0.002$) was found between the number of items on the back of the duty belt and waist circumference, as well as between waist circumference and the total number of items on the duty belt ($r(12) = 0.709, p = 0.050$). Similarly, there was a significant negative correlation between the mean lower back discomfort score and the total number of items on

Table 1. Participant information.

			Body anthropometry						
Gender	*N*	Age (years)	Stature (m)	BM (kg)	BMI	DBM (kg)	VM (kg)	DBM/BMI (%)	VM/BM (%)
Male	10	33.3 (7.0)	1.78 (0.07)	95.20 (12.30)	29.40 (3.32)	5.47 (0.70)	2.59 (0.51)	5.80	2.64
Female	6	38.0 (1.7)	1.70 (0.05)	69.50 (8.99)	23.90 (2.26)	4.76 (0.91)	1.89 (0.55)	6.95	2.83
Total	16	35.1 (6.2)	1.75 (0.07)	84.90 (16.70)	27.20 (3.85)	5.19 (0.82)	2.32 (0.61)	6.25	2.72

Note: Mean (*SD*) reported participant demographics and specific DBM and VM. BM = body mass; BMI = body mass index; DBM = duty belt mass; VM = vest mass.

Table 2. Number of items on duty belt along with waist circumference and body mass index provided for each participant.

			Items on duty belt				
Participant	Waist circumference (cm)	BMI	Front	Back	Right side	Left side	Total
Male1	101.60	30.30	3	4	1	2	10
Male2	104.14	32.07	1	3	4	3	11
Male3	81.28	28.42	3	2	2	3	10
Male4	–	22.59	3	2	2	3	10
Male5	91.44	28.79	4	2	2	2	10
Male6	80.01	25.82	3	0	1	3	7
Male7	111.00	33.08	6	4	1	3	14
Male8	111.76	32.07	0	4	2	3	11
Male9	91.44	28.61	4	3	2	4	13
M (*SD*)	96.57 (12.45)	29.10 (3.30)	3.00 (1.70)	2.67 (1.30)	1.90 (0.90)	2.90 (0.60)	10.70 (2.00)
Female1	67.31	23.71	2	3	1	3	9
Female2	76.20	24.73	0	0	2	3	5
Female3	81.28	26.68	2	0	1	2	5
Female4	80.01	23.83	2	1	2	3	9
Female5	66.04	19.93	4	0	1	2	7
Female6	77.47	25.07	3	1	1	2	7
M (*SD*)	74.68 (6.60)	23.90 (2.26)	2.20 (1.30)	0.83 (1.20)	1.30 (0.50)	2.50 (0.50)	7.00 (1.80)
Group total, *M* (*SD*)	87.22 (14.45)	27.05 (3.72)	2.67 (1.59)	1.93 (1.53)	1.67 (0.81)	2.73 (0.59)	9.20 (2.62)

Note: A value is missing for waist circumference. BMI = body mass index.

the duty belt ($r(12) = –0.643$, $p = 0.018$). There were no significant correlations found between body mass index and lower back pain or between waist circumference and lower back pain.

3.2. *Seat features and occupational demands questionnaire*

Scores (0–100 mm) for the SFODQ questionnaire were recorded for each participant. The questionnaire was subdivided into two categories representing seat features and occupational features/gear, and the results are presented in Table 3. The three items that rated the highest on the questionnaire were all in the occupational gear and occupational features category. The highest discomfort of 54.0 ± 31.6 mm was attributed to the duty belt. This was followed by computer use and the equipment on the back of the duty belt with discomfort scores of 50.9 ± 33.5 mm and 50.6 ± 31.8 mm, respectively. The highest discomfort scores in the seat features category were all related to the lower back support characteristics. The lower back support itself was the car seat feature with the highest discomfort score (fourth overall across both categories), with a mean discomfort rating of 46.9 ± 36.7 mm. The vertical location of the lower back support had a mean discomfort rating of 41.6 ± 36.6 mm, followed by lumbar support stiffness (40.4 ± 36.4 mm). Ingress and egress had relatively low discomfort ratings, averaging 24.7 ± 25.4 and 22.3 ± 29.4 mm, respectively. The car had an overall discomfort rating of 40.8 ± 30.8 mm.

Table 3. Rank-ordered mean and standard deviation for the seat features and occupational demands questionnaire (SFODQ).

SFODQ findings	*M* (mm)	*SD* (mm)
Duty belt	54.00	31.63
Computer use	50.87	33.52
Equipment on back of duty belt	50.62	31.77
Lower back support	46.85	36.73
Vertical location of the lower back support	41.56	36.65
Overall discomfort level of seat	40.80	30.84
Lumbar stiffness	40.44	36.35
Pressure from the lower back support	37.44	36.28
Side arm/radio	34.60	34.69
Back rest height	34.44	37.09
Center of the seat cushion	32.31	32.00
Seat cushion bolsters (sides)	29.86	32.95
Contour of the seat cushion	29.00	31.45
Backrest contour	26.75	33.63
Backrest bolsters (sides)	26.56	34.75
Seat cushion firmness	25.8	29.56
Egress	25.47	26.08
Ingress	24.67	25.45
Width of the seat cushion	22.25	29.39
Backrest firmness	21.69	23.54
Seat cushion length	21.38	29.91
Backrest width	18.87	32.82
ASP baton	18.14	25.96
Soft body armor	17.87	24.86
Trim	14.63	23.51
How the upholstery (trim) feels	9.93	13.04
Seat belt	9.60	15.86
Friction with upholstery	9.50	21.79
Radio use	7.73	13.71

Note: ASP = Armament Systems and Procedures (Armament Systems, and Procedures, Inc.; www.asp-usa.com).

Table 4. Mean (*SD*) discomfort scores (mm) (T1, T6, T12) and mean difference scores for the day shift (T6–T1, T12–T6, T12–T1).

	Day shift					
Body area	T1	T6	T12	T6–T1	T12–T6	T12–T1
Neck	7.81 (10.90)	12.70 (14.90)	24.40 (23.90)	4.87	11.8	16.60*
Left-side upper back	3.81 (8.59)	12.50 (14.80)	20.40 (26.70)	8.69	7.93	16.23*
Right-side upper back	7.20 (13.90)	15.60 (17.70)	22.40 (26.70)	8.38*	6.88	15.25*
Mid back	8.31 (20.10)	14.00 (17.10)	22.50 (31.90)	5.69	8.50	14.20*
Lower back	11.60 (14.40)	17.50 (16.90)	29.70 (22.50)	5.86	12.2	18.10*
Left-side pelvis	4.20 (5.45)	13.90 (19.90)	17.90 (24.10)	9.73	4.00	13.70
Right-side buttocks	3.20 (4.14)	14.60 (20.36)	19.60 (26.50)	11.40*	5.00	16.40

*Significant based on the Kruskal–Wallis test with $p < 0.5$. Corresponding χ^2 values are provided in the text.
Note: T1 = beginning of shift; T6 = middle of shift (time = 6 h); T12 = end of shift (time = 12 h).

Table 5. Mean (*SD*) discomfort scores (mm) (T1, T6, T12) and mean difference scores for the night shift (T6–T1, T12–T6, T12–T1).

	Night shift					
Body area	T1	T6	T12	T6–T1	T12–T6	T12–T1
Neck	8.29 (11.80)	28.60 (17.09)	35.10 (23.50)	20.0*	6.50	26.90*
Right-side shoulder	3.70 (6.18)	13.00 (15.03)	20.90 (26.30)	9.30	7.86	17.20
Left-side upper back	5.86 (9.09)	12.71 (14.30)	18.60 (21.60)	6.85	5.93	12.80
Right-side upper back	7.86 (12.80)	15.80 (16.30)	23.40 (22.90)	6.84	8.66	15.50*
Mid back	6.71 (9.67)	13.40 (15.30)	22.80 (20.50)	6.72	9.36	16.10*
Lower back	12.00 (22.80)	24.50 (23.50)	37.10 (33.60)	12.00	12.6	24.60*
Right-side pelvis	4.86 (6.48)	17.70 (21.80)	18.70 (24.90)	12.90	1.00	13.90
Right-side upper thigh	3.69 (7.17)	16.80 (22.80)	21.90 (31.30)	13.10	5.15	18.20*
Right-side low thigh	4.46 (7.91)	21.20 (26.10)	24.30 (31.10)	16.70	3.15	19.80*

*Significant based on the Kruskal–Wallis test with $p < 0.5$. Corresponding χ^2 values are provided in the text.
Note: T1 = beginning of shift; T6 = middle of shift (time = 6 h); T12 = end of shift (time = 12 h).

3.3. *Body part discomfort questionnaire*

Mean discomfort scores by body region are presented for each time collection (T1, T6 and T12) for both day and night shifts in Tables 4 and 5, respectively. During the first 6 h, the right upper back ($\chi^2 = 4.3$, $p = 0.04$) and buttocks ($\chi^2 = 5.9$, $p = 0.02$) were reported as having significant increases in discomfort, while the neck ($\chi^2 = 11.6$, $p = 0.001$) and the right side of the body ($\chi^2 = 5.9$, $p = 0.02$) were identified as increasing in discomfort during the night shift. While there were no statistically significant changes in body discomfort between the T6 and T12 data collection, there was a large number of significant increases from the start and end of both the day and night shifts, respectively.

During the day shift, officers reported increased discomfort in the following body areas: neck ($\chi^2 = 4.4$, $p = 0.04$), left upper back ($\chi^2 = 5.5$, $p = 0.02$), right upper back ($\chi^2 = 5.3$, $p = 0.02$), mid back ($\chi^2 = 5.6$, $p = 0.02$) and lower back ($\chi^2 = 8.9$, $p = 0.01$). During the night shift, the officers reported increased discomfort in a larger number of body areas, including the neck ($\chi^2 = 12.1, p = 0.001$), right upper back ($\chi^2 = 4.1$,

$p = 0.04$), mid back ($\chi^2 = 4.3$, $p = 0.04$), lower back ($\chi^2 = 4.2$, $p = 0.04$), right side of the body ($\chi^2 = 7.3$, $p = 0.01$), right buttocks ($\chi^2 = 5.3$, $p = 0.02$), left buttocks ($\chi^2 = 4.4$, $p = 0.04$), right upper thigh ($\chi^2 = 4.6$, $p = 0.03$) and right lower thigh ($\chi^2 = 6.9, p = 0.01$).

The only reported body discomfort difference between shifts was an increase in neck pain during the night shift ($\chi^2 = 6.3, p = 0.01$).

3.4. Health and lifestyle questionnaire

Twelve H&L questionnaires were completed and returned, representing a 75% response rate. The average length of time working for this police force was 10.1 ± 5.6 years. In total, 66.7% of respondents reported currently suffering from lower back pain, with 87.5% reporting that they felt it was due to work. The average length of time suffering from lower back pain was 5.2 ± 4.3 years. When asked how much lower back pain was *normal* for them on a 100-mm VAS (where 0 mm = *no pain at all* and 100 mm = *greatest amount of pain possible*), the average response was 33.0 ± 12.2 mm (*moderate pain*). A total 58.3% of respondents reported currently experiencing neck pain, and the average time suffering from this neck pain was 7.0 ± 7.6 years. The average normal amount of neck pain among these officers was 42.0 ± 22.1 mm, and 57% attributed this neck pain to work.

There was a significant correlation between the length of time working in the police force and the amount of time suffering from their current lower back pain ($r(5) = 0.829$, $p = 0.024$). A similar correlation was not found for neck pain.

When compared with other individuals of the same age, 16.6% of respondents felt that they were in excellent health, 41.7% felt that they were in very good health and another 41.7% felt that they were in good health. When asked how satisfied they were with their health, 33.4% answered that they were completely satisfied, 58.3% were somewhat satisfied and 8.3% were somewhat dissatisfied. When asked about their physical activity levels and how long they had been participating in weekly physical activity, 8.3% did not do an activity each week, 16.7% have been doing physical activity for 3–5 years and 75% for more than 5 years. Lastly, when asked how fit they felt compared with other individuals their age, 50% felt they were as fit and the other 50% felt that they were fitter.

4. Discussion

The primary aim of this study was to investigate differences in discomfort levels that exist between a day shift and a night shift amongst patrol officers. Discomfort scores were measured through questionnaires and it was hypothesized that discomfort scores would be greater during a night shift than the day shift.

4.1. Seat features and occupational demands questionnaire

The results from the SFODQ were similar to the results reported by Donnelly et al. [9], where the computer, duty belt and features of the lower back support were among the items perceived by a city police force to cause the most discomfort.

The SFODQ was subdivided into two sections gathering subjective information regarding car features and occupational features the officers felt caused them the most discomfort. The item that had the highest perceived discomfort rating was the duty belt, followed by computer use and equipment on the back of the duty belt. The duty belt is required, but the mass and number of items varied between officers. The number of items varied between 5 and 14, and the mass varied between 3.4 and 6.3 kg. Many of the female officers (and those with a smaller waist circumference) chose to leave some seldom-used items off of the duty belt. It is interesting to note that there was a negative correlation between number of items on the duty belt and the amount of lower back discomfort. The officers with the least number of items on the duty belt reported the highest amount of lower back discomfort.

Computer use had a high rating of discomfort. The mobile data terminal (MDT) is located to the right of the driver's seat. Computers were first introduced in police vehicles as a means to increase police officer presence in the community [19]. Having a computer in the car allows the officer to complete paperwork while maintaining community presence and eliminating the need to set aside office time. Police officer job satisfaction increased because they were able to accomplish more tasks in a shorter period of time (i.e., license plate checks, communicate with other officers) [19]. Computer work in the police cruiser is problematic because the inside of the police vehicle is not designed as an office and has limited adjustability. According to Cardoso et al. [19] approximately 7% of an entire 12-h shift was spent using the MDT (when combining one-handed and two-handed MDT use). It was also found that two-handed MDT use caused the officers to work in awkward trunk postures; nearly 100% of the task time was spent in mild axial twist coupled with 60% of the task spent in lateral bend. Therefore, major design changes are needed in order to accommodate MDT use inside the police cruiser. It is important to note that there is an adjustable mount for the laptop, although the space is very limited. The MDT has to be outside the airbag deployment zone; consequently, regardless of the placement, MDT use will require some neck and trunk axial twist, and enough arm reach to type on the device. The ideal location of the MDT would allow the officers to work in neutral neck, spine and shoulder postures; however, this might not be feasible due to the configuration of the vehicle [20].

The lower back support and its features (i.e., lumbar stiffness and the vertical location of the lower back support) were the seat features with the highest discomfort ratings. The lumbar support is meant to promote lumbar lordosis while in a seated position, thereby decreasing lumbar spine compression. However, the average seat is often designed for the 50th percentile male [9,21], therefore the lumbar support does not always align properly with the lumbar lordotic curve of the driver's back. This may explain the perceived discomfort rates found among the participants. Proper lumbar support while seated, in both office chairs and car seats, has been shown to decrease discomfort scores [3]. De Carvalho and Callaghan's [3] study found that increasing lumbar support prominence resulted in increased lumbar lordosis in the Ford Crown Victoria car seat, compared with no lumbar support. Lumbar support prominence of 2 and 4 cm was tested, with 4 cm resulting in the most lumbar lordosis in the seated postures, but still not as much as when the participants were standing. Even with 4 cm of lumbar support prominence, the lumbar lordosis angle was still significantly different than in standing. However, it is important to note that 3 cm lumbar prominence regardless of anthropometry is the recommended lumbar support setting [22]. A recent study suggests that an active lumbar support (ALS) can enhance the sitting posture, which should reduce the chance of developing lower back pain over time. According to Holmes et al. [12] the ALS has been shown to produce less posterior rotation (meaning less lumbar spine flexion) and less pressure in participant–duty belt interaction in comparison with a standard police car seat (Ford Crown Victoria).

Police officers are sitting in the car for approximately 6 h/day, which is a concern [23]. The lumbar support system in the police cruisers was adjustable in height, but its use was not monitored. The officers' anthropometry ranged between 1.61 and 1.91 m in height, 56.02 and 110.68 kg in mass, and 66.04 and 111.76 cm in waist circumference. Many officers simply adjusted the seat back angle as well as the distance from the steering wheel. The location of the lumbar spine curvature is different for everyone, depending on their height and anthropometrics. Therefore, the lumbar support cannot be suitable for each and every person if left unadjusted and the lower back–seat interaction can quickly become problematic due to bulky equipment. Lumbar support was not monitored, but it was anecdotally reported that the lumbar support was rarely adjusted.

4.2. Body part discomfort questionnaire

Although there was no difference in body discomfort between shifts, there was a larger number of regions in which the police officers reported increased discomfort over the 12-h shift period. The lower back had the highest mean discomfort during either shift schedule. The neck had the second highest, reporting moderate discomfort. A change of at least 18 mm on a 100-mm VAS has been shown to have clinical significance [24]. In this study, the neck, lower back, right upper thigh and right lower thigh regions all had reported values that met the clinically significant increase in discomfort between the first and last hours of their shifts. The neck also experienced a clinically significant increase in discomfort during the first 6 h of the night shift. In addition, the neck and lower back experienced an average discomfort score above 30 mm, which indicates at least moderate discomfort. Cardoso et al. [19] found in the same sample population that officers spend approximately 50% of their shift inside the vehicle to perform tasks such as driving or office work (i.e., on-paper documentation or MDT use). During the time spent inside the vehicle, frequent time was spent in non-neutral posture when performing in-vehicle tasks. These tasks included one-handed MDT use, two-handed MDT use, on-paper documentation, one-handed driving and ingress/egress. According to previous research [25,26], sitting itself is not the main concern for injury development but rather time spent in awkward body postures; a likely contributor to the high rates of reported discomfort found amongst the officers.

During the day shift, the neck, left upper back, right upper back, mid back and lower back all had a significant increase in discomfort over the 12-h shift. In addition to these body regions, significant increases in discomfort were reported for the right and left buttocks, right upper thigh and right lower thigh during the night shift. The discomfort experienced in the back area could be attributed to prolonged driving, which can elicit:(a) neuromuscular fatigue; (b) nutritional restriction to the intervertebral disks; and (c) stress–relaxation phenomenon of the spinal ligaments [27,28]. The lower thigh was highlighted as the area ranging from the mid-thigh to just behind the knee. The discomfort reported in this area is likely to be attributed to the long length of the seat pan, causing pressure behind the knee (which could be perceived as discomfort in the lower thigh region). Donnelly et al. [9] found that a shortened seat pan and a modified seat foam structure, coupled with an ALS seat, were able to decrease perceived discomfort in a police officer population. The higher reported discomfort to the right side of the body is intuitive given the reported time spent using the video display terminal, which is placed on the right side of the driver, as well as the right leg always being engaged with the pedals in operating the vehicle for a 12-h period.

The left upper back and the right buttocks both had significantly higher discomfort scores at T6 compared with T1 during the day shift. Meaning, within the first half of their day shifts, the officers began feeling discomfort. This is of potential concern, because this early development of discomfort in those body parts might indicate insufficient recovery both during shift breaks and in between shifts. The officers work two 12-h day shifts, followed by two 12-h night shifts followed by 4 days off. The days off in between may not be enough to provide adequate rest and recover. Shift work is a concern for employees; it has been shown to affect injury rates, sleep patterns, work conditions, medication, safety and family and social life and to have other negative effects on the physiological system [29,30]. Individuals are more prone to injury during night shifts. In fact, accidents are three times more likely to happen during night shifts in comparison with the morning shifts: with injuries tending to be more serious and require more time away from work [30,31]. Because of the alteration in sleeping patterns, workers are more prone to fatigue. Fatigue impairs mental (reaction time, alertness) and physical (decrease in job performance) capacities due to sleepiness, depressed mood, lack of motivation and reduction in physical and mental performance, thereby making them more susceptible to injury [30,32,33]. Violanti et al. [29] monitored payroll records from 1994 to 2010 to determine the rates of injury associated with shift work in the past. In conjunction with analyzing payrolls, sleep patterns of current police staff were monitored ($n = 430$). According to Violanti et al.'s [29] findings, police officers are 72% more likely to develop an injury during a night shift in comparison with officers working on the morning shift (after adjusting for age) and 66% more at risk in comparison with afternoon shifts. It is important to highlight that the shifts worked were 8-h shifts and risk of injury/accidents reported was associated with cognitive fatigue. Other concerning factors are the lengths of shifts; when exceeding 8-h shifts, the risk of injury development increases fourfold. Workers are twice as likely to develop an injury during 12-h shifts than during an 8-h shift [30,34]. Although fatigue was not monitored in our research, Violanti et al.'s work supports the importance of monitoring cognitive fatigue due to the adverse effects of shift work and injury rates.

The left and right sides of the upper back both experienced significant increases in discomfort throughout during the day shift, however the discomfort was higher on the right side. Only the right side was reported to increase in discomfort on the night shift. Overall, the right side of the body experienced more discomfort than the left. As for the left side of the body, the left upper back discomfort score significantly increased within the first 6 h of the day shift. The officers spend approximately 3 h per shift driving with the left hand only [23]. It is possible that left-handed driving is in part causing their perceived discomfort in the left upper back. Discomfort reported in the right upper, mid and lower back is most likely due to the right-hand dominance of tasks (i.e., reaching for the radio for calls or doing one-handed MDT work). These tasks cannot be accomplished with the left hand. Driving could be done with both hands or with the left hand in a rested position, and this might help decrease discomfort in the left upper back.

According to our research, no significant differences were found in body part discomfort scores between day and night shifts. Although according to Violanti et al. [29] the risk of injury/accidents might be higher during the night shift (due to fatigue), our research suggests that discomfort levels do not differ between shifts. The comparisons were made between the same time points (i.e., between T1 day and T1 night). Discomfort scores were expected to be significantly higher during the night shift, because the officers would have already worked two 12-h shifts, and might not be fully recovering in between. However, this did not seem to be the case, although all of the same body parts that experienced significant increases in discomfort during the day shift also experienced the same symptoms during the night shift (with the addition of three extra body parts during the night shift).

4.3. Anthropometrics, duty belt and discomfort

There were interesting relationships between officer anthropometrics, the duty belt and lower back discomfort scores. Generally, the higher the body mass index, the more items on the duty belt. The same relationship was found for waist circumference. There was also a positive correlation between waist circumference and the number of items on the back of the duty belt. Perhaps the most interesting finding was the negative correlation between the number of items on the duty belt and lower back discomfort scores. This finding seems counterintuitive. The participants who seemed to have the highest discomfort scores were also the ones with the smallest waist circumference (generally females). No significant correlations were found between body mass index and lower back pain, or between waist circumference and lower back pain. High body mass index and waist circumference have been associated with an increase in lower back pain [35], but this relationship was not obvious from the results of this study. According to our descriptive statistic findings, females had a smaller mean body mass index and waist circumference than the males, but the females tended to have higher ratings of discomfort. Previous studies have reported increased pain sensitivity in females, which could have occurred here [12,35]. However, current equipment and in-vehicle design are androcentric, causing the females to adopt awkward postures to work in an environment that is not suited to their body anthropometrics. For example, as already mentioned, the current vehicle seat is designed for the 50th percentile male [9,21]; therefore, an ergonomic redesign of the vehicle seat is necessary to accommodate both genders. For a more immediate recommendation, a reduced duty belt and a modified configuration might help decrease discomfort in the lower back and the hips. According to Holmes et al. [12] a reduced duty belt (no items on the back) helps reduce perceived discomfort and may be more beneficial for males due to the anthropometric differences. Males had lower seat pan and backrest pressure scores whereas females did not depict these changes. Items should be placed on the front of the duty belt, and the smallest items, if necessary, could be placed on the back. The officers also had large pockets in their uniform pants and on their vest. Smaller, seldom used items could be placed in those pockets, reducing the amount of items around the waist. The biggest challenge would be repositioning the firearm, because it has to be readily accessible. This could be placed more towards the front of the duty belt when they are driving, providing relief from the pressure it causes on the hips (if needed, the firearm could be re-positioned to the side of the belt when they are standing). Another solution is a load-bearing vest. Filtness et al. [14] found that a load-bearing vest/belt combination appears to reduce some discomfort and helps distribute the weight load of the duty belt.

5. Study limitations

Although care was taken to try and limit the factors that could affect discomfort questionnaire responses (i.e., asking all officers to fill them out before their shift started), these are subjective ratings and only represent what the officers are feeling at that point in time. However, the questionnaires are still useful because they help paint a picture of where the major problems lie (i.e., body parts that are experiencing the most pain and discomfort, and the car seat features and occupational gear that they feel are making their symptoms worse). Another study limitation is that each shift is different and unique. Our findings therefore represent a snapshot of a whole spectrum of activities and incidents that can occur during a night shift and a day shift.

6. Conclusion

Based on the results from this study and the growing amount of research relating to police officer musculoskeletal disorders, the following conclusions can be drawn:

(1) significant increases in body discomfort were reported by police officers over the course of 12-h day and night shifts – although there were no statistical differences in the discomfort level between shifts, more areas of body discomfort were reported during the night shift;
(2) higher rates of discomfort were reported on the right side of the body, with the highest rates attributed to all regions of the back – the percentage of time sitting, coupled with the right-side dominant vehicle configuration of equipment and mobile display terminal, is a major contributor to this reporting;
(3) because of the high rates of musculoskeletal disorders associated with this occupation, change and further research is needed on this research topic – future research should focus on how the mobile display terminal, duty belt and seat design can be modified (either from modifying the inside of the vehicle or decreasing the time spent in the vehicle) in order to decrease the amount of pain and discomfort.

Disclosure statement

No potential conflict of interest was reported by the authors.

ORCID

Jack P. Callaghan http://orcid.org/0000-0002-8245-7084

References

[1] Callaghan JP, Coke SK, Beach TA. Gender- and time-varying postural and discomfort responses during prolonged driving. Occup Ergon. 2010;9(1):41–53.
[2] Chen J, Chang W, Chang W, et al. Occupational factors associated with low back pain in urban taxi drivers. Occup Med (Lond). 2005;55(7):535–540. doi:10.1093/occmed/kqi125
[3] De Carvalho DE, Callaghan JP. Influence of automobile seat lumbar support prominence on spine and pelvic postures: a radiological investigation. Appl Ergon. 2012;43(5):876–882. doi:10.1016/j.apergo.2011.12.007
[4] Gallais L, Griffin MJ. Low back pain in car drivers: a review of studies published 1975 to 2005. J Sound Vib. 2006;298(3):499–513. doi:10.1016/j.jsv.2006.06.012
[5] Gyi DE, Porter JM. Musculoskeletal problems and driving in police officers. Occup Med (Lond). 1998;48(3):153–160. doi:10.1093/occmed/48.3.153
[6] Kelsey JL, Hardy RJ. Driving of motor vehicles as a risk factor for acute herniated lumbar intervertebral disc. Am J Epidemiol. 1975;102(1):63–73.
[7] Wang B, Jin X, Cheng B, et al. Assessment of driver movements during prolonged driving using seat pressure measurements. Paper presented at the Proceedings of the Human Factors and Ergonomics Society. 2011;55:1568–1572. doi:10.1177/1071181311551327
[8] El Falou W, Duchêne J, Grabisch M, et al. Evaluation of driver discomfort during long-duration car driving. Appl Ergon. 2003;34:249–255. doi:10.1016/S0003-6870(03)00011-5
[9] Donnelly CJ, Callaghan JP, Durkin JL. The effect of an active lumbar system on the seating comfort of officers in police fleet vehicles. Int J Occup Saf Ergon. 2009;15(3):295–307. doi:10.1080/10803548.2009.11076809
[10] Kyung G, Nussbaum MA. Driver sitting comfort and discomfort (part II): relationships with and prediction from interface pressure. Int J Ind Ergon. 2008;38(5–6):526–538. doi:10.1016/j.ergon.2007.08.011
[11] McKinnon CD, Callaghan JP, Dickerson CR. Evaluation of the influence of mobile data terminal location on physical exposures during simulated police patrol activities. Appl Ergon. 2012;43(5):859–867. doi:10.1016/j.apergo.2011.12.009
[12] Holmes MWR, McKinnon CD, Dickerson CR, et al. The effects of police duty belt and seat design changes on lumbar spine posture, driver contact pressure and discomfort. Ergonomics. 2013;56(1):126–136. doi:10.1080/00140139.2012.739206
[13] Smith DR, Andrews DM, Wawrow PT. Development and evaluation of the automotive seating discomfort questionnaire (ASDQ). Int J Ind Ergon. 2006;36(2):141–149. doi:10.1016/j.ergon.2005.09.005
[14] Filtness AJ, Mitsopoulos-Rubens E, Rudin-Brown CM. Police officer in-vehicle discomfort: appointments carriage method and vehicle seat features. Appl Ergon. 2014;45:1247–1256. doi:10.1016/j.apergo.2014.03.002

[15] Mergl C. Predicting long term riding comfort in cars by contact forces between human and seat. Warrendale (PA): SAE International; 2005. (SAE technical paper No. 2005-01-2690).
[16] Gruevski KM, McKinnon CD, Dickerson CR, et al. The impact of mobile data terminal use on posture and low-back discomfort when combined with simulated prolonged driving in police cruisers. Int J Occup Saf Ergon. 2013;19(3):415–422. doi:10.1080/10803548.2013.11076998
[17] Stevenson JM, Weber CL, Smith JT, et al. A longitudinal study of the development of low back pain in an industrial population. Spine (Phila Pa 1976). 2001;26(12):1370–1377. doi:10.1097/00007632-200106150-00022
[18] Albert WJ, Everson D, Rae M, et al. Biomechanical and ergonomic assessment of urban transit operators. Work. 2014;47(1):33–44.
[19] Cardoso MM, Girouard MM, McKinnon CD, et al. Quantifying the postural demands of patrol officers: a field study. Int J Occup Saf Ergon. 2016; [13 p.]. doi:10.1080/10803548.2016.1249729
[20] Kolich M. Automobile seat comfort: occupant preference vs anthropometric accommodation. Appl Ergon. 2003;34:177–184.
[21] Carcone SM, Keir PJ. Effects of backrest design on biomechanics and comfort during seated work. Appl Ergon. 2007;38(6):755–764.
[22] Knox TH, Funk JP. The minimum clinically important difference in physician–assigned visual analog pain scores. Acad Emerg Med. 1996;3(2):142–146.
[23] McKinnon CD, Callaghan JP, Dickerson CR. Field quantification of physical exposures of police officers in vehicle operation. Int J Occup Saf Ergon. 2011;17(1):61–68.
[24] Lis AM, Black KM, Korn H, et al. Association between sitting and occupational LBP. Eur Spine J. 2007;16: 283–298.
[25] Ariens G, Bongers P, Douwes M, et al. Are neck flexion, neck rotation, and sitting at work risk factors for neck pain? Results of a prospective cohort study. Occup Environ Med. 2001;58(3):200–207.
[26] Jasen C, Bendix T. Spontaneous movements with various seated-workplace adjustments. Clin Biomech (Bristol, Avon). 1992;7(2):87–90.
[27] Dunk NM, Callaghan JP. Lumbar spine movement patterns during prolonged sitting differentiate low back pain developers from matched asymptomatic controls. Work. 2010;35:3–14.
[28] Knauth P, Hornberger S. Preventive and compensatory measures for shift workers. Occup Med (Lond). 2003;53(2):109–116.
[29] Violanti J, Fekedulegn D, Andrew M, et al. Shift work and the incidence of injury among police officers. Am J Ind Med. 2012;55(3):217–227.
[30] Folkard S, Tucker P. Shift work, safety and productivity. Occup Med (Lond). 2003;53(2):95–101.
[31] Moore-Ede M, Davis W, Sirois W. Advantages and disadvantages of twelve-hour shifts: a balanced perspective. Stoneham (MA): Circadian; 2010.
[32] Belenky G, Wesensten N, Thorne D, et al. Patterns of performance degradation and restoration during sleep restriction and subsequent recovery: a sleep dose-response study. J Sleep Res. 2003;12(1):1–12.
[33] Wagstaff A, Lie J. Shift and night work and long working hours – a systematic review of safety implications. Scand J Work Environ Health. 2011;37(3):173–185.
[34] Shiri R, Karppinen P, Leino-Arjas P, et al. The association between obesity and low back pain: a meta-analysis. Am J Epidemiol. 2010;171(2):135–154.
[35] Albert WJ, Bonneau J, Stevenson JM, et al. Back fitness and back health assessment considerations for the Canadian physical activity, fitness and lifestyle appraisal. Can J Appl Physiol. 2001;26(3):291–31.