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An Investigation Into Vehicles, Duty Belts and Boots

by

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Executive Summary

In the current contract, the three factors identified for their possible association with low back pain in RCMP force were investigated with a view to discerning their possible role and proposing strategies to minimize their impact. These factors were car seats, duty belts, and foot wear.

Four makes of vehicles which are currently used by RCMP (Suburban, Crown Victoria, Lumina and Caprice) were studied. Other than Suburban, all other makes and models had significant constraints which necessitated considerable postural stress for RCMP constables during ingress and egress. Furthermore, they exposed the constables to low frequency vibration (2-3Hz) which are reported to be significantly injurious. The backrests of the seats were largely unusable due to the distribution of equipment on the duty belts. Recommendations have been made for the use of a gel cushion, adjustable seat and back support to eliminate some of these problems.

For investigation on duty belts and boots, three male and three female constables were studied in the Ergonomics Research Laboratory of the University of Alberta. Within each gender, a small, a medium, and a large sized constable was tested. The testing involved measurement of effects of boots and duty belt on posture and flexibility of the constables. The biomechanical loads on the constable's spine were also determined. Though there was a small effect of wearing boots on the posture and biomechanical load on spine, it was marginal. The duty belt did not have any significant effect on the flexibility and range of motion of the officers. However, wearing of the duty belt did increase the resting metabolic rate in standing as well as sitting postures due to the weight of the equipment carried on it. It was suggested that this drain in metabolic cost could tire constables by the end of the day and predispose them to low-back pain precipitation. The boots were found to have a reasonable grip on many of the surfaces tested but were very slippery on ice.

Subsequent to the study, two sets of recommendations have been made- one set to implement immediately and the other to develop desirable features to incorporate in near future.

Recommendations for immediate implementation:

1. Provide gel cushions for the seat pan of the patrol cars.
2. Mount handles for hand support on interior door opening to reduce twisting.
3. Provide ingress and egress training to minimize twisting stress.
4. Move the prisoner partition backwards to allow adequate leg room for the officers.
5. Ensure that the head rests are appropriately deployed in police vehicles at all times.
6. There should be a redistribution of the equipment carried on the belt to other parts of the body to allow officers to utilize back support of the car seats.
7. The soles and the heels of RCMP boots should be made of dual texture, dual density impregnated composite material to reduce slipping.
6. Officers should be allowed postural brakes by carefully designed job rotation.
9. Officers should be encouraged to use the back rests of their car seats while in the vehicle.
10. Officers should be instructed not to assume foward leaning posture for driving their vehicles.
11. A back safety program should be included in initial training of the RCMP cadets and periodical refreshers should be provided following joining the force.
12. A life style education for officers should be developed with standards to be met.

Recommendations for consideration in near future:

1. Back rest of police vehicles should be redesigned with police force, their uniform, and policing function in mind.
2. A swivelling and locking seat pan should be designed to incorporate in seats to permit rotation free ingress and egress.
3. Install a computer bracket to eliminate trunk twisting of officers and allow them to function in their cars with computer.
4. The heels of the boots should be provided with heel spikes to reduce slipperiness on icy surfaces.

Résumé

Dans le cadre du contrat actuel, nous avons étudié le lien possible entre les trois facteurs mentionnés (siege d'auto, ceinturon de service et chaussures) et les douleurs lombaires basses éprouvées par les membres de la Gendarmerie. Nous voulions ainsi determiner le rôle que joue ces facteurs et trouver des moyens d'en atténuer les effets.

Notre etude a porté sur quatre modèles de vehicules utilisés à la GRC (Suburban, Crown Victoria, Lumina et Caprice). A l'exception du Suburban, tous les vehicules imposent de telles contraintes que les membres subissent un stress postural considerable lorsqu'ils y entrent ou qu'ils en sortent. En outre, les membres sont exposes à une vibration à basse fréquence (2 à 3 Hz) qui aurait un effet néfaste important. Il est pratiquement impossible d'ajuster convenablement les dossiers étant donné la position des accessoires sur le ceinturon. Ainsi, pour éliminer certains de ces problèmes, nous avons recommande l'emploi d'un coussin de gel, d'un siege réglable et d'un coussin lombaire.

En ce qui a trait au ceinturon de service et aux bottes, nous avons mené une etude auprès de six gendarmes, trois femmes et trois hommes, au laboratoire de recherche en ergonomie de l'Université de l'Alberta. L'échantillon était compose d'un gendarme de petite taille, d'un gendarme de taille moyenne et d'un gendarme de grande taille pour chacun des deux sexes. Nous avons mesuré les effets des bottes et du ceinturon sur la posture et la souplesse des membres, puis determine quelles étaient les charges biomecaniques sur leur colonne vertébrale. Bien que reel, l'effet des bottes sur la posture et la charge biomecanique a été jugé negligeable, et il en a été de même pour celui du ceinturon sur la souplesse et la liberté de mouvement. Le port du ceinturon augmente toutefois le rythme metabolique au repos des membres, qu'ils soient debout ou assis, en raison du poids des accessoires qui y sont fixes. Cette dépense d'énergie supplementaire pourrait causer de la fatigue en fin de journée et contribuer à la predisposition aux douleurs lombaires basses. Sur de nombreuses surfaces, les bottes ont une adherence suffisante, mais sur la glace, elles demeurent très glissantes.

Deux series de recommandations ont été formulées. La premiere doit être mise en oeuvre immediatement et la seconde, qui concerne la conception des caracteristiques voulues, le sera prochainement.

Recommandations à mettre en oeuvre immédiatement :

1. Installer des coussins de gel sur les sieges des autos-patrouilles.
2. Installer des appuie-bras à l'interieur des portieres pour reduire au minimum les torsions du corps.
3. Montrer aux membres comment monter à bord du vehicule et en descendre de façon à reduire au minimum le stress dû aux torsions du corps.
4. Reculer l'écran de protection contre les prisonniers pour donner aux policiers suffisamment d'espace pour les jambes.
5. Veiller à ce que les appuie-tête soient dans la bonne position en tout temps.
6. Répartir sur d'autres parties du corps le materiel transporté sur la ceinture de service de façon à permettre aux policiers de bien s'appuyer le dos sur le siege de l'auto-patrouille.
7. Munir les bottes des policiers de semelles et de talons faits de matériau composite imprégné à texture et densité mixtes pour reduire les risques de glisser.
8. Permettre aux policiers de se reposer le dos en planifiant soigneusement la rotation des tâches.
9. Encourager les policiers à utiliser l'appuie-dos du siege de l'auto-patrouille.
10. Dire aux policiers d'éviter de conduire en se penchant vers l'avant.
11. Intégrer à la formation des cadets de la GRC un volet sur la prevention des maux de dos et donner des cours de recyclage après qu'ils sont devenus membres de la Gendarmerie.
12. Élaborer un programme d'éducation sur le mode de vie, qui comprend des normes à suivre.

Recommandations à envisager dans un proche avenir :

1. Concevoir les appuie-dos des autos-patrouilles en tenant compte de l'uniforme et du travail policier.
2. Concevoir un siege pivotant muni d'un dispositif de blocage qui permet aux policiers de monter à bord du vehicule ou d'en descendre sans avoir à faire de torsions du corps.
3. Installer l'ordinateur sur un support pour permettre aux policiers de l'utiliser sans avoir à faire de torsions du corps.
4. Munir les talons des bottes de crampons pour reduire les risques de glisser sur les surfaces glacées.

Introduction:

a) Job Profile

Law enforcement, maintenance of peace and order are essential to all societies. For this reason, alljurisdictions have their own police force with unique requirements, and also for this reason, policing is a complex occupation with a wide variety of tasks. Bonneau in Trottier and Brown (1,994) characterized that police work required physical abilities that enable peace officers to run, chase, grapple, tackle, forcibly restrain, and handcuff a suspect. In addition, they stated that peace officers may be required to exercise a high level of discriminatory judgement in assessing a variety of situations, ranging from discovery of a possible crime in progress to mediation of domestic disputes, or even the negotiation for release of hostages. While the responsibilities of a police officer may be varied, he/she has to stay in a state of physical readiness at all times. There may always be potential for peace officers to use necessary force, thus making the physical fitness and capability absolutely essential for doing their job. Shear appearance of physical strength and capability may serve as a deterrent preventing some of the potential problems. It is, therefore, critical that the peace officers be physically fit and capable, and they must also be seen as such. Lack of these basic traits may even endanger public, property, colleagues, and society safety in general. Trottier and Brown (1994) state, “the peace officer who is charged with the protection of public safety must not suffer a condition that carries an increased risk of sudden incapacitation. Such a circumstance could lead to an obvious danger to the public if, for example, the peace officer were to lose consciousness while in the midst of a high speed chase. Less obvious, but equally important, is the risk that the peace officer would be unable to complete a task necessary for the safety of the public such as restraining a dangerous criminal”.

McGinnis and Fine (1994) inTrottierand Brown have broken down the job of a general duty constable into fourteen (14) different jobs with ninety-six (96) individual tasks (Table 1.

Table 1.

		No. of Tasks
1.0	Problem Identification and Resolution	7
2.0	Patrol: Attend Calls, Apprehend Suspects	14
3.0	Maintain Order: Deter, Defuse Problems	6
4.0	Protect Public Safety and Security	8
5.0	Provide General Assistance to the Public	3
6.0	Conduct Investigations	4
7.0	Enhance Highway Safety	14
8.0	Conduct Traffic Accident Investigations	6
9.0	Provide Air Travel Related Security	5
10.0	Prepare and Complete Paperwork	11

11 .0	Assemble Evidence: Testify in Court	6
12.0	Community Relations/Community Education Promotion of RCMP Image	5
13.0	Assist RCMP Administration and Other Agencies	6
14.0	Maintain Equipment	1
TOTAL NO. OF TASKS		96

A review of the list indicates that in ten out of the fourteen (14) jobs, the peace officer may have to rely on physical capabilities in addition to other attributes. A comprehensive review of all ninety-six (96) tasks revealed that at least forty-six (46) tasks were heavily physical. There are many other tasks where excellent physical condition may not be absolutely essential but is highly desirable. Based on the job requirements, the RCMP has adopted a physical standard for entry into the Force. These standards are tested using the Physical Ability Requirement Evaluation (PARE) test. This test was developed in consultation with police officers and is meant to be a test of occupational fitness based on a job analysis of the Force's duties after the work of Mr. Doug Farenholtz (cited by Trottier and Brown, 1994). It tests physical abilities such as the ability to walk, run, jump, vault, climb, rapidly change direction, lift, carry, pull and push. Remarkable similarities between this test and others performed in North America suggests that policing may be similar across the continent in spite of regional 'differences. These same activities are employed in policing to different extents in each of the five categories of policing, namely 1) municipal policing, 2) rural policing, 3) airport policing, 4) highway patrol, and 5) rural policing of aboriginal populations. None of these activities can be performed by a peace officer if he/she is suffering from disabling back pain and/or injury. Injury or pain of the back results in an inability of the individual to use any of one's limbs as force generated during every activity passes through the low back causing an exacerbation of pain. Thus such health problems may impair the officers and prevent them from doing their jobs.

b) Back Health Profile

Occurrence of low-back pain and injury is common in general population (Papageorgiou et al. 1995). In fact, it has been estimated that up to eighty percent (80%) of people would suffer low-back pain during their working life (Kelsey and White 1980). Papageorgiou et al. (1995) in their study of the general population of the UK reported that, for a one month period, the prevalence rate of low-back pain was 39% (35% in males, 42% in females). In a study of the Royal Canadian Mounted Police, Brown et al. (1997) surveyed a random sample of 1,000 members of the Force. With a high response rate of 80% they found that the prevalence of chronic or recurring low-back pain since joining the Force was 54.9%. However, after corrections for other factors, a one year prevalence rate of 41.8% emerged. This prevalence rate is not very different from that of the general population (Papageorgiou et al., 1995; di Girolamo, 1995; Walsh et al., 1996; Masset and Malchaire, 1994; Rotgoltz et al., 1992; and Biering-Sorensen 1989).

According to some authors physical fitness and activities are important measures for prevention of back injuries (Cady et al., 1979; Manniche et al., 1991; Mallet et al., 1991; Toroptsova et al., 1995; and others). Others have reported no role of such variables (Battie et al. 1989). Thus, while the low back pain incidences in RCMP officers are not higher than general public, there is little reason to be content or complacent. In fact, an informal review of sick days in the RCMP in the Edmonton region revealed an absence of 4,823.2 days by the members due to back related problems over a period of three years (1994-97)(Tworek1997). This lost time translates to $341,000 per year on an average. The nationwide cost of lost time in the RCMP is $1.2 million with an additiional $1.2 million as indirect cost (Brown 1997 - personal communication).

A consistent occurrence of low-back pain/injury among RCMP officers is not unique. Many other forces have reported similar experience with life time prevalence ranging between 33% to 75% (Ovall,1995; Finkelstein, 1995; Burton et al., 1996). The occurrence of low back pain among people who are subjected to vehicular vibration during significant part of their work day has been reported by many authors (Kelsey, 1975; Kelsey and Hardy, 1975; Troup, 1978; Kelsey et al., 1984; Bongers et al., 1990. Burdorf and Zordervan, 1990; Anderson, 1992; Boshuizan et al., 1992 and others). A significant increase in the prevalence of low back pain among police officers who drive for a significant portion of their work day has been reported by Ovall(1995). Similarly, Burton et al., (1996) have reported that the officers who wear body armourweighing 8.5 kg had an additional hazard of approximately 8%. In their survey of RCMP officers, Brown et al. (1997) reported that the mismatch between Force members and the car seats on one hand and fully equipped duty belts on the other hand were important contributory factors to low back pain. The members also suspected that their boots may have something to do with increasing the probability of precipitation of back injury. Once the injury has precipitated, in most cases recurrence is common (Troup et al. 1981; Biering-Sorensen et al., 1989; Clinical Standards Advisory Group, 1994; Toraptsova et al., 1995; Kumar, 1996 and others).

c) Objectives

i) Global objective

The overall objectives of this investigation were two fold:

1. To conduct an ergonomic analysis of the identified factors which have been associated with low-back pain among RCMP officers quantitatively.

2. To recommend measures for reducing their impact and controlling back injuries to the RCMP officers.

ii) Specific objectives

Part I. Police cars

1. To look at the seat and cab characteristics and their adaptation to the job.

2. To measure the relevant aspects of the cab interior of all car makes and models which are used by RCMP.

3. To determine the adjustability of the cab interior to suit the Force members.

4. To measure the vibration characteristics of the makes and models of the cars used by the Force.

5. To measure vibration on the duty belt of the officers to determine vibration exposure to the low back of the officers.

Part II. Duty belts

1. To determine the biomechanical effect of wearing duty belts in terms of restriction of motion, if any.

2. To determine any change in posture due to wearing duty belt.

3. To determine the duty belts pressure on the body.

4. To determine the metabolic cost of wearing duty belt loaded with all equipment required to be carried by police officers.

Part III. Footwear

1. To determine the effects of the boots on the posture and stance of the officers.

2. To determine the coefficient of friction between the RCMP footwear and wooden surface, linoleum, gravel, dry concrete, ice and wet concrete.

Materials and Methods:

Part I. Car seats and Cab Interior

Equipment and Devices

Cars

1996 models of Chevrolet Lumina, Caprice, Ford Crown Victoria and GMC Suburban were made available for inspection and measurement in the RCMP garage in Edmonton. These are the only vehicles used by RCMP in policing across the country.

Measuring Devices

Anthropological instruments were used to measure the dimensions of the cab interface components for the officers. The layout was recorded photographically using a 35 mm camera.

The vibrational characteristics of the vehicle and the vibrational exposure to the constables were measured using an uniaxial accelerometer with frequency response of O-30 Hz. The signals of the accelerometer were fed to a portable FM instrumentation tape recorder with internal charged battery (Teat-R71).

Sample

Three constables on duty were observed and photographed for their ingress and egress to and from the car and their position within the cab. Similarly the vibrational characteristic measurements were made by mounting the uniaxial accelerometer initially on the rigid part of the seat while the vehicle was idling and then cruising different terrains. In the second half of the measurement the accelerometer was mounted on the officer's belt and the procedure repeated. Such measurements were made only on Caprice and Crown Victoria.

Part II. Duty Belts and Boots

Equipment and Devices

Weighing and measuring machines were used for measuring and weighing officers as well as weighing the belts and boots.

Fully equipped duty belts of six police officers were used for the study. These belts had baton, hand gun, two sets of bullet magazines, radio, hand cuffs and pepper spray on them. One of the pair of boots from each of the six participating officers was used to determine their coefficient of friction on wooden surface, linoleum, gravel, dry concrete, ice and wet concrete.

The subjects were applied spherical photo-markers on preselected landmarks. The photograph of subjects in needed postures was taken using a still 35 mm camera. The processed pictures were scanned by the scanmaker 1850colour slide scanner and fed to a Pentium computer to print the pictures and calculate the desired angles.

Sample

Since the RCMP has male and female officers who are of different sizes, three male and three female officers were chosen from the Force to represent the total spectrum. From each gender, a small, a medium and a large officer were recruited. Their demographic characteristics are presented in Table 2.

Table 2. Anthropometric characteristics of RCMP Officers

Gender	Size	Height cm	Weight kg	BMI	Age yrs	Boot wt kg	Belt wt kg	Belt press. mm Hg..
Male	Small	177	83.8	28.7	42	2.05	5.0	22
	Medium	181.5	93	28.5	42	2	4.9	20
	Large	181.5	132.3	40.6	37	2.2	5.3	30
Female	Small	165.5	66	24.3	31	1.8	5.3	20
	Medium	169.7	69.3	24.3	32	2	4.8	15
	Large	183	98.6	29.5	40	1.8	4.4	12

Procedure

Upon arrival of informed and consenting police officers, they were fully apprised of objectives, total scope and the procedures of the experiment and given the opportunity to ask any questions and seek clarification. These informed officers were then weighed and measured in their full uniform. They were then asked to remove their boots, belts and uniform shirt leaving their underwear on. Spherical photo markers were placed level with their shoulder joints bilaterally, C_7 spinous precess, lumbo-sacral disc, right hip joint, right knee joint centre, right lateral malleolus, right elbow joint and right wrist. Such prepared subjects were asked to stand upright with their right side to the camera. A profile picture was taken for reference. They were then asked to fully flex their torso while keeping their knees straight, and subsequently hyperextend. In each of these postures another set of photographs were taken. Finally, they were asked to turn to their left by 90” showing their backs to the camera. A picture of this standard posture was taken. As well, their left and right extreme lateral flexions were recorded. The same sequence of photographs were repeated with the officers wearing their boots (but not their belts), and then boots and belts both.

Subsequent to the above described posture and flexibility test, the officers were asked to take off their belts. These subjects were fitted with Polar heart rate monitor, a face mask with one-way valve and air hose feeding the Oxylog. The Oxylog was tied to the constable's waist by means of a belt. These subjects were then asked to stand at ease without doing anything for a period of five minutes. Following this five minute period, they were asked to sit down on a chair provided to them for a period of five minutes. At the conclusion of this period, the constables put on their duty belts and stood still and sat still for five minutes. During each of these four 5 minute periods a continuous on-line monitoring of heart rate, oxygen uptake, and ventilation volume was done using a Metrabyte DAS 20 A to D card and a 486 microcomputer.

At the completion of the above monitoring session the officers were asked to take off their boots which were then tested for their traction on six different surfaces. For this test one of the boots (right) was loaded with a pop bottle filled with lead shots to weigh 4.4 kg. The loaded boot's coefficient of friction was tested on the following six surfaces in the order of their appearance.

1. Wooden floor (dry)
2. Linoleum floor (dry)
3. Gravelly surface (dry)
4. Dry concrete
5. Icy surface
6. Wet concrete

After the testing, the officers, dressed in their full uniforms, were interviewed with structured questions.

Interview

The interviews were conducted such that structured questions were asked in four different categories: a) General, b) Cars, c) Duty-belts, and d) Boots. Following are the questions which were asked of each of the six officers.

General

1. How do you think that chronic back injuries occur in your job?
2. In that respect, what is the most hazardous job?
3. Can you avoid it? How?
4. Is there anything else you would like to add?

Cars

1. How long is your work shift?

2. What proportion of your shift you spend in the car?
3. How many times, on an average, do you get in and out of your car during your shift?
4. What don't you like about your duty cat?
5. What problems do you face in car patrolling- either from your car or from your uniform?
6. Are there any other problems you perceive in car patrolling?
7. Does the car (or can it) contribute to low-back problems?
8. What features/aspects of the car may/do contribute to this problem?
9. How would you modify the car to make it safer and more comfortable for you?
10. What are your driving stresses?

Duty Belts

1. Do you prefer wearing your duty belt? Why?
2. How do you feel when wearing the belt?
3. Does your duty belt affect your flexibility?
4. Do you think that the duty belt contributes to the low-back problem? How?
5. How would you like to see the duty belt change?

Boots

1. Do you like wearing your boots?
2. If not, what would you like to wear?
3. How do you find its friction on different surfaces?
4. Do you ever slip on it? Which surfaces?
5. How do you think that the boots may contribute to back problems?

Analysis

Car Characteristics

The interior cab dimensions were measured using anthropometric tape and anthropometers. These were collated and tabulated in a comparative table. The internal layout was examined using photographs taken of these makes and models of the car. These variables were then tabulated comparatively in one table.

The vibrational characteristics of the vehicles in idling and driving on highways as well as regular terrain was determined by calculating power spectrum density using Fast Fourier Transform of MatLab software. Similar power spectrum densities were calculated and plotted using autoregressive method using the same software (MatLab v.4.2- Unix - Math Works Inc.).

Ingress, Egress and Posture

The ingress, egress and driving postures were analysed qualitatively and semi-quantitatively using photographs of constables getting in and out of the car and assuming their driving posture when inside the car.

Posture and Flexibility

The posture and flexibility due to wearing boots and duty belts were analysed by comparing the angles of the body components and posture against the reference standard posture of each of the officers.

The biomechanical load of the posture change was calculated using the biomechanical model (Kumar and Hill, 1989). The cumulative effect of the difference in biomechanical load was calculated after Kumar (1990). The effect of the duty belt on postural flexibility was analysed by comparing the magnitude and range of motion in flexion, extension, and lateral flexion without and with duty belts.

Metabolic Cost

The resting oxygen uptake and, thus, the metabolic cost was calculated from the Oxylog reading samples during standing and sitting without the duty belt. These values were calculated again from separate readings which were obtained when the constables wore their respective duty belts.

Footwear-surface Interface Coefficient of Friction

The coefficient of friction for each of the six interfaces were calculated by using the formula given below.

$$F_{max} = \mu N$$

$$\therefore \mu = \frac{F_{max}}{N}$$

where, F max is the maximum possible friction force at which the boot broke away from the surface and began to slide, μ is the coefficient of friction, and N is the 'normal' force perpendicular to the surfaces in contact (the boot's under surface and the surface of the material it was on).

The coefficient of friction is an index of slipperiness (or lack thereof) to indicate the stability of constable's movement over different surfaces.

Interview Variables

The results of the interviews conducted were collated qualitatively to assess the impact of different variables as subjectively perceived by the constables.

Results

Car Characteristics

While the dimensions and characteristics of Lumina, Caprice and Crown Victoria were similar, they were significantly different in dimensions, shapes, and ease of use compared to GMC Suburban. The dimensional characteristics of these vehicles are presented comparatively in Table 3.

Table 3. Relevant ergonomic dimensions of the police cars (all dimensions in cm).

No..	CARS				
		Suburban	Crown Victoria	Lumina	Caprice
	Variable				
1.	Cab Entrance				
	a. Floor above ground cm.	55	40	40	40
	b. Ht. of the opening cm.	120	97	95	95
	c. Width of the opening cm	105	64	60	60
2.	Dash (slid forward)				
	a. Seat back cm.	70	60	68	68
	b. Seat edge cm.	12	12	13	18
	c. Seat horizontal adjustability cm.	12	20	20	17

3.	**Front Seat Dimensions**				
	a. Width cm.	56	56	50	57
	b. Depth cm.	50	55	46	51
	c. Ht. backrest cm.	53	60	60	56
	d. Ht. headrest width	19	12	17	14
	e. Headrest adjustability	8	4	6	4
4.	Headroom cm	43	32	27	28
5.	Legroom cm	48	70	61	51
6.	Seat type	Bucket	Bucket	Bucket	Bucket
7.	**Inter-seat space** cm	33	24-29	24	26
6.	Armrest	Yes	**Only on door**	**Only o door**	**Only on door**
	a. Length beyond backrest cm.	20			
	b. Ht. above seat surface cm.	18	15	15	15
9.	Window opening				
	a. Height cm.	50	44	43	46
	b. Width cm.	75	72	69	85
10.	Steering				
	a. Tilt	Yes	Yes	Yes	Yes
	b. Space thigh				
	i) Highest tilt	**28**	22	**24**	**23**
	(ii) Lowest tilt	**15**	15	**19**	**18**
11.	Seat				
	a. Plush/hard	plush	plush	hard	plush
	b. Backrest	Bieonvex	Bieonvex	flat	Biconvex
12.	Gunrack	Yes	Yes	No	No
13.	Passenger legroom	Sufficient	45 cm	30 cm	31 cm
14.	Mounted	passenger	none	none	none

Due to the size and physical location of the door opening, the Suburban was easiest to get in and out of. The construction of the seat and its design allowed a comfortable seating posture as well as a comfortable ride. The size of the door opening of the Crown Victoria and Lumina were progressively smaller and lower in space making it a little less convenient to get in these cars. The seats and back rests were plush in Crown Victoria allowing a more comfortable seating as well as some accommodation for the equipments mounted on the officer's belts. The seat pan as well as the backrest of the Lumina was firm and rather flat. They were not contoured to conform to the human shape and did not have much give. A fully uniformed officer will have a variety of equipment between his/her torso and the backrest. These will be, therefore, sticking in the back, making driving uncomfortable and necessitating a postural adjustment with forward flexion.

Invariably the location of the headrest in each of the makes and models of the cars were found unadjusted. Even if they were adjusted for height, their spatial location (by design) was poor. It was flat, convex or uncontoured and projecting backwards, increasing the distance between the head and the rest.

Due to the equipment carried by the officers and the lack of spatial accommodation for them, the officers sat somewhat forwardly flexed and not taking much support form the backrest. Such a posture further increased the horizontal distance between the head and the headrest.

The adjustability of the seat allowed average and shorter officers sufficient legroom to operate the vehicle. However, big and tall officers felt slightly (but significantly) constrained for legroom. The prisoner partition between the front and back seat restricted the distance by which the front seat could be slid back. For taller officers inadequate legroom and lack of accommodation from the backrest and seat for their equipment further increased discomfort forcing them to adopt a constrained posture for a prolonged driving shift.

Ingress and Egress

Ingress into the vehicle was carried out by placing the right foot on the floor while holding the door and twisting the trunk to the left (Figure 1). The subsequent procedure was to twist the trunk further to the left and flex at the same time to position the body adjacent to the door opening and entering the opening by ducking the head and further twisting the trunk while standing on left leg. Once the buttocks reached and touched the backrest the officers simply slid down on the seat pulling their heads into the cab. After reaching the seat pan the twisted torso was straightened and the left leg was lifted in.

During the egress the reverse process took place (Figure 2). First the door was opened and the left leg was planted outside on the ground. Holding the door, the officers twisted their torso to the left. They emerged out of the vehicle by clearing their head out by further twisting and flexing their torso At the same time they pushed against both feet and raising their buttocks, sometimes even rubbing the backrest. Once most of the body was out they

Fig.1 (1) An officer entering entering the vehicle - activities in sequence

Fig.1 (2) An officer entering entering the vehicle - activities in sequence

Fig.1 (3) An officer entering entering the vehicle - activities in sequence

Fig.1 (4) An officer entering entering the vehicle - activities in sequence

Fig.2 (1) An officer exiting the vehicle - activities in sequence

Fig.2 (2) An officer exiting the vehicle - activities in sequence

Fig.2 (3) An officer exiting the vehicle - activities in sequence

Fig.2 (4) An officer exiting the vehicle - activities in sequence

were considerably twisted to the left. As a final step they lifted their right foot from the car floor finally exiting the car.

Vibration Characteristics:

a) Vehicles

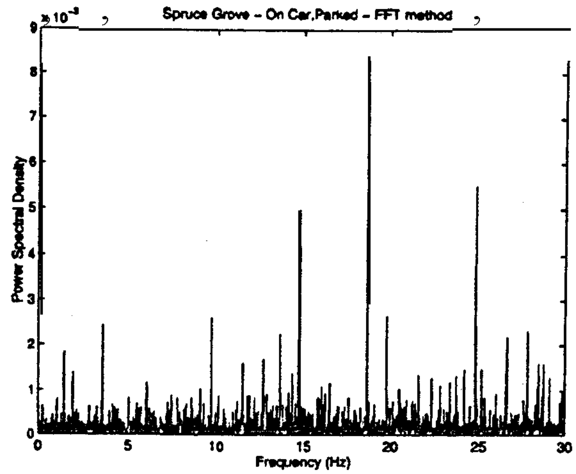
The vibration characteristics of the vehicles were measured for municipal policing., rural policing, and highway patrol. For municipal policing the vibrational characteristics while idling had more or less similar power in frequencies from 0 to 30 Hz. The change in the power spectrum of the frequencies due to moving of the vehicle remained similar to that of idling with a difference that the powers of very low frequencies (1 to 3 Hz) increased considerably (Figure 3). An identical pattern of idling and policing frequency spectrum and power density were found for rural policing (Figure 4). In highway patrolling the powers of frequencies between .5 to 2.5 Hz were considerably accentuated (Figure 5).

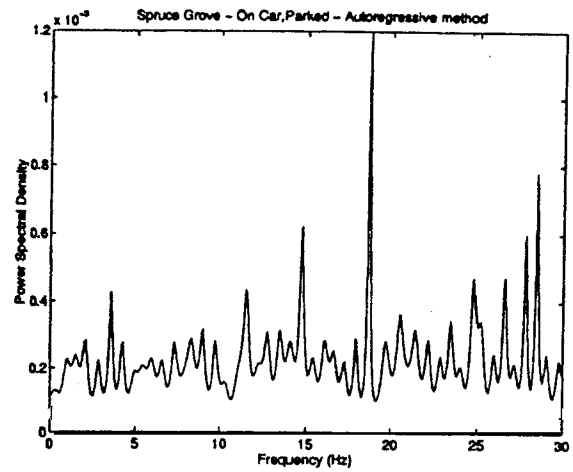
b) Officers

The vibration experienced by the officers in their hip regions on their duty belts in municipal policing was very similar to those recorded on the vehicles (Figure 6). In rural policing during cruising the territory there was an increased power of the frequencies from 5 to 1 Hz (Figure 7). During the highway patrol duty the vibration recorded on the officers duty belt had maximal power at 1 Hz (Figure 8).

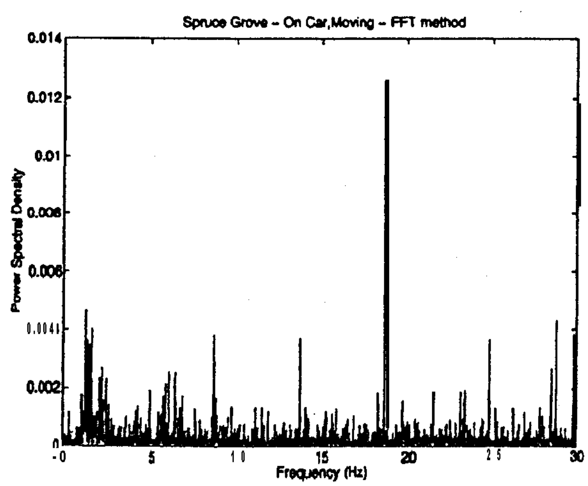
Fig. 3 Vibration: Power spectra of police vehicle in municipal policing

a) Idling' vehicle





b) Cruising Vehicle



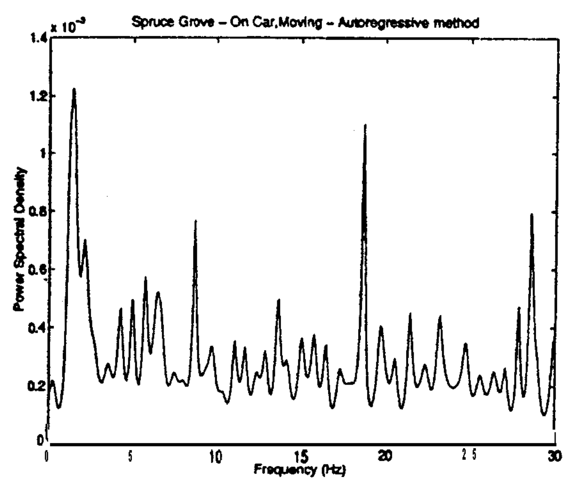
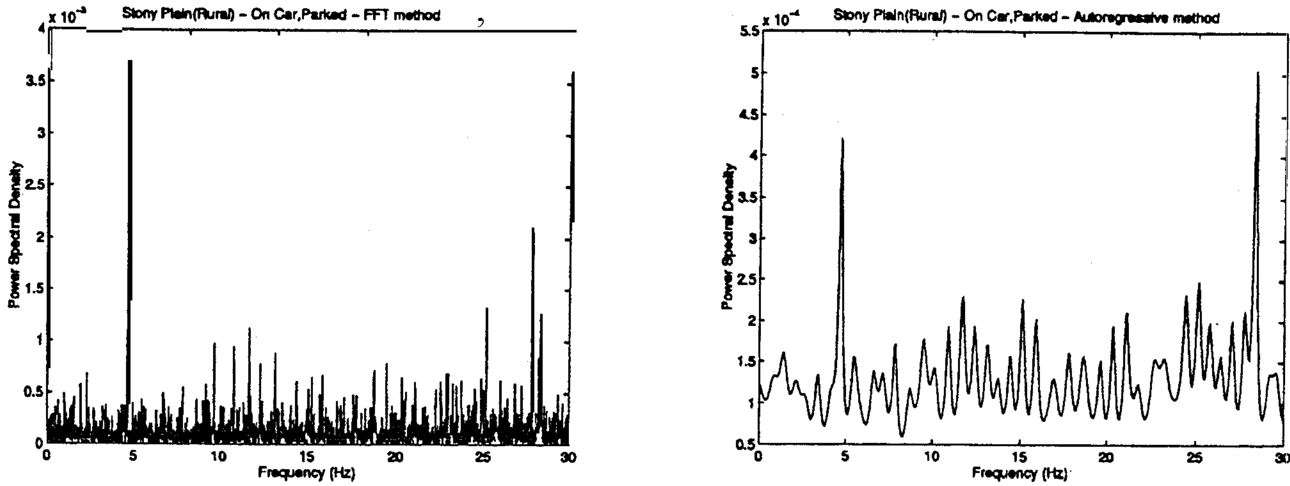


Fig. 4 Vibration: Power spectra of police vehicle in rural policing

a) Idling vehicle



b) Cruising Vehicle

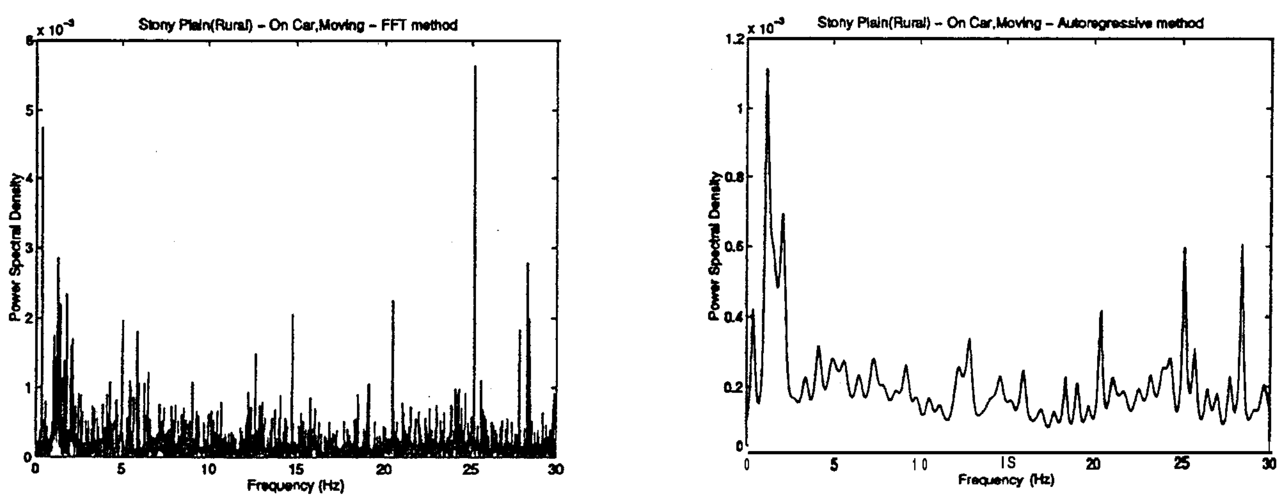
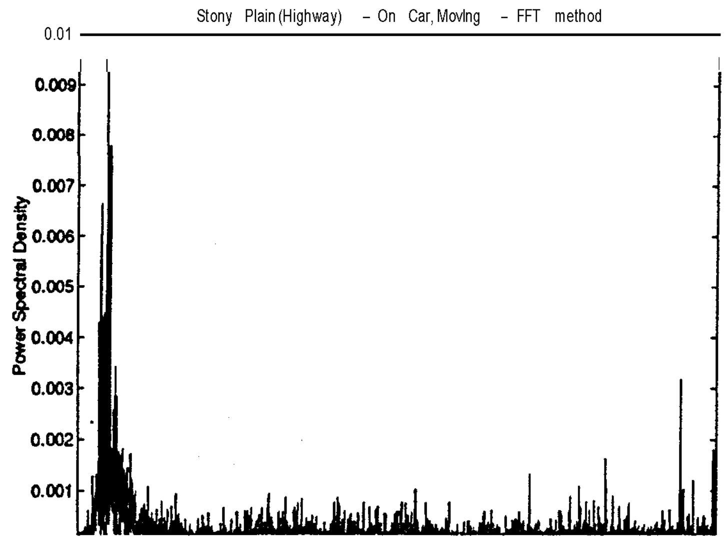


Fig. 5 Vibration: Power spectra of police vehicle during highway patrol



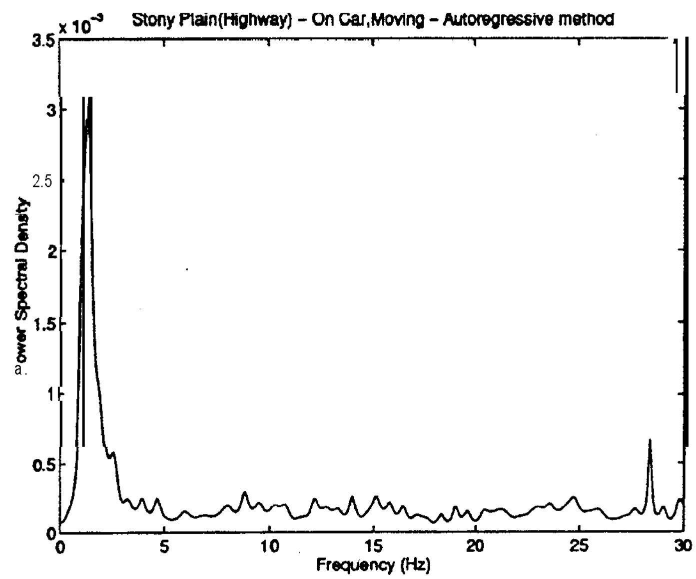
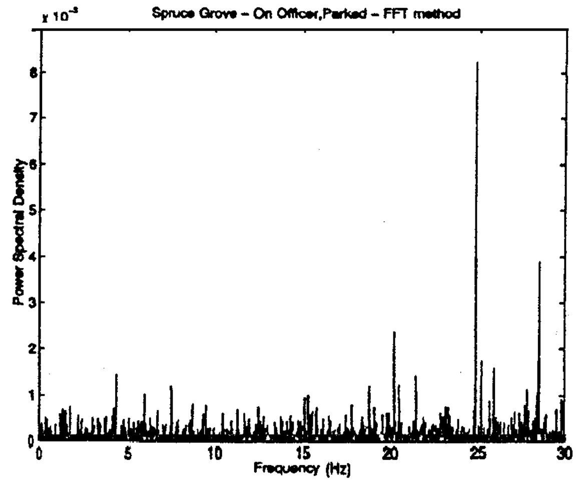
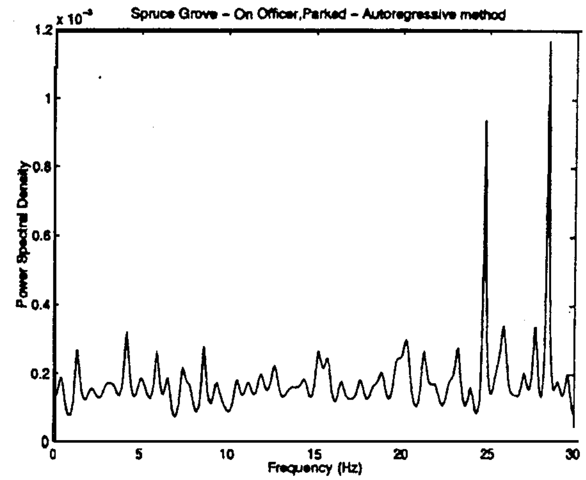


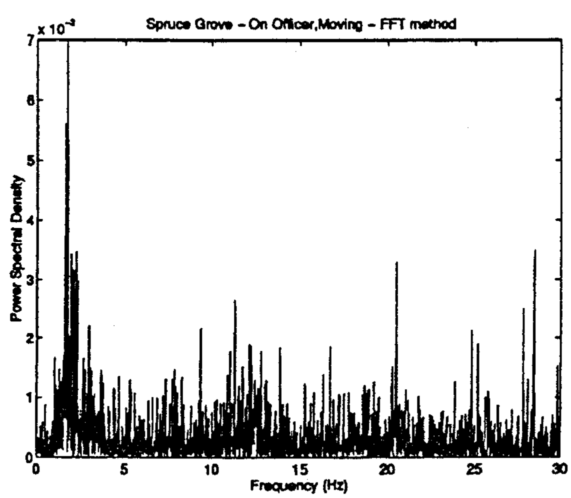
Fig. 6 Vibration: Power spectra of vibration on police officers in police vehicle during municipal policing

a) Idling vehicle





b) Cruising Vehicle



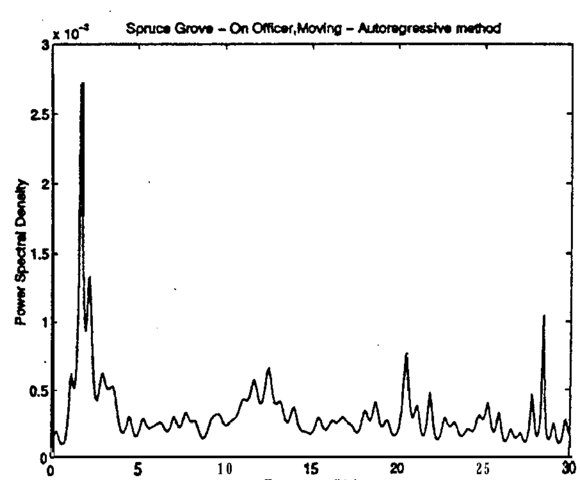
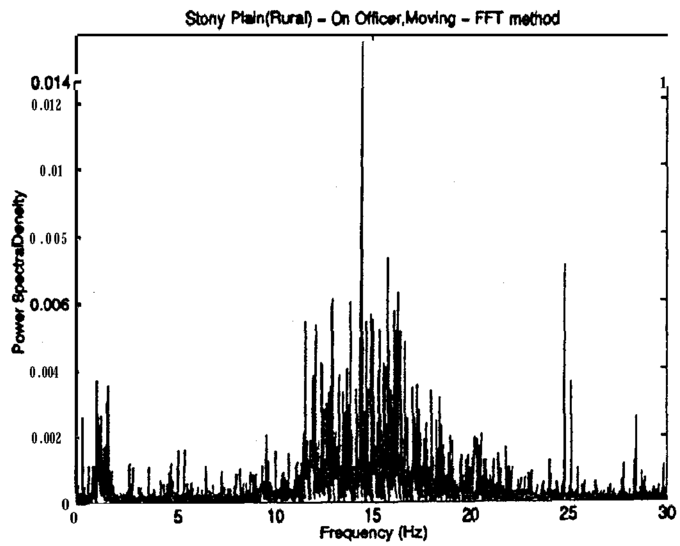


Fig. 7 Vibration: Power spectra of vibration on police officers in police vehicle during rural policing



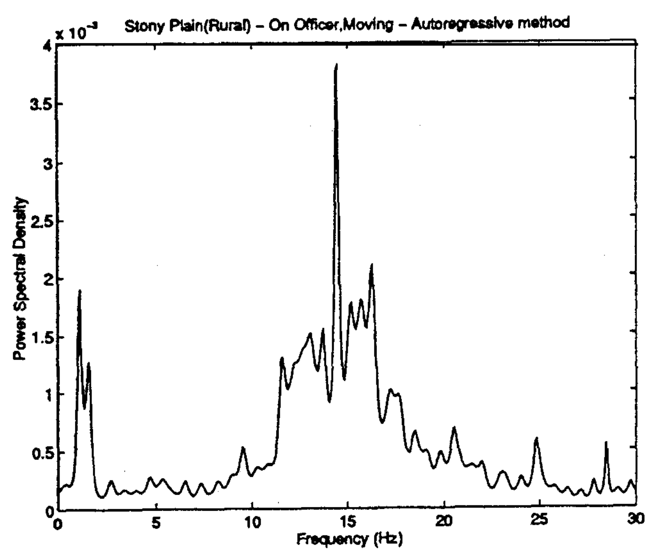
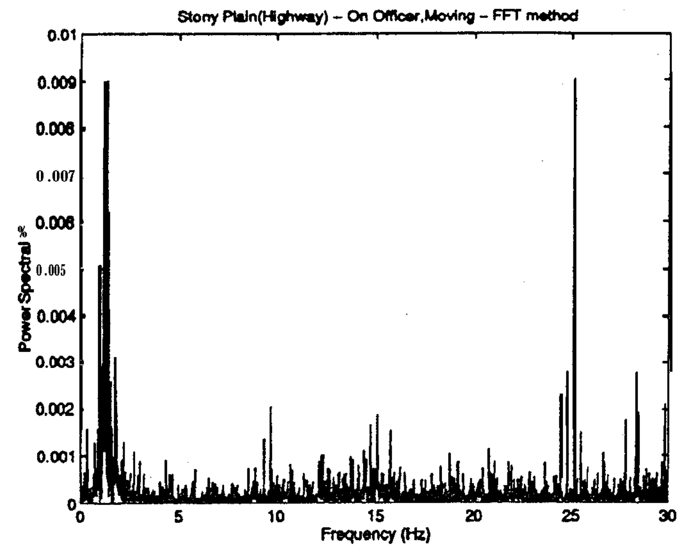
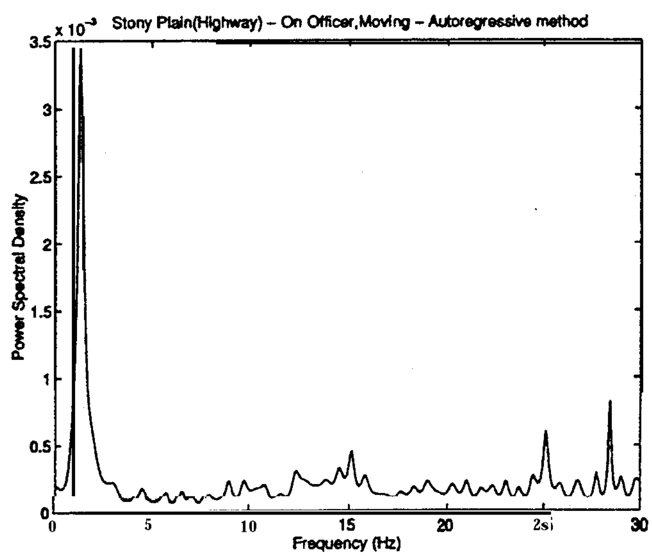


Fig. 8 Vibration: Power spectra of vibration on police officers in police vehicle during highway patrol





Posture, Flexibility and Biomechanical Load

a) Posture

All officers had a healthy posture and deviated little from a symmetrical balanced posture. In the sagittal plane, the subjects stood with a very small amount of extension ranging between 0°to 5°in males and 2.5° to 11°among females. There was no significant pattern of variation with wearing of boots or wearing of boots and belts both. It appeared to be individual variation rather than a systematic variation due to the boots or belts (Table 4). In the coronal plane, however, there was much greater uniformity rarely a subject deviating from the reference vertical (Table 4). The duty belts were worn by different constables with different tightness generating a belt pressure on the paraspinal muscles and skin ranging between 15 to 30 mm Hg. This pressure is not expected to have any influence on blood circulation in torso.

Table 4. Torso posture with respect to vertical in sagittal and coronal planes in degrees.

Gender	Size	Foot & Waist Wear	Sagittal Plane Extension (in degrees)	Coronal Plane Deviation (in degrees)
Males	Small	None	**5.0**	1.5L
		BootsNone	**0.0**	0.0
		Boots	3.0	0.0
		B&B		
	Medium	None	3.5	**0.0**
		Boots	5.0	**0.0**
		B&B	1.5	**0.0**
	Large	None		
		Boots		
		B&B		
Females	Small	None	2.5	**0.0**
		Boots	6.5	**0.0**
		B&B	11.0	4.0 L
	Medium	None	**5.0**	**0.0**
		Boots	6.0	**0.0**
		B&B	7.0	**0.0**
	Large	None	6.0	**0.0**
		Boots	3.0	**0.0**
		B&B	4.0	**0.0**

B&B = Boots and belt both

b) **Flexibility**

The flexibility of the experimental subjects was photographically recorded. The sagittal as well as coronal range of motions were largest in slim subjects. With increase in size of the subjects, the range of motion decreased in both planes (Table 5). No consistent effect of footwear or the duty belt was found in the experimental sample (Table 5).

Table 5. Torso posture and range of motion in degrees

Sex	Size	Foot & Waist Wear	Flexion	Extension	Sagittal ROM	Lat. Flexion Left	Lat. Flexion Right	Coronal ROM
		None	121.0	27.0	148.0	28.5	34.0	62.5
Male	S	Boots	119.5	31.0	150.5	33.0	33.0	66.0
		B&B	118.0	32.5	150.5	36.0	36.0	72.0
		None	100.5	26.5	127.0	34.0	31.5	65.5
	M	Boots	119.0	24.0	143.0	33.0	35.0	68.0
		B&B	99.5	29.5	129.0	31.5	30.0	61.5
		None						
	L	Boots						
		B&B						
		None	125.5	46.5	172.0	40.0	50.0	90.0
Female	S	Boots	131.5	34.5	166.0	49.0	44.0	93.0
		B&B	134.0	40.0	174.0	44.0	43.0	87.0
		None	124.0	26.0	150.0	38.0	35.0	73.0
	M	Boots	130.0	22.5	152.5	32.5	32.0	64.5
		B&B	133.0	21.0	154.0	38.5	36.0	74.5
		None	111.0	30.0	141.0	28.0	32.0	60.0
	L	Boots	118.0	24.0	142.0	30.0	31.0	61.0
		B&B	118.0	32.0	150.0	35.0	31.0	66.0

B & B = Boots and Belts both

c)Lumbosacral Compression

The lumbosacral compression during quiet upright standing and full flexion and extension was calculated for all subjects (Table 6). When this compression was compared between bare feet and no belt with those obtained while wearing the boots, and wearing boots and duty belts both, individual variations were found obscuring any clear pattern. In all upright standing, however, the compression was of low order generally around 500 N or less.

Table 6. Lumbosacral compression in quiet upright standing and maximal flexion and hyperextension (Newtons)

Gender	Size	W/out B&B			With Boot			With B&B		
		Upright	Flexion	Extension	Upright	Flexion	Extension	Upright	Flexion	Extension
	S	410	1949	349	353	1880	353	411	1974	335
Male	M	458	2621	396	400	2278	400	536	2607	392
	L									
	S	309	1219	302	229	1178	229	298	1219	191
Female	M	318	1401	317	280	1296	280	316	1251	281
	L	451	2518	53A	281	2281	404			

Metabolic Cost Considerations

The resting oxygen uptake of the participating officers was measured in standing and sitting postures without and with their fully equipped duty belts. These values are presented in Table 7. In standing posture the metabolic cost of wearing the duty belt ranged from .22 to .24 Kcal. min for males and from .l8 to .23 Kcal. min for females. While seated these increases for males and females ranged between .l88 to ,194 Kcal min respectively. The differences in the heart rate and ventilation volume as a result of wearing the duty belt are presented in Table 8 and 9 respectively.

Table 7. The energy expenditure of the officers in quiet standing and sitting without and with duty belts

Gender	Size	Posture					
		Standing			Sitting		
		W/out Belt Kcal. min	With Belt Kcal. min	Diff.	W/out Belt Kcal. min	With Belt Kcal. min	Diff.
Male	Small	1.3705	1.5915	.221	1.5511	1.7501	.199
	Medium	1.7935	2.0305	,237	1.7035	1.8920	.188
	Large	2.3420	2.5875	.245	2.2270	2.4255	.198
Female	Small	1.1980	1.3820	.184	1.1980	1.3430	.145
	Medium	EF	EF	EF	EF	EF	EF
	Large	1.506	1.743	.236	1.6855	1.8795	.194

EF = Equipment ıailure

Table 8. The heart rate of the officers in quiet standing and sitting without and with duty belts

Gender	Size	Posture					
		Standing			Sitting		
		W/out Belt Beats/ min	With Belt Beats/ min	Diff.	W/out Belt Kcal. min	With Belt Kcal. min	Diff.
Male	Small	107	115	8	93	97	4
	Medium	105	107	2	90	93	3
	Large	74	77	3	67	70	3
Female	Small	95	100	5	74	80	6
	Medium	75	75	0	66	67	1
	Large	75	76	1	59	60	1

Table 9. The ventilation volume of the officers in quiet standing and sitting without and with duty belts

Gender	Size	Posture			
		Standing		Sitting	
		W/out Belt l/min	With Belt l/min	W/out Belt l/min	With Belt l/min
Male	Small	9.1698	10.9525	9.1526	10.1152
	Medium	10.5818	10.9814	8.1366	9.9876
	Large	10.1100	10.9756	9.3941	10.5851
Female	Small	7.7650	8.1772	6.1517	7.7797
	Medium	EF	EF	EF	EF
	Large	10.5110	10.6660	10.7160	11.0782

EF = Equipment Failure

Boot Traction

The traction of the boot's sole and heel on different surfaces such as wood, linoleum, gravel, concrete (dry and wet), and ice were measured and are presented in the Table 10. These boots provided strong friction on concrete and were most slippery on ice. Wood and gravel had comparable coefficient of friction, both being in mid range. The highest coefficient of friction was observed with dry concrete and lowest on ice. RCMP boots were found very slippery on ice.

Table 10. The coefficient of friction at the interface between boot and six surfaces.

Gender	Size	Wood	Linoleum	Gravel	Concrete		Ice
					Dry	Wet	
Male	Small	.520	.720	.581	.868	.801	.219
	Medium	.526	.825	.525	.850	.789	,163
	Large	.620	.680	.560	.883	.792	.236
Female	Small	.562	.540	.521	.833	.801	.146
	Medium	.506	.698	.586	.875	.762	.100
	Large	.599	.540	.581	,879	.807	.167

Interview

Interview Findings (comments repeated do not have repeated entries)

General Comments

1. Fitness prevents or reduces injury. (Literature divided on this issue)
2. Back injuries are generally caused by violent encounters, car accidents, sports and body weight.
3. Prevention of back problems can be achieved through exercise and awareness.
4. Frequently required to indulge in a sudden activity without any warm-up. This is an important factor in incidence of low-back pain.
5. Weather conditions and the time of the day also contribute to low-back pain problem.
6. Lifting and physical encounters, prolonged standing and prolonged driving are serious causes of low-back pain.

Cars

1. The ride of the Crown Victoria is quite firm passing on the vibration and bumps.
2. Of the 10 hour shift, I spend 7 hours in the car. During this period I get in/out for at least 20 times.
   - I spend approximately 6 out of 10 hours of the shift in my car.
   - I spend half of my time in the police car and get in/out of the car between 25 to 35 times during one shift.
3. Car seat and back rest modification to provide support will be very desirable.
4. Getting in and out of the car is uncomfortable and stressful. It may be responsible for low-back pain/injury causation.
5. Lack of adequate lumbar support is a real problem.
6. Seats are not sufficiently adjustable.
7. Car is my office and I do lot of office work in it, yet it is not designed to facilitate office work. Such duties require a lot of trunk twisting which is problematic.

Duty belts

1. Duty belts are heavy due to all the equipment mounted on it and I am glad to get it off in the evening.
   - Duty belts are comfortable but heavy and make me tired after wearing for long time. Given the choice, I would prefer not to wear it.
   - Would prefer a lighter duty belt, wouldn't wear if I didn't have to.
2. Duty belts are restrictive and do not allow even deep breath - extended fast pursuit or traffic duty becomes quite tiring.
3. Combination of wearing duty belt and riding in police car affects the posture in driving due to the equipment digging in the back, causing me to sit with forward flexion.
   The Chevy's back was softer and was not nearly as bad as the contoured seats of Crown Victoria.
4. Duty belts do not restrict flexibility (small subject)
   Duty belts do interfere with flexibility (large subject)
5. Removing some of the equipments form the duty belt will help.

Boots

1. Overall I like to wear these boots. They are comfortable and warm. However, I like ankle boots better.
2. Perhaps the boots could be made of lighter materials
3. While these boots provide good traction on other surfaces, they are very slippery on ice - poor traction.

Discussion

Law enforcement requires fit, strong and able bodied personnel. Perhaps, it is for this reason that 54.5 percent of the total Force is under 40 years of age. Another 40 percent of the Force is between the ages of 41 and 50 (Brown et al., 1997). Roughly one third of the Force (31.5%) have been policing for up to ten years. Another 31.2 percent of the Force has ten to nineteen years of policing experience. The members of the Force like their work (96.1%) and a majority of them (95.9%) have a good working relationship with their supervisors (Brown et al., 1997). They also reported that the members of the Force display a heightened awareness for physical fitness and indulge in physical activities (74.3%). With the foregoing demographic and physical profile of the Force members, the findings of Brown et al. (1997) that the prevalence of low-back pain and injuries were similar to those of general population may on one hand be reassuring, but on the other hand is concerning, The low-back pain literature has reported that the psychosocial factors such as disliking the job, not getting along with supervisors had a profound impact on the prevalence of low-back pain reporting (Bigos et al., 1991, Biering-Sorensen et al 1989, Burton et al 1995). Furthermore, lack of fitness has also been reported to be a major factor in such problems (Cady et al., 1979; Manniche et al., 1991; Mattel et al., 1991; Toropotsova et al., 1995). Clearly then the the fact that the prevalence of low-back incidencesin highly committed, motivated and seemingly fit Force members equals that of the general population may mean that there may be a significant problem. An important implication of this observation is that psychosocial factors play little or no role in low-back syndrome causation or reporting in the Force, and therefore, the majority of the causative factors have to be job related physical factors. The impact of physical factors are accentuated in lack of fitness and poorer physical attributes. On closer examination, a possibility of another scenario emerges. Since the fitness level of Force members is not tested after they join the Force and all reports of exercise are self reports, it is possible that there may be a mismatch between the reported activity level and desired fitness level for maintaining a healthy back. In this sense then, the RCMP may not be significantly different from general population The observation of Brown et al (1997) may be an indirect proof of such a situation. With such a background of information, it may be most advantageous to take an ergonomic approach.

In an excellent internal document, Brown et al. (1997) have reported on the causes oflow-back pain perceived by the Force members. More than half the Force members (51%) spend in excess of half of their working day in their vehicles, 55.9% usually wear their duty belts, perform frequent twisting motion of torso or legs (70.4%), are involved in physical confrontation (48.5%) spend more than half the day standing on the job (23.1%) frequently lift or carry heavy objects (22.6%), and experience accidents in police cars (10.2%).

A large body of literature has reported that automobile driving or driving other motorized vehicles and machines are associated with low-back pain. Kelsey and Hardy (1975) reported that motor vehicle driving increases the risk of disc herniation; in fact, men who spent half of their work time in motor vehicles were three times more likely to develop disc herniation. Automobile driving or using vibratory equipment have been reported to be positively associated with low-back pain problem (Damkot et al., 1984; Kelsey et al., 1984; Pietri et al., 1992; Masset and Malchaire, 1994; Magnusson et al., 1996; Burton et al., 1996). Exposure to vibration due to driving fork lift (Boschizen et al., 1992), city bus (Andersen, 1991; Bavenzi and Zadini, 1992) (Bovenzi and Zadini, 1992) tractors (Bovenzi and Betta, 1994) and flying helicopters (Bongers et al., 1990) are all positively associated with low-back pain. Clearly, when over half the members of the Force (51%) spend more than half their working day in their vehicles driving it is expected to be a significant risk factor.

Roughly 56% of the peace officers usually wear their duty belts (weighting approximately 5 kg.), 22% frequently lift and carry heavy objects, and 48.5% are involved in confrontation subjecting the officers to considerable load on the spine. Spinal loads have also been widely documented to be strongly associated with the causation of the low-back pain. Lifting has been reported to be a major physical factor associated with the low-back pain (Damkot et al., 1984; Kelsey et al., 1984; Videman et al., 1984; Kumar, 1990; Pietri et al., 1992; Mundt et al., 1993; Woodruff et al., 1994; Toroptsova et al., 1995; Magnusson et al., 1996; and many others).

Postural loads, such as prolonged standing and sitting, which are also reported to comprise a modest part of the RCMP members duty, have been widely reported to be factors strongly associated with low-back pain syndrome (Troup, 1978; Damkot et al., 1984; Riihimaki et al., 1989; Pietri et al., 1992; Bovenzi and Zadini, 1992; Bovenzi and Betta, 1994; Adams and Dolan, 1995; and others). In fact, Bovenzi and Betta (1994) found that the postural load and vibration exposure were independent contributors to the low-back pain problems. Adams and Dolan (1995) have reported that the mechanical fatigue of the spinal tissues are frequently the underlying cause of the low-back pain. Given the prolonged postural loads, heavy lifting, exposure to vibration, and frequent bending and twisting, mechanical fatigue of the spinal tissues is the most likely outcome predisposing precipitation of low-back pain problems. Some members of the Force (70.4%) indicated that they indulge in frequent twisting motion and others indicated that bending was common for them. Several authors have established an association of low-back pain with twisting (Kelsey et al., 1984; Manning et al., 1984; Videman et al., 1984; Kumar, 1990; Marras et al., 1993; Masset and Malchaire 1994; and others). Similarly, bending was reported associated with low-back pain by authors such as Kumar (1990), Woodfuff et al., (1994); Toroptsova et al., (1995), and others. Clearly, the simultaneous presence of most of these factors increases the risk of low-back pain/injuries to RCMP officers significantly due to their combined effect (Kumar, 1994).

With the job profile stated above, Brown et al., (1997) further reported that officers experiencing low-back symptoms perceived the following factors to be problems for low-back pain:

- The seat in the police car (75.4%)
- Driving or sitting in a police car for long periods (82.6%)
- Wearing of duty belts (58.1%)
- Twisting movement at work (52.4%)
- Sitting at desk for long periods (57.1%)
- Getting in/out of the police car (46.9%)
- Accident or incident not involving police vehicles (42.9%)
- General fatigue (30.7%)
- Physical confrontation/altercation (39%)
- Work related lifting and carrying (36.1%)
- Articles or equipment in back pocket while driving (25.4%)
- Lack of exercise facilities at work (36.3%)
- Off-duty accident or incident (20.7%)

All of these factors, as stated before, have been established as significant risk-factors for low-back pain. Numerical distribution of percentages of the perceived causes clearly indicates that the Force members have simultaneous presence of several factors. Since the risk factors have been suggested to have a multiplicative effect in cases of multiple physical risk factors (Kumar 1994), the likelihood of the problem is surmised to have been considerably accentuated. It was interesting to note that in the paper by Brown et al., (1997) physical features such as height, weight and body mass index had no relation to the prevalence of low-back pain problems, contrary to previously published findings of Orrieto et al., (1994).

The car characteristics as observed and measured in this study indicate that the spatial position of the car door opening for the Suburban was optimal to reduce the stress of ingress and egress. Tall officers could get in and out without ducking or twisting. Upon initial and partial entry, the officers slid sideways by pushing with their left leg and, once they reached the appropriate position, they lifted their left leg in. On the contrary, ingress in Lumina, Caprice and Crown Victoria was more difficult due to the door opening being lower and smaller. The ingress involved a significant bending at the knee (lowering of centre of gravity), lateral flexion and axial rotation of the torso to the left, and simultaneously placing the right foot inside of the cab on right side of the floor well (driver's space). While holding the open door by left hand and the steering wheel by the right, the officers bent their left knee further to lower their buttocks into the seat and finally twisted towards the right to get into the neutral position. For egress, this procedure was followed in reverse. Such ingress and egress involved considerable axial rotation and lateral bending of the torso. In torso twisting, electromyographic studies have shown a fifty percent muscle silence (Kumar et al., 1996) necessitating the mechanical load to be borne only by half of the muscles thus doubling the load on them. Furthermore, with axial rotation, the compressive force on the spine will increase due to concurrent discal shortening. These forces will be further accentuated due to a simultaneous and controlled lateral bending. In foregoing paragraphs, it has been stated that these factors have been reported to be major risk factors in causation of low-back pain,

As reported in the results, on an average, the officers during the course of a shift performed ingress and egress twenty times. These activities, combined with those of prolonged driving and sitting in a car with duty belts which do not allow supported sitting, result in concurrence and overlap of several stress factors for a significant portion of their shift. Once the officers complete their patrolling portion of their duty, they stand at the desk to interact with the public or sit at a desk to complete their paper work. Thus there is a significant static load on officers for considerable length of time interspersed with sudden dynamic and stressful activities. Static load for many officers are further accentuated due to insufficient leg room due to the prisoner partition in the car disallowing adequate adjustment of the seat position. Due to the job requirement of quick response as well as the physical culture of the police force environment, sudden movements are common and are likely to exceed the strain rate tolerance of the tissues in some activities involving sudden movement and thereby precipitating the problem. It may be due to this culture in addition to high motivation, job satisfaction and good working relationship that an accurate magnitude of low-back problem may be somewhat obscured in the Force. The latter is evident from the findings of Brown et al., (1997) that 60.7% of the pain sufferers had sufficient severity of the problem to warrant sick leave, but went to work regardless.

The impact of the boots and belts with respect to the resting posture and flexibility was found to be small and somewhat variable. The change in posture was such that it improved the postural stability, especially after wearing of boots. Smaller and lighter subjects tended to undergo slight flexion of a few degrees. The biomechanical loads resulting from such postural changes were also of quite small magnitude and are not thought to have any significance in causation of low-back pain. Again, by wearing boots officers did not change their range of motion in any plane. Thus, the torso motion characteristics and thereby biomechanical loading in RCMP's regular duty is expected to remain unaltered.

The duty belt with concentrated additional equipment affects the officers in deleterious ways. Since members of the Force spend a significant proportion of their time in their vehicles with the car seats not designed to allow accommodation for extra equipment, it forces officers not to take adequate support form the back rest. If they try to take this support the equipment mounted on the belts digs into their backs making it quite uncomfortable. This lack of useability of the back rest causes a prolonged increased static load on the spinal structures. The static load has two unfavourable effects. First, a continuous static contraction (in abdominal, spinal and paraspinal muscles) in itself is likely to cause soreness of the back due to circulatory occlusion, restricting availability of nutrients and oxygen, and collection of metabolites. Secondly, the static load on spinal structures will cause viseoelastic deformation (disc narrowing) predisposing the tissues to mechanical injuries.

The boots were generally liked by the constables for their comfort and warmth, but they were considered somewhat heavy and bulky. These boots provided reasonable grip on most surfaces but were very slippery on ice. The coefficient of friction on ice was found to be between .100 and .236. Though such a variation on the same surface was not expected, it is explainable. The ice was artificially made in a tray inside a freezer by leaving the tray filled with water overnight. Due to access to the freezer to multiple users the ice surface was not always found uniform. It is on those specimens where the surface was found rough or corrugated that we recorded higher coefficient of friction. It is suggested, however, that the coefficient of friction of these boots on ice will probably be around .100 rendering it very slippery. Since, in a large portion of the country, winter is long and harsh, it poses a real problem. From the survey of Brown et al., (1997) it is not clear if slips and falls were a factor in low-back pain. It is, however, thought that an incomplete fall or just a slip may be a significant factor in precipitating a low-back pain/injury. Sudden uncoordinated and unnatural motion can clearly exceed the viscoelastic tolerance characteristics of the spinal tissue.

Finally, a brief comment will be made on invariable observation of lack of adjustment of headrest in any of the vehicles studied. Over ten percent of the officers have reported that they were involved in an auto accident with a police vehicle (Brown et al., 1997). This is also seen as a significant factor in causation of low-back injury, in addition to whiplash, due to a high compressive component of the lumbar spine during hyperextension of the cervical spine (McConnell et al., 1993, Bailey et al., 1995).

Recommendations:

The recommendations are going to be presented in four sections each dealing with one item. These are: a) Car seat and car, b) Duty belts, c) Boots, and d) Practice in the force. Each of these items are focussed on controlling and reducing the injuries. A careful consideration has been given to the cost of changes and efficiency of officers. Therefore, from the perspective of the problem at hand, other recommendations can be made which may be superior to the ones included in this list. But, either such solutions may be too expensive and, thereby, unfeasible or they may interfere with the work of the officers. Thus, a conscious effort has been made to recommend low cost and least interfering solution. Further among these some recommendations can be implemented immediately and others can be implemented at a later date.Therefore, recommendations are divided into two categories in each section:

1. Immediately implementable, and
2. For consideration in near future

These are as follows:

a) **Car seats and cars**

Immediately Implementable

i) Vibration reduction: It is recommended that a nonfreezing gel or thick fluid filled seat pan cushion be used to attenuate vibrational components, both the magnitude and frequency, and reduce the hazard for precipitation of back injuries.

ii) Hand support: It is recommended the a grip handle, like the handle of a case, be installed on the driver's side on the inside edge of the car slightly anterior to the driver's head space and that a second be installed on the inside edge of the front of the opening, providing devices for support.

iii) Ingress and Egress Training It is recommended that the officers should be trained in the optimal method of ingressing and egressing after mounting the hand support on police vehicles. The central thrust in developing this method should be to minimize axial rotation by holding on to hand support by left hand and balancing the body between left and right legs and finally sliding sideways. For egress, the process in reverse should be used. This will allow the officers to maintain their gaze on a suspect with right hand free for the gun deployment if necessary. The method can be used with no difficulty in normal times and will not interfere with policing efficiency in emergencies. Even if this practice is not followed in emergency situation it would have eliminated stressful twisting from all of the routine policing.

iv) Prisoner Partition: It is recommended that this partition should be moved back as much as possible (at least six inches) to allow sufficient leg room for the members. This can be accomplished by modifying the back seat such to allow room to accomplish this goal.

v) Head: It is recommended that the headrests be designed such that they come forward from their place of installation, reducing the distance between the head and the headrest and minimizing the amount of possible cervical extension in the event of a rear end impact. The headrest should provide sufficient adjustability to fit every constable. In addition, the headrest should be slightly concave rather than being flat or convex as is the case now.

For consideration in near future

i) The : This is considered to be the single most difficult problem facing the officers. Due to lack of backrest usability, it causes considerable postural stress. It is suggested that a different backrest be designed to provide appropriate support to the officer on duty in the car. Some designs have been conceptualized but have not been prototyped and tried for appropriateness and efficacy. The latter will require additional time and resources.

ii) Computer location: It was understood, through interviewing officers, that some of the cars are equipped with small computers located between the two front seats. Such a car was not available for inspection. However, it is clear that the only way it could be used by the officer would be by him/her twisting his/her trunk. This has the potential of considerably accentuating the risk of back injury. It is, therefore, suggested to have an adjustable and "out-of-the-way" mounting of the equipment which could be brought in front of the constable when needed. Again, a few conceptual designs have been developed, but none prototyped and tried. This item will also require additional time and resources.

iii) The seat pan for elimination or reduction of twisting during Ingress and egress: It is suggested that a similar swivelling and locking seat pan be installed which will allow rotation free ingress and egress. This feature will also need to be prototyped and tried for effectiveness. The latter also requires additional time and resources. Some of the stress reduction can take place by the recommendation 1. ii.

b) Duty belts

Immediately Implementable

i) Component redistribution: It will be desirable to minimize the equipment attached to the duty belts. It is proposed to move the batons to a pocket on the thigh, the walkie talkie radio to a pocket on the chest in a designed uniform. Such an arrangement will free up the officers hands as well. The magazine of bullets, the handcuffs, and the pepper spray should be placed in the front. This component redistribution may reduce the unusability of the backrest.

c) Boots surface grip

Immediately Implementable

i) Impregnated material: The coefficient of friction can be considerably increased by using a dual texture, dual density impregnated composite material for soles and heels of the boots. Due to different wearing properties and densities, this material will hold on most surfaces quite well. It will also increase the friction on icy surfaces until the spaces between hard particles get packed with snow. At this stage, the boots can be banged to regain the frictional properties. In addition, traction treads should be designed for these soles and heels.

For consideration in near future

ii) Heel spikes: It will be desirable to mount four hard synthetic material spikes on the heels of the boots in precut recesses to allow only about 1 mm protrusion from the surface. It can be achieved by having "screw-on" spikes to be screwed in during winters and removing when not needed. Alternatively, they can be built into the heels to be lowered or raised to desired level by a screw in the back of the heel. These too will need to be prototyped and tried for maximal efficiency and minimal cost. If not, then an overshoe with built in spikes could be tried. However, the latter is likely to be a little less reliable as well as clumsy.

d) Practice in Force

Immediately Implementable

i) Postural breaks (changes): During normal policing when emergencies are not expected, officers should consciously and periodically change their postures, move around or change physical activity. This practice is expected to be very beneficial. It is recommended that after every 50 minute continuous work of one type a 10 minute change be instituted.

ii) Back rest during driving: The constables should be encouraged to arrange their duty belt equipment such that it allows useability of the backrest.

iii) Driving posture: During driving the officers should be encouraged to sit back with the torso at approximately 100° or more.

iv) Safety Training: The constables must be given a back safety training before joining the Force and a refresher should be provided every two years.

v) Life Style Education: The law enforcement officers should be given a life style education periodically which must be specifically designed for their needs. RCMP officers are highly motivated and committed to doing the right thing. Any useful advice and education is likely to have significant impact among the officers of this Force Periodic fitness testing may be considered.

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