Police officer in-vehicle discomfort:
appointments carriage method and vehicle seat features

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Abstract

Musculoskeletal pain is commonly reported by police officers. A potential cause of officer discomfort is a mismatch between vehicle seats and the method used for carrying appointments. Twenty-five police officers rated their discomfort while seated in: (1) a standard police vehicle seat, and (2) a vehicle seat custom-designed for police use. Discomfort was recorded in both seats while wearing police appointments on: (1) a traditional appointments belt, and (2) a load-bearing vest / belt combination (LBV). Sitting in the standard vehicle seat and carrying appointments on a traditional appointments belt were both associated with significantly elevated discomfort. Four vehicle seat features were most implicated as contributing to discomfort: back rest bolster prominence; lumbar region support; seat cushion width; and seat cushion bolster depth. Authorising the carriage of appointments using a LBV is a lower cost solution with potential to reduce officer discomfort. Furthermore, the introduction of custom-designed vehicle seats should be considered.

Key words: occupational injury, vehicle seat design, automotive seating discomfort questionnaire (ASDQ)

Highlights:

- Carrying appointments on a load bearing vest reduces police officer subjective in-vehicle discomfort
- Vehicle seat backrest bolsters, lumbar region and seat cushion affect discomfort of police officers
- Police vehicle purchasers are encouraged to seek seats encompassing high degrees of adjustability
1 Introduction

Lower back pain and/or discomfort is commonly reported by police officers (Trotter et al., 2009). Two aspects of police work have previously been implicated as causes of lower back pain: driving for long periods of time (Gyi and Porter, 1998), and the carriage of equipment (i.e., “appointments”) on a belt (Kumar and Narayan, 1999). As back pain is one of the leading causes of loss of productive work time (Stewart et al., 2003) any factors which could be linked to back pain within an occupational setting warrant research attention. Police vehicles are highly specialised and modified for police use through the addition of instrumentation and other devices; however, the seat is often overlooked, being no different than that of a normal passenger vehicle, despite the additional demands that are placed on it. One possible source of discomfort may be the interaction between appointments carriage method and vehicle seat design.

Traditional carriage of police appointments is on a dedicated belt worn around the waist. Police appointments include the firearm, spare magazine, handcuffs, capsicum spray, and portable radio, amongst others. In New South Wales (NSW), Australia, officers could choose to wear their appointments on a belt or a combination belt with load bearing vest (LBV), at the time this study was conducted. The current study considers the ‘Belt’ alone and LBV belt combination (henceforth referred to as ‘LBV’) carriage options. Both options can be seen in Figure 1.

< Insert Figure 1 here>

1.1 Measuring discomfort

‘Comfort’ as a concept is difficult to define. One way to consider comfort is as “the absence of discomfort”. Alternatively, ‘comfort’ may be considered as being “the opposite to discomfort” (Kolich, 2008). A further difficulty is that the measurement of ‘comfort’ is linked to aesthetic perception (Helander and Zhang, 1997), which may make it more difficult for end users to rate it in an unbiased manner. In consideration of vehicle seats, ‘discomfort’ appears to be of greater relevance than ‘comfort’, as the presence of any discomfort implies a less than ideal situation.

Comparison of subjective ‘discomfort’ is a common approach for investigating differences between subjective opinion of seats (e.g., Ahmed and Babski-Reeves, 2009; Donnelly et al., 2009). The relationship between seat features and discomfort is a complex one, with subjective measures not always being in agreement with more objective physical measures, such as interface pressure (Gyi and Porter, 1999). Nonetheless, as comfort / discomfort is a personal experience, there is significant value to using subjective measures as opposed to objective measures, such as muscle activation.
(Annett, 2002). As such, the subjective experience remains a key metric of vehicle seat discomfort assessment and the only way to measure an occupant’s personal experience.

Although there is a wealth of information investigating seat comfort/discomfort, occupational studies have traditionally focused on office workers. As seating comfort/discomfort is not uniform across environments, it is not possible to infer the outcomes of studies of non-vehicle based workplaces to vehicle based workplaces (Kyung et al., 2008). When considering a seat as a workplace any assessment of its comfort should take into consideration the requirements for the vehicle seat and the activities to be undertaken while occupying it (da Silva et al., 2012; Kolich, 2003). It has been suggested that a seat which is otherwise comfortable may be considered uncomfortable if it is not suitable for the activity demands of the occupant (da Silva et al., 2012).

Subjective discomfort can be measured in a structured manner by questionnaire. One discomfort assessment tool which has been demonstrated to be highly valid and reliable is the Automotive Seating Discomfort Questionnaire (ASDQ) (Smith et al., 2006). The ASDQ was developed systematically and subsequently tested to ensure that results are not influenced by gender and are sensitive to changes of physical seat components (Smith et al., 2006). The questionnaire is designed specifically to identify individual seat features which contribute to discomfort and does not require subject matter expertise to complete. Questions investigate four seat features: upholstery, cushion, back rest and lumbar support, and the sub-components of each feature. The ASDQ is designed to be administered while a vehicle is stationary, thereby allowing participants to identify any physical seat components contributing to their discomfort and to avoid any effect of vibration (Smith et al., 2006).

Vehicle seats pose a specific area of interest for seated comfort/discomfort; in addition to being functional, vehicle seats must also be designed for comfort. Therefore, it may be expected that even when driving is an occupational requirement (as it is for a taxi driver, for example) the majority of occupants would experience ‘no’ or only ‘slight’ discomfort (Daruis et al., 2008); although, repeated exposure to a mild but recognisable level of discomfort may contribute towards occupant musculoskeletal pain in the long term (Donnelly et al., 2009).

Occurrence of ‘extreme discomfort’ is unlikely with modern vehicle seats. Therefore, identifying seats or seat features ascribed a clinically significant degree of discomfort is just as, and perhaps even more, important than identifying statistically significant inter-seat differences (Donnelly et al., 2009). In this context, clinical significance is defined as the minimum discomfort rating corresponding to a clinically meaningful level of subjective discomfort. Donnelly et al., (2009) specify an ASDQ discomfort score of 30 mm or more (on a visual analogue scale, ranging from “0 mm”, no
discomfort, to “100 mm”, extreme discomfort) as being clinically significant. Donnelly et al. (2009) do not provide justification as to why a minimum score of 30 mm was defined as clinically significant. However, an investigation to determine what constitutes a clinically significant change in subjective pain, reports that a difference of at least 9 mm is necessary for clinical significance (Kelly, 1998). Additionally, the same study reports that a 20 mm change corresponds with a relatively large clinical effect, with no influence of age or gender (Kelly, 1998). By extension, it is reasonable to conclude that a discomfort level of at least 30 mm (or 3/10) is sufficiently large to signify clinical relevance.

1.2 Police officer in-vehicle discomfort
The ASDQ has been used previously with a police officer population. In a Canadian study, police officers completed the ASDQ at the beginning and end of each shift (Donnelly et al., 2009). Police officers reported experiencing discomfort due to the lumbar support, the seat width, seat firmness and seat cushion contour. The lower back was rated as an area of significant discomfort, in line with results of previous police officer research (e.g., Gyi and Porter, 1998). Following on from their survey, Donnelly et al., (2009) demonstrated that greater control over the adjustability of the seat lumbar area in combination with an in-built lower back massage system allowed the seat to be set up to minimize pressure on the appointments and, consequently, to reduce discomfort. However, installing in-built massage systems on police vehicle seats would be costly as well as potentially distracting to drivers.

Donnelly et al., (2009) assessed officer discomfort while officers used a belt to carry appointments. Appointments belts have been found to render seat back rests largely unusable and, consequently, to offer little or no support for those officers who wear belts (Kumar and Narayan, 1999). It is possible that alternative appointments carriage methods, such as a LBV, may reduce discomfort; however, no investigations of officer discomfort while wearing a LBV were identified in our literature search.

It is apparent from published research that police officers experience musculoskeletal discomfort while working and that vehicle travel and appointments carriage on the belt may be contributing factors. Thus, the interaction between appointments carriage method and police vehicle seat features has the potential to moderate this discomfort. Structured consultation was undertaken with police officers who are regularly exposed to driving while carrying appointments to assess discomfort specifically experienced due to vehicle seat features. Both “General Duties” and
“Highway Patrol” police officers spend a large proportion of their work shift seated in vehicles while wearing appointments (Trotter et al., 2009). Thus, participants in this study were drawn from both duty types. Nonetheless, their responses were considered separately in order not to blur any potential differences in reported discomfort between duty types. Discomfort experiences were recorded while officers wore appointments on: (1) a traditional appointments belt, and (2) a combination of a LBV and appointments belt, and while seated in: (1) ‘Standard’ and (2) ‘Custom’ vehicle seats.

2 Method

2.1 Design

A 2 x 2 repeated measures study design was utilised with two types of appointments carriage method (‘Belt’ and ‘LBV’) and two types of vehicle seats (‘Standard’ and ‘Custom’). Order of exposure was counterbalanced. The research was approved by the Monash University Human Research Ethics Committee.

2.2 Participants

Participants were 25 sworn police officers (four female) recruited from the NSW Police Force. All participants used a police vehicle as part of their usual work duties and worked in a metropolitan area. The majority of participants (92%) ranked either Constable or Senior Constable. Two officer duty types were represented: 14 General Duties officers (GDs) and 11 Highway Patrol (HwP) officers. Two officers in each group were female. In addition, two officers in each group were left-handed (all males). All other participants were right-handed.

2.3 Equipment

2.3.1 Appointments carriage

Two appointments carriage options were examined: ‘Belt’ and ‘LBV’. When on duty, officers are permitted to arrange their appointments to their personal preference, although within certain constraints: prescribed placement of the firearm worn in the hip holster of the belt over the dominant hip and the spare magazine over the other hip, and limits on what can be included in the LBV pockets given their form and size. In accordance with NSW Police Force operating requirements, the firearm and spare magazine are not carried on the LBV but on the belt. Therefore, in line with the applied nature of the study protocol and in order to reflect real work conditions, participants were asked to bring their own appointments and to set the position of each appointment to their
preference on each carriage method. All the belts and LBVs were those authorized for use in the NSW Police Force. An example set up is show in Figure 1. More recently, officers may also choose a combination belt, LBV and thigh holster, in this case the firearm may be carried either in a hip holster off the belt or in a thigh holster, however, this combination is not investigated in the current work.

2.3.2 Vehicle Seats

Three vehicle seats were used – a ‘Custom’-designed police vehicle seat (same for both duty types) and two police ‘Standard’ seats.

The ‘Custom’ vehicle seat (Figure 2 a) was developed specifically to be used in police vehicles. Its main characteristics include;

• Lower cushion bolster for easy entry;

• Cut-away bolster to assist comfort with laden appointments belt;

• Re-defined lumbar region to assist comfort with laden appointments belt; and

• Robust material selection in high wear areas.

The seat was developed by Futuris, designers and manufacturers of automotive interiors, in collaboration with the National Safety Agency in Australia. Throughout the study the ‘Custom’ seat was experienced in a Holden Commodore Omega, which is a popular, 4-door passenger sedan in Australia.

The ‘Standard’ seat was the stock seat of a vehicle model commonly used as a police vehicle by the NSW Police Force. In line with the applied nature of the investigation, the standard vehicle seats were selected to be ones which participants would regularly use in their normal work duties and were presented in the appropriate police vehicles. As participants represented two police duty types, two different ‘Standard’ seats were used. GD participants experienced the Hyundai iLoad seat (Figure 2 b). HwP participants experienced the Ford Falcon XR6 seat (Figure 2 c). The Ford Falcon XR6 “sport” style vehicle is most appropriate for the work under taken by HwP officers as it has enhanced acceleration and cornering capabilities. Vehicles used for highway patrol are those most suited to pursuit and urgent duty. The Ford Falcon XR6 has a “sporty” seat with prominent seat cushion and seat back bolsters. The Hyundai iLoad seat has a “van” seat with subtle seat cushion and seat back bolsters and, unlike the other two seats used, the iLoad offers no lumbar support adjustability. In essence, vehicles used for highway patrol are most suited to pursuits and urgent
duty, while the vehicles used for general duties are the least suited to pursuits and urgent duty. Thus, the seats in the highway patrol vehicles tend to be more “figure-hugging” and restrictive than those in the general duties vehicles. This comes about largely because of the more prominent bolsters. Approximate, non-technical measurements of certain vehicle seat components are given in Table 1.

<Insert Figure 2 here>

<Insert Table 1 here>

2.4 Structured questionnaires

2.4.1 Automotive Seating Discomfort Questionnaire (ASDQ)

The ASDQ is a comprehensive questionnaire designed to assess the effect of four seat features on musculoskeletal discomfort: upholstery, seat cushion, back rest and lumbar support (Smith et al., 2006). Participants rated the discomfort they experienced from each vehicle seat feature by its individual components using an adapted version of the ASDQ. Adaptation of the ASDQ was necessary because the original ASDQ is completed as a visual analogue scale. In the current study protocol it was desirable that participants remain in an emulated driving position whilst completing the questionnaire, in order that movement unrelated to driving (such as that required to complete a paper-based questionnaire) would not influence results. Consequently, use of a categorical, fixed-point scale was necessary to facilitate verbal response. Additional questions were included that pertained to the head restraint and seatbelt. In all cases, participants rated discomfort on an 11 point scale (0 = ‘no discomfort at all’ to 10 = ‘extremely strong discomfort’).

2.4.2 Overall discomfort rating

While seated in each vehicle seat using each appointments carriage method, participants were asked to rate their overall discomfort level on an 11 point scale (0 = ‘no discomfort at all’ to 10 = ‘extremely strong discomfort’). This single question scale provides participants overall opinion of their discomfort related to each experimental condition; and is the final question of the ADSQ.

2.4.3 Body region discomfort questionnaire

An adapted version of the Discomfort Rating Scale (DRS) used by Kyung et al., (2008) was completed following the ADSQ questions for each particular seat feature. Discomfort level was recorded for
seven body areas: neck, upper back, lower back, left hip, right hip, left thigh, right thigh, using an 11 point scale (0 = ‘no discomfort at all’ to 10 = ‘extremely strong discomfort’).

2.5 Procedure

Participants completed one test session lasting approximately 90 minutes. On arrival participants gave informed consent and completed a background questionnaire.

Wearing the first appointments carriage option participants entered vehicle one and adjusted the seat as they would do if they were working in that vehicle. For five minutes participants were seated in the vehicle seat with their seat belt fastened in a position emulating driving. At one minute intervals participants completed five reaching tasks characteristic of police work: turn on/off the warning lights and sirens, operate the radio, use the mobile data terminal, retrieve/return an item from the passenger foot well, and retrieve/return an item from the rear passenger compartment.

After five minutes, the adapted ADSQ and the body region discomfort questionnaire were completed. In all cases the questions were read aloud by an experimenter and participants responded verbally. This procedure allowed participants to remain in the emulated driving position. Consequently, as noted above, visual analogue scales were not used. The procedure was repeated in the second vehicle.

When the questionnaires had been completed in both vehicles the participant reset their appointments on the second carriage option and the in-vehicle procedure was repeated.

2.6 Data analysis

Results from the ASDQ and body region questionnaire are presented as means and standard deviations of discomfort ratings (out of 10). A repeated measures ANOVA compared appointments ‘Carriage’ method (2 levels: Belt vs. LBV) and vehicle ‘Seat’ type (2 levels: Custom vs. Standard). Due to the different vehicle seats used, analyses were completed separately for each duty type. An alpha level of .05 was used to determine statistical significance.

As expected (see section 1.1), discomfort ratings were generally low. To supplement statistically significant results, clinical significance was considered. Overall discomfort ratings equal to or greater than three were considered clinically significant in-line with Donnelly et al., (2009) and in relation to the findings of Kelly (1998). In our adapted scale, an average rating of three is equivalent to an average rating of 30 on the traditional scale. To establish which seat features contributed to overall discomfort ratings, it was also desirable to consider adapted ASDQ ratings equal to or greater than three as clinically significant. However, the results of discomfort from individual seat features are all
less than three. In order that practical differences between adapted ASDQ items would still be identified, ratings of two were considered as contributing towards discomfort. This allows for practical distinction between the seat features, while still representing a large enough difference (from zero) to detect a large clinical effect (Kelly, 1998). Clinically significant results are highlighted on figures where appropriate. In cases of clinical discomfort resulting from seat features, body region discomfort results were examined.

3 Results

3.1 Participant Characteristics

On average, HwP participants had been police officers for significantly longer (12.6 y compared with 5.9 y) and worked significantly shorter shifts (9.6 h compared with 11.7 h) than GD participants. Despite the shorter shift length, the average number of vehicle hours per shift did not differ significantly between the two duty types. Additionally, HwP officers had significantly larger average waist circumferences (103.2 cm compared with 91.8 cm). Full participant characteristics are given in Table 2.

The number of appointments carried by officers varied significantly by duty type and carriage method. A 2 x 2 ANOVA revealed a significant main effect of duty type. GDs (‘Belt’ = 13.0, ‘LBV’ = 12.3) wore significantly more appointments than HwP officers (‘Belt’ = 8.0, ‘LBV’ = 11.4) (F(1,21) = 15.17, p =.001).

3.2 Overall discomfort

Overall discomfort ratings are presented in Figure 3. Three scenarios resulted in clinically significant discomfort (average rating ≥ three): GDs in the ‘Standard’ seat using the ‘Belt’ and HwPs in the ‘Standard’ seat using both the ‘Belt’ and the ‘LBV’. Participants reported experiencing significantly more discomfort when seated in the ‘Standard’ vehicle seat compared with the ‘Custom’ seat. This was true both for GDs (F(1,13) = 28.24, p <.001) and HwP (F(1,10) = 0.74, p =.008). There was a significant main effect of appointments carriage method with the ‘Belt’ resulting in greater overall discomfort than the ‘LBV’. This was true for both GDs (F(1,13) = 5.64, p = .034) and HwP (F(1,10) = 12.20, p = .006).
3.3 Discomfort according to seat feature

3.3.1 General Duties

The results of the seat feature components of the adapted ASDQ for GD participants are presented in Figure 4. Participants reported significantly greater objection to the feel of the ‘Standard’ seat upholstery compared to the ‘Custom’ seat (\(F(1,13) = 6.5, p = .024\)). Discomfort produced by the backrest bolsters was significantly greater in the ‘Standard’ seat than the ‘Custom’ seat (\(F(1,13) = 5.23, p = .004\)). The greatest discomfort reported by GD participants was from the backrest bolsters in the ‘Standard’ vehicle while wearing the ‘Belt’.

Regardless of seat type, levels of discomfort associated with the lumbar support were greater when officers wore the ‘Belt’ compared with the ‘LBV’. In particular, discomfort due to the provision of support of the lumbar area (\(F(1,13) = 6.76, p = .022\)) and discomfort from the lumbar support pressure (\(F(1,13) = 5.89, p = .019\)) were significantly greater. Although these two components of the lumbar area were both associated with significantly higher discomfort when wearing the ‘Belt’ compared to ‘LBV’, only the discomfort from the lumbar support reached a clinically significant (average rating \(\geq\) two) level.

<Insert Figure 4 here>

3.3.2 Highway Patrol

The results of the adapted ASDQ among HwP officers are presented in Figure 5. Discomfort ratings related to the seat cushion width and seat cushion bolsters differed between seat types. Discomfort caused by the seat cushion width was significantly greater when participants were seated in the ‘Standard’ seat (\(F(1,10) = 8.42, p = .016\)) as was discomfort due to the seat cushion bolsters (\(F(1,10) = 20.60, p = .001\)). The seat cushion bolsters in the ‘Standard’ seat resulted in clinically significant (average rating \(\geq\) two) ratings of discomfort when officers were wearing both the ‘Belt’ and ‘LBV’.

Regardless of seat type, greater discomfort from the backrest bolsters was experienced when participants were wearing the ‘Belt’ compared to the ‘LBV’ (\(F(1,10) = 5.71, p = .038\)). The greatest discomfort experienced by the HwP participants related to the backrest bolsters of the ‘Standard’ seat when wearing the ‘Belt’.

<Insert Figure 5 here>
3.4 Body region discomfort for specific seat features

Body region discomfort results are presented in relation to the backrest and lumbar support seat features for GD, and to the backrest and seat cushion for HwP. These seat features were those that resulted in clinically significant (average rating ≥ two) levels of discomfort on the adapted ASDQ.

3.4.1 General Duties

Figure 6 shows the results from the body region discomfort questionnaire for the backrest and lumbar support features. Discomfort experienced in the lower back reached a clinically significant (average rating ≥ two) level while officers were wearing the ‘Belt’ in the ‘Standard’ vehicle for both seat features.

Significantly greater discomfort was experienced from the backrest when officers were seated in the ‘Standard’ compared with ‘Custom’ vehicle seat, for the lower back ($F(1,13) = 5.18, p = .040$), left hip ($F(1,13) = 15.80, p = .002$) and right hip ($F(1,13) = 7.22, p = .019$) regions. There was also a significant ‘Seat’ by ‘Appointments Carriage’ interaction for discomfort caused to both the left ($F(1,13) = 14.62, p = .002$) and right ($F(1,13) = 7.22, p = .037$) hip from the backrest.

The discomfort experienced from the lumbar support in the left hip was significantly greater when seated in the ‘Standard’ compared with the ‘Custom’ seat ($F(1,13) = 4.79, p = .047$). The lumbar support feature also affected discomfort in the lower back; this was significantly greater when officers were wearing the ‘Belt’ compared with the ‘LBV’ ($F(1,13) = 7.71, p = .016$).

<Insert Figure 6 here>

3.4.2 Highway Patrol

Figure 7 shows the results of the body region discomfort questionnaire for the backrest and seat cushion features for HwP participants.

Discomfort due to the backrest, experienced in the lower back and right hip, while wearing the ‘Belt’ reached a clinically significant (average rating ≥ two) level in both the ‘Standard’ and ‘Custom’ seat. Significantly greater discomfort due to the backrest was experienced in the left hip in the ‘Standard’ seat compared with the ‘Custom’ seat ($F(1,10) = 5.48, p = .042$). Significantly greater discomfort due to the backrest was experienced in the right hip when wearing the ‘Belt’ compared with the ‘LBV’ ($F(1,10) = 5.98, p = .035$).

Discomfort ratings related to the seat cushion did not reach clinical significance in any body region. However, significantly greater discomfort was experienced in the left hip ($F(1,10) = 5.61, p = .039$)
and right thigh \(F(1,10) = 10.63, p = .009\) from the seat cushion when officers were seated in the ‘Standard’ compared with the ‘Custom’ seat.

<Insert Figure 7 here>

4 Discussion

Prolonged vehicle travel and appointments carriage on the belt have previously been identified as potential sources of pain and discomfort for police officers (Donnelly et al., 2009; Gyi and Porter, 1998; Trotter et al., 2009). The current study was designed to quantify, in a structured manner, police officer discomfort caused by vehicle seat features, appointments carriage method, and their interaction. Twenty-five sworn officers from the NSW Police Force completed adapted versions of the ASDQ and body region discomfort questionnaire. Officers reported a significantly greater amount of discomfort when seated in the ‘Standard’ compared with the ‘Custom’ vehicle seat, and while carrying appointments on the ‘Belt’ compared to the ‘LBV’. The vehicle seat components which contributed most to the discomfort were the backrest bolsters, lumbar support, cushion bolsters and cushion width. The lower back and hips were the body areas most affected by discomfort.

Overall discomfort ratings confirm that officers experience discomfort in their traditional work environment (i.e., a ‘Standard’ vehicle seat and wearing appointments on a ‘Belt’); and that this discomfort can be alleviated by adjustments in vehicle seat design and appointments carriage method. Knowing that officers experience overall discomfort when they are seated in vehicles goes some way to explain the high prevalence of back pain reported by officers who drive regularly (Burton et al., 1996; Gyi and Porter, 1998). It is important to note that the average overall discomfort in all cases was higher than that rated with respect to any individual seat component on the adapted ADSQ. Therefore, it is likely that a combination of slight discomfort among a variety of different seat components weighs up to an overall discomfort rating that is higher than one for any individual cause.

Backrest bolsters are the vehicle seat component associated with the greatest discomfort, particularly when wearing the ‘Belt’ in a ‘Standard’ seat. The backrest bolsters in the ‘Standard’ GD seat were less prominent than those in the HwP ‘Standard’ seat. Nevertheless, the more subtle GD bolsters were still capable of causing discomfort for some GD officers. Backrest bolsters have previously been implicated as causing discomfort in a civilian population (Udo et al., 1997). Therefore, it is not surprising that the backrest bolsters are also a source of discomfort for officers,
who have the added requirement of carrying appointments. The main difference between the backrest bolsters of the ‘Custom’ and ‘Standard’ seats was the length, with bolsters not extending to the base of the ‘Custom’ seat. Subsequently, the backrest bolster of the ‘Custom’ seat was associated with significantly less discomfort for GD officers than their ‘Standard’ seat. However, shorter backrest bolsters may not be the solution to all backrest bolster-caused discomfort as HwP officers still experienced discomfort in the ‘Custom’ seat. Regardless, reduction of backrest bolster discomfort can still be achieved as HwP discomfort was reduced by wearing appointments on the ‘LBV’ rather than on the ‘Belt’. It is likely that the most effective way to achieve a reduction to officer discomfort is through a multi-method approach.

The bolsters of the seat cushion were also a significant source of discomfort: the ‘Custom’ seat was associated with reduced discomfort for the HwP officers. The ‘Custom’ seat has a wider seat cushion than either the ‘Standard’ seat, and the seat cushion bolsters do not extend rearward as far as is typical. Results for HwP officers suggest that seat width is a potential problem; however, this was not corroborated by results for GD officers. Two likely contributing factors to this discrepancy are, firstly, that the seat cushion bolsters of the GD ‘Standard’ seat are less prominent that the ‘Standard’ HwP seat, and therefore may interact less with appointments. Secondly, the HwP officers had a significantly larger average waist size than GD officers. The failure of seat cushion bolsters to accommodate larger occupants has been recognised as a problem in a civilian population (Reed et al., 1994). Therefore, the larger HwP officers may be more likely to experience discomfort due to seat cushion bolsters than the GD officers.

The third seat component identified as causing discomfort was the lumbar support region (GD officers only). This discomfort for GD officers could be reduced by moving appointments from a ‘Belt’ to a ‘LBV’. One potential factor influencing this difference between GD and HwP officers may be lumbar support adjustability, which has previously been identified as a problem for ‘Belt’-wearing police officers (Kumar and Narayan, 1999). The HwP ‘Standard’ seat had an adjustable lumbar support and the GD ‘Standard’ seat did not. A further, potential influencing factor is that the GD officers carried more appointments, on average, than HwP officers, particularly when wearing a belt. This additional load around the waist may have interacted with the vehicle seat lumbar region to increase discomfort. The variation of results suggests that further research into the lumbar region of vehicle seats could be beneficial.

Finally, the upholstery was reported as a source of discomfort for GD officers. In this case, the GD officers preferred the upholstery of the ‘Custom’ seat which was leather look, compared to the
‘Standard’ seat which had woven fabric. The difference in preference ratings was statistically significant, however, the difference was very small, suggesting that, although officers have a preference, upholstery is not of major importance for discomfort. This contrasts to the opinions of vehicle seating experts, whereby pressure from upholstery onto appointments and breathability qualities of upholstery have been reported as important (Molenbroek et al., 2009). Consequently, further research into the contribution of upholstery to occupant safety and discomfort may be warranted.

Lower back pain is one of the leading causes of lost productive work time (Stewart et al., 2003). As such, it would be beneficial for police forces around the world to minimise the discomfort experienced within this body area. The current study considered body region discomfort in relation to discomfort-causing seat features: backrest (GD and HwP), lumbar support (GDs) and seat cushion width (HwP). In line with previous research, discomfort was most frequently reported in the lower back (Gyi and Porter, 1998; Kumar and Narayan, 1999; Trotter et al., 2009). It is concerning that the “traditional” police vehicle and appointments carriage methods (‘Standard’ seat and ‘Belt’) resulted in clinically significant ratings of lower back discomfort associated with the backrest for both GDs and HWP. Results suggest that a potential solution is to provide custom-designed seats for police vehicles. The ‘Custom’ seat in the current study reduced lower back discomfort due to both the backrest (GD and HwP) and to lumbar support (GD).

The hip region was also sensitive to discomfort from vehicle seat features. For right-hand dominant officers the firearm is located above the right hip and the spare magazine on the left hip. Greater hip discomfort from the backrest (GD and HwP), lumbar support (GD) and seat cushion (HwP) was experienced by officers in their ‘Standard’ seat compared to the ‘Custom’ seat. It is likely that the shorter-than-usual backrest bolsters of the ‘Custom’ seat allowed space to accommodate the firearm and magazine, thereby putting less pressure on the hips. Altering appointments carriage method also has potential for reducing hip discomfort as, for the HwP officers, right hip discomfort was rated lower when carrying appointments on the ‘LBV’ compared with the ‘Belt’.

It is important to draw attention to the large degree of individual differences in reported discomfort. The large standard deviations observed demonstrate that symptoms and sources of discomfort in one person may not be the same for another. This highlights the difficulty of a “one size fits all” approach to reducing seating-related discomfort. In order for all officers to be accommodated, with their appointments, and have sufficient spare space to complete all work activities, a high degree of seat feature adjustability is needed. Allowing freedom of movement is particularly important for
reducing discomfort, as shifting the pelvis allows drivers to make postural adjustments, which change the distribution of pressure. These subtle movements delay discomfort onset (Reed et al., 1994). The current study suggests that wide parameters of adjustability for the backrest, lumbar support and seat cushion bolsters, would result in the greatest potential benefits.

A potential limitation of the current study is that it was not possible to ‘blind’ officers to which seat and appointments carriage option they were using. It is therefore possible that some bias due to aesthetics or prior expectation may have occurred. Also, each seat was presented in a different vehicle. It was important for participants to be exposed to each seat in their intended context of use (in a vehicle), and participants were instructed to consider only the seat when making discomfort ratings. However, it is possible that specific features of a vehicle or past driving experience of that type of vehicle may have influenced officers’ discomfort ratings (Cascioli et al., 2011; Donati and Patel, 1999; Groenesteijn et al., 2009). In line with the applied nature of the study participants used their own appointments and set up each carriage method to their own preference. Consequently, the number of appointments was not consistent across participants or conditions. Finally, participants were only exposed to the vehicle seats for five minutes. During this time the vehicle was stationary. The restricted time was necessary because of a short time window in which police officers were able to participate. While a minimum twenty minutes seating time would have been preferable (Reed & Massie, 1996), the repeated-measures design was considered important and therefore exposure was restricted to five minutes in order that each vehicle and appointments carriage method combination could be experienced. This protocol facilitated the repeated-measures design being completed in a timely fashion; however, longer exposure periods would have been more representative of vehicle-based police work.

The results of the current research are important as they confirm that police officers experience discomfort under traditional work conditions ('Belt’ and ‘Standard’ vehicle seat). The backrest bolsters, seat cushion bolsters and lumbar support were highlighted as the vehicle seat components which are most likely to cause discomfort, with the lower back and hips being implicated the most. The simple change of carrying appointments on a ‘LBV’, rather than on a traditional appointments ‘Belt’, appears to alleviate some discomfort. Furthermore, customising police vehicle seats, making them wider and reducing the length of backrest and seat cushion bolsters also reduced officer discomfort. However, ‘LBVs’ and ‘Custom’ seats do not eliminate all discomfort. Further benefits could likely be achieved by widening the range of adjustable vehicle seat features and in particular including adjustable back rest and seat cushion bolsters. Purchasers of police vehicles are encouraged to seek vehicles equipped with seats encompassing seat features with a high degree of
adjustability, thus ensuring the best chance of meeting the broadest range of officers’ requirements. Practical application of these findings should be factored within considerations for crashworthiness.
5 Acknowledgements
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6 References


**Figures**

**Figure 1:** Appointments carriage options, ‘Belt’ only (left), ‘LBV’ (with belt) (right)

**Figure 2:** Vehicle seats. (a) ‘Custom’, (b) ‘Standard’ for General Duties (c) ‘Standard’ for Highway Patrol
Figure 3: Overall discomfort rating by vehicle seat type and appointments carriage method. General duties on the right, Highway patrol on the left. Error bars represent standard deviation.

~ denotes clinical significance (average rating of ≥3 out of 10)
Figure 4: Adapted ASDQ results for General Duties officers by vehicle seat type and appointments carriage method. Error bars represent standard deviation, ~ denotes clinical significance (average rating of ≥ 2 out of 10)
Figure 5: Adapted ASDQ results for Highway patrol officers by vehicle seat type and appointments carriage method. Error bars represent standard deviation, ~ denotes clinical significance (average rating of ≥ 2 out of 10)
Figure 6: Body region discomfort results for General Duties officers by vehicle seat type and appointments carriage method. Error bars represent standard deviation, ~ denotes clinical significance (average rating of ≥ 2 out of 10)
Figure 7: Body region discomfort results for Highway Patrol officers by vehicle seat type and appointments carriage method. Error bars represent standard deviation, ~ denotes clinical significance (average rating of ≥ 2 out of 10)
### Tables

<table>
<thead>
<tr>
<th>Seat type</th>
<th>Custom seat</th>
<th>Standard GD seat</th>
<th>Standard HwP seat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seat Cushion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Width including bolsters:</td>
<td>51.5 cm</td>
<td>54.0 cm</td>
<td>51.0 cm</td>
</tr>
<tr>
<td>Width excluding bolsters:</td>
<td>33.0 cm</td>
<td>31.0 cm</td>
<td>34.0 cm</td>
</tr>
<tr>
<td>Bolsters:</td>
<td>Prominent</td>
<td>Not prominent</td>
<td>Prominent</td>
</tr>
<tr>
<td>Do not extend to the back of the seat cushion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Backrest</td>
<td>Length from seat base to top of seat (not including head restraint)</td>
<td>72 cm</td>
<td>73 cm</td>
</tr>
<tr>
<td>Width including bolsters:</td>
<td>53.0 cm</td>
<td>51.0 cm</td>
<td>54.0 cm</td>
</tr>
<tr>
<td>Width excluding bolsters:</td>
<td>29.0 cm</td>
<td>28.0 cm</td>
<td>32.0 cm</td>
</tr>
<tr>
<td>Bolsters:</td>
<td>Prominent,</td>
<td>Not prominent</td>
<td>Prominent</td>
</tr>
<tr>
<td>Do not extend to the base of the backrest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lumbar support</td>
<td>Adjustable</td>
<td>minimal, not adjustable</td>
<td>adjustable</td>
</tr>
</tbody>
</table>

Table 1: Non-technical vehicle seat description and approximate dimensions (Note. All measurements were taken using a standard measuring tape)

<table>
<thead>
<tr>
<th>General duties Mean (SD)</th>
<th>Highway patrol Mean (SD)</th>
<th>t value (degrees of freedom)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age 33.4 (8.7)</td>
<td>37.7 (6.9)</td>
<td>1.36 (23)</td>
<td>.187</td>
</tr>
<tr>
<td>Years of service (years) 5.9 (7.2)</td>
<td>12.6 (7.4)</td>
<td>2.29 (23)</td>
<td>.032*</td>
</tr>
<tr>
<td>Shift length (hours) 11.7 (0.7)</td>
<td>9.6 (1.5)</td>
<td>4.75 (23)</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td>Hours in vehicle per shift 7.7 (2.2)</td>
<td>7.3 (1.9)</td>
<td>0.45 (23)</td>
<td>.650</td>
</tr>
<tr>
<td>Height (cm) 178.8 (6.4)</td>
<td>180.5 (9.3)</td>
<td>0.53 (23)</td>
<td>.600</td>
</tr>
<tr>
<td>Weight (kg) 87.0 (8.1)</td>
<td>97.8 (22.7)</td>
<td>1.66 (23)</td>
<td>.111</td>
</tr>
<tr>
<td>Body Mass Index (BMI) 27.3 (3.0)</td>
<td>29.8 (4.7)</td>
<td>1.60 (23)</td>
<td>.122</td>
</tr>
<tr>
<td>Waist circumference (cm) 91.8 (9.4)</td>
<td>103.2 (12.6)</td>
<td>2.56 (23)</td>
<td>.024*</td>
</tr>
</tbody>
</table>

Table 2: Participant characteristics by duty type. Standard deviation (SD) shown in parentheses.

* denotes statistical significance at the 0.05 level