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Evaluation of load carriage systems used by active duty police officers: Relative effects on walking patterns and perceived comfort

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Objectives: This study aimed to examine the effects of two different load carriage systems on gait kinematics, temporospatial gait parameters and self-reported comfort in Swedish police.
Methods: 21 active duty police officers were recruited for this crossover study design. Biomechanical and self-report data was collected on two testing occasions. On occasion 1, three dimensional kinematic data was collected while police wore a/no equipment (control), b/their standard issues belt and ballistic protection vest and c/a load bearing vest with ballistic protection vest. Police then wore the load bearing vest for a minimum of 3 months before the second testing occasion.
Results: The load bearing vest was associated with a significant reduction in range of motion of the trunk, pelvis and hip joints. Biomechanical changes associated with the load bearing vest appeared to reduce with increased wear time. In both the standard issue belt condition and the load bearing vest condition, police walked with the arms held in a significantly greater degree of abduction. Self-report data indicated a preference for the load bearing vest.
Conclusion: The two load carriage designs tested in this study were found to significantly alter gait kinematics. The load bearing vest design was associated with the greatest number of kinematic compensations however these reduced over time as police became more accustomed to the design. Results from this study do not support selection of one load carriage design over the other and providing individuals with the option to choose a load carriage design is considered appropriate.

1. Introduction

As an occupational group police have been reported to experience a high incidence of musculoskeletal injuries with low back pain being the most commonly reported condition (Nabeel et al., 2007; Jahani et al., 2002). In Swedish police, low back pain experienced one day per week or more, is reported by 43% of active duty officers (Elgmark et al., 2013). In the Swedish general working population this figure is 29% (Arbetsmiljöverket, 2011). Evidence is increasingly suggesting that the underlying cause of musculoskeletal injury in police is associated with the requirement to wear heavy ballistic protection vests and carry equipment belts (Burton et al., 1996). Given that there is an established link between load carriage and low back pain (Picavet and Schouten, 2000; Orloff and Rapp, 2004), it is considered important to determine how the load carried by police affects performance of tasks typically encountered in policing. This information could significantly aid future researchers in the development of safer and healthier load carriage designs for police.

The uniform of a police officer has a great impact on how they are perceived. The colour of the material, style of clothes and equipment carried all have an influence on how police are perceived by the general public (Johnson, 17th June 2015). A standardised uniform for police can be dated back to the early 1800's (Johnson, 17th June 2015) and has been adopted by police forces worldwide. While a standard uniform for all police ensures that they are highly recognizable to the general public, it also means that changes in uniform come at a great economic cost and must be carefully considered.

The Swedish police force issues all active duty officers with equipment belts to be worn around the waist for the carriage of mandatory equipment (pistol, extra ammunition, torch, handcuffs, pepper spray, radio, and baton). The belts are fabricated from

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reinforced nylon with holster and accessory pouches fastened to the belt. Individuals may choose to place accessory pouches as they please however, in order to minimize sitting discomfort, equipment is typically placed anteriorly and laterally. Swedish police are also issued a ballistic protection vest that is worn firmly around the torso and has adjustment possibilities at the shoulders and trunk.

Limited information is available regarding the effect of the present load carriage design on gait and posture however similar designs to those worn by the Swedish police have been documented as significantly reducing mobility, compromising dynamic balance and negatively affecting performance of job related activities (Dempsey et al., 2013). In a study exploring Swedish police officers perceptions of musculoskeletal injury, the duty belt worn by police was considered to be a major factor contributing to low back pain (Ramstrand and Bæk Larsen, 2012).

In order to minimize problems associated with use of heavy equipment belts, several countries have introduced load bearing vests which are designed to eliminate the need for an equipment belt and redistribute the weight borne by police by carrying items in specially designed pouches on the vest itself (Filtness et al., 2014). At the present time the decision by certain authorities to alter the equipment carriage of police appears to lack a sound evidence base. While research has indicated that load bearing vests are associated with improved sitting comfort in police officers while driving standard and modified fleet vehicles (Filtness et al., 2014), there is presently no research investigating the relative effects of different load carriage designs on gait, posture and performance of other police related tasks. Given the high incidence of low back pain reported by police, an important first step when considering a new load carriage design for police is to understand how it interacts with the body, to ensure that the incidence of injuries will not increase and that job performance will not be affected.

To support the increased weight when a load is added to the body, humans tend to make adjustments in order to maintain balance (Orloff and Rapp, 2004; Caron et al., 2013). A well-documented example of this is the kinematic adjustments to gait and posture that occur in response to wearing a backpack. The load of a backpack shifts the centre of gravity of the body posteriorly; in order to compensate, individuals have been demonstrated to lean forward with the trunk and/or head (Caron et al., 2013; Simpson et al., 2012) or to increase anterior tilt of the pelvis (Smith et al., 2006). These postural adjustments have been suggested as contributing to back pain by increasing muscle activity and stress applied to ligaments or muscles in the back (Orloff and Rapp, 2004; Simpson et al., 2012). The degree of postural adjustment made by persons wearing backpacks has been demonstrated to increase with the magnitude of load applied but is also affected by the position of the load. Several authors have demonstrated that loads placed higher on the trunk result in a more upright posture than loads placed in a low position (Simpson et al., 2012; Knapik et al., 2004). Double packs, in which the load is distributed equally on the front and back of the body, have been shown to reduce forward lean of the trunk. By distributing the load closer to the centre of mass of the body it has also been suggested that double packs move in synchrony with the body, reducing cyclic stress to structures in the back such as muscles, ligaments and spine (Knapik et al., 2004).

As police forces look towards altering the load carriage of their officers it is necessary that we understand the biomechanical effects that this may have on gait and posture. While much can be learned from backpack studies, the results cannot be generalized to police who typically carry smaller loads that are positioned anteriorly around the hips or, in the case of a load bearing vest, on the chest. Based upon results from backpack studies one can however hypothesize that moving the load carriage from the waist to the trunk; closer to the center of mass, will ensure that the load carriage moves in synchrony with the body (Knapik et al., 2004). This will result in a more upright posture, less compensatory movements during gait and would be less likely to cause low back pain. Given this hypothesis, the aim of the present study was to investigate the effects of varying load carriage in active duty police officers on gait kinematics and self-reported comfort during walking.

2. Methods and materials

2.1. Study participants

Twenty-one police were recruited for the present study including nine women and twelve men. Participants represented 11 of the 21 police municipalities in Sweden. To be eligible for the study, participants were required to be currently serving as active duty uniformed officers who routinely wore a standard issue equipment belt and ballistic protection vest. Police who had previously trialed the load bearing vest were not included in the study. All testing procedures were approved by the Linköping regional ethics committee (dnr 2010/261-31).

2.2. Procedure

Police were tested on two separate occasions with a minimum of three months between each testing occasion. On each of the two testing occasions, three-dimensional motion analysis data (Qualisys AB, Gothenburg) was collected as police walked on a nine meter walkway. Police were also required to complete a questionnaire related to their physical health at the time of testing. On testing occasion one, three-dimensional motion analysis data was captured under three load carriage conditions (a) control (no belt or vest), (b) standard issue belt and ballistic protection vest, (c) load bearing vest and ballistic protection vest (Fig. 1). In both the belt and load bearing vest conditions police were required to carry their standard issue equipment including pistol, extra ammunition, pepper spray, handcuffs, baton, torch and radio. After the first testing occasion participants were provided with a load bearing vest and requested to use it for all shifts until the time of their scheduled second testing occasion. On the second testing occasion motion analysis data was collected for the control and load bearing vest conditions only. Throughout testing all participants wore underwear or tight neoprene shorts together with their standard issue boots. Those who routinely used a thigh holster were able to choose to continue using it together with the load bearing vest if they wished otherwise the pistol was placed in a pouch on the hip which was attached to the load bearing vest. The load bearing vest used in the study was a prototype commissioned by the Swedish national police. It included adjustable pockets in which equipment could be carried.

2.3. Three-dimensional gait analysis

In order to capture three-dimensional kinematic data and temporospatial parameters, spherical reflective markers (⌀ 12 mm) were applied bilaterally to the following landmarks: Head of the 1st metatarsal (MT1), head of the 5th metatarsal (MT5), heel, malleoli, knees, greater trochanter, anterior superior iliac spine (ASIS), Posterior superior iliac spine (PSIS), iliac crest, acromion, 3 around the elbows, 2 at the wrists, 2 at the metacarpophalangeal joints and finally 3 on the head. Three markers were placed anteriorly on the torso and one marker posteriorly on C7. Clusters of 4 markers were placed laterally on the thigh and shank of both legs. In order to account for markers hidden by the equipment belt, a purpose designed carbon fiber U-shaped cluster containing three markers