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Effects of thigh holster use on kinematics and kinetics of active duty police officers

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ABSTRACT

Background: Body armour, duty belts and belt mounted holsters are standard equipment used by the Swedish police and have been shown to affect performance of police specific tasks, to decrease mobility and to potentially influence back pain. This study aimed to investigate the effects on gait kinematics and kinetics associated with use of an alternate load carriage system incorporating a thigh holster.
Methods: Kinematic, kinetic and temporospatial data were collected using three dimensional gait analysis. Walking tests were conducted with nineteen active duty police officers under three different load carriage conditions: a) body armour and duty belt, b) load bearing vest, body armour and thigh holster and c) no equipment (control).
Findings: No significant differences between testing conditions were found for temporospatial parameters. Range of trunk rotation was reduced for both load carriage conditions compared to the control condition ($p < 0.017$). Range of hip rotation was more similar to the control condition when wearing thigh holster rather than the belt mounted hip holster ($p < 0.017$). Moments and powers for both left and right ankles were significantly greater for both of the load carriage conditions compared to the control condition ($p < 0.017$).
Interpretation: This study confirms that occupational loads carried by police have a significant effect on gait kinematics and kinetics. Although small differences were observed between the two load carriage conditions investigated in this study, results do not overwhelmingly support selection of one design over the other.
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1. Introduction

Load carriage is a necessary part of the physical activities of police. The mandatory equipment worn by police can be conceptualised as part of a human factors model where the individual, equipment and tasks are components of a system which interact to affect health and wellbeing (Salvendy, 2012). Body armour and duty belts worn by police can subsequently be considered to affect the individual and their ability to perform job related tasks.

Studies investigating the effects of occupational load carriage on health and wellbeing have generally been divided into two areas, one focusing on physiological variables (Dempsey et al., 2013; Lewinski et al., 2015) and the other on biomechanical variables (Birrell and Haslam, 2010; LaFiandra et al., 2003). Research to date has focused mainly on backpack weight and design in military personnel and hikers while very little attention has been directed towards load carried by other occupational groups, including police.

The impact of police body armour and duty belt on activities performed by police was investigated by Dempsey et al. (2013) who demonstrated that mobility was reduced when performing key occupational tasks and that a greater physiological effort was required to perform specific tasks as the weight of the load carried increased. Decreased sprinting velocity and acceleration were also found to be associated with use of duty belts and body armour (Lewinski et al., 2015). The biomechanical effect of relocating equipment from a duty belt to a so-called load bearing vest was studied among a group of Swedish police (Ramstrand et al., 2016). Results showed no major impact on temporospatial parameters of gait but a restriction in lateral trunk bending, trunk rotation and anterior pelvic tilt when wearing the load bearing vest.

In studies of backpack load carriage, a decrease in stride length, pelvic and thoracic rotation with a resulting increase in stride frequency has been associated with bearing loads of 40% body weight (LaFiandra et al., 2003). Changing the load carriage design and consequently the mass distribution of load carriage systems in military personnel has been shown to have a limited effect on ground reaction force parameters (Birrell and Haslam, 2010). There is some indication that load carriage weight, placement and design has an effect on pain experienced by the wearer, however results are inconsistent and limited evidence is available (Golriz and Walker, 2011). The extent to which load carried by police affects pain is unclear, although body armour and duty belts have been associated with an increased incidence of pain and

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restrictions in movement and work performance (Brown et al., 1998; Dempsey et al., 2013; Ramstrand and Larsen, 2012; Stubbs et al., 2008).

Low back pain is experienced one day per week or more by 43% of active duty police officers in Sweden (Elgmark et al., 2013) and use of a duty belt and body armour is perceived as contributing to low back pain by Swedish active duty police (Ramstrand and Larsen, 2012). The duty belt worn by Swedish police officers houses an extendable baton, torch, handcuffs, OC spray, radio, weapon and extra ammunition which, together with body armour, adds between 6 and 7 kg of weight (Ramstrand et al., 2016). Equipment is preferably placed anteriorly and laterally on the duty belt in order to increase sitting comfort when driving fleet vehicles. The size and shape of the officer determines if this placement of the equipment is possible. Smaller females for example may have to place some equipment posteriorly in order to fit everything on their belt.

In some regions of Sweden, relocating the weapon from a belt mounted hip holster to a thigh holster (also termed tactical or drop leg holsters) has been an option for police officers experiencing low back pain. Due to regional differences in opinion regarding thigh holsters, the opportunity to test a thigh holster varies across the country. To date the only study investigating use of thigh holsters versus belt mounted hip holster has compared draw performance and demonstrated that this is not affected by holster position (Campbell et al., 2013).

The aim of the present study was to investigate gait kinematics and kinetics in active duty police fitted with an alternate load carriage system incorporating a thigh holster in comparison to standard police load carriage system incorporating a belt mounted hip holster.

2. Methods

2.1. Participants

Twenty participants were recruited for the study including eleven women and nine men. All participants worked as active duty police officers in a middle-sized municipality in Sweden. To be eligible for the study the participants could not have any musculoskeletal injuries or lower back pain at the time of data collection. One female participant was excluded due to insufficient footwear on the day of data collection which resulted in a total of nineteen participants in the study. All testing procedures were approved by the Regional Ethics Committee in Linköping, Sweden (dnr 2010/261-31).

2.2. Procedures

2.2.1. Load carriage

Use of a duty belt is the standard load carriage system among Swedish police and the weapon is to be carried in a belt mounted hip holster attached to the duty belt. Use of a thigh holster is an alternate load carriage system for the weapon. In this case the holster is firmly attached around the thigh with a complementary attachment to the waist belt. Each participant in the present study was tested under three conditions wearing: a) body armour and duty belt (standard load carriage) b) load bearing vest, body armour and thigh holster (alternate load carriage condition) and c) no equipment. Throughout all three conditions participants wore their standard issued boots and body armour (SAFE4U, Stockholm, Sweden). The weight of the body armour varied between gender and size of each individual (1690–1850 g for males and 1290–1450 g for females). The body armour was adjustable above the shoulders and around the lateral sides of the thorax to ensure optimal fit to the individual's body shape.

In the standard load carriage condition all equipment was borne in the duty belt issued by the Swedish police. If participants wore additional equipment in the duty belt at the time of testing they were asked to remove these. In the alternate testing condition, a load bearing vest was specially designed to fit on top of the body armour and included pockets for extra ammunition, torch, handcuffs and pepper spray. Baton and weapon (standardised dummy) were carried in a thigh holster, which together weighed almost 1500 g. All testing conditions were randomised and each participant had a five-minute warm up on a treadmill at self-selected walking speed to familiarise themselves with the set-up before each testing condition. During all trials participants were requested to walk at their self-selected speed as defined by Ralston (1958).

2.3. Three-dimensional gait analysis

Kinematic and kinetic data were collected using an eight camera Qualisys motion analysis system (Qualisys AB, Gothenburg Sweden) and two AMTI force plates (Advanced Mechanical Technologies, Inc., Watertown, MA, USA). A standing calibration file was collected for each participant and for each condition and a minimum of three walking trails were collected for each condition. A total of 38 reflective markers where placed on each participant's body based on the principle of the cluster marker model proposed by Cappozzo et al. (1997), see Table 1. Due to the placement of duty belt and body armour it was not possible to use the standard marker placement around the pelvis (left and right ASIS and mid sacrum) during dynamic testing. To overcome this problem, a specially designed rigid u-shaped carbon fibre frame was mounted on the sacrum carrying three reflective markers. The three markers on the sacrum cluster were used as tracking markers for the pelvic segment during dynamic testing. Using three markers placed on the sacrum has been proven to be as repeatable in tracking pelvic movement during normal gait as standard marker configurations (Borhani et al., 2013). Marker placement on the right thigh also had to be adjusted due to the position of the thigh holster. The standard placement of three markers on a rigid cluster placed on the lateral aspect of the thigh was replaced with three makers mounted on the skin on the anterior aspect of the thigh for all test conditions.

Marker trajectories were filtered using a fourth-order zero-lag Butterworth low-pass-filter, with a cutoff frequency of 15 Hz for kinematic data. Ground reaction force data were filtered with a cutoff frequency at 20 Hz (moments) and 30 Hz (powers). Visual 3D™ software (C-Motion, Inc. Germantown, USA) was used to calculate temporospatial parameters and kinematic and kinetic variables. The body weight of participants was adjusted to account for the weight of the load carried for relevant trials.

2.4. Data analysis

Comparison between load carriage conditions for temporospatial, kinematic and kinetic data were conducted using a Friedman test for non-parametric related samples. When a significant difference was found, pairwise comparisons were performed (IBM SPSS statistics 21) with a Bonferroni correction for multiple comparisons. A symmetry index (SI) based on temporospatial parameters was calculated to compare left and right sides. The SI was initially proposed by Robinson et al. (1987) for comparison of ground reaction forces and several authors have adapted it to investigate symmetry in temporospatial data (Arazpour et al., 2015; Blazkiewicz et al., 2014; Petersen et al., 2010).

3. Results

When wearing their standard uniform all nineteen participants chose to carry their weapon on their right side. Eighteen participants chose to wear the weapon it in a belt mounted hip holster and one wore it in a thigh holster. Details of the participants are included in Table 2. Average age and height for the whole group was 33 years (SD = 4.6; range 26–41) and 1.75 m (SD = 0.07; range 1.61–1.93). Average age for female and male police separately were 32 years (SD = 4.2; range 26–41) and 34 years respectively (SD = 4.9; range 27–40). Average height for female police was 1.70 m (SD = 0.06; range 1.61–1.80) and male police 1.80 m (SD = 5.2; range 1.74–1.93).

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