ASSESSMENT OF AN ALTERNATIVE DUTY BELT:

THE CASE OF LAW ENFORCEMENT OFFICERS

By

MERCAN HADDAD DERAFSHI

Bachelor of Science in Textile Engineering
Ege University
Izmir, Turkey
2008

Master of Arts in Apparel, Merchandising, and Textiles
Washington State University
Pullman, Washington
2013

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF PHILOSOPHY
July, 2017

ASSESSMENT OF AN ALTERNATIVE DUTY BELT:

THE CASE OF LAW ENFORCEMENT OFFICERS

Dissertation Approved:

Dr. Adriana Petrova

Dissertation Adviser

Dr. Semra Peksoz

Dr. Aditya Jayadas

Dr. Isaac Washburn

Dr. Bert H. Jacobson

Name: MERCAN

Date of Degree: JULY, 2017

Title of Study: ASSESSMENT OF AN ALTERNATIVE DUTY BELT: THE CASE OF LAW ENFORCEMENT OFFICERS

Major Field: Human Sciences

Abstract

The purpose of this study was to offer an alternative duty belt that is lighter in weight and evaluate the new duty belt by comparing it to the current duty belt used by officers. A questionnaire was administered at the State level to various police departments. The results from the survey were used to determine the composition of a belts (FDB) and a reduced duty belt (RDB). Two separate laboratory assessments were carried out. On the first session, 11 officers (nine males and two females) were tested for electromyography (EMG) muscle activity for eight superficial muscles and ratings of perceived discomfort for various body regions while wearing three duty belt conditions (CON, RDB, and FDB). On the second session, nine officers (six males and three females) rated perceived ease of movement for all three duty belt conditions. The control (CON) condition resulted in significant increase in muscle activity compared to the RDB condition and no differences with the FDB. The RDB resulted in the lowest muscle activity. Ratings of perceived discomfort indicated clinically significant differences among the RDB condition, compared to the FDB, RDB being more desirable. Ratings of perceived ease of movement showed statistically significant differences between the FDB and the RDB. In conclusion, wearing the RDB significantly reduced muscle activity, increased perceived comfort, and allowed officers to move easily. The results of this study may be of importance to higher authorities in providing further options to their officers with respect to duty gear.

TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

Table Page

LIST OF FIGURES

CHAPTER I

Introduction

Over the last two decades, patrol officers' duties have required them to place new equipment and technology onto their uniform and inside their patrol vehicle. Less lethal weapons such as the TASER, pepper spray, and the baton, have added weight on officers' duty gear, total weight being 18-22 pounds (Edmonds & Laswson, 2001; Stubbs, David, Woods, & Beards, 2008). Furthermore, officers are spending prolonged hours seated inside the vehicle while conducting occupational tasks. High occurrences of low back pain among patrol officers have brought the attention of researchers to assess the influence of physical stressors on low back pain. There is evidence supporting that prolonged driving, sitting, and adopting awkward postures while typing on a mobile data terminal is associated with low back pain (Gyi & Porter, 1998; Holmes, McKinnon, Dickerson, & Callaghan, 2013; McKinnon, Callaghan, & Dickerson, 2011). To address musculoskeletal issues, there have been suggestions to change the vehicle seat to accommodate the officers' duty gear, to use alternative carriage methods for the equipment around the duty belt, and to relocate the mobile data terminal to a more comfortable position (Holmes et al., 2013; Ramstrand, Zügner, Larsen, & Tranberg, 2016; Stubbs et al., 2008). However, less research has been conducted on officers' duty belt with respect to low back pain and little information is available as to what officers perceive to be a comfortable duty belt. It is unclear what officers' preferences are with respect to carriage methods that accommodate their comfort needs as well as their functional needs, that is, to have their equipment readily available.

Officers are permitted to arrange the duty gear to their personal preferences and it is mandatory to carry their equipment on them at all times. That said, heavy, rigid, and bulky duty gear has been reported to increase discomfort and decrease the mobility of officers (Burton, Tillotson, Symonds, Burke, & Mathewson, 1996; Ramstrand et al., 2016). A fully equipped duty belt exerts pressure to soft tissues and may have an effect on the curvature of the spine (Holmes et al., 2013). Wearing equipment on the vest as an alternative to the duty belt has shown to alleviate some discomfort in the hip area during prolonged driving (Filtness, Mitsopoulos-Rubens, & Rudin-Brown, 2014). In pursuance of improving discomfort, items in the low back area could be removed, allowing the person to lean to the backrest, correcting the lumbar posture, and reducing pressure of the weight (Holmes et al., 2013). However, which items could be removed from the belt and where they could be place, is yet to be answered.

Police departments issue their officers with required uniforms and equipment and urge their officers to present a well-ordered and professional appearance to public. Nonetheless, modification to improve the comfort of the duty belt, while maintaining a professional image, is needed. That said, providing information regarding physical risks of carrying heavy and rigid items around the waist and increasing awareness among the law enforcement community might open doors for introducing health, safety, and comfort interventions to their current duty gear.

Therefore, the *purpose* of this study was to evaluate an alternative duty belt that is lighter in weight by removing items off of the duty belt and placing them in alternative locations on the body. The objectives of this study were to a) understand officers' experiences with the current duty belt configuration, b) to identify design specification and establish design criteria based on officers' input, and c) to develop and evaluate an alternative duty belt prototype.

The *rationale* for the current study was that an alternative duty belt design may reduce discomfort experienced by officers. The following four *Specific Aims* were proposed:

Specific Aim 1: Establish a design criteria for a lighter duty belt based on officers' discomfort experiences. *Specific Aim 2*: Determine if the prototype duty belt would reduce perceived discomfort in officers compared to their current configuration. *Specific Aim 3*: Determine if the prototype duty belt would increase perceived ease of movement in officers compared to their current configuration. *Specific Aim 4*: Determine if the prototype duty belt would reduce back and shoulder muscle activity in officers while performing occupational tasks as compared to their current configuration.

At the completion of this study, it was *expected* that, a lighter duty belt with less duty gear attached to the belt would be developed based on officers' discomfort experiences. The *impact* of this study was to introduce an alternative carriage method to the law enforcement community. Over all, the understanding of officers' preferences in their duty gear would guide authorities in their duty gear purchases, and it would assist manufactures and functional apparel designers in designing duty gear that reduces discomfort by removing items away from the duty belt and distributing it in alternative locations on the body. The results of this study may be applicable to other countries with officers who are experiencing similar low back issues with respect to their duty gear.

CHAPTER II

Background Information

Low Back Pain

In the United States prevalence of low back pain is reported to be high. As reports indicate 80% of the general population suffers one episode of low back pain at time in their lives. Approximately half of those individuals will have reoccurring low back pain within the first year of the first episode, leading to a possible history of chronic low back pain (Luo, Pietrobon, Sun, Liu, & Hey, 2004). Furthermore, 22% of the general population report disabling back pain (Cassidy, Côté, Carroll, & Kristman, 2005). Past survey results indicate that 26% of the general population with back pain will recover and out of those who do, 28% will have at least one reoccurring back pain within the next 6 months (Cassidy et al., 2005). In the United States there are more than 30 million office visits to physicians and other health care providers such as chiropractors each year due to back pain (Andersson, 1999; Gary Hart, Deyo, & Cherkin, 1995). Back pain is one of the most costly illnesses and health care expenditures are rising steeply in the United States (Blumenthal, 2001; Luo et al., 2004). According to a household survey, conducted by Luo et al. (2004), total health care expenditures acquired by individuals with back pain in the United States in 1998 were approximately $91 billion. It is important to note that there is an increasing trend in these expenditures by $78 billion since 1977, suggesting an annual cost of health care for back pain, in the United States to be doubled by 2019.

Occupational low back pain.

According to Hildebrandt (1995), occupational back pain is a major issue among the working population. Prevalence of back pain, depending on the type of occupation, ranges from 12-41%. Moving towards the working population in the United States, in an epidemiologic study, Manchikanti (2000) denoted that 28% of the working population will experience disabling back pain at some time in their lives. Furthermore, 8% of the entire working population will be disabled in any given year thus, back pain contributes to 40% of all lost work days. Estimated costs of occupational injuries and illnesses were $171 billion with $145 billion covering musculoskeletal injury costs (Leigh, Markowitz, Fahs, Shin, & Landrigan, 1997). According to the U.S. Bureau of Labor Statistics (2015) there are six occupations that have the highest incident rates of all occupations; heavy truck drivers, nursing assistants, correctional officers/jailers, construction laborers, firefighters, and law enforcement officers.

Law Enforcement Officers.

In 2011, state and local law enforcement agencies employed more than one million officers on a full-time basis, including about 700,000 sworn personnel who have the authority to make arrests. Seventy-three percent of the sworn personnel were male and 27% were female officers (Federal Bureau of Investigation, 2011). The Bureau of Labor Statistics (2016) identifies patrol officers as having "one of the highest rates of injuries and illness of all occupations". Incidence rates per year are 520 per 10,000 full-time workers accounting for 24,000 injury cases (U.S. Bureau of Labor Statistics, 2015, 2016). Officers' musculoskeletal injury rates have been found to be substantially higher than the general public with low back pain being the most common reported injury (Brown, Wells, Trottier, Bonneau, & Ferris, 1998; Dawes et al., 2017; Ramstrand & Larsen, 2012; Sullivan & Shimizu, 1988). In the State of California alone, cost for filing worker's compensation, that are preventable injuries, has risen to $28 million (J. Dolan, 2015). Over the last two decades, officer duties and responsibilities have expanded, requiring them to adopt new technologies into the patrol car and onto their uniform (e.g. mobile data terminal, on-body camera, and radio). Furthermore, the introduction of less lethal weapons such as the TASER, pepper spray, and the baton, has added weight to officers' duty gear, total weight being 18-22 pounds (Edmonds & Laswson, 2001; Stubbs et al., 2008). Keeping in mind the link between muscle strains and carrying weight, sudden rapid moves, and twisting, it is expected to find that low back issue in patrol officers is a universal issue and not just limited to the United States[1] (Brown et al., 1998; Filtness et al., 2014; Jahani, Motevalian, & Asgari, 2002; Ramstrand & Larsen, 2012).

The shoulder muscles are also addressed in patrol officers' musculoskeletal studies due to prolonged driving and typing inside the vehicle (McKinnon, Amy, Callaghan, & Dickerson, 2014; McKinnon, Callaghan, & Dickerson, 2012). To address

[1] Other studies reported low back pain in officers include but not limited to articles from Iran, Turkey, Britain, Germany, Sweden, Canada, and Australia.

musculoskeletal concerns in officers, it is imperative to understand factors causing physical discomfort in the workplace. When investigating the effect of duty gear on muscle activity of the superficial muscles of the back, it is important to understand the structure and articulations of the spinal column.

Anatomy

The following section covers anatomy of the human trunk, related to the biomechanical assessment of this study. In this section anatomy of the shoulder muscles will be explained due to the relevance to the electromyography assessment of this study.

The skeletal anatomy of the trunk includes the spinal column, the ribs, and the sternum. The spinal column, consists of seven cervical (C1-C7), twelve thoracic (T1-T12), five lumbar vertebrae (L1-L5), the sacrum (S1-S5), and the coccyx (three to five fused vertebrae) (see Figure 1). The ribs and sternum make up the anterior portion of the thoracic wall. There are twelve pairs of ribs that are connected by cartilage and intercostal muscles. From C1 to L5, the vertebral bodies are increasingly larger as they play a weight-bearing role of the spine. Moving from the sacral area to the coccygeal area, vertebral bodies decrease in size. The sacral vertebrae complete the pelvic girdle, which transmits the weight of the head and the trunk onto both femur heads. Each vertebra is separated in the spinal column by means of fibrocartilages also known as intervertebral discs constituting one-fourth of the length of the spinal column. This elastic material between the vertebral bodies, constitutes a center of motion and allows compression in any direction as well as rotation. They also play an important role in shock absorption, vibration forces, and in resisting compressive forces (Luttgens & Hamilton, 1997).

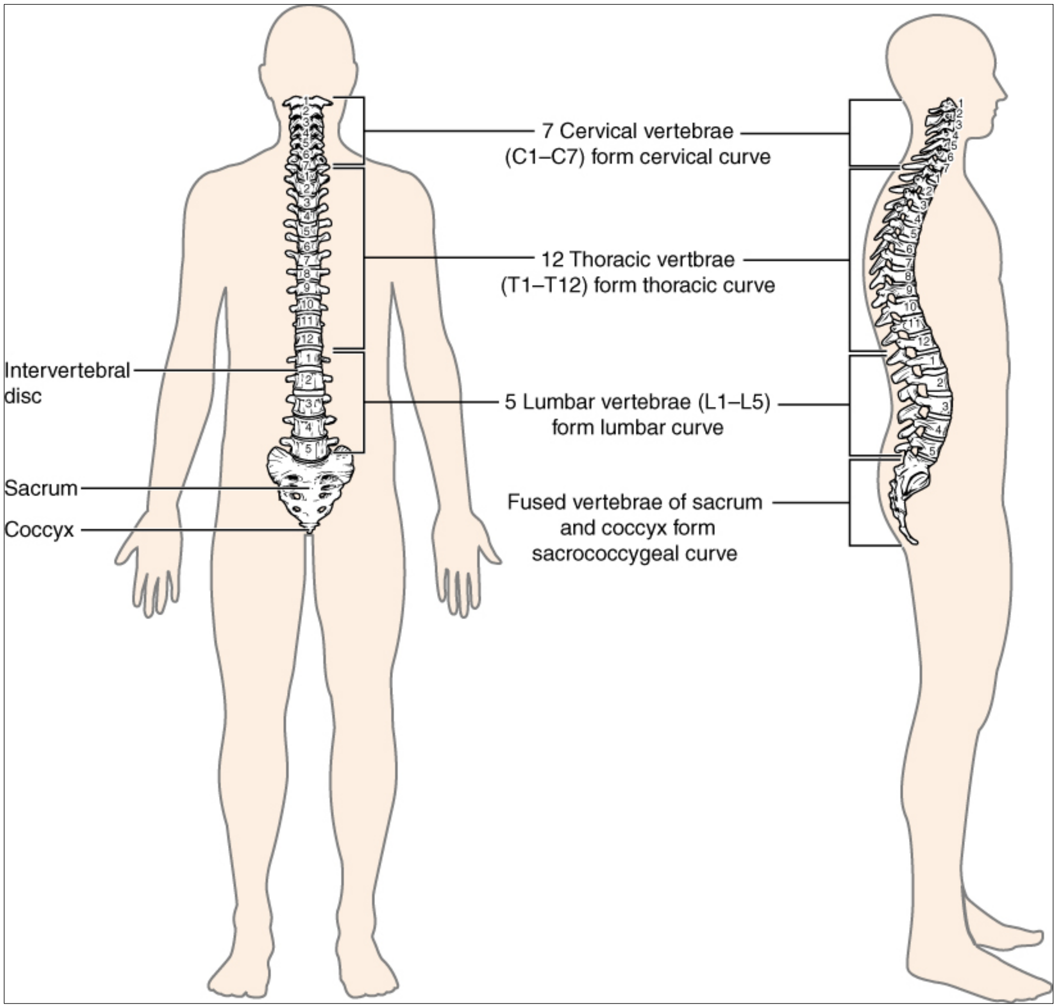


Figure 1. The spinal column from the frontal (left) and sagittal (right) plane (https://en.wikipedia.org/wiki/File:715_Vertebral_Column.jpg)

Muscles around the spine play an important role to support the spine, allow the trunk to move, and twist in various directions. Three types of back muscles that help the spine function are extensor muscles, flexor muscles, and oblique muscles. Extensor muscles are the erector spinae and allow the trunk to extend. Flexor muscles are the abdominal muscles that enable the trunk to crunch and flex. The oblique muscles contain two groups, internal obliques and external obliques that, enable the trunk to flex and rotate. It is appropriate to mention the deeper muscles of the back running from the transverse processes to the spinous processes of the vertebrae. These intervertebral muscles are the **rotator** muscles that are short and run the entire length of the vertebrae column extending and rotating the vertebrae column. **Interspinales** unite the spinous process of contiguous vertebrae and the **intertransversaii** muscles, unite the transverse processes of consecutive vertebrae.

Ligaments.

Ligaments are fibrous structures that connect the vertebral bodies. The anterior longitudinal ligament connects the anterior surfaces of the vertebral bodies from the skull to the coccyx. Posterior longitudinal ligament connects the posterior surfaces of the vertebral bodies. The anterior and posterior ligaments control flexion and extension of the spine. The interspinous ligament is in between the spinous process of the vertebrae. The supraspinous ligament is on top of the spinous processes of the vertebrae. The ligament flava connects the laminae of adjacent vertebrae, all the way from the second vertebra, axis, to the first segment of the sacrum. These ligaments work together to limit flexion and extension of the spine but also, work together to prevent displacement of the intervertebral disc during hyperextension (Wikipedia.com).

Erector Spinae.

These muscles start from the lumbosacral region of the back and extend toward the thoracic region. The erector spinae are the largest surface muscle of the back, responsible for controlling flexion, lateral flexion, and rotation of the vertebral column. These muscles are divided into three branches; iliocostalis, longissimus, and spinalis further grouped into three portions (Figure 2). Iliocostalis contains three portions called iliocostalis cervicis, iliocostalis thoracis, and iliocostalis lumborum. Similarly, longissimus and spinalis of the erector spinae are broken down into three portions. The longissimus muscles lying close to the spine is connected to each rib while the spinalis branch lies against the spine. Electromyography results indicate the surface back muscles are most active during a flexed position while standing to support the trunk weight, during extending the trunk back to straight standing position, hyperextension, and lateral flexion against gravity or a resisting force during standing. Despite the major role of the erector spinae in moving the trunk, it tends to demonstrate low muscle activity compared to the shoulder muscles and lower extremities (Pauly, 1966). Another set of muscles that run from the transverse processes to the spinous processes of the vertebrae are the transversospinales muscles. Multifidus is a muscle from this group that extends laterally and flexes the vertebral column and rotates the head. The rotator muscles of this group are short and run the entire length of the vertebral column rotating the vertebral column.

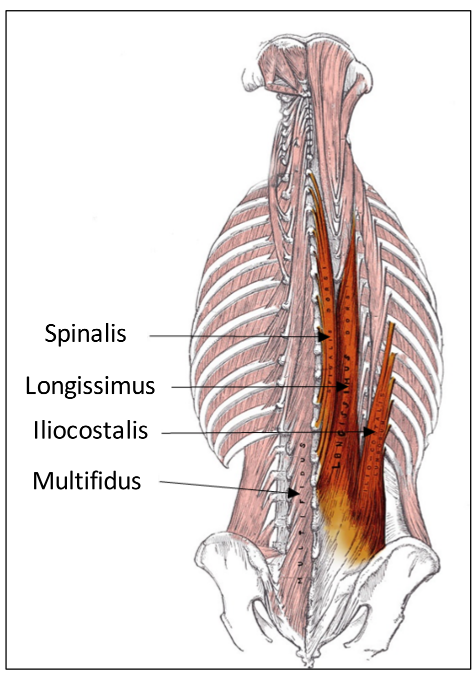


Figure 2. Muscles of the erector spinae
(https://commons.wikimedia.org/wiki/File:Gray389_-_Erector_spinae.png)

Anterior Deltoid.

Among the scapular muscles, the deltoid is a powerful shoulder muscle that covers the glenohumeral joint. The anterior part of the deltoid aids in all flexion movements of the shoulder and inward rotation of the humerus (Figure 3).

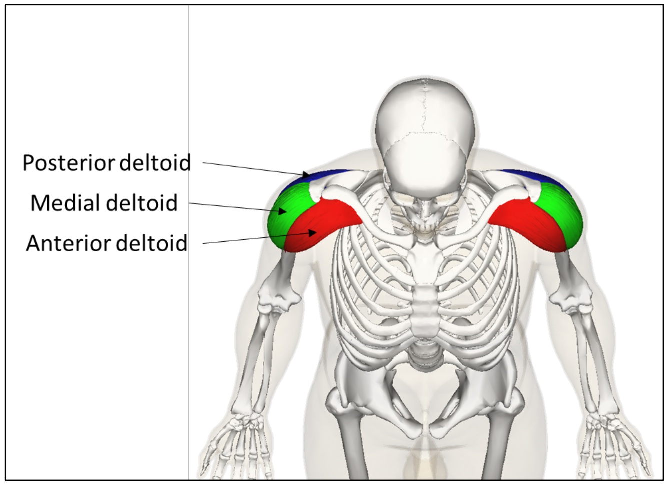


Figure 3. Deltoid muscles: posterior deltoid (blue region), medial deltoid (green region), and anterior deltoid (red region) (https://commons.wikimedia.org/wiki/File:Deltoid_muscle_top2.png)

Understanding anatomy of the human trunk along with type of movements the muscles are responsible for is essential in functional apparel design and determining design criteria that meet comfort and functional needs. Product development requires a systematic approach that records every step of the way in determining design criteria. Therefore, the next section will focus on describing the design process implemented in the current study.

Functional Design Process

DeJonge (1984) seven-step functional design process provides a systematic approach for the development of functional apparel from early stages of ideation through final prototype evaluation. DeJonge's systematic approach reduces the designer's reliance on spontaneous approaches and maintains an open door for creative ideas. Table 1 lists seven stages of the design process with activities included in each step. Each box incudes excellent examples of product-development studies demonstrating how they implemented the corresponding step of the functional design process. Researchers may choose to follow all the steps or adapt several steps of the design process based on the purpose of their research.

Step 1 of the functional design process is the *general request made*. This request may be formally made from the wearer or it can be a general statement of an objective made by the designer.

Step 2, *design situation explored*, involves focusing on the critical factors that comprise the user needs. Identifying a problem in the current design of the product could be best obtained through the consumer's experiences and perceptions (Lamb & Kallal, 1992). Thus, understanding the user's functional and expressive needs defines what the consumer's actual need is, setting the foundation for empathic design. In empathic design, designers make an attempt to get closer to the lives and experiences of the users in order to design a product that actually meets the needs of the user (Kouprie & Visser, 2009). To explore the design situation, further observations, interviews, focus group discussions, and literature review, along with market analysis are required.

Step 3, *problem structure perceived*, involves further assessment of critical areas and narrows down to find the actual problem. Depending on the type of garment needed, a designer may find needs assessment, thermal assessment, performance testing, or impact testing helpful.

Table 1.

Stages of DeJonge (1984) design process and examples of studies employing techniques. This table is a courtesy of McRoberts (2008)

DeJonge (1984) design process	Activities Included	Studies used or adapted 7-step design process
Stage 1 Request Made	Personal experience Observation Third party request Review of literature	(Bye & Hakala, 2005), (McRoberts, Black, & Cloud, 2015), (C. Black, Grice, & Fowler, 2003)
Stage 2 Design situation explored	User interviews Brainstorming Observation analysis Market analysis Review of literature	(Carroll, 2001; Kim & Farrell-Beck, 2003) (Krenzer, Starr, & Branson, 2005) (Starr, Branson, Ricord, & Peksoz, 2006) (Fratto, Jones, & Cassill, 2006)
Stage 3 Problem structure perceived	Isolate critical factors Narrow the perspective Define the problem Visual analysis	(Barker, Black, & Cloud, 2010) (Lawson & Lorentzen, 1990) (Lyman-Clarke, Ashdown, Loker, & Schoenfelder, 2005)
Stage 4 Specifications described	ROM Impact assessment Thermal assessment Social-psychological assessment	(Horridge, Caddel, & Simonton, 2002) (Huck & Kim, 1997) (Mitchka, Black, Heitmeyer, & Cloud, 2009)
Stage 5 Design criteria established	Check specifications against objectives Reassess critical factors Charting, ranking, and weighing Prioritizing	(Bergen, Capjack, McConnan, & Richards, 1996) (Bye & Hakala, 2005) (Barker & Black, 2009) (Starr et al., 2005)
Stage 6 Prototype developed	Materials selection Pattern development Construction methods Finishing techniques	(Krenzer et al., 2005) (Cho et al., 2005) (Barona-McRoberts, 2005)
Stage 7 Design evaluation	User acceptability Fit evaluation Movement assessment Thermal assessment Functional effectiveness	(Chae, Black, & Heitmeyer, 2006) (Huck, Maganga, & Kim, 1997) (Rutherford-Black & Khan, 1995) (Maher & Sontag, 1986)

During steps 4 and 5, *design specifications* and *design criteria* are established. These two steps involve charting, ranking, and weighing the data collected from various assessments.

During steps 6 and 7, *prototype developed* and *design evaluation,* researchers determine whether the prototype meets the design specifications. At this stage, objective and subjective assessments are utilized to test the prototype and subjects appropriate for the end use of the prototype are recruited (Son, Bakri, Muraki, & Tochihara, 2014).

Preliminary Data from Campus Patrol Officers

In exploration of patrol officers' duty gear needs, preliminary data was collected from campus patrol officers through interviews, focus group discussions and ride-along sessions in the fall of 2015. The first three stages of the DeJonge (1984) design process, as described below, was followed by the researchers to identify patrol officers' duty gear needs.

Step 1*, request made,* was obtained through police blogs and phone conversations with 3 officers. It was brought to the researchers' attention that officers have back pain complaints and discomfort issues with respect to their duty gear. This initial idea was confirmed by a personal contact, a patrol officer that experienced back pain and emphasized that back pain was a common issue among patrol officers.

Step 2, *design situation was explored* by conducting focus group discussions, face-to-face interviews, and multiple ride-along sessions with officers from day shift and night shift. Researchers collected qualitative data related to officers' issues with respect to their uniform, duty gear, vehicle seat, and occupational tasks. At this stage, our goal was to gather as much as information possible regarding advantage and disadvantage of officers' duty gear and physical discomfort experienced while conducting occupational tasks. From the initial focus group discussion and ride-along sessions, it was revealed that prolonged sitting and standing caused musculoskeletal pain in the hips and low back areas and the duty belt interacted with the vehicle seat resulting in aggravated pain. This problem was consistent across the interviews, focus group discussion, blogs, and the literature (see Appendix A). Concerns were stated as the duty gear being heavy up to 18 to 22 pounds with 8 to 12 pounds belonging only to the duty belt and items attached to it. In addition to the weight, the belt was reported to be tight and rigid, and some items such as the handcuffs and magazine pouches were digging into the lower back and hip area when seated. In an effort to address the heavy weight of the duty belt and items attached, the campus police department adapted suspenders that were attached to the belt reaching the shoulders. Other changes adapted to officers' uniform was the outer ballistic vests for cooling excess heat from the Kevlar vest. However, neither of these interventions (outer ballistic vest and suspenders) resolved the rigidity and tightness of the duty belt. Furthermore, suspenders were said to be "detrimental" while seated and useful only when on foot patrol and standing for prolonged hours such as graduation ceremonies and sport events. Another issue officers reported to have was the interaction between duty gear and vehicle seat. The vehicle seat was damaged due to bulky duty gear abrading against the seat. Officers believed that the seat pan and bolsters were not wide enough to accommodate the bulk around their waist. Particularly for campus officers, *image* (referred as the appearance of the officer) was a major concern and a "business-like" appearance was perceived to be very important in conveying a message of service to the community and even more important than physical discomfort associated with the high-gloss leather belt.

In order to gain a deeper understanding of officers' duty gear issues, literature review was carried out to better understand what could be done to distribute the excessive weight of the duty belt. There appeared to be little indication in the literature on how the duty belt should be constructed to eliminate discomfort issues. Stubbs et al. (2008) argues that soft pouches and padding should be placed over the lumbar spine and that some equipment on the belt should be removed or rearranged to accommodate driving. In a similar study, Edmonds and Laswson (2001) adapted suspenders to lift the weight off of the waist and distribute it towards the shoulders. Their findings indicate that suspenders were the best option in reducing the weight of the duty belt but interfered with the accessibility of equipment when donning a jacket over the suspenders. The same authors also offered a load bearing vest which improved the accessibility of the equipment but placed a greater weight toward the front of the body hence, was not desired by female officers with a large bra cup size.

Step 3, *problem structure perceived*, included biomechanical assessment of currently available duty gear and pilot testing with campus officers (one male and one female officer). Data obtained from pilot tests and preliminary qualitative data lead the researchers to identify comfort problems with respect to the duty belt. A summary of the design criteria obtained from previous interviews, literature, and pilot testing are reported in (see Table 2). Second phase of step 3 through step 7 were the focus of the current study and are to be discussed in chapter three.

Table 2.

Design specifications and duty belt criteria from literature and focus group discussion

Safety	Comfort	Fit & Mobility	Wearer acceptance
Equipment readily available Interaction with duty gear	Perceived discomfort Perceived ease of movement	ROM Muscle activity Pressure	Maintain professionalism "image" Style of duty belt and vest

The following duty belt criteria resulted from campus patrol officers and available in literature.

- All of the duty gear must be on the officer's uniform at all times (focus group OSU)
- Magazine pouches, hand cuffs, pepper spray, and radio should be in the front and moved up from the belt (Kumar & Narayan, 1999, p. 33)
- Firearm is deployed by strong hand and the TASER by the opposite hand (Katz, 2013)
- High gloss leather duty belt must be used due to its professional appearance (Stone, 2005)
- Handcuffs should be either placed on the front or the rear of the belt (both options should be provided) (Katz, 2013)
- The rear of the belt must be free of rigid and bulky equipment (Espinoza, 2010)
- The weight must be distributed evenly on the belt

- Belt edges and equipment must not exert pressure to soft tissues (Czarnecki & Janowitz, 2003)
- The duty belt should not move up and down; it should be tight without compromising comfort.

It is important to keep in mind that DeJonge's (1984) process emphasizes the design process may deviate from a linear path. In other words, the designers and researchers find themselves going back to previous steps instead of creating a product using one linear path. This model is used as the framework of the design process rather than a road map of linear arrows leading to the ultimate solution.

Establishing Design Criteria

In the design community, it is widely accepted for designers to become familiar with users' lifestyle, preferences, and experiences. Reaching to a high level of understanding of the users' problem, requires great amount of literature review on the subject matter, communicating with the user, and generating new ideas (Kouprie & Visser, 2009). Past research used surveys, interviews, and observation as an objective instrument to identify users' preferences and reflect such presences into the construction of a new product. Such studies include design criteria of a sports bra (Starr et al., 2005), design criteria of sailing apparel (Bye & Hakala, 2005), children's swimwear (Chau, 2012), posture corrector (McRoberts et al., 2015) that were concluded through surveys or obtained through interviews and observation. Preliminary data is limited to campus patrol and past research excludes officers' preferences and experiences within the limits of the available equipment and requirements of their duty gear. Therefore, a survey was appropriate to reach out to the law enforcement community and identify patrol officers' duty belt configuration practices.

Comfort

Clothing comfort has long been a scientific consideration, however, the meaning associated with comfort has not been consistent and varies in different cultures (Branson & Sweeney, 1991). It is difficult to define what is comfortable and even more complex to assess comfort. Slater (1985) defined comfort as "a pleasant state of physiological, psychological, and physical harmony between a human being and the environment (p. 4)." Meaning that, clothing comfort is a neutral state, when the person is physiologically and psychologically unaware of the clothing they are wearing (Branson & Sweeney, 1991; Slater, 1985). According to Slater (1985) humans continuously strive to maintain a balance between the human, clothing, and environment. Measuring comfort is possible by addressing factors relating directly or indirectly to comfort. Likewise, comfort is obtained in the absence of discomfort and is easily described by terms such as tight, hot, rigid, or numb (Li & Dai, 2006). Comfort is a natural state of being and it cannot be felt unless it is absent thus, it is referred as discomfort. As defined by Hatch (1993), "comfort is freedom from pain, freedom from discomfort. It is a neutral state (p. 26)." Difficulties in assessing discomfort has been overcome by comparing things on comfort thus, comfort is comparative. Perceptions of comfort are subjective and can have different meaning among the users and even to the product developer. Comfort plays an important role in product-buying decisions as employers are getting interested in purchasing comfortable equipment for their employees to create a safe and healthy work environment (De Looze, Kuijt-Evers, & Van DieËN, 2003). That said, design and assessment of an ergonomic duty belt would not be possible without considering factors that affect officers' perceived discomfort. The current study will use Sontag's (1985) comfort model to frame the design and assessment of an ergonomic duty belt. The following section will focus on various comfort models.

Fourt and Hollies.

Fourt and Hollies (1970) conceptualized comfort based on a triad, person, clothing, and environment. The authors emphasized that clothing may be either part of the environment or an extension of the body. Psychological, sociological, and cultural factors were considered as a person's judgment and were omitted from the comfort concept. Other models contributed to Fourt and Hollies (1970) comfort triad by including social and psychological aspects of comfort.

Pontrelli.

Pontrelli's (1977) "Comfort's Gestalt" introduced a new psycho-physiological dimension that was missing in Fourt and Hollies' (1970) model. Psycho-physiological variables included in the model were state of being, end-use, style, fashion, fit, and tactile aesthetics. Furthermore, Pontrelli (1977) added stored modifiers (filter) to the model, suggested that a person's past experiences and expectations played an important role in comfort judgment further stressing that perceptions of comfort is subjective and personal.

Sontag.

Sontag (1985) later combined Fourt and Hollies' triad (1970) and Pontrelli's (1977) stored modifiers into one theoretical model. In her model, Sontag presented the triad as three concentric circles with the person attributes being the core (see Figure 4). The person is surrounded by the clothing attributes and by the environmental attributes, respectively. A double-ended arrow travels through three circles, representing Pontrelli's filter, an individual's comfort perception and response, indicating interaction between the levels.

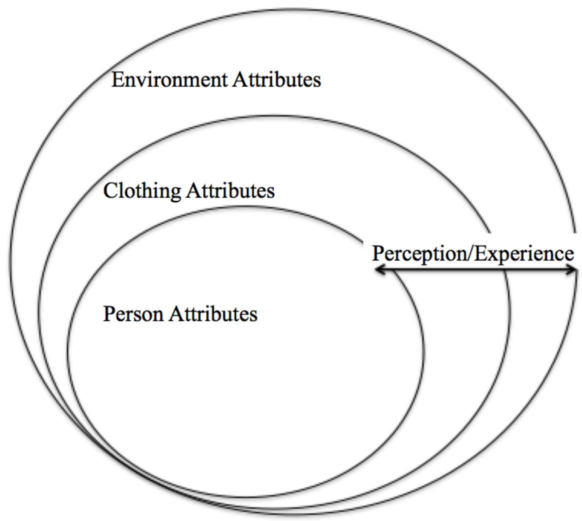


Figure 4. Adapted from Sontag's (1985) clothing comfort triad

Branson and Sweeney.

A more recent clothing comfort model proposed by Branson and Sweeney (1991) highlights four elements that influence judgments of clothing comfort (see Figure 5). Clothing comfort is a state of balance between a person, the clothing they wear, and the environment surrounding them, also referred as the person, clothing, and environment triad (Sontag, 1985). In the clothing comfort model it is proposed that "each element of the triad has both physical and social-psychological dimensions that potentially influence physiological and /or perceptual responses and the subsequent comfort judgment for an individual in a given context" (Branson & Sweeney, 1991, p. 100). According to this model while a person’s age, race, weight, height, etc. (physical attributes) influence comfort judgment, also person’s personality, body image, values, attitudes, etc. effect one’s perception in clothing comfort.

PHYSICAL DIMENSION TRAID	SOCIAL-PSYCHOLOGICAL DIMENSION TRAID
PHYSIOLOGICAL/PERCEPTUAL RESPONSE	
FILTER	
CLOTHING COMFORT JUDGMENT	

Figure 5 Branson and Sweeney (1991) Clothing Comfort Model

Review of literature revealed that many researchers have referred to Branson and Sweeney’s clothing comfort model to describe the physical dimensions (Barker et al., 2010; Horridge et al., 2002) as well as social psychological dimensions in measuring clothing comfort (Chattaraman & Rudd, 2006; Sidberry, 2011; Stokes & Black, 2012). This study will address physical attributes of Sontag’s (1985) comfort triad with respect to officers’ duty belt and occupational tasks. The following section elaborates on discomfort experienced by officers as it relates to Sontag’s (1985) triad.

Physical Risk Factors and Discomfort in Officers

In the model used for the current study, physical risk factors for occupational back pain and discomfort are static work postures, frequent bending, twisting, lifting, vibration, and/or postural stress. Additionally, there are individual factors that influence low back pain, such as genetics, age, height, weight, gender, smoking habits, physical factors, and marital and social factors (Bigos et al., 1991 as cited in ; Manchikanti, 2000). Sontag’s (1985) model was similar to the case with police officers discomfort. Based on preliminary data obtained from interviews, focus group discussion and ride-along sessions, causal factors for discomfort from officers’ perception and experiences were grouped into three factors; person characteristics (physical fitness, age, anthropometric variables, gender, occupational task), duty gear (uniform, duty belt, ballistic vest, etc.), and work environment (vehicle seat, shift, physical altercation, etc.). Arches that connect each factor represents an overlap between causal factors and that they are not independent of each other. For example, paths between 'person' and 'duty gear' were in items such as magazines that would dig into the abdomen (reported by male officers) and the firearm would exert pressure onto the hip and cause numbness towards the end of the shift (reported by a female officer). Furthermore, officers who had a smaller waist size did not have enough space on their duty belt and had to remove certain items such as pepper spray and baton and place those items in the patrol vehicle (reported by both male and female officers). Overlaps between 'duty gear' and 'work environment' were mainly related to the duty belt items getting caught to the vehicle seat, seat belt, and the steering wheel. Majority of the officers mentioned that the backrest of the vehicle seat did not accommodate the bulk around the officers' waist causing the officers to sit without fully leaning back to the seat. 'Person' and 'work environment' overlaps were related to shifts being too long and not allowing sufficient time for incorporating physical fitness regimen into their daily schedules. According to officers, multiple factors played a role making low back discomfort and low back pain inevitable in law enforcement occupation.

Attributes considered in this study were; person attributes (male and female officers), clothing attributes (duty belt configuration), and environmental attributes (work environment as the vehicle seat and seated occupational tasks) (see Figure 6).

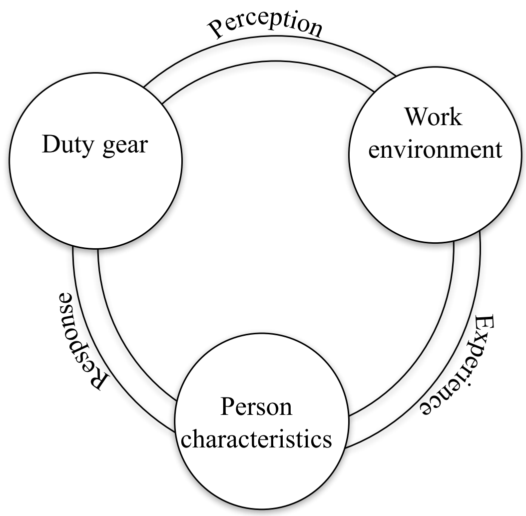


Figure 6. Causal factors of discomfort in officers

Musculoskeletal issues in officers.

Officers have a unique work environment where their sedentary work regimen does not condition them or physically prepare them for tasks that require muscle conditioning and strength, such as physical alteration in arresting a disorderly conduct (Gyi & Porter, 1998). Moreover, unvaried tasks such as driving, typing, ingress/egress, and carrying equipment, might gradually result in overworking the muscles and is often associated with first-time back injuries in officers (Sullivan & Shimizu, 1988). Literature indicates strong evidence of back pain associated with awkward body postures and whole body vibration (K. M. Black, Lis, & Nordin, 2011; Movahed, Ohashi, Kurustien, Izumi, & Kumashiro, 2011; Wikström, 1993). That being said, sedentary occupational tasks such as sitting, typing, and/or driving are linked to back pain in many driving professions including officers (Gyi & Porter, 1998; Porter & Gyi, 2002; Poulsen, Jensen, Bach, & Schostak, 2007). The cramped environment in a patrol vehicle, the restraint cage, location of mobile data terminal has been studied and reported to have an effect on officers' discomfort, posture, and muscle activity when seated (Cardoso, Girouard, McKinnon, Callaghan, & Albert, 2017; Holmes et al., 2013; McKinnon et al., 2014; McKinnon et al., 2011; McKinnon et al., 2012). According to McKinnon et al. (2011) officers spend approximately 50% of their shift seated inside the patrol vehicle and 33% of that time is spent entering data or working with the mobile data terminal. It is not surprising that officers who spend more than half of their shift in a vehicle driving and absorbing vehicle vibration have high incidences of back pain (Burton et al., 1996; Magnusson, Pope, Wilder, & Areskoug, 1996; Wilder, Woodworth, Frymoyer, & Pope, 1982). Likewise, wearing a ballistic vest and duty belt both have been reported as major sources of discomfort for officers (Brown et al., 1998; Donnelly, Callaghan, & Durkin, 2009; Holmes et al., 2013). Ramstrand and Larsen (2012) conducted focus group discussions to investigate the major causes of musculoskeletal injuries among Swedish officers. The authors found that the duty belt worn by officers was perceived to be a major source of musculoskeletal injuries followed by vehicle seat, uniform, work hours, and physical fitness. It is therefore, appropriate to state that comfort in officers' duty gear could be obtained when there is a balance between the person and his or her environment. It is evident from the above-mentioned literature that using a more ergonomic duty gear for officers and excluding the amount of time spent in a vehicle seat, will positively affect officers' discomfort. The ability to perform functional tasks without duty gear restriction may increase efficiency; increase mobility, and may decrease the chances of sustaining musculoskeletal injury and back pain. Due to strong association of back pain with prolonged sitting in awkward postures and in order to improve officers' overall musculoskeletal health, it is imperative for researchers to assess trunk kinematic, trunk muscle activity, and perceived discomfort with respect to occupational tasks and duty gear.

Performance Assessment

Given the high injury rates of officers and the financial costs associated with treating musculoskeletal issues, it is crucial to offer an alternative duty belt and evaluate the outcome of an alternative duty gear configuration on muscle activity, perceived discomfort, and perceived ease of movement. There needs to be a biomechanical assessment that focuses on the effect of the duty gear on wearer's comfort and performance. Thus, it is imperative to explain how equipment properties such as weight and configuration impact wearer performance.

Functional apparel and equipment.

Functional apparel or equipment is utilized performing a set of unique occupational tasks. It is particularly of interest for functional apparel designers to protect the wearer being obstructed, through garment design. A growing body of knowledge has associated carrying heavy and bulky equipment, such as the body armor, firefighter coveralls, and law enforcement duty gear, with muscle fatigue and musculoskeletal injuries (Dempsey, Handcock, & Rehrer, 2013; Park et al., 2014; Son et al., 2014). Adams, Slocum, and Keyserling (1994) highlighted studies that assessed garment properties in association with objective and subjective performance measures. The authors' inclusive literature review revealed that majority of studies focused on fabric and garment properties related to thermoregulation issues and thermal comfort (Fan & Keighley, 1991; O'Brien et al., 2011; Rissanen, Jousela, Jeong, & Rintamäki, 2008).

Relatively few studies have looked at physical issues such as weight, bulk, and size related to human performance (Adams & Keyserling, 1995; Elder, Hennessy, & Kanagaki, 2010). All kinds of physical issues related to human performance should be taken under consideration in performance assessment and ergonomic evaluation of functional apparel (Adams et al., 1994). According to Adams et al. (1994) factors that affect worker performance are four categories; person characteristics (anthropometry, physiology, motivation, etc.), garment properties (stiffness, size, bulk, etc.), environment (space constraints, harmful agents, etc.), and occupational task (movement, direction, force, etc.). Muscle activity, that is related to the physiology of the person, observed through electromyography (EMG) amplitude of the muscles, can provide a comprehensive understanding of how protective clothing and equipment impact the body while performing occupational tasks. Electromyography has been used in the current study to better understand muscle activities of areas associated with discomfort in officers. EMG is considered to be one physiological measurement other measures are body temperature, skin moisture, perspiration, oxygen uptake, and hear rate.

While range of motion was not addressed in this study it is worthwhile to note that movement in occupational tasks can be measured by the change in joint angle or the distance moved. Mobility has been previously studied by assessing subjective perceptions and measurement of joint angles (Barker et al., 2010; Huck et al., 1997). Motion capture technology tracks human body movements and continuously provides accurate measurement of range of motion (ROM) under different garment treatments. Also, movement involves the contraction of muscles. Clothing or equipment that do not slide across the skin, do not expand, bend, or compress as the body moves, may restrict the wearer mobility and interfere with normal muscle activity and lead to discomfort (Adams & Keyserling, 1995; Kirk & Ibrahim, 1966; Nakahashi, Morooka, Nakamura, Yamamoto, & Morooka, 2005).

Mobility.

When assessing the effectiveness of functional apparel, it is important to consider mobility. According to Kreighbaum and Barthels (1996), mobility is defined as "the ease with which an articulation, or a series of articulations, is allowed to move before being restricted by the surrounding structures" (p. 64). In comfort studies related to protective clothing, mobility has been linked to comfort. Wearers prefer protective clothing that allow maximum range of motion over garments that restrict the wearer mobility while performing occupational tasks (Adams & Keyserling, 1996; Huck et al., 1997). It is also important to assess range of motion concurrent with perceived discomfort and muscle activity, as restricted mobility may negatively affect comfort, inhibit efficient movement of the body thus affect muscle activity. Details on muscle activity and perceived discomfort will be discussed in the following section. In this study perceived ease of movement is measured using Liker-scales after carrying out standard movements (trunk flexion/extension, trunk lateral bend, and trunk rotation). It is evident from the above-mentioned research that weight of personal protective equipment effects mobility of joints and perceived movability of the wearer.

Muscle activity and protective clothing.

Estimation of muscles' activity is a direct indicator of local physical risk, and is essential to understanding the mechanism of kinematics and strength in the given surface muscle for a given time (McKinnon et al., 2012). Electromyography, or EMG, involves testing the electrical activity of muscles. Muscular activity involves the action of muscles and nerves and electrical current. EMG testing is conducted in two different methods, invasive and non-invasive methods. Needle EMG, an invasive method, is conducted in a clinical setting where needles are inserted through the skin into the muscle. A non-invasive method, surface EMG is carried on surface muscles where electrodes are placed on the skin. The application of these methods is different; needle EMG is used for diagnostic examinations and provides information on voluntary motor activity in deep muscles that can also be obtained using surface EMG. Studies have taken advantage of the linear relationship between EMG and muscle force and have validated predicted forces from EMG data using muscles of interest while performing lifting tasks (Dolan et al., 2001; Fathallah, Marras, & Parnianpour, 1999; Granata & Marras, 1995), trunk extensions (Granata & Marras, 1993), lateral bending (Marras & Granata, 1997; McGill, 1992), and axial twisting (Marras & Granata, 1995; McGill, 1991). Dolan et al. (2001) quantified the spinal loadings on the erector spinae while participants lifted various weighed boxes. To stimulate asymmetric occupational tasks participants in their study lifted boxes at a 45° angle. The authors found an increase in muscle activity at the T10 and L5 levels of the thoracic region as the weight and lifting speed increased. Axial twisting of the torso has been identified to increase the risk for occupation-related low back pain. Biomechanical assessments indicate high muscle activity and consequently spinal loading when twisted. Granata and Marras (1995) assessed several trunk muscles while rotating the trunk and found that latissimus dorsi, rectus abdominis, and internal oblique muscles show increased activity with higher exertion. Other factors increasing muscle activity were direction of the twist (e.g. left external oblique is more active when acting as antagonistic muscle while twisting counter-clockwise compared to acting as agonistic while rotating clockwise) and increased velocities required greater EMG activity. Results from these studies indicate that, muscle activity increases with exertion level, increased velocities of the trunk, and torsional directions. In a practical sense, these studies explain how rapid movements of the trunk might increase the risk of low back injury during occupational tasks. In another similar study conducted by Kumar, Narayan, and Zedka (1996) focused on occupations in which workers are seated and exposed to twist trunk posture without having a break in the middle of their prolonged twist posture. Kumar et al. (1996) measured muscle activity of the latissimus dorsi and rectus abdominis muscles while their participants completed axial rotation by rotating to their extreme left, to their neutral position, and twisting to their extreme right without stopping anywhere in between. The ROM when twisting from neutral seated position to the extreme left or right varied between 70° and 82° (Kumar et al., 1996; Torén, 2001). Up to 10-15° twist on either side of their neutral seated position little to no muscle effort was obtained. However, when rotated beyond these points there was an increasing effort to twist the torso as the bones and ligaments became stiffer. In Torén (2001) study on tractor drivers, low muscle activity was obtained in 0° to 20°. Indicating that any occupation such as tractor driving or office work, requiring the person to work seated and twisted more than 20° requires high muscle effort from the external obliques and erector spinae muscles and this could be a risk factor for back pain. Patrol officers have similar seated positions as tractor drives. McKinnon et al. (2011) looked at muscle activity while officers performed occupational tasks. The authors found mobile data terminal use, requiring the person to adapt a twisted posture, and on-paper documentation to be the most likely activity-based risk factors for musculoskeletal pain and injury aside from prolonged sitting on a vehicle seat. Later on, McKinnon et al. (2012) conducted a unique study with officers that use mobile data terminal inside the patrol vehicle and assessed the effect of mobile data terminal locations on muscle activity of the trunk and upper extremities. Twenty patrol officers carried out a typing task in their preferred mobile data terminal location and repeated the same task at their current fixed mobile data terminal location and three other preselected mobile data terminal locations. Results indicate the lowest muscle activity was in the posterior deltoid and supraspinatus muscles for the self-selected and current mobile data terminal location. The authors conclude that the self-selected and current mobile data terminal locations had the minimal right-shoulder elevation and most increase in perceived comfort in the lower back area.

The closest research to the effect of belt on muscles of the back were related to weight-lifting belts and how the belt affects muscles of the torso. Granata, Marras, and Davis (1997) investigated the effect of three different lifting belts on trunk motion, muscle activity, and spinal loading with participants lifting 14 and 23 kg boxes. The belts decreased range of motion associated with trunk during lifting. Also, while wearing the back belts, subjects' muscle activity reduced in the erector spinae muscles, increasing activities in the oblique muscles. The authors suggested that there was a redistribution of muscle forces with lifting when wearing a back belt compared to unbelted lifting. Similarly, weigh-belts have been reported to increase the pressure in the abdominal area by increasing compression forces As the abdomen supports some of the load, the muscles of the lower back are also relieved resulting in less muscle activity compared to the unbelted condition (Lander, Simonton, & Giacobbe, 1990). Another factor that has been shown to affect muscle activity was the repetition of the task and fatigue despite the presence of belts or no belts. Patrol officers' tasks are more similar to driving occupations where their muscles sustain low level of muscle activity that may increase fatigue and lead to musculoskeletal issues (Hostens & Ramon, 2005).

Past research indicates an interaction between the duty belt and vehicle seat and that both components increase officers' discomfort. Thus, it is imperative to understand this phenomenon prior to any ergonomic interventions. Considering the high rate of low back pain among the law enforcement community and correlation of discomfort with high muscle activity, future research should further assess the interaction of vehicle seat, duty belt, and occupational tasks on the trunk movement and muscle activity.

Perceived discomfort.

Empathic design takes into account target users' experiences such as discomfort issues while using a product. Discomfort experienced during work has been linked to musculoskeletal injuries, further justifying the importance of assessing perceived discomfort. In police officer research, discomfort is usually reported through subjective questionnaires (Brown et al., 1998; Gyi & Porter, 1998). Discomfort is also assessed during simulated occupational tasks and used as a complement of objective measures (Donnelly et al., 2009; Holmes et al., 2013). The results of discomfort or comfort assessment can help to understand the objective values measured. For example, to determine a threshold and quantify the maximum discomfort associated with a garment, subjective evaluations such as discomfort have to be considered. Another value that comfort assessment provides is improving functional apparel. If we want to make better quality products the amount of discomfort they cause must be measured and improvements must be made accordingly. Kelly (1998) determined the minimal clinically-significant difference in the visual analog scale as 9 mm. Differences smaller than this amount, even if they were statistically significant, they would not be considered clinically significant. Also, difference of 10 mm showed small treatment effect and of 20 mm - difference showed a large treatment affect. For research on patrol officers' vehicle seat and duty gear discomfort clinical significance has been determined as 30 mm or above (Donnelly et al., 2009; Filtness et al., 2014).

Donnelly et al. (2009) identified car seat features, occupational equipment and tasks with respect to officer discomfort using the visual analog scales and Automotive Seating Discomfort Questionnaire (ASDQ). Computer use, duty belt, firearm, radio, and lumbar support were the main features causing discomfort. Discomfort on various body regions were in the low back, tailbone, right and left upper pelvis, and middle back. The authors noted several factors causing elevated levels of discomfort such as cramped environment inside the car, duty belt with equipment, body armor, and use of mobile data terminal. It is important to note that any discomfort equal or greater than 30 mm is considered to have clinical significance (Filtness et al., 2014; Kelly, 1998).

In another similar study, Filtness et al. (2014) aimed to assess perceived discomfort of a load bearing vest and compared it to a regular duty belt and ballistic vest while participants were seated in two different car seats. The duty belt and regular ballistic vest created overall higher discomfort compared to the load bearing vest. Also, great amount of discomfort was experienced in the low back and left/right hip due to the seat lumbar support and backrest of the seat. The authors concluded that this could be avoided by moving equipment from the duty belt onto the load bearing vest and also by widening the vehicle seat.

Holmes et al. (2013) reported ratings of perceived discomfort in a laboratory simulated driving test. Each discomfort location on the body was recorded using a 100-mm visual analogue scale. Females reported more discomfort than male participants in the lower back, pelvis, and sacrum. Also, the weight of the duty belt created discomfort in the pelvis area for both genders. Holmes et al. (2013) study is also concurrent with that of Donnelly et al. (2009) that with the effect of time perceived discomfort increased significantly. Ratings of perceived discomfort was also used in a study with officers to assess the effect of mobile data terminal location on muscle activity (McKinnon et al., 2014; McKinnon et al., 2012). Major discomfort was experienced in the lower back and right shoulder due to the location change of mobile data terminal and most desired mobile data terminal location resulted in decreased discomfort. Based on literature findings mentioned above, there appears to be a negative relationship between range of motion and discomfort and with perceived impediments. When range of motion is decreased discomfort increases as well as perceived impediment.

Gap Statement

Frequent reports of low back pain among patrol officers raise the question whether there is an alternative carriage method for duty gear. There is a *critical need* for an alternative duty belt configuration that meets the comfort and safety needs of officers without compromising their professional image. Less is known about patrol officers' duty belt configuration and their preferences. Thus, it becomes necessary to highlight officers' practices to offer an alternative duty belt configuration. By fulfilling this gap, the *long-term goal* is to improve the musculoskeletal health of officers. The *short-term goal* is to offer an alternative duty belt configuration that is comfortable when performing seated occupational tasks.

Purpose

The purpose of this study is to investigate patrol officers' experiences with the current duty belt configuration, to remove some items from the current duty belt with the intention of placing them in other body areas, and to assess the effectiveness of the lighter duty belt using objective and subjective measures.

Justification

At the completion of this study, it is *expected* that an alternative duty belt configuration would have a *positive impact* on officers who drive for prolonged hours or work while seated in a patrol vehicle. Therefore, it becomes necessary to assess the effect of a lighter duty belt with less items attached, on muscle activity of the back and shoulder, on perceived discomfort of various body regions, and on perceived ease-of-movement of the trunk.

Objectives

The *objectives* of this study were:

1. To understand officers' practices of current duty belt configuration (Phase II of Step 3 of the design process),

a. Conduct a regional survey,

b. Review current equipment carried on officers' duty belt,

c. Identify frequency and importance of the duty gear usage from officers' perspective,

d. Establish a baseline belt configuration for the experimental study

2. To identify design specification and establish design criteria (steps 4 and 5 of the design process),

    a. Incorporate end user inputs to establish design criteria of a new duty belt configuration appropriate for patrol officers

    b. Establish a protocol for the experimental study

3. To develop and evaluate the duty belt prototype (Steps 6 of design process)

4. To evaluate the effect of the duty gear prototype on perceived discomfort, perceived ease of movement, and trunk muscle activity (Step 7 of the design process)

Hypotheses

The *central hypothesis* was that the alternative duty belt configuration would have a positive impact on trunk muscle activities, alleviate perceived discomfort, and improve perceived ease of movement. The *rationale* for the study was that an alternative duty belt that was lighter might reduce discomfort experienced by officers. The following hypotheses were tested:

$H_0 1$: There are no significant differences in activity of the back muscles between the reduced duty belt and full duty belt.

$H_0 1a$: There are no significant differences in activity of the iliocostalis muscles between the reduced duty belt and full duty belt.

$H_0 1b$: There are no significant differences in activity of the longissimus muscles between the reduced duty belt and the full duty belt.

$H_0 1c$: There are no significant differences in activity of the multifidus muscles between the reduced duty belt and full duty belt.

$H_0 2$: There are no significant differences in muscle activity of the anterior deltoid muscles between the reduced duty belt and full duty belt.

$H_0 3$: There are no significant differences in perceived discomfort between the reduced duty belt and full duty belt.

H_{04}: There are no significant differences in perceived ease of movement the reduced duty belt and full duty belt.

Assumptions

It is assumed that the functional tasks for the EMG test were carried in the same velocity, load, range of motion, and duration by giving clear instructions to the participants and redoing the recording of the activity if needed. The maximum voluntary isometric contraction (MVIC) test was validated by following scientific guidelines (SENIAM) in placing electrodes on each muscle. If the MVIC test showed weak signaling of the muscle assessed, electrode of that muscle was removed, skin was cleaned and prepped, and the electrode placement was corrected and the MVIC was repeated to make sure a clear and strong signal from the muscles under investigation was observed.

Participants were trained prior MVIC testing and static contractions were practiced prior to the actual test. It was assumed that the participants performed their maximum effort in contracting their muscles.

It is also assumed that the load of the duty belt and the ballistic vest will influence muscle activity and that recording and analyzing EMG activity of surface muscles is an effective method of assessing the effect of the duty belt on muscles of the back. Regarding the duty belt, it is assumed that a lighter and symmetrical duty belt configuration will affect perceived discomfort and ease of movement.

Limitations

This study did not account for anthropometric variables that might affect the results. There were limitations in recruiting female officers for that gender was not controlled for in this study. Also, data collection was limited only to the state of Oklahoma and laboratory testing was taken place with volunteer officers from an urban college town. Activities carried out in a laboratory setting are only simulations of real case scenarios and are conducted in a controlled environment.

CHAPTER III

Methodology

Study I: Survey

Background information and preliminary data was used to develop the questionnaire of this study. A survey was administered at the state level to identify the current duty belt practices, discomfort issues associated with officers' duty belt items, and to investigate alternative carriage methods based on officers' outputs (second phase of step 3, *problem structure perceived*). Table 3 shows details of the steps taken herein, to construct and assess the new duty belt prototype. The survey was administered online. Invitation to participants was sent via email to a list of contacts including chief director of law enforcement associations and captain of the police departments. List of contacts were obtained from campus police department. Contacts were invited to participate in this survey. Those who were interested and agreed to participate forwarded the email to their officers. The criteria for being eligible to participate in the survey was to have patrolling experience in the past 10 years and to be above the age of 21. The output of this survey was generated using Qualtrics software Copyright© 2005, version January-March 2017. Survey results were exported to Microsoft Excel spreadsheets. Data was screened, filtered, coded, and analyzed using SPSS (version 23.0).

Table 3.

Design process of this study

Steps	Activities of this study
1. Request made (past research)	Police blogs and personal contact.
2. Design situation explored (past research)	Officers' perceptions regarding the duty belt was obtained through qualitative data
Study I	
3. Problem structure perceived (past & current research)	Phase 1: biomechanical assessment (past research). Phase 2: questionnaire (current research)
4. Design specifications (current research)	Ranking and charting data based from questionnaire outcome
5. Design criteria (current research)	Establish design criteria based on survey information and develop a baseline duty belt
6. Prototype development (current research)	Offer a reduced duty belt prototype configuration based on officers' perceptions
Sudy II	
7. Evaluation (current research)	Conduct a wear study (biomechanical, perception)

Questions of the survey included demographic (questions 21-27), occupation (questions 1-6, 8-10), attitudes toward image (question 13), duty gear information (questions 7,11-12, 20), officers' preferences in duty gear configuration (questions 16-17) and discomfort (questions 14-15,18-19). Content from the survey was analyzed and used to establish design specification and duty belt criteria. For the survey refer to Appendix B.

Survey analysis.

Percentages and frequency tables were employed to rank the importance of the duty gear equipment. First, a baseline duty belt was determined that included all the equipment a right-dominant hand officer would carry on his/her duty belt. Baseline duty belt was obtained from questions 11 and 12 of the survey. Second, a lighter duty belt was determined based on officers' discomfort and duty belt configuration preferences. Reduced duty belt criteria were determined considering answers from questions 14 till 19. Answers were ranked, conflicted criteria were reported, and a final decision was made as to which items would be appropriate to be removed from the duty belt and placed in alternative places. Items removed were intended to reduce the weight of the duty belt and keep a symmetrical distribution of the duty belt. The reduced duty belt had less equipment attached with the intention of putting equipment in other locations. Both duty belt conditions were evaluated to investigate any differences between them and observe any affect they might have on surface muscles.

Study II: Laboratory Assessment

A biomechanical assessment of the duty belt was conducted with volunteer officers who wore the duty belt conditions and rated their level of discomfort and ease of movement. The following part elaborates on the sample participants of the laboratory assessment, variables measured, equipment used to assess the dependent variables, and the protocol adapted for the laboratory study.

Participants.

For this experimental design, 12 officers (9 males and 3 females) over the age of 21 who had at least 1 year of patrol experience in the last 10 years were recruited from a South-Western State that included officers from campus patrol, city police department, and the State Bureau of Investigation. Fliers were distributed to the police departments and permission was granted from the captain of the police departments to contact officers via email and invite them to participate in the laboratory testing of this study. A total of 17 officers were contacted via email to schedule a time to meet in the laboratory. Reminder emails were sent to these contacts. Out of the 17 officers, 12 participated in this study. Their mean height and weight were 175 cm (*SD*=10 cm) and 100 kg (*SD*= 50 kg) respectively. All of the participants were in good health with no history of low back pain over the last 12 months. Institutional review board approval was obtained prior to any data collection. Volunteers gave written consent prior to the testing. No incentive was offered at any stage of the data collection in this study.

Independent variables.

The independent variable for this study was clothing treatment, a duty belt that had three levels (see Figure 7);

1. **Control** includes patrol officers' regular uniform, ballistic vest, pants, and button-up shirt.
2. **Full duty belt** includes patrol officers' regular uniform and baseline duty belt.
3. **Alternative duty belt** includes patrol officers' regular uniform and a reduced duty belt.

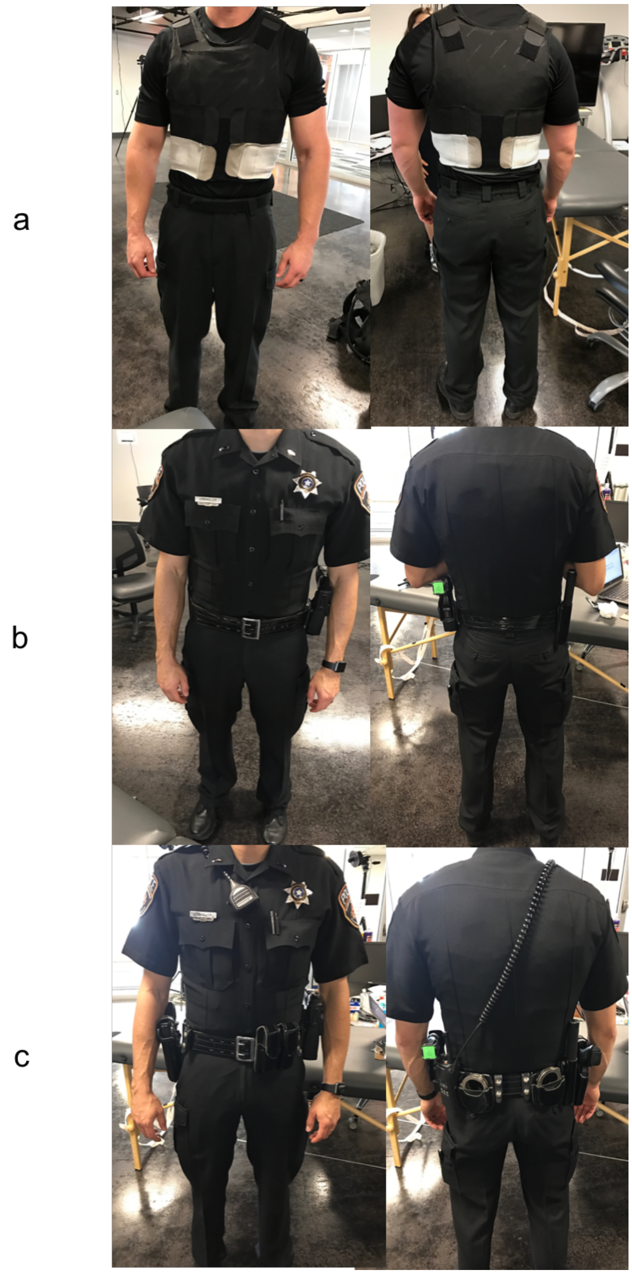


Figure 7. Three duty belt conditions a) control front and back, b) alternative duty belt front and back, c) full duty belt front and back.

Dependent variables.

Three dependent variables that were measured in this study, include electromyography recordings from four pairs of muscles (anterior deltoid, iliocostalis, longissimus, and multifidus), perceived ease of movement, and perceived discomfort as described below (survey instruments and scales used to measure the DVs are shown in Appendix C):

DV1: Amplitude of Electromyography (EMG) was recorded for the following superficial muscles;

1. Anterior deltoid (left and right)
2. Iliocostalis at the L1 or L3 level (left and right)
3. Longissimus (left and right)
4. Multifidus (left and right)

DV2: Perceived discomfort for various body regions (100 mm Visual Analog Scale);

1. Discomfort in front body regions
2. Discomfort in back body regions

DV3: Perceived ease of movement (5-point Likert scale)

Materials

Muscle activity was measured using eight-channel wireless EMG probes from BTS Bioengineering (Milano, Italy), placed bilaterally on the surface of six trunk and low back muscles and two shoulder muscles. EMG probes were snapped onto Kendall ARBO disposable electrodes H124SG (24 mm diameter). The skin was prepared by applying NuPrep®, an abrasive gel. Alcohol swabs BD™ were wiped to clean the residue of the abrasive gel. Spectra® 360 electrode gel (Parker Laboratories, INC.) was used to increase electrical conductivity. Figure 8, depicts electrodes, probes, and skin preparation materials used in this study.

Figure 8. From left to right: electrodes, probes with charging unit, and skin prep materials

To perform the maximum voluntarily isometric contraction test (MVIC), a wall and a padded bench was used. For details on MVIC test see section *Procedures*. Few other equipment used for range of motion movements were, a stool, a foot rest, and a scale to weight duty gear items.

Procedure

The EMG test and range of motion test were conducted in two separate sessions at the Mixed Reality Laboratory. Each session lasted approximately 75 minutes. The tasks to be completed were explained to the participants and consent form was signed before proceeding with any testing.

Electromyography (EMG).

For the EMG testing participants 11 participants performed a set of six functional activities shown in Figure 9:

a) Lift
b) Squat
c) Left leg lunge
d) Right leg lunge
e) Left reach
f) Right reach

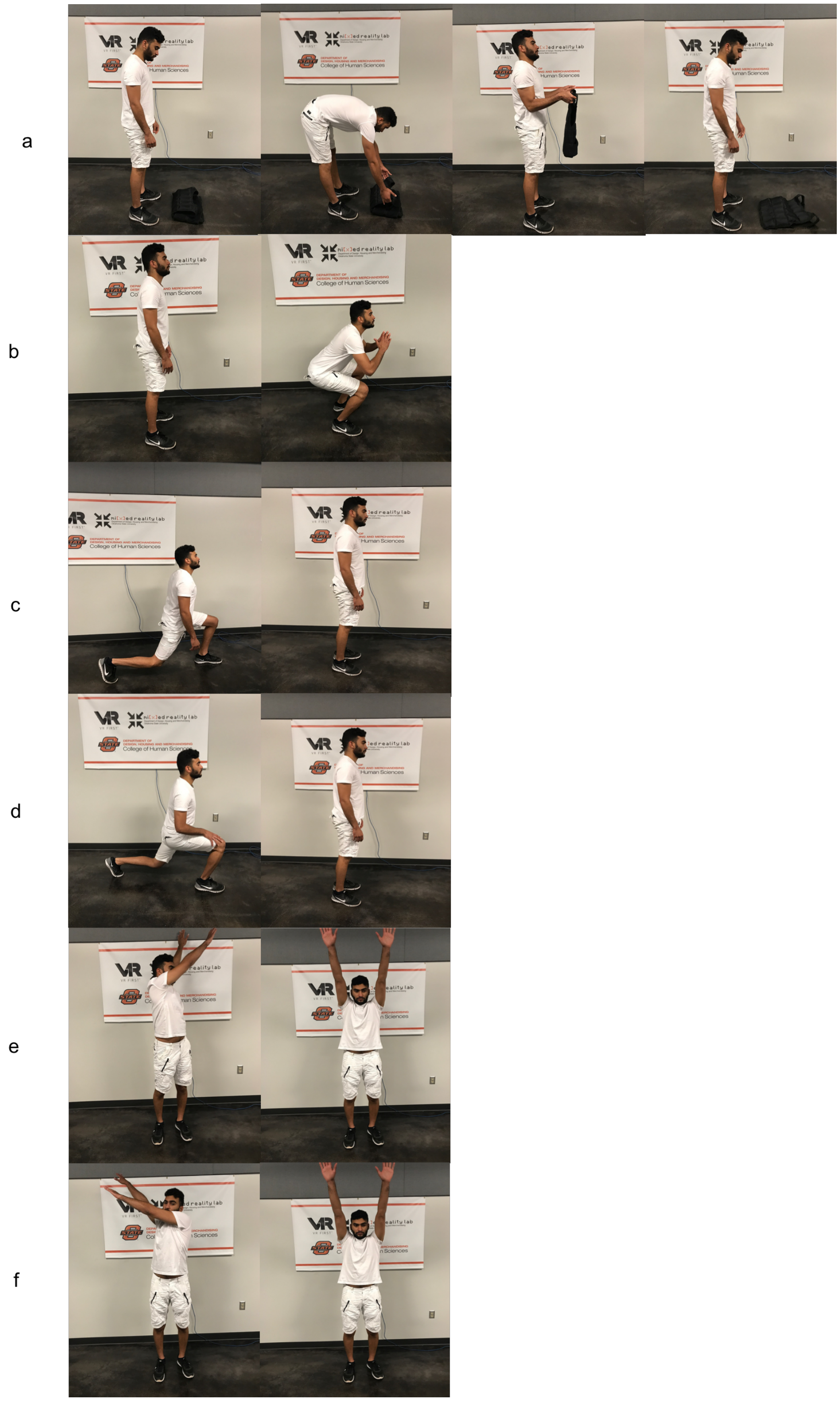


Figure 9. Functional activities labeled as: (a) lift, (b) squat, (c)left leg lunge, (d) right leg lunge, (e) left reach, and (f) right reach.

Location of the muscles were determined by palpations. Inter-electrode spacing of 20 mm and along an axis parallel to the muscle fibers were followed based on standard procedures (Konrad, 2006). Electrodes 1 and 2 were placed on the right and left anterior deltoid muscles at one finger width distal and anterior to the acromion (see Figure 10). Electrodes 3 and 4 were placed on the right and left of the iliocostalis muscle of the erector spinae, at one finger width medial from the line from the posterior superior iliac spine superior to the lowest point of the lower rib, at the level of L2 (see Figure 11). Electrodes 5 and 6 were placed on the right and left longissimus muscles of the erector spinae at two finger width lateral from the spinal process of L1 (see Figure 12). Electrodes 7 and 8 were placed on the right and left multifidus, two finger with lateral from the spinal process between L5 and L3 (see Figure 13).

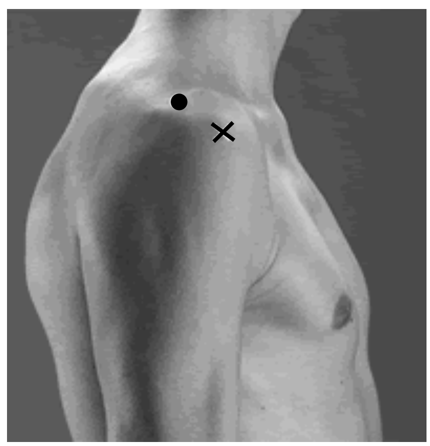


Figure 10. EMG electrode placement on right anterior deltoid (RAD) of the shoulder, marked with an **X**. The same location was marked for the left anterior deltoid (LAD) not shown in this image (Source Seniam.org)

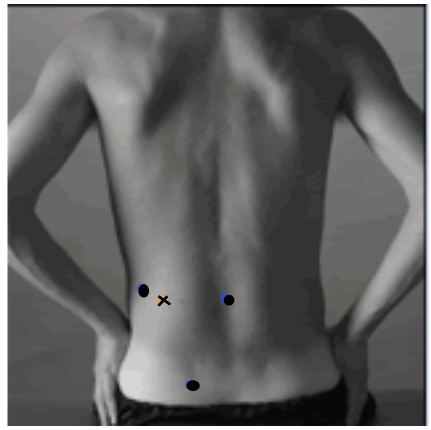


Figure 11. EMG electrode placement on the left iliocostalis (LILIO) of the erector spinae muscle marked with an **X**. The same location was marked for the right iliocostalis (RILIO) not shown in this image (Source Seniam.org)

Figure 12. EMG electrode placemen on the left longissimus (LLONG) of the erector spinae muscle marked with an **X**. The same location was marked for the right longissimus (RLONG) not shown in this image (Source seniam.org)

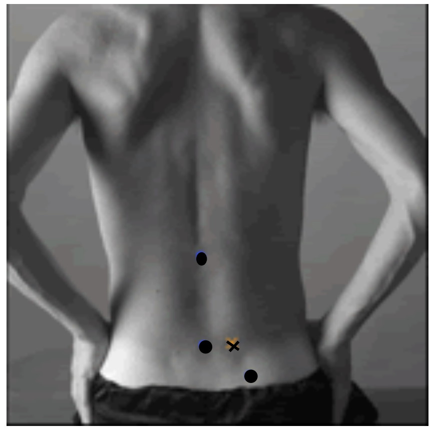


Figure 13. EMG placement on the right multifidus (RMUL) muscle marked with an **X**. The same location was marked for the left multifidus (LMUL) not shown in this image (Source Seniam.org)

Maximum voluntary isometric contraction test.

Maximum voluntary isometric contraction (MVIC) was recorded and used as a baseline to normalize each muscle activity for that person. A padded platform with restraints allowed the participants to restrict their lower body during back extension exercise (see Figure 14). For shoulder exercise, participants pushed against the wall standing still, only using the shoulder muscle for resistance (Boettcher, Ginn, & Cathers, 2008).

A series of MVIC was performed based on the protocol suggested by Kendall, McCreary, Provance, Rodgers, & Romani (1993) where, each muscle was contracted for 3 seconds with 30 seconds of rest time in between each trial for a total of three trials. Participants performed a maximal back extension exercise, which activated the four pairs of muscles on the back. Participants laid prone on a padded platform, strapped down across the lower body, and extended their backs as high as possible and as fast as possible (see Figure 14.a). For the shoulder exercise, participants pushed against the wall with the palm of their hand performing a combination of adduction and flexion while their arm was positions 30° degrees from the medial point, repeating it with right and left hand (see Figure 14.b). These tests were modified from previous protocols to conduct the EMG using the current laboratory facilities (Boettcher et al., 2008).

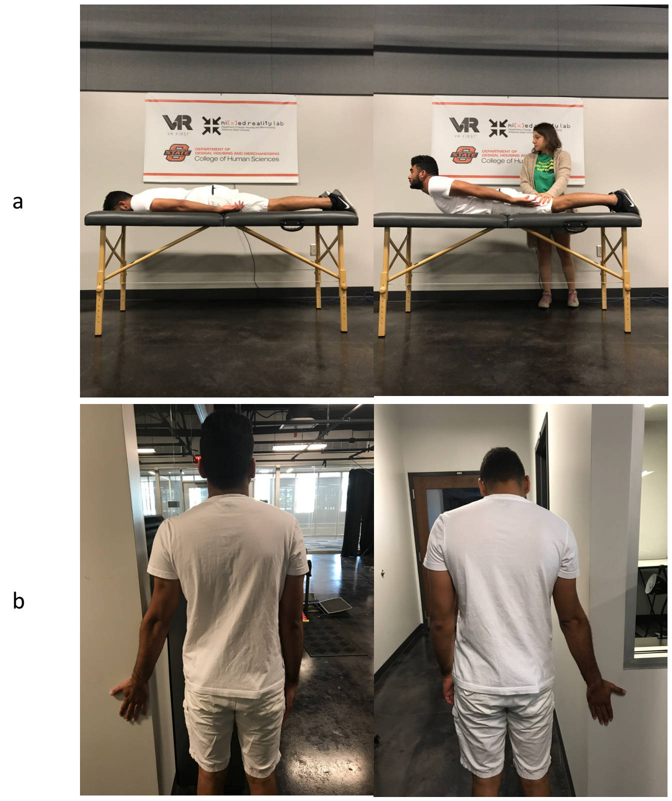


Figure 14. a) MVIC for back muscles (iliocostalis, longissimus, and multifidus for both left and right sides). b) MVIC for left anterior deltoid and right anterior deltoid performed by pushing against the wall.

Protocol for EMG assessment.

A set of functional tasks were performed to activate the back muscles to better understand the effect of the duty belt on low back muscles. First set of moves were overhead reach with a twist to the right and left (see Figure 9 e and f) second, lifting weight (see Figure 9 a) third, squats (see Figure 9 b), and final move was lunges with right leg forward and left leg forward (see Figure 9 c and d). Due to limited number of subjects, each move was repeated four times across all three conditions (control, alternative duty belt, and full duty belt). After functional tasks for each condition was completed, participants filled out the perceived discomfort visual analog scale for different body regions.

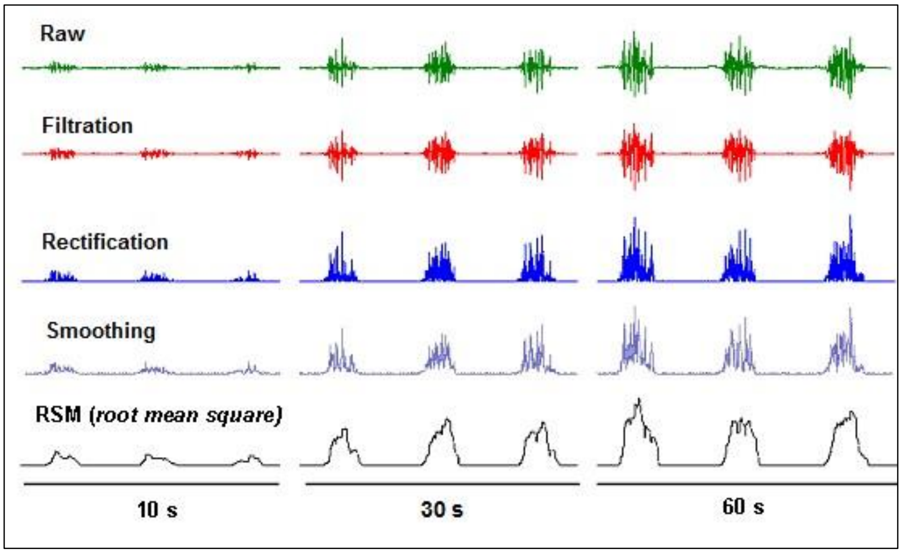
EMG signal processing.

EMG data were amplified through the hardware system with a sampling rate of 1500 Hz. According to scientific guidelines the sampling rate is usually double the low-pass bandpass around (1000-1500 Hz) (Konrad, 2006). The first step in processing raw EMG amplitude was to convert negative amplitudes to positive amplitudes referred as *rectification* of raw EMG recording (see Figure 15). The recommended amplifier bandpass settings are between10 Hz high-pass up to at least 500 Hz low-pass; most of the surface EMG frequency power is located between 10 and 250 Hz. In our study, bandpass filtering was set to 20 Hz high-pass and low-pass of 450 Hz, meeting the scientific guidelines. After filtering and using the formula below, root mean square was calculated (RMS), reflecting the mean power of the EMG signal.

$$RMS = \frac{\sqrt{x_1^2 + x_2^2 + \cdots + x_N^2}}{N}$$

In the above formula, X_1 is the amplitude for time period 1 (T_1) and X_N is the amplitude for time period N (T_N), implying that the raw EMG data was used for a single activity from start (T_1) of that activity till the end of one repetition (T_N). The last step was to normalize the filtered EMG amplitude to a reference value, in this case the maximum voluntary isometric contraction (MVIC) of the relevant muscle (Konrad, 2006).

$$Normalized\ EMG\ (\%) = \frac{RMS_{\ Rectified\ EMG}}{RMS_{\ MVIC}} \times 100$$



.
Figure 15. EMG raw recording is filtered removing noise, rectified to keep the positive end of the data, smoothed from random spikes, and presented with the mean value of the signal (RMS) (source: https://cdn.intechopen.com/pdfs-wm/40117.pdf)

Perceived discomfort.

After completing the six-functional activities (see Figure 9), participants were asked to rate their discomfort in front and back body areas. Visual analog scales adapted from previous research were given to the participants to rate their discomfort (for VAS scale see Appendix C).

Perceived ease of movement.

In a separate session, 9 participants came to the same lab to conduct ease of movement evaluation where they sat on a stool and conducted trunk movements of flexion/extension, hyperextension, lateral bend to the right and left side, and rotation to the right and left side. These moves were repeated across all three conditions of the duty belt (control, reduced duty belt, and full duty belt). After range of motion for each condition was completed, participants filled out the perceived ease of movement using a modified ASTM F1154-11 protocol (ASTM, 2011), a Likert-scale (see Appendix C).

Ease of movement motions are listed below and shown in Figure 16.

a) Hip flexion/extension and hyperextension

b) Trunk lateral flexion (right and left)

c) Trunk rotation (right and left)

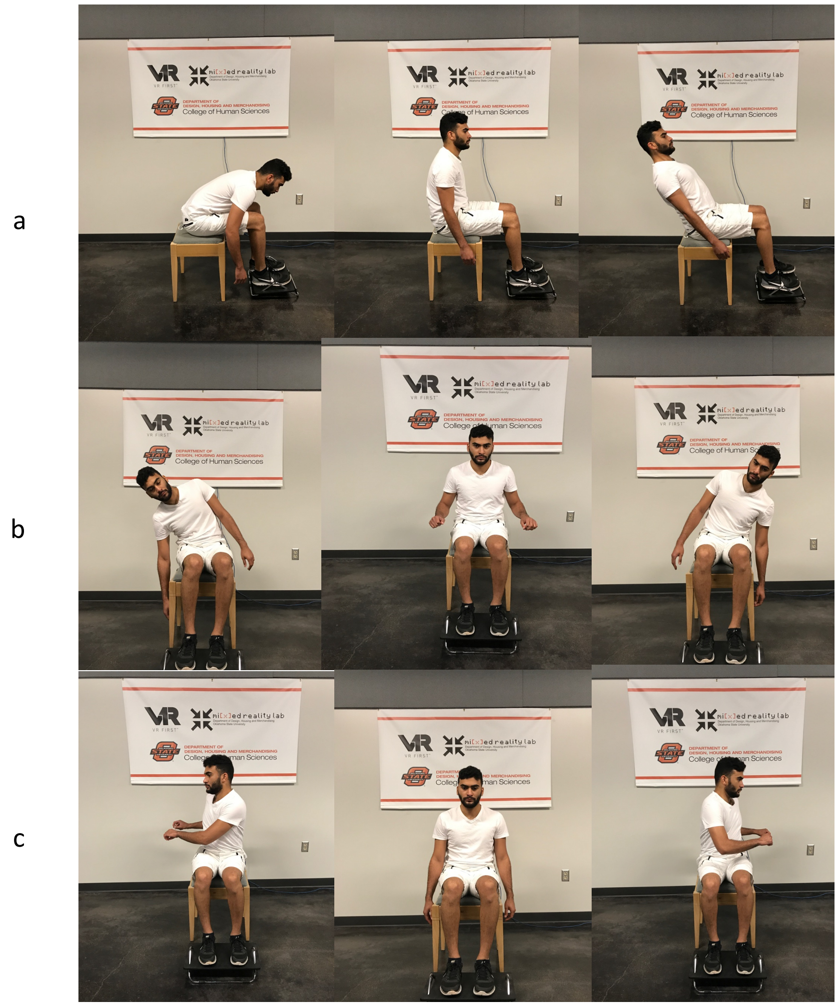


Figure 16. Ease of movement activity: (a) hip flexion/extension (left) and hyperextension (right), (b) lateral right and lateral left, (c) right rotation and left rotation.

Analysis

Dependent variables for the eight muscles, perceived discomfort and perceived ease of movement were analyzed with Kolmogorov-Smirnov test for normality. Furthermore, histograms were used to identify non-normal distributions. All the data showed a non-normal distribution slightly being skewed to the left side of the curve. Thus, data was compared using a nonparametric Kruskal-Wallis H test. The rejection level for all analyses were set as $p = 0.05$. A Kruskal-Wallis H test was conducted to assess the effect of the duty belt conditions for each functional activity. Pairwise comparisons were conducted where statistically significant differences were observed. The adjusted alpha score was considered in pairwise comparisons. To assess the effect of the duty belt on perceived discomfort VAS scores were averaged to a total of two levels for the perceived discomfort scale (Front discomfort and back discomfort) using SPSS (version 23).

Missing data analysis.

Normalized EMG values that were below 100% were kept for analysis and any value greater than 100% was removed to prevent wrong interpretation of the data being analyzed. Then, the EMG continuous variables were tested for missing data for each muscle and each functional activity in SPSS. Next, t-tests were run to examine missing complete at random and none of the *p* values were significant. This showed that our data were not missing at random, and thus, could not be computed. Cases containing missing data were deleted using list wise comparison.

CHAPTER IV

Results and Discussion

Study I

Demographics

Survey responses (N = 145), based on the police department locations, were divided into 5 regions, Northeast (51%), Northwest (12%), South west (4%), Southeast (5%) and Central Oklahoma (28%). Three-quarters of the responses came from the Northeast and Central Oklahoma, representation the population density in the State of Oklahoma. The bottom half of Figure 17 illustrates the population estimates by county and the darker counties indicate the highest populated areas in the State of Oklahoma where majority of the responses came from. Table 4 depicts detailed demographic information of the survey respondents. Participants of this study were predominantly male (n = 108, 78%), age ranging between 22 and 78 (M= 43, SD=11 years). Approximately half of the participants were between the ages of 41 and 60 (n = 66, 47%). Majority of the respondents were white (n = 106, 76%) and perceived to be living in a rural environment (n = 88, 63%).

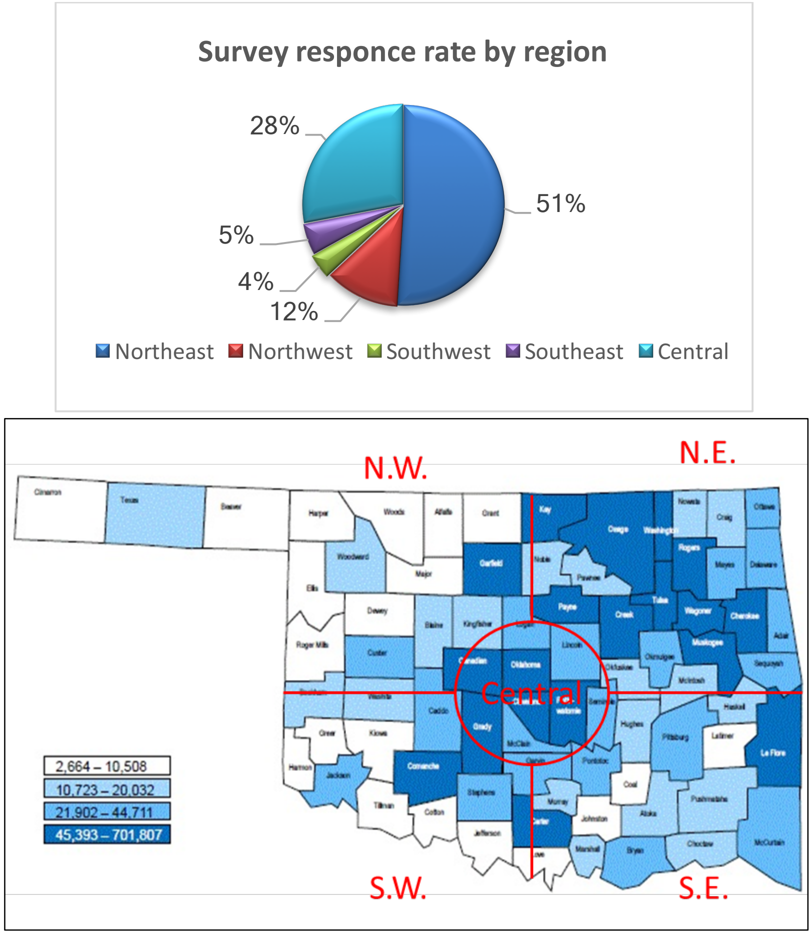


Figure 17. Survey responses based on police departments location (Top) and population estimates by county (Bottom).

Occupation

Occupation specific information highlights that chiefs (*n* = 35, 25%), patrol officers (*n* = 35, 25%), and sergeants (*n* = 27, 19%) were the major respondents (see Table 5). More than one-half of the participants (70%) had minimum of 10 years of experience and approximately one-half worked in day shift (*n* = 68, 49%).

Table 4.

Demographic information of the survey respondents

	Population (N)	Number (n)	Percent (%)
Age (years)	139		
22-30		15	11
31-40		28	20
41-60		66	47
>61		7	5
Missing		23	17
Education (years)	139		
High school		4	3
College		57	41
Bachelor's Degree		33	24
Some Graduate work		14	10
Graduate Degree		10	7
Missing		21	15
Gender	139		
Male		108	78
Female		9	6.5
Missing		22	16
Population density	139		
Urban		49	35
Rural		88	63
Missing		2	1.4
Race	139		
White		106	76
Black or African American		2	1.4
American Indian or Alaska Native		8	6
Missing		23	16.5

N = 139

Note. "missing" category indicates people not responding the number of respondents leaving a certain question blank.

Table 5.

Occupational information of the survey respondents

	Population (*N*)	Number (*n*)	Percent (%)
Rank	139		
Chief		35	25
Captain		6	4
Deputy		1	0.7
Corporal		1	0.7
Detective		7	5
Major		1	0.7
Master		5	4
Lieutenant		17	12
Sergeant		27	19
Senior Police Officer		4	3
Patrol Officer		35	25
Missing		6	4
Years of Service	139		
<3		9	6.5
3-10		33	24
11-15		18	13
16-20		28	20
21-30		31	22
>30		20	14
Missing		0	0
Current Shift	138		
Day shift		68	49
Evening shift		25	18
Night shift		23	16.5
Specialized unit		22	16
Missing		1	0.7

Note. "Missing" cells, indicated the number of respondents leaving a certain question blank.

Duty Gear

With respect to duty gear, approximately half of the officers used the high gloss leather belt (n = 66, 47.5%) and the second half reported wearing a nylon belt (n = 67, 48%). Officers can have both nylon and leather duty belt and choose to wear one over the other depending on their duty (bike patrol wear a nylon belt). Approximately a quarter of the officers were not allowed to use tactical vest (n = 38, 27 %). Specialized units such as

Special Reaction Team or Criminal Investigation Department were officers who have an option to use a tactical vest; however, regular patrol officers are issued a duty belt to use. One of the patrol officers stated "Tactical vest is worn only in active shooter response" meaning that in regular daily activities while encountering citizens, patrol officers are required to maintain a professional business-like appearance. That said, more than half of the officers (*n* = 80, 58%) liked the appearance of a high gloss leather belt and perceived the high gloss leather belt to have a business-like appearance (*n* = 94, 67%). Despite the low count, it was brought to our attention that there were officers who believed their duty belt was uncomfortable (*n* = 54, 39%) and that some officer would sacrifice their comfort to maintain a business-like appearance (*n* = 29, 21%) (see Table 6 and Table 7).

Table 6.

Carriage method

	Population (*N*)	Number (*n*)	Percent (%)
Current Duty Belt	139		
Leather Belt		66	47.5
Nylon Belt		67	48
Other		4	3
Missing		2	1.4
Does your department allow wearing a tactical vest?	139		
Yes, tactical vest is a given option		53	38
No, we are not allowed to use tactical vest		38	27
We use an alternative carriage method		13	23
Other		11	8
Missing		3	2

Note. Other duty belt type was described as using "both" (n=2), "Padded Nylon" (n=1) and "High Gloss Leather Belt" (n=1).

Table 7.

Attitudes toward image

	Agree		Neutral		Disagree	
	Number (*n*)	Percent (%)	Number (*n*)	Percent (%)	Number (*n*)	Percent (%)
I like the appearance of high gloss leather belt	80	57	26	19	13	9
High gloss leather belt has a business-like appearance.	94	67	18	13	7	5
It is uncomfortable to sit with the high gloss leather belt.	54	39	42	30	23	16.5
I will sacrifice my comfort to have a uniform with business-like appearance.	29	21	41	29.5	49	35

N = 139

Full Duty Belt Configuration

Most frequent reported items carried were firearm (100%), spare magazine (*n* = 138, 99%), radio (*n* = 130, 93.5%), keys (*n* = 131, 94%), pen (*n* = 125, 90%), knife (*n* = 118, 85%), cellphone (*n* = 115, 83%), and flashlight (*n* = 111, 80%) (see Table 8). Required equipment by the police departments was firearm (*n* = 131, 94%), spare magazine (*n* = 128, 92%), and radio (*n* = 121, 87%). Less than half of the participants reported the following items to be required on top of the above, flashlight (*n* = 68, 49%), TASER (*n* = 61, 44%), keys (*n* = 60, 43%), handcuffs one pair (*n* = 55, 40%), pen (*n* = 55, 40%), baton (*n* = 49, 35%), handcuffs two pairs (*n* = 47, 34%) and pepper spray (*n* = 35, 25%). Out of all the items carried on the officers, specific items on the duty belt were firearm (*n* = 137, 99%), spare magazine (*n* = 133, 96%), radio (*n* = 124, 89%), flashlight (*n* = 98, 71%), handcuffs two pairs (*n* = 88, 63%), TASER (*n* = 82, 59%), keys (*n* = 79, 57%), baton (n = 78, 56%), handcuffs 1 pair (n = 61, 44%), pepper spray (n = 56, 40%), gloves (n = 31, 22%), and knife (n = 15, 11%).

Table 8.

Items carried on the officer and the duty belt

	Items Carried on the person		Items Required		Items on Duty Belt	
	Number (n)	Percent (%)	Number (n)	Percent (%)	Number (n)	Percent (%)
Handcuffs 1 pair	63	45	55	40	61	44
Handcuffs 2pairs	91	65.5	47	34	88	63
Baton	82	59	49	35	78	56
Pepper Spray	62	45	35	25	56	40
TASER	86	62	61	44	82	59
Flashlight	111	80	68	49	98	70.5
Radio	130	93.5	121	87	124	89
Firearm	139	100	131	94	137	99
Spare magazine	138	99	128	92	133	96
Cellphone	115	83	26	19	11	8
Knife	118	85	4	3	15	11
Keys	131	94	60	43	79	57
Gloves	82	59	20	14	31	22
Note pad	102	73	35	25	1	0.7
Paperwork	17	12	4	3	0	0
Pen	125	90	55	50	2	1.4
Wallet	103	74	21	15	2	1.4
Extra firearm	33	24	1	0.7	0	0
Extra knife	45	32	0	0	5	4
Other	43	31	11	8	16	12

N=139
Note. Other items carried on the officer include: individual first aid kit, tourniquet, wooden baton, body camera, badge, evidence bags, glove case, handcuff key, insulin pump, Leatherman, sharpies, reading glasses.

Figure 18 shows the carried items on the officer, required items, and items that are carried on the duty belt. It is appropriate to say that three items - the firearm, magazines, and radio - are the most frequently reported items to be carried and required by the department at the same time. Other items such as handcuffs, flashlight, TASER, baton were less frequently reported to be carried. One explanation is that ranks such as captain, chief, deputy, and detective may not need all the less-lethal weapons and handcuffs to be on them at all times. Also, 47% of the participants work in day shift and it may be possible that they do not carry a flashlight on them and keep it in the patrol vehicle. Another explanation is that less-lethal weapons such as the pepper spray, are not always desired by officers due to the possibility of drifting in windy weather, exposing the people nearby, including the officer. Items on the right-hand side of Figure 19. are important to carry however, these are not carried on the duty belt. For example, every patrol officer has a notepad and a pen to take notes during their duties but they are usually kept in pockets.

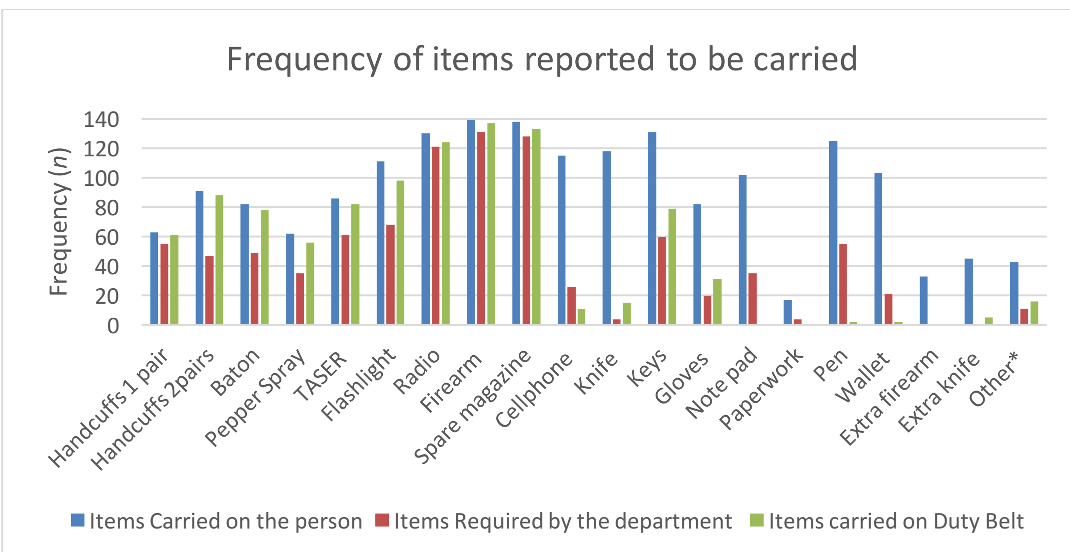


Figure 18. Frequency of the duty gear times reported to be carried on the person (N = 139), items that are required by the department (N = 139), and items that are only carried on the duty belt (N = 139).

To potentially classify a pattern of the duty belt configuration, officers were asked to identify the location of the items carried around their duty belt. Table 9 shows the location of each item carried on the duty belt. Using this table, a duty belt baseline was determined to be one of the duty belt conditions of the independent variable. Full Duty Belt condition (FDB) was determined by looking at the maximum percentage of duty gear items reported. Highest percentage of each duty gear items, included in the FDB condition, are highlighted in gray and in bold. Region 2 was left blank and two items, pepper spray (n = 12, 10%) and keys (n = 36, 26%), were both located in region 1. The only region that had an overlap was region 1 and because region 2 was empty, there was enough space in fitting two items in the same region. Items that are carried on the duty belt but were excluded from the FDB condition were cellphone (n = 4, 3%) and extra knife (n = 2, 1.4%) due to low percentages. Gloves had a higher percentage (n = 20, 14%) compared to cellphone and extra knife though, looking back at Table 8, it is seen that one-quarter of the officers reported to carry gloves on their duty belt and for that reason it was appropriate to exclude it from the FDB condition. As a result, the FDB condition carried the following listed items clockwise from the buckle, keys, pepper spray, firearm, handcuffs (first pair), handcuffs (second pair), flashlight, radio, TASER, and extra magazines.

Table 9.

Location of the duty gear attached on to the duty belt

	Hand cuffs 1 pair		Hand cuffs 2 pairs		Baton		Pepper spray		TASER		Flash light		Radio		Firearm		Magazine		Cellphone		Knife		Keys		Gloves		Extra knife	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
R1	6	4	7	5	0	0	12	**10**	6	4	3	2	0	0	0	0	19	14	2	1.4	1	0.7	36	**26**	0	0	0	0
R2	0	0	0	0	1	0.7	9	6.5	4	3	1	0.7	1	0.7	0	0	7	5	4	3	1	0.7	12	9	0	0	1	0.7
R3	1	0.7	0	0	2	1.4	0	0	1	0.7	2	1.4	7	5	107	**77**	0	0	0	0	0	0	0	0	0	0	0	0
R4	7	5	4	3	38	**27**	4	3	0	0	14	10	3	2.2	0	0	0	0	4	3	2	1.4	4	3	0	0	1	0.7
R5	19	**14**	41	29.5	6	4	3	2	0	0	2	1.4	0	0	0	0	0	0	1	0.7	1	0.7	2	1.4	2	1.4	0	0
R6	2	1.4	5	4	0	0	0	0	0	0	0	0	1	0.7	0	0	0	0	0	0	0	0	0	0	20	**14**	0	0
R7	10	7	47	**34**	0	0	4	3	0	0	15	11	3	2	0	0	1	0.7	0	0	0	0	0	0	3	2	0	0
R8	3	2	3	2	12	9	7	5	0	0	32	**23**	29	21	0	0	0	0	1	0.7	1	0.7	0	0	0	0	0	0
R9	4	3	2	1.4	5	4	4	3	17	12	11	8	51	**37**	11	8	0	0	0	0	0	0	0	0	1	0.7	0	0
R10	0	0	0	0	6	4	7	5	27	**19**	7	5	11	8	0	0	13	9	1	0.7	3	2	7	5	0	0	1	0.7
R11	2	1.4	1	0.7	1	0.7	3	2	14	10	0	0	1	0.7	0	0	75	**52**	1	0.7	4	3	8	6	2	1.4	2	1.4

N=139

Figure 19 depicts the location of each duty gear attached to the duty belt, the name of the item, and the highest percentage of a certain item reported as carried in a certain region. This figure is a summary and an interpretation of the results obtained from Table 9, where respondents were asked to look at an image and select the region that they carry their duty gear around their belt. For example, if an officer is a right-handed and deploys his/her firearm with their dominant right hand they would select region 3 for the item firearm and similarly they would select a region for all the other items they reported carrying on their duty belt.

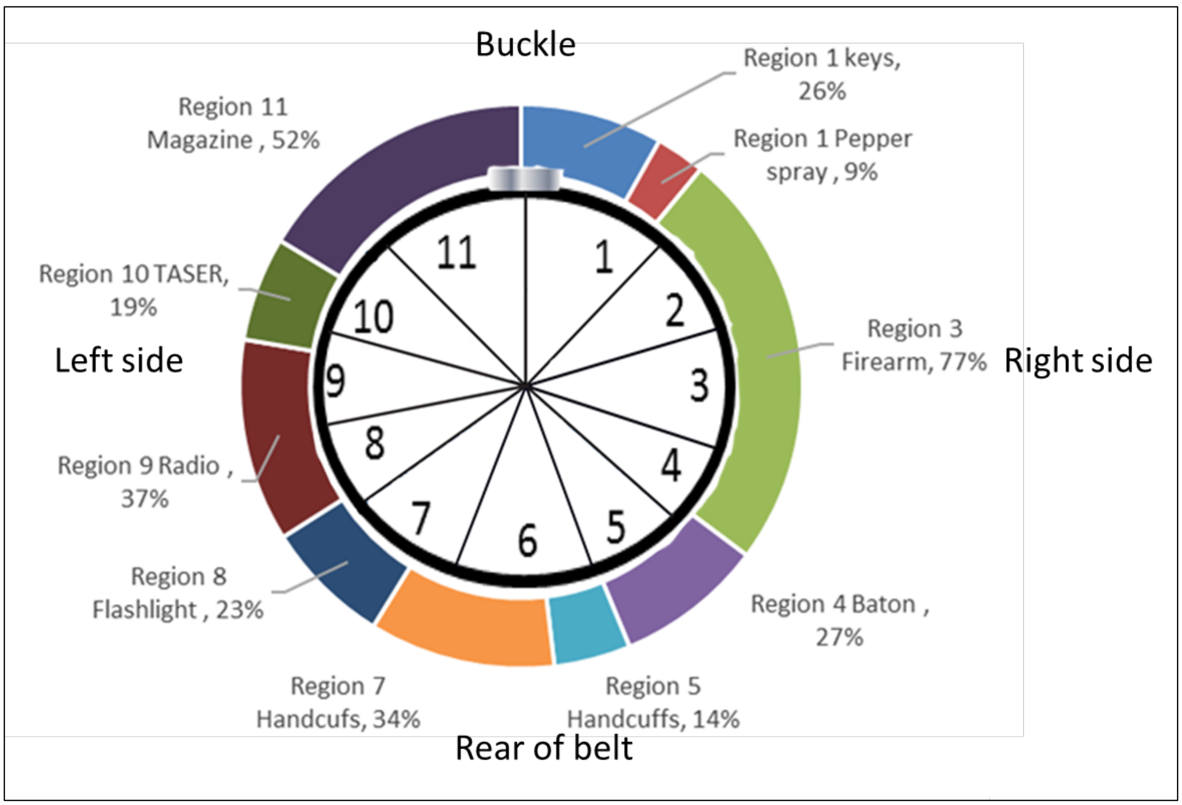


Figure 19. Full Duty belt configuration divided into 11 areas with each number indicating a certain area of the duty belt while worn (bottom).

Reduced Duty Belt Configuration

Survey respondents were asked to express their opinions on selecting items that must be on the duty belt, which of the items on their duty belt cause discomfort and which items could be removed and placed in other alternative locations on the body. Table 10 shows that all mandatory items on the duty belt are the same items that cause the most frequently reported discomfort. For example, more than half of the respondents reported firearm (n = 116, 83.5%) magazines (n = 102, 73%) and radio (n = 78, 56%) had to be carried on the duty belt. The same items were reported as causing discomfort, firearm (n = 67, 48%), magazines (n = 58, 42%), radio (n = 40, 29%), handcuffs (n = 29, 21%), TASER (n = 27, 19%), flashlight (n = 24, 17%), expandable baton (n = 18, 13%), pepper spray (n = 9, 6.5%), and keys (n = 9, 6.5%). It is also not surprising to see that items causing most discomfort was also the heavier category of items with the belt and firearm being the same weight (1213g) followed by two pairs of handcuffs (542g, each being 271g), extra magazine (547g), radio (537g), TASER (350g), flashlight (456g), pepper spray (126g), and knife (112g). The type of discomfort was reported as, digging into soft tissues (57%), pinching (41%), pressure from tightness (40%), pain (39%), and numbness (28%). Other discomfort related issues were described as bruising of the hipbone, fatigue from the duty gear, hip stiffness, sacroiliac discomfort, and low back pain.

Table 10.

Officers perceptions of items mandatory on the duty belt, items causing discomfort, and items that could be placed in alternative locations on the body

	Weight (g.)	Items must be on the duty belt		Items that cause discomfort on the duty belt		Items that could be moved to alternative locations	
		n	%	*n*	%	*n*	%
Duty belt	1213	N/A	N/A	N/A	N/A	N/A	N/A
Firearm	1205	116	83.5	67	48	9	6
Magazine	547	102	73	58	42	22	15
Radio	537	78	56	40	29	28	19
TASER	350	56	40	27	19	19	13
Handcuffs 2nd pair	542	55	40	29	21	21	14.5
Baton	555	54	39	18	13	10	7
Flashlight	456	52	37	24	17	19	13
Handcuffs 1st pair	271	43	31	14	10	12	8
Pepper Spray	126	34	24.5	9	6.5	20	14
Keys	146	29	21	9	6.5	13	9
Gloves	-	12	9	2	1.4	11	8
Knife	112	6	4	3	2	2	1.4
Other	-	4	3	2	1.4	4	3
Cellphone	-	2	1.4	2	1.4	6	4
Extra knife	-	2	1.4	1	0.7	1	1
Note pad	-	1	0.7	0	0	0	0
Pen	-	1	0.7	0	0	0	0
Wallet	-	1	0.7	0	0	0	0
Paperwork	-	0	0	0	0	0	0
Extra firearm	-	0	0	0	0	0	0

N=139

As mentioned before FDB (5677 g) holds the following items: keys, pepper spray, firearm, two pairs of handcuffs, baton, radio, TASER, and magazines. Based on the items that caused the most discomfort and to suggest an alternative and lighter duty belt, all of the items except TASER and baton were removed thus, the reduced duty belt RDB (2118 g) was remained. Removed items from the FDB were assumed to be placed in other areas of the body. To determine alternative locations, officers were asked to suggest alternative places on the body to place each removed duty gear. Table 11, shows alternative locations for the removed duty gear items suggested by officers. Majority of the removed items were suggested to be placed on a vest or inside a pocket on a vest or on the pants. For example, handcuffs were suggested to be placed in pockets on a tactical vest or on a load baring vest. Similarly, baton, pepper spray, TASER, flashlight, radio, and spare magazines were suggested to be placed on outer vest. Thigh rig or leg holster was another alternative carriage method that is not commonly used among regular patrol officers. Nevertheless, thigh holster still remains as an alternative method to carry the firearm. In fact, according to the survey respondents, officers prefer to use a thigh holster, if it was a given option to them. In order to evaluate the effect of the low-weight alternative duty belt, or reduced duty belt (RDB) on the back muscles and shoulder muscles, removed items were put aside without placing the items in alternative locations. The reason for keeping the TASER (350 g) and baton (555 g) despite their discomfort causing properties was being light weight compared to the firearm and having approximately similar weight. Additionally, another reason for removing very important items such as the firearm and magazines from the FDB, was the interaction of these items with movement, the surrounding environment, body parts, and other duty gear. Table 12 depicts the interaction of each duty gear with movement (standing, squatting, and sitting), surrounding work environment (car seat, steering wheel, seat belt), body parts (hips, arms, thighs), and other duty gear (shirt, pants, vest). For example, the firearm was most frequently reported to interact while sitting (n = 20, 14%), with the car seat (n = 42, 29%), with the hips (n = 31, 21%), and with the vest (n = 13, 9%). Similarly, the magazines were mostly interacting while siting (n = 20, 14%) and squatting (n = 16, 11%), with the seat belt (n = 23, 17%), the hips (n = 16, 11%), vest (n = 18, 12%), and thighs (n = 13, 9%).

Table 11.

Officers' preferences of removing items off the duty belt and placing them in alternative locations

	Vest		Pocket		Thigh Rig	
	n	%	n	%	n	%
Handcuffs 1 pair	11	8	1	0.7	1	0.7
Handcuffs 2nd pair	19	13	3	2	1	0.7
Expandable baton	8	6	0	0	1	0.7
Pepper Spray	15	11	3	2	0	0
TASER	19	13	1	0.7	1	0.7
Flashlight	14	10	6	4	1	0.7
Radio	30	21	2	1.4	1	0.7
Firearm	4	3	0	0	5	4
Spare magazine	19	13	2	1.4	2	1.4
Cellphone	2	1.4	1	0.7	0	0
Knife	1	0.7	1	0.7	0	0
Keys	7	5	6	4	0	0
Gloves	8	6	2	1.4	0	0
Note pad	0	0	0	0	0	0
Paperwork	0	0	0	0	0	0
Pen	0	0	0	0	0	0
Wallet	0	0	0	0	0	0
Extra firearm	0	0	0	0	0	0
Extra knife	0	0	1	1	0	0
Other	0	0	0	0	0	0

Table 12.

Interaction of items on the duty belt with body parts and the duty gear in the surrounding work environment

	Interaction with movement						Surrounding environment						Body parts and duty gear														
	Standing		Squatting		Sitting		Car seat		Steering wheel		Seat belt		Hips		Arms		Pants		Shirt		Vest		Thighs		Other		Sum
	f	%	*f*	%	*f*	%	*f*	%	*f*	%	*f*	%	*f*	%	*f*	%	*f*	%	*f*	%	*f*	%	*f*	%	*f*	%	
Handcuffs 1 pair	0	0	1	1	5	3	11	8	0	0	3	2	10	7	0	0	0	0	2	1	3	2	1	1	1	1	37
Handcuffs 2nd pair	0	0	3	2	10	7	21	15	1	1	6	4	18	12	1	1	1	1	5	3	8	6	2	1	0	0	76
Baton	1	1	4	3	9	6	17	12	1	1	8	6	7	5	2	1	2	1	7	5	8	6	1	1	0	0	67
Pepper Spray	0	0	0	0	0	0	3	2	0	0	8	6	3	2	1	1	1	1	1	1	6	4	3	2	1	1	27
TASER	3	2	11	8	10	7	12	8	2	1	24	17	10	7	4	3	6	4	9	6	11	8	5	3	0	0	107
Flashlight	0	0	4	8	12	8	17	12	0	0	5	3	5	3	1	1	2	1	4	3	4	3	1	1	3	2	58
Radio	1	1	1	1	14	10	22	15	0	0	21	15	12	8	5	3	5	3	7	5	12	8	3	2	3	2	106
Firearm	3	2	3	2	20	14	42	29	6	4	42	61	31	21	5	3	12	8	7	5	13	9	4	3	3	2	191
Spare magazine	2	1	20	14	16	11	2	1	3	2	23	17	16	11	3	2	7	5	11	8	18	12	13	9	2	1	136
Cellphone	0	0	0	0	0	0	0	0	0	0	2	1	1	1	0	0	1	1	0	0	0	0	0	0	0	0	4
Knife	0	0	0	0	0	0	0	0	0	0	0	0	4	3	0	0	0	0	1	1	0	0	0	0	0	0	5
Keys	0	0	1	1	3	2	0	0	3	2	1	1	0	0	0	0	3	2	0	0	0	0	3	2	0	0	14
Gloves	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Wallet	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	2
Extra knife	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Other	0	0	0	1	2	1	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
Sum	10		49		103		150		16		144		117		22		41		54		83		36		13		

N=145

A summary of this Table 12 is made by summing the rows as most frequently reported interacting duty gear (see Figure 20) and by summing the columns as most frequently reported interacting movement, body part, and duty gear (see Figure 21). By doing so, another perspective highlights most problematic items currently experienced by officers. Items that interacted the most were firearm, magazine, TASER, and Radio. By removing majority of items and keeping only the baton and TASER the weight of the duty belt became lighter and the weight was distributed evenly. Participants who came to the laboratory, verbally mentioned that they did not feel the belt digging into their waist and they felt as if the belt was no longer on them. Firearm was heavier than the TASER but had similar size for that it was decided to remove the firearm and keep the TASER on the belt. The baton interacted mostly when seated (n = 9, 6%), with the vehicle seat (n = 17, 12%), the hips (n = 7, 5%), and the vest (n = 8, 6%). However, by keeping the baton on the belt and removing everything else there was enough room to move the baton anterior or posterior to prevent any kind of interaction of the baton with body parts and duty gear.

The RDB was determined as a result of analyzing Tables 9 till Table 12. We decided that the most problematic duty belt items were firearm, magazines, and radio mainly due to their weight and interaction caused by these items. Other items removed from the FDB were keys, pepper spray, handcuffs were lighter in weight and smaller in size. For this, they were removed with the intention of placing them in pockets on the vest.

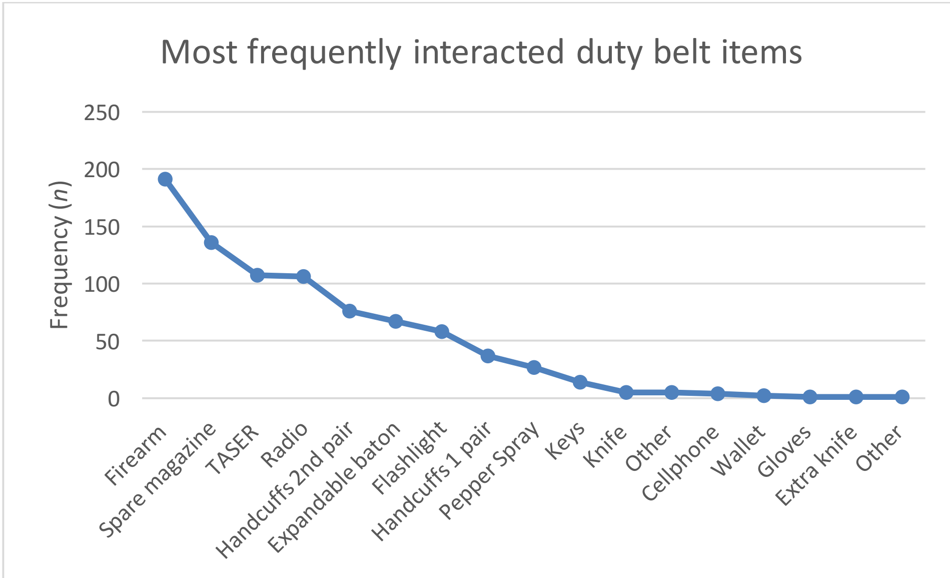


Figure 20. Frequency of the duty belt items that were reported to interact the most with movement (standing, squatting, and sitting), surrounding work environment (car seat, steering wheel, seat belt), body parts (hips, arms, thighs), and other duty gear (shirt, pants, vest).

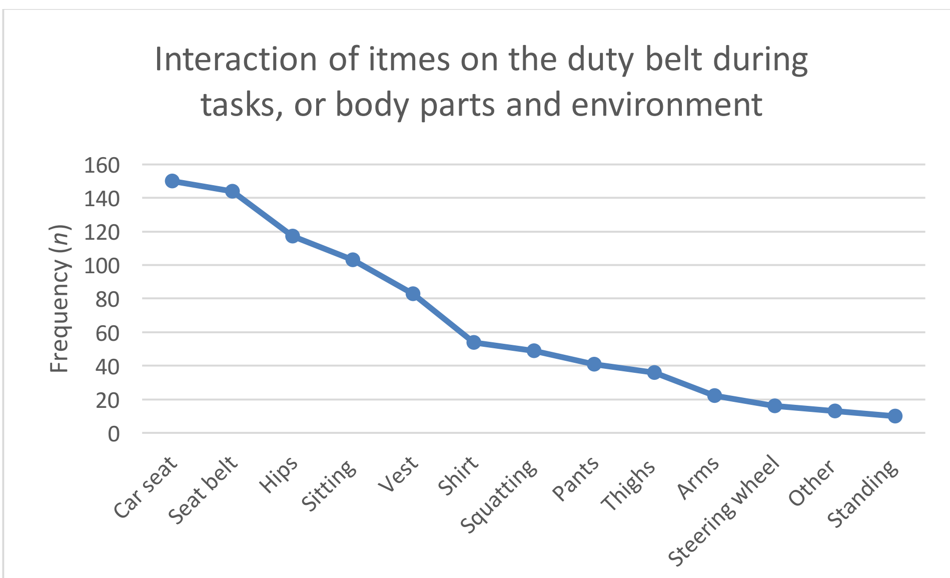


Figure 21. Frequency of the interaction of the surrounding environment with items around the duty belt.

Study II

Laboratory Assessment

For the laboratory assessment, 11 participants (9 male and 2 female) with an average height of *M* = 175 cm (*SD* = 11cm) and average weight of *M* = 86 kg (*SD* = 16 kg) volunteered to carry out an EMG test on six back muscles and two shoulder muscles. In a separate session, 9 participants came to the same lab to conduct a set of mobility activities and rated their ease of movement across three duty belt conditions. Anthropometric information of the officers who participated in the laboratory assessment are shown in Table 13.

Table 13.

Anthropometric information of the laboratory assessment sample

EMG	Gender	Mobility	Height (cm)	Weight (kg)	Body Mass Index (kg/m^2)
1	Male	1	180	102	31
2	Male	-	191	93	26
3	Male	3	185	98	28
4	Male	4	183	86	26
5	Male	5	183	116	35
6	Male	-	183	76	23
7	Male	-	173	82	27
8	Male	8	173	98	33
9	Female	9	168	63	22
10	Female	10	163	56	21
11	Male	11	160	71	28
-	Female	12	155	77	32

Electromyography activity of the surface muscles.

EMG data for each muscle, activity, and for each duty belt condition were tested for normality using Kolmogorov-Smirnov (K-S) test and by evaluating histograms for eight superficial muscles under each activity. K-S test appeared to be significant therefore, rejecting the null hypothesis that the data fits a normal distribution. The independent variables had a non-normal distribution and were skewed thus, they were treated with non-parametric statistics. A Kruskal-Wallis H test a non-parametric equivalent to a one-way Analysis of Variance (ANOVA), was conducted to assess the effect of duty belt on EMG activity of surface muscles. The null hypothesis was that the median of the EMG activity is the same across three conditions of the duty belt. The following section will describe the effect of the duty belt treatments on eight muscles.

Lifting and squat activities.

The effect of duty belt treatment on the muscles were determined by separating for each functional activity. The alpha score considered for the tests was $\alpha = 0.05$. During the lift activity, there were statistically significant differences between the median of the EMG activity of the RAD with ($\chi^2(2) = 7.248$, $p = 0.027$), RLONG with ($\chi^2(2) = 20.295$, $p < 0.000$), and LLONG with ($\chi^2(2) = 10.992$, $p = 0.004$) (see Table 14).

The effect size (μ^2) was calculated using the χ^2 with the following formula:

$$\mu^2 = \frac{\chi^2}{N-1}$$

According to Cohn (1988), $\mu^2 = 0.2$ indicates a small effect size, $\mu^2 = 0.13$ is a medium effect size, and $\mu^2 = 0.26$ indicates a large effect size in ANOVA. Calculated effect sizes for the RAD, RLONG, and LLONG were 0.05, 0.16, and 0.08 indicating a small relationship between the RAD and LLONG and a medium effect size in the RLONG muscle activity and change in the duty belt condition. It is not surprising to find a small to medium relationship between the duty belt condition and muscle activity. One reason may be that we are only observing activation of one surface muscle among many other muscles that may be affected by the duty belt but we are not able to account for every muscle affected. Small to medium relation should take into account the cumulative effect it may have across a timeline and small muscle activities may have a significant effect on musculoskeletal health when considered for long term effects.

During the squat activity, there was a statistically significant difference between the median of the EMG activity of the RAD with ($\chi^2(2) = 7.241$, $p = 0.027$), RILIO with ($\chi^2(2) = 7.644$, $p = 0.022$), and LLONG with ($\chi^2(2) = 9.989$, $p = 0.007$) (see Table 14). Calculated effect sizes for the RAD, RILIO, and LLONG, were 0.06, 0.05, and 0.08.

Table 14.

Chi-square values of eight superficial muscles during lift and squat activities

	Lift				Squat			
Muscles	n	χ^2	*df*	*p*	n	χ^2	*df*	*p*
RAD	132	7.248	2	**.027***	119	7.241	2	**0.027***
LAD	125	1.113	2	.573	117	0.307	2	.858
RILIO	132	2.329	2	.312	131	7.644	2	**.022***
LILIO	132	0.692	2	.707	132	0.882	2	.643
RLONG	127	20.295	2	**.000***	109	2.453	2	.293
LLONG	125	10.992	2	**.004***	120	9.989	2	**0.007***
RMUL	132	1.728	2	.422	131	1.809	2	.405
LMUL	129	4.661	2	.097	119	0.287	2	.866

Note. significance level of $\alpha = .05$

Post-hoc test for the lift activity, revealed significant differences between RDB (*Mdn* = 17.3, *SD* = 18.55) and CON (*Mdn* = 38.25, *SD* = 26.68) for the RAD with ($\chi^2(1) = 20.022$, $p = 0.031$), RDB (*Mdn* = 29.27, *SD* = 18.89) and FDB (*Mdn* = 50.44, *SD* = 18.85) for RLONG with ($\chi^2(1) = -29.747$, $p < 0.000$), RDB (*Mdn* =29.27, *SD* = 18.89) and CON (*Mdn* = 52.55, *SD* = 15.85) for RLONG with ($\chi^2(1) = 29.747$, $p < 0.000$), and

RDB (*Mdn* =36.91, *SD* = 23.66) and CON (*Mdn* = 58.28, *SD* = 19.25) for LLONG with ($\chi^2(1) = 25.052$, $p = 0.004$) (see Table 15 and Table 16).

For the squat activity post-hoc tests revealed significant differences between RDB (*Mdn* = 13.09, *SD* = 25.87) and FDB (*Mdn* = 35.82, *SD* = 25.93) for the RAD with ($\chi^2(1) = -19.615$, $p = 0.036$), RDB (*Mdn* = 27.51, *SD* = 16.04) and CON (*Mdn* = 33.73, *SD* = 21.02) for the RILIO with ($\chi^2(1) = 20.954$, $p = 0.03$), and RDB (*Mdn* =26.21, *SD* = 18.6) and CON (*Mdn* = 47.53, *SD* = 17.51) for the LLONG with ($\chi^2(1) = 24.3$, $p = 0.005$) (see Table 15 and Table 16).

Table 15.

Pairwise comparisons of duty belt condition on four superficial muscles for lift and squat activities

	Muscles	Treatment	χ^2	α
Lift	RAD	RDB-CON	20.022	0.031
	RLONG	RDB-FDB	-29.747	.000
	RLONG	RDB-CON	29.747	.000
	LLONG	RDB-CON	25.052	.004
Squat	RAD	RDB-FDB	-19.615	.036
	RILIO	RDB-CON	20.954	0.03
	LLONG	RDB-CON	24.3	0.005

Note. adjusted significance level of α = .05

In summary, the effect of the duty belt was mainly seen in RAD and LLONG muscles during both activities of lift and squat. The back muscles are mainly activated during these activities. The null hypotheses that were rejected were related to the changes in the RLONG during lifting and RAD during squatting.

$H_0$1b: There are no significant differences in activity of the longissimus muscles between the reduced duty belt and the full duty belt.

$H_0 2$: There are no significant differences in muscle activity of the anterior deltoid muscles between the reduced duty belt and full duty belt.

One explanation could be the removal of the firearm from the right side of the duty belt and replacing it with a baton. The effect of the firearm on the RAD could be the posture of the arm may have changed due to the notion of having a firearm during the FDB condition. None of the other muscle activities significantly changed between the two RDB and FDB conditions. The other significant findings were between the CON and RDB conditions. This was in contradiction to our expectations and hypothesis. Muscle activity appeared to be highest during the CON conditions, lowered during FDB condition, and the lowest at the RDB condition. This pattern is seen for majority of the muscles. There are variations between each muscle activity.

Table 16.

Descriptive of EMG activity of superficial muscles during lift activities

Lift	CON						RDB						FDB					
	n	SD	Skewness	Median	Min	Max	n	SD	Skewness	Median	Min	Max	n	SD	Skewness	Median	Min	Max
RAD	38	26.68	0.68	**28.13**	9	96	43	18.55	1.73	**17.3**	5	84	40	25.25	1.07	22.19	6	99
LAD	35	24.01	0.39	22.86	3	81	43	26.11	0.56	27.29	6	91	36	23.48	1.16	26.85	5	99
RILIO	41	18.49	0.10	50.12	10	90	42	21.57	0.69	45.15	18	94	41	18.05	0.71	38.26	15	85
LILIO	41	17.57	0.58	36.66	6	84	43	18.27	1.14	33.76	15	94	40	15.29	1.02	32.88	16	78
RLONG	35	15.85	-0.50	**52.55**	9	79	36	18.89	1.25	**29.27**	13	91	40	18.45	0.27	**50.44**	19	97
LLONG	41	19.25	-0.24	**58.28**	5	99	39	23.66	0.77	**36.91**	8	92	40	22.46	0.81	41.20	15	98
RMUL	36	28.13	-0.04	54.67	10	99	38	25.88	0.39	43.53	12	97	43	21.83	0.42	45.60	11	94
LMUL	40	24.11	0.44	38.43	6	92	37	16.03	0.58	51.68	25	94	34	19.53	0.49	38.27	17	87

Note. RAD (right anterior deltoid), LAD (left anterior deltoid), RILIO (right iliocostalis), LILIO (Left iliocostalis), RLONG (right longissimus), LLONG (left longissimus), RMUL (right multifidus), and LMUL (left multifidus).

Table 17.

Descriptive of EMG activity of superficial muscles during squat activities

Squat	CON						RDB						FDB					
	n	SD	Skewness	Median	Min	Max	n	SD	Skewness	Median	Min	Max	n	SD	Skewness	Median	Min	Max
RAD	41	24.85	0.92	25.88	4	99	39	25.87	1.31	**13.09**	2	98	39	25.93	0.83	**35.82**	3	95
LAD	38	22.01	1.58	23.85	3	100	39	22.23	1.80	22.23	3	96	40	20.09	0.47	21.03	3	66
RILIO	43	21.02	0.79	**33.73**	10	87	44	16.04	0.70	**27.51**	5	68	44	19.91	1.29	26.23	11	88
LILIO	44	12.47	1.01	24.58	11	61	44	7.15	0.69	24.01	12	44	44	9.21	0.95	24.90	9	54
RLONG	36	19.93	0.05	45.50	14	93	37	25.98	0.58	36.66	9	98	36	15.11	0.80	32.74	15	71
LLONG	40	17.51	-0.38	**47.53**	5	79	40	18.60	1.12	**26.21**	18	82	40	16.04	0.95	35.45	18	81
RMUL	44	23.38	-0.18	55.52	15	90	43	25.67	0.61	37.43	11	96	44	20.27	0.59	42.25	15	89
LMUL	43	19.87	0.20	39.17	11	85	38	20.85	0.54	42.40	14	94	38	24.34	0.80	38.86	10	98

In summary, the muscles significantly affected during lift activity were RAD, RLONG, and LLONG. Muscle activity was significantly higher in CON condition compared to the RDB for the RAD, RLONG, and LLONG muscles. There was also a significant duty belt effect between the RDB and FDB only for the RLONG muscle with the median of RDB being higher than the FDB condition. During the squat activity, muscles significantly different across the duty belt conditions were RAD, RILIO, and LLONG. While muscle activity of the CON was higher than the RDB for the two RILIO and LLONG, median of FDB was higher than RDB for RAD muscles.

There is a lot of variability between muscle groups. We did not expect to see an effect of the duty belt on the anterior deltoid muscles however, they do show different muscle activity due to the nature of the activity where the arms were lowered and raised. During lifting, back muscles were more active than the shoulder muscles and the highest activity was observed for RLONG being close to 30%. Similar pattern is also visible for the squat activity with the longissimus and multifidus muscles showing activity up to 50% and being higher than the rest.

Looking at Figure 22, we can see that the median values are closer to the minimum value of the EMG data. This shows that the median is far from the mean and closer to zero on the x axis, in other words the data is skewed to the left side of the curve. A similar pattern of the median for CON > RDB and RDB > FDB for several muscles RAD, RILIO, LILIO, RLONG, LLONG, and RMUL during lifting task. Generally, there were differences between the right and left side of the superficial muscles.

Figure 23 shows the normalized EMG during squat activity, with a similar pattern of CON>RDB>FDB for the muscles LLONG and RMUL. The median values are closer to the minimum value of the EMG data, indicating skewed distribution of the data with a tendency to the left side of the curve. There is no clear pattern in the muscle activity of the right compared with the left side.

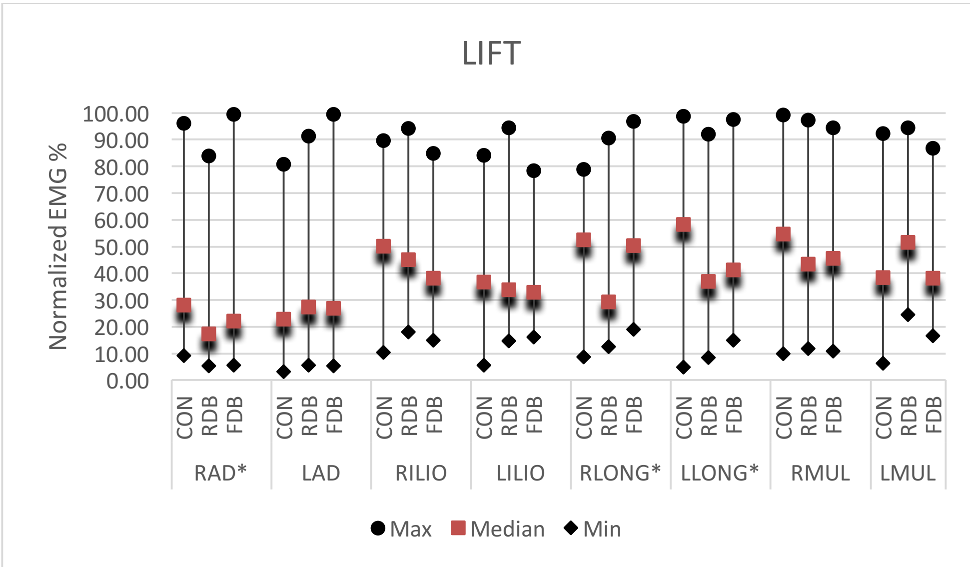


Figure 22. Maximum, minimum, and median scores of superficial muscles for the lift task ($N = 44$)

Figure 23. Maximum, minimum, and median scores of superficial muscles for the squat task ($N = 44$)

Lunge activity.

Table 18 shows that during lunge with left foot forward there was a statistically significant difference between the median of the EMG activity of the RMUL with ($\chi^2(2) = 6.201$, $p = 0.045$). Lunge with right foot forward resulted in a significant difference in LLONG with ($\chi^2(2) = 11.989$, $p = 0.002$). Calculated effect sizes for the RMUL and LLONG, were 0.04 and 0.09 indicating a small effect size.

Table 18.

Chi-square values of the superficial muscles during left lunge and right lunge activities

	Left Lunges				Right Lunges			
Muscles	n	*χ2*	*df*	*p*	n	*χ2*	*df*	*p*
RAD	132	1.974	2	.373	132	0.344	2	.842
LAD	125	2.628	2	.269	125	2.908	2	.234
RILIO	132	1.404	2	.496	132	0.446	2	.800
LILIO	132	0.776	2	.679	132	5.512	2	.064
RLONG	129	3.442	2	.179	127	2.173	2	.337
LLONG	127	4.864	2	.088	125	11.989	2	**.002***
RMUL	131	6.201	2	**.045***	132	3.2	2	.202
LMUL	130	0.813	2	.666	129	4.34	2	.114

Note. significance level of $\alpha = .05$

Pairwise analysis for the left lunges, revealed significant differences between RDB (*Mdn* = 17.11, *SD* = 11.43) and CON (*Mdn* = 27.67, *SD* = 13.86) for the RMUL muscle with ($\chi^2(1) = 19.727$, $p = 0.044$). There were also significant differences in the LLONG between RDB (*Mdn* = 17.02, *SD* = 15.46) and FDB (*Mdn* = 22.03, *SD* = 15.77) with ($\chi^2(1) = -19.278$, $p = 0.043$) and RDB (*Mdn* = 17.02, *SD* = 15.46) and CON (*Mdn* = 25.05, *SD* = 10.57) with ($\chi^2(1) = 26.965$, $p = 0.002$) during right lunges (see Table 19 and Table 20).

In summary only two muscles were significantly affected by the duty belt during lunges, RMUL and LLONG. During the left lunge, there were significant differences in the LLONG and RMUL with the right lunge activity. Muscle activity was higher in the CON compared to the RDB for the RMUL. Similarly, for the left longissimus, with the addition of FDB higher than the RDB following a pattern of CON>RDB>FDB with no significant differences between the CON and FDB. CON condition held higher muscle activity compared to the RDB for all the back muscles during left and right lunge with the exception for RILIO.

Looking at Figure 24 and Figure 25, we can see similar muscle activity during the left lunge and right lunge with the exception of RLONG where it follows a CON>RDB>FDB during left lunges, whereas, in the right lunges the pattern is CON>FDB>RDB. Close to identical patterns between the left and right side were not observed during the lift and the squat activities. Similar to the muscle activity in the lift and squat activities, median value is closer to the minimum normalized EMG value, indicating a skewness to the left side of the curve.

Table 19.

Pairwise comparisons of duty belt condition on two superficial muscles for left lunges and right lunges

	Muscles	Treatment	χ^2	α
Left Lunges	RMUL	RDB-CON	19.727	0.044
Right Lunges	LLONG	RDB-FDB	-19.278	0.043
	LLONG	RDB-CON	26.965	0.002

Note. adjusted significance level of $\alpha = .05$

Table 20.

Descriptive of EMG activity of the superficial muscles during left lunges

Left lunge	CON						RDB						FDB					
	n	SD	Skewness	Median	Min	Max	n	SD	Skewness	Median	Min	Max	n	SD	Skewness	Median	Min	Max
RAD	44	9.86	2.92	6.41	2	49	44	6.97	1.42	4.91	3	27	44	4.20	0.75	7.41	3	19
LAD	40	8.06	2.56	5.57	2	38	44	21.59	2.25	6.02	2	78	41	15.35	5.41	4.99	2	100
RILIO	44	15.13	0.91	21.09	5	70	44	16.10	1.35	17.82	4	69	44	18.66	2.05	16.63	3	93
LILIO	44	7.88	1.49	15.31	5	48	44	5.66	0.27	14.17	6	28	44	7.30	0.41	14.48	5	31
RLONG	44	20.27	0.66	31.08	8	89	42	24.51	0.64	26.41	6	93	43	21.28	1.54	23.13	5	94
LLONG	40	16.37	0.93	22.98	4	69	43	19.15	2.20	15.99	5	96	44	18.58	1.55	22.63	6	86
RMUL	44	13.86	0.34	**27.67**	7	62	44	11.43	0.80	**17.11**	7	44	43	16.18	3.46	18.11	9	93
LMUL	44	17.91	1.12	24.22	7	90	44	12.46	0.75	17.67	8	52	42	17.91	1.42	25.21	8	87

Table 21.

Descriptive of EMG activity of the superficial muscles during right lunges

Right lunge	CON						RDB						FDB					
	n	SD	Skewness	Median	Min	Max	n	SD	Skewness	Median	Min	Max	n	SD	Skewness	Median	Min	Max
RAD	44	9.16	3.38	6.22	2	54	44	6.75	1.27	5.14	2	24	44	4.26	1.35	5.98	2	21
LAD	40	8.15	2.00	5.63	2	40	44	21.37	2.32	5.64	3	78	41	14.83	5.54	5.13	2	97
RILIO	44	12.61	0.88	18.60	4	53	44	18.90	1.56	17.53	4	84	44	17.51	1.40	16.69	4	66
LILIO	44	6.43	0.53	17.28	8	33	44	6.21	0.99	13.42	7	32	44	6.59	0.29	14.20	4	31
RLONG	44	16.92	0.33	31.15	6	68	41	23.44	0.87	20.91	5	95	42	18.45	1.76	26.07	7	95
LLONG	40	10.57	0.35	**25.05**	11	52	41	15.46	2.80	**17.02**	6	90	44	15.77	1.66	**22.03**	7	80
RMUL	44	11.97	-0.31	29.25	6	43	44	10.35	0.67	18.44	9	44	44	12.79	2.22	22.35	12	73
LMUL	43	13.01	3.20	22.91	7	90	44	12.37	1.04	16.84	7	52	42	19.82	1.33	24.33	9	93

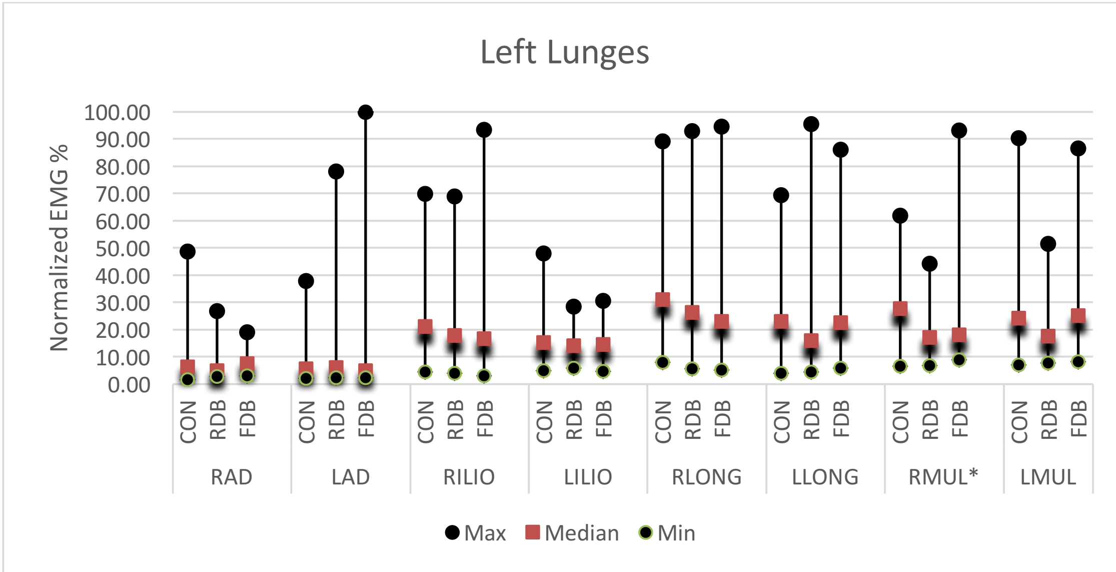


Figure 24. Maximum, minimum, and median scores of the superficial muscles for the left lunges ($N = 44$)

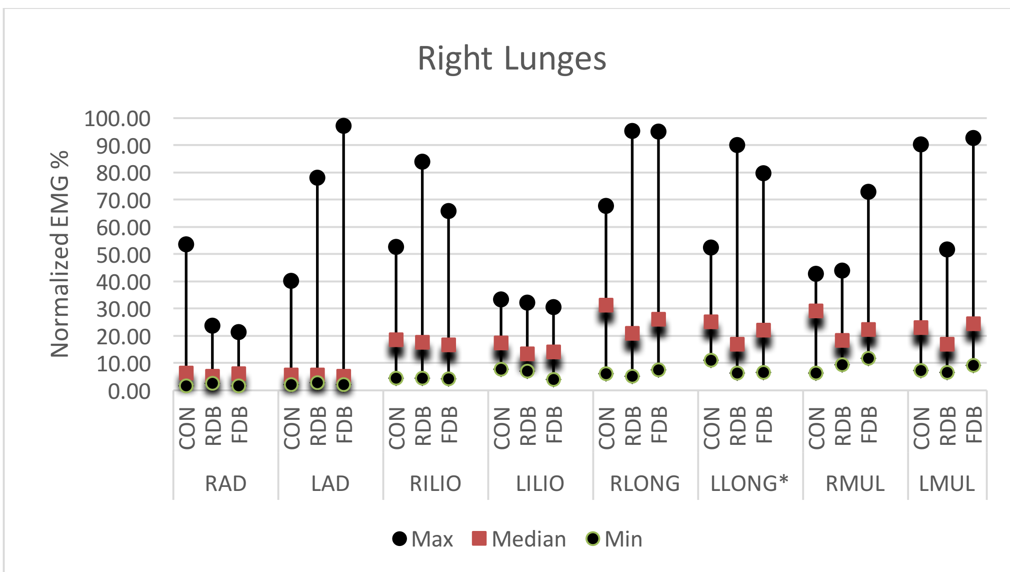


Figure 25. Maximum, minimum, and median scores of the superficial muscles for the right lunges ($N = 44$)

Reach activity.

During the overhead reach with a twist to the left, there was a statistically significant difference between the median of the EMG activity of the LMUL with ($\chi^2(2)$

= 7.443, p = .024). Reach to the right resulted in a significant difference in RLONG with ($\chi^2(2) = 6.615$, $p = 0.0037$) (see Table 22). Calculated effect sizes for the LMUL and RLONG, were 0.05 and 0.05 indicating a small effect size.

Table 22.

Chi-square values of the superficial muscles during left reach and right reach activities

	Left Reach				Right Reach			
	n	*χ2*	*df*	*p*	n	*χ2*	*df*	*p*
RAD	47	0.884	2	.643	96	0.211	2	.900
LAD	97	3.344	2	.188	50	0.03	2	.985
RILIO	131	5.26	2	.072	121	1.188	2	.552
LILIO	132	2.325	2	0.313	132	0.867	2	.648
RLONG	130	5.877	2	.053	128	6.615	2	**.037***
LLONG	130	3.069	2	.216	127	1.539	2	.463
RMUL	130	1.697	2	.428	127	3.155	2	.206
LMUL	128	7.443	2	**.024***	132	4.065	2	.131

Note. significance level of $\alpha = .05$

Pairwise analysis for the left reach, revealed significant differences between RDB (*Mdn* = 26.56, *SD* = 18.97) and CON (*Mdn* = 15.88, *SD* = 17.28) for the LMUL muscle with ($\chi^2(1) = -20.842$, $p = .028$). There were also significant differences in the RLONG between RDB (*Mdn* = 24.94, *SD* = 19.08) and FDB (*Mdn* = 33.37, *SD* = 20.92) with ($\chi^2(1) = -20.35$, $p = .031$) (see Table 23).

The null hypothesis was rejected for the longissimus muscle, showing a difference between the RDB and FDB in the RLONG during right reach.

$H_0$1b: There are no significant differences in activity of the longissimus muscles between the reduced duty belt and the full duty belt.

In summary only two muscles were significantly affected by the duty belt during reach activities, LMUL and RLONG. During the left reach, there were significant differences in the LMUL and RLONG with the right reach activity. Muscle activity was higher in the CON compared to the RDB for the LMUL. In the right longissimus, muscle activity was significantly higher in the FDB compared to the RDB. This was also the case for the CON being higher than the RDB however, the difference was not significant (see Table 24 and Table 25).

Looking at Figure 26 and Figure 27we can see that there is similar muscle activity during the left reach and right reach activates only for the RLONG, LLONG, and LMUL. The rest of the muscles show almost a contrasting activity with each other.

Table 23.

Pairwise comparisons of duty belt condition on two superficial muscles for left reach and right reach activity

	Muscles	Treatment	$\chi2$	α
Left reach	LMUL	RDB-CON	-20.842	0.028
Right Reach	RLONG	RDB-FDB	-20.38	0.031

Note. adjusted significance level of $\alpha = .05$

Table 24.

Descriptive of EMG activity of the superficial muscles during left reaching

Left reach	CON						RDB						FDB					
	n	SD	Skewness	Median	Min	Max	n	SD	Skewness	Median	Min	Max	n	SD	Skewness	Median	Min	Max
RAD	11	34.14	0.50	42.94	9	99	20	22.69	0.90	40.13	17	99	16	25.89		35.51	4	86
LAD	32	21.63	1.22	25.00	9	97	33	26.42	1.50	24.39	7	96	32	18.09	2.09	21.71	5	97
RILIO	44	23.02	1.30	27.84	8	92	44	21.22	1.25	19.20	5	85	43	21.11	1.75	18.64	6	94
LILIO	44	12.87	0.95	19.25	6	60	44	16.30	0.91	20.12	7	66	44	22.51	0.98	24.59	6	84
RLONG	42	15.13	0.61	29.01	10	69	44	18.12	1.35	21.98	8	77	44	14.53	1.12	28.83	11	74
LLONG	44	19.80	1.58	24.31	5	94	42	20.03	1.15	20.99	6	89	44	20.34	0.78	29.58	9	81
RMUL	42	16.75	1.28	28.97	6	83	44	15.77	0.88	23.30	13	67	44	14.03	1.46	27.64	11	73
LMUL	44	17.28	1.78	**15.88**	6	80	42	18.97	2.05	**26.56**	10	97	42	25.14	1.82	18.36	4	96

Table 25.

Descriptive of EMG activity of the superficial muscles during right reaching

Right reach	CON						RDB						FDB					
	n	SD	Skewness	Median	Min	Max	n	SD	Skewness	Median	Min	Max	n	SD	Skewness	Median	Min	Max
RAD	31	26.39	0.33	41.85	10	96	31	30.19	0.05	50.37	6	93	34	32.08	0.17	41.28	4	93
LAD	13	24.06	0.99	39.44	15	95	21	28.78	0.80	23.03	11	96	16	35.37	0.36	35.84	8	97
RILIO	44	20.19	1.10	27.80	6	92	37	22.67	0.44	33.74	5	89	40	28.82	0.39	38.09	6	98
LILIO	44	15.19	1.18	22.86	5	76	44	14.54	2.83	18.50	6	92	44	10.22	0.23	20.67	6	41
RLONG	44	14.26	0.77	30.38	12	74	42	19.08	1.41	**24.94**	5	96	42	20.92	0.96	**33.37**	12	98
LLONG	44	12.75	1.11	20.05	5	59	40	12.20	0.74	17.14	4	48	43	17.03	1.38	18.43	5	73
RMUL	44	20.36	1.15	19.82	6	82	41	20.90	1.24	21.12	7	80	42	22.81	1.25	26.96	6	94
LMUL	44	11.79	2.38	19.57	8	75	44	12.25	0.72	21.97	5	58	44	13.95	1.32	19.98	5	62

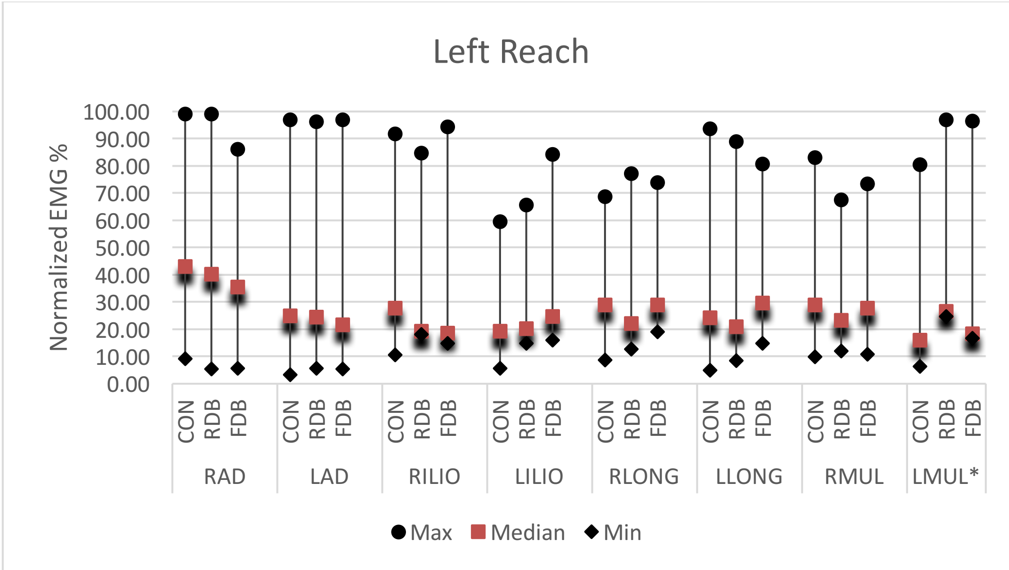


Figure 26. Maximum, minimum, and median scores of the superficial muscles for the left reach ($N = 44$)

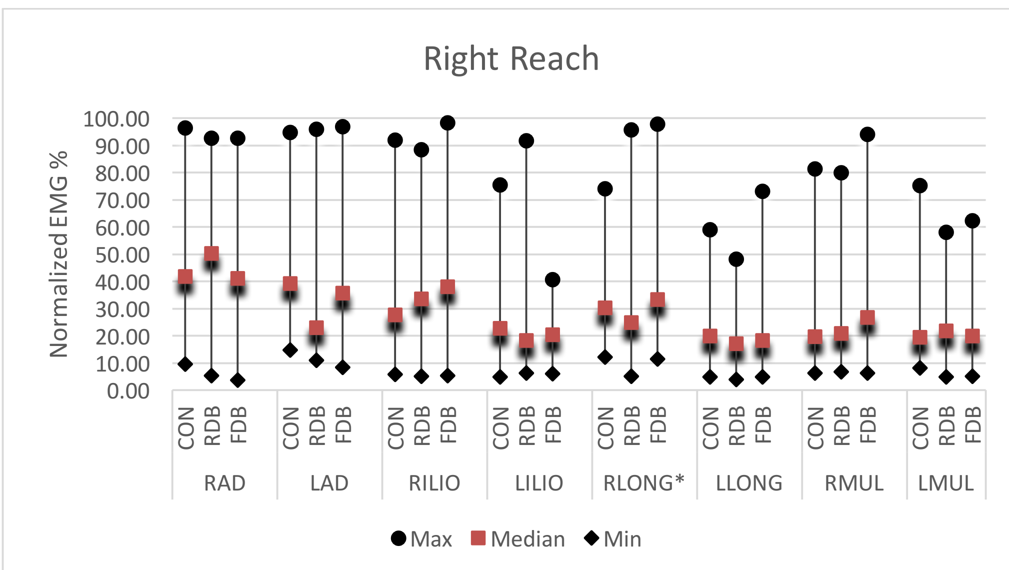


Figure 27. Maximum, minimum, and median scores of the superficial muscles for the right reach ($N = 44$)

Looking at the effect of duty belt weight on EMG muscle activity, we can see that the median muscle activity for the various duty belt configuration could be summarized into CON>FDB>RDB. In other words, muscle activity was at its highest in the no-belt condition and the lowest in the reduced belt condition. This is contradictory to what we initially expected. We expected to see a difference in muscle activity between the RDB and FDB with FDB being much higher than the CON and the RDB conditions. There are several possible reasons as to why the EMG activity could have appeared to be the highest in the CON condition. One reason may be that officers, regardless of the items attached, felt restricted with the duty belt on (RDB) compared to no duty belt condition (CON). The CON condition may have allowed the participant to move easier without feeling any restriction and weight on them resulting in more physical activity thus, higher EMG activity. This assumption is supported by our observations in the lab, that the participants had difficulty in carrying out lunges and squats with the FDB condition. With the FDB on, balance was not easily obtained and mobility was reduced according to officers while conducting functional tasks. It is possible that the time to conduct the activities were longer, indicating that officers moved slower to obtain balance thus, reducing their muscle activity levels. After wearing the reduced duty belt officers verbally mentioned a sudden relief and were able to do the activities with full balance and control. Wearing a belt could inhibit mobility, increase pressure, and decrease muscle activity of the muscles around the belt. In this vein, Granata et al. (1997) found that weight belts decreased the muscle activity of the erector spinae and increased the muscle activity of the external obliques. Studies have shown that weight belts increase the intra-abdominal pressure by aiding the compression of the abdomen and allowing low back muscle activation lowered and passed from the back toward the abs and external obliques (Lander et al., 1990). Although duty belts are much narrower (2.5”) than the weight belts

(8-10”), similar effect to weight belts might occur by wearing a duty belt and a vest, where pressure may be guided to the abdomen, reducing the activity of the back muscles. We need more electrodes in these areas to observe the changes in muscle activity in the front and back of the torso or the anterior deltoid muscles could be omitted and assessed more of the torso muscles. There is evidence that posture of the person is also affected by the duty belt thus, affecting the muscle activity of the low back area (Holmes et al., 2013; Ilori, Li, Mahesh, & Craig, 2017; Ramstrand et al., 2016).

It is possible that the repetition of each movement may have led to muscle fatigue in participants. The duration of each EMG session took approximately 75 minutes. Similar durations of muscle activity has been shown to cause fatigue. Hostens and Ramon (2005) assessed muscle activity of the trapezius and deltoid and found signs of fatigue after 60 minutes of driving which is a monotonous and low labor activity. In this study after 60 minutes, participants reported their muscles were stiff, which is another indication of fatigue.

Based on the result of this study we understand that there is not much difference in muscle activity between the two belt conditions when reducing the items attached to it. It may mean that differences are hidden in other parameters and may mean that measuring muscle activity should be conducted with supplement tests such as pressure contact area, video recording, range of motion, and/or balance test. Each test would provide more insight to the complex pattern of muscle activity. For example, video recording and motion capture recordings, would shed light to the time and posture during certain muscle activation patterns. Based on the results of the EMG testing, it may be appropriate to suggest remove the duty belt in order to increase muscle activity which may lead to increase in movement and flexibility. Alternative locations for the firearm and TASER would be the thigh holster. Other high priority items such as magazines, radio and flashlight could be placed on the left side of the torso on the side where they are kept on the belt. Remaining items, handcuffs, expandable baton, pepper spray, could be distributed onto the left side of the external vest. Nevertheless, there are several possible explanations for the subjective benefits of a light duty belt: increased awareness and ease of movement and balance when wearing a lighter belt or no belt.

Perceived discomfort.

Each participant rated their discomfort level after completing functional tasks for the EMG test. Descriptive statistic related to perceived discomfort with respect to body parts (front and back) are listed in Table 26. The null hypothesis was that the median of perceived discomfort is the same across three conditions of the duty belt. In order to reduce the number of dependent variables and the possibility of making a type II error, front body parts were averaged in the following order and summarized in Table 26;

Front body discomfort rating = upper torso (neck + shoulder (L) + shoulder (R) + chest (L) + chest (R))/5, lower torso (abdomen + hip (L) + pelvis +hip (R))/4, and extremities (upper thigh (L) + (upper thigh (R))/2. Similarly, back body parts were averaged in the following order: Back body discomfort rating = upper torso (back neck + back shoulder (L) + back shoulder (R) + upper back (L) + upper back (R) + middle back)/6 and lower torso (lower back + side body (L) + side body (R) + upper pelvis (L) + sacrum + upper pelvis (R))/6.

Figure 28 shows the discomfort ratings in back body areas. Three most problematic areas were low back, upper pelvis (R), upper pelvis (L), and sacrum in the FDB condition. Almost in every body area discomfort in RDB was lower than CON. This may be due to a feeling of relief when putting on a lighter duty belt instead of their regular everyday belts and officers may have reflected their relief by marking lower in the RDB condition than in the FDB condition. Misunderstanding of the scale is a limitation of objective measures. Looking back at muscle activity, CON>RDB and perceived discomfort in body areas were rated as CON>RDB. Muscle activity increased possibly due to less weight and bulk around the waist helped the officer to move easily and faster resulting in higher muscle activity. However, this was not reflected in the ratings of perceived discomfort. FDB condition had the highest ratings of perceived discomfort in the back showing a pattern of FDB>CON>RDB. Compared to the muscle activity pattern CON>FDB>RDB we can suggest that FDB created the most discomfort and the bulk with weight of the FDB resulted in lest muscle activity than the CON condition.

Figure 29 shows discomfort in the front body areas and most problematic areas were reported to be hip (L), hip (R), pelvis, upper thigh (L), and upper thigh (R) for the FDB condition. Similar to the back ratings, almost in every front area discomfort in RDB was lower than CON. The reason may be due to misunderstanding the VAS and officer may have rated their discomfort according to their everyday experience.

The average ratings of perceived discomfort in the front and back do not exceed 30 mm which was not the case in previous studies. Donnelly et al. (2009) found much higher discomfort ratings in their study with different chair structures. Also, the participants rated their discomfort based on their experience through a typical 8-hour shift. In this study, officers rated only the effect of the duty belt conditions. Therefore, it is not surprising to find less ratings compared to discomfort experience throughout a regular shift. Another thought is that, the discomfort of a vehicle chair is not the same discomfort caused by the duty belt. In this study movements were done standing to be able to observe muscle activity of the back and seated activities were not taken into consideration while rating discomfort. Filtness et al. (2014), found less discomfort in the load baring vest condition compared to the full duty belt while officers were seated in a vehicle seat. Our results also show a similar pattern however, our method was very different that of Filtness et al. (2014).

Kolmogorov-Smirnov test for normality was conducted and non-normal distribution of the data was observed through histograms. Kurskal-Wallis test revealed that there were no statistically significant differences in the median of the perceptions of discomfort in body parts and duty gear across various duty belt conditions (see Table 27). Although there are differences observed in the median however, this may not result in significance due to the scale being very broad. Another possibility is that officers' perceptions may have effected their final decision as the officers were not blinded to the treatments.

Table 26.

Descriptive statistics of perceived discomfort with respect to body parts

	Mean	Median	SD	Min	Max	Skewness	Kurtosis
Back upper torso							
CON	8	5	9.04	0	29	1.559	1.878
RDB	6.8	6.6	6.03	0	21	1.290	2.015
FDB	9.4	7.5	8.1	0	25.83	0.750	-0.067
Back lower torso							
CON	13	7	14.21	0	46.17	1.464	1.908
RDB	9	7	8.9	0	30.83	1.635	3.013
FDB	17.3	10	18.47	0	48	0.908	-0.949
Front upper torso							
CON	6	6.2	6.1	0	20	1.220	1.344
RDB	6.38	6	5.2	0	18.2	1.023	1.363
FDB	8.2	7	7.4	0	25.8	1.247	2.115
Front lower torso							
CON	16.	7.5	18.4	0	56	1.530	1.367
RDB	9.4	7	7.1	0	24.75	1.083	0.610
FDB	20.6	12.7	18.57	0	55.5	0.972	-0.336
Front lower extremities							
CON	10.4	4	15.4	0	51	2.115	4.736
RDB	7.6	5	7.8	0	28	2.009	4.575
FDB	22	7	26.9	0	73	1.242	0.125

Note. All the discomfort ratings presented in this table are gathered from 100 mm visual analog scale with 0 mm indicating no discomfort and 100 mm indicating extreme discomfort.

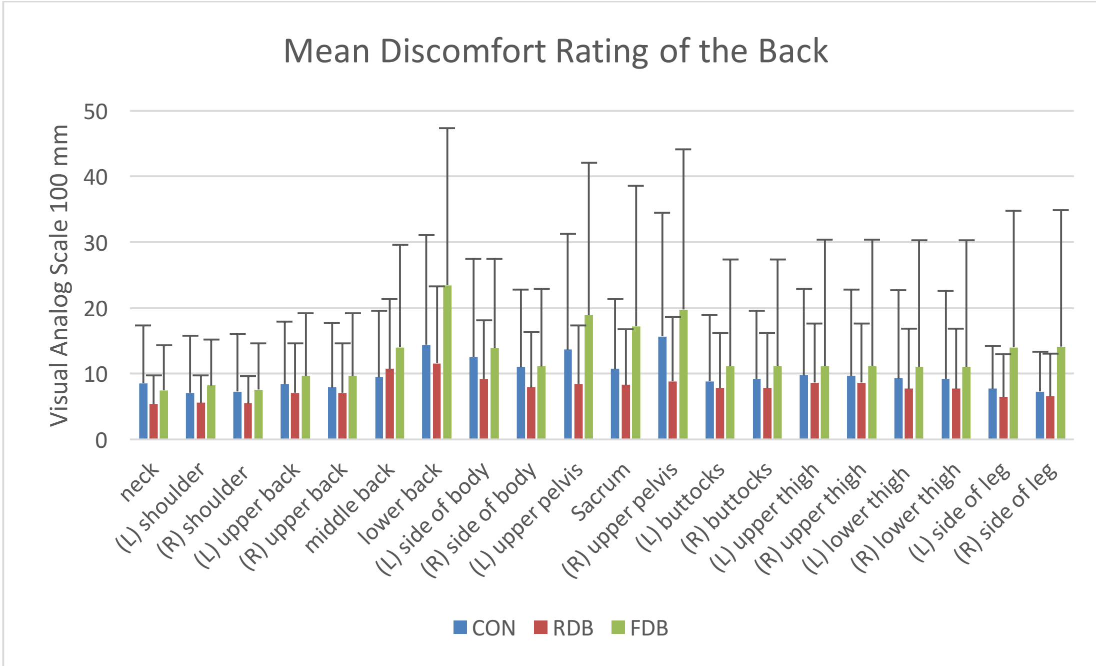


Figure 28. Discomfort ratings of back body parts (0 mm no discomfort and 100 mm extreme discomfort) (*N* = 11)

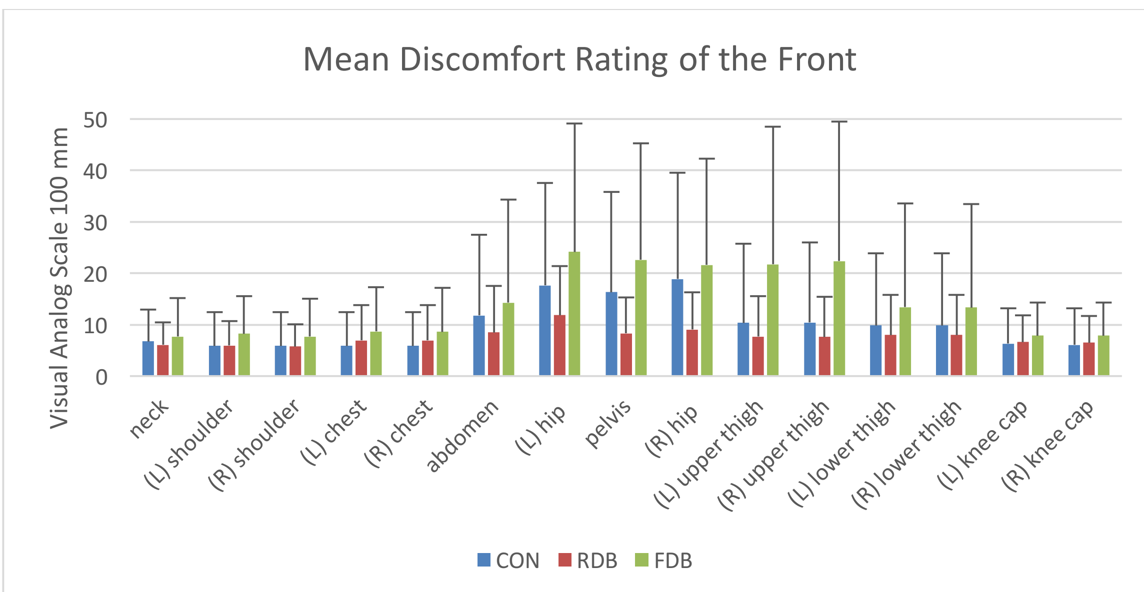


Figure 29. Discomfort ratings of front body parts (0 mm no discomfort and 100 mm extreme discomfort) (*N* = 11)

Kelly (1998) argues that, to prevent injuries and manage pain using visual analog scales, it is important to consider the clinical significant differences regardless of the statistical significance. It is suggested that differences greater than 9 mm is considered to be clinically significant and if differences are greater than 20 mm the effect size is considered large (Kelly, 1998). Difference between ratings for left and right hip, pelvis, and upper thigh in the front body areas vary more than 10 mm suggesting a clinical significance and requiring in greater attention to these body areas. As for the back-body areas, lower back, left upper pelvis, and right upper pelvis were areas that resulted in clinically significant higher rating with the FDB condition.

Perceived discomfort with respect to duty gear was also assessed in this study however, questions were raised about the validity of the results thus, were not reported.

Table 27.

Chi-square values of the perceived discomfort across all three levels of the duty belt conditions.

	N	$\chi 2$	*df*	*p*
Back upper torso	33	0.594	2	0.743
back lower torso	33	0.651	2	0.722
front upper torso	33	0.724	2	0.696
front lower torso	33	1.998	2	0.368
front lower extremities	33	1.667	2	0.435

Perceived ease of movement.

Unlike perceived discomfort, there was a statistically significant difference in the median of perceived ease of movement for flexion with ($\chi^2(2) = 10.049$, $p = 0.007$), for hyperextension with ($\chi^2(2) = 12.437$, $p = 0.002$), for left lateral bend ($\chi^2(2) = 9.373$, $p = 0.009$), for right lateral bend ($\chi^2(2) = 12.112$, $p = 0.002$), and for both left and right rotation ($\chi^2(2) = 13.471$, $p = 0.001$). Calculated effect sizes for perceived ease of movement are reported in Table 28, indicating a large effect size that 36-51% of the variability in perceived ease of movement is accounted for by the duty belt configuration.

Pairwise comparisons revealed a statistically significant difference in the median of perceived ease of movement between CON and FDB for all movements. There was also a significant difference between RDB and FDB for left and right rotation (see Table 29). Figure 31 shows perceived ease of movement ratings for all movements. The ratings follow a pattern of FDB>RDB>CON. As expected, the FDB was the most difficult condition to move in, followed by the RDB, and CON was the rated as the lowest. Although minimal, there is slight difficulty in moving with CON condition and this may be due to the vest. CON condition was rated the easiest to move with. Showing higher muscle activity during the EMG testing, and less perceived discomfort, it is appropriate to say that the no belt condition allowed the officers to move easily with less discomfort and more flexibility thus, resulting in higher muscle activity. It was not surprising to see a significant increase in ratings for FDB condition.

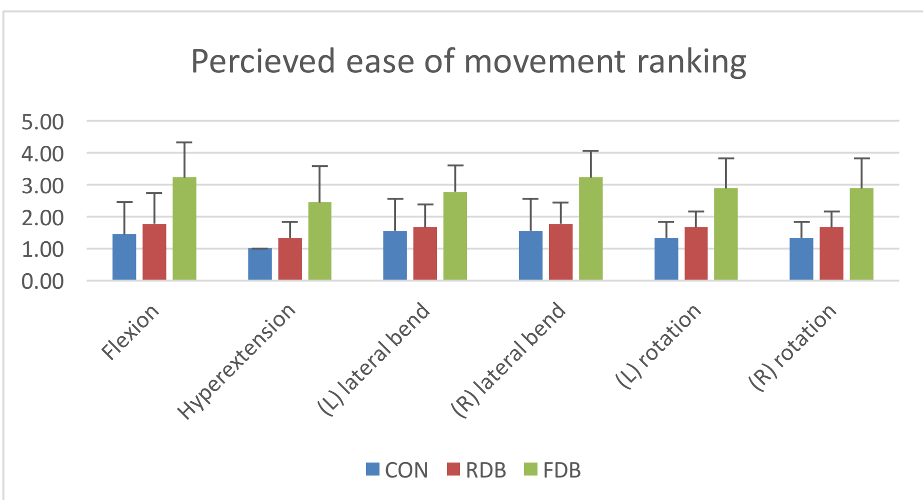


Figure 30. Ranking of perceived ease of movement for three duty belt conditions. (1=extremely easy, 5= extremely difficult) ($N = 9$)

Table 28.

Chi-square values of the perceived ease of movement across all three levels of the duty belt conditions

	N	$\chi 2$	*df*	μ^2	*p*
Flexion	27	10.049	2	0.38	**0.007***
Hyperextension	27	12.437	2	0.47	**0.002***
Left lateral bend	27	9.373	2	0.36	**0.009***
Right lateral bend	27	12.112	2	0.46	**0.002***
Left rotation	27	13.471	2	0.51	**0.001***
Right rotation	27	13.471	2	0.51	**0.001***

Table 29.

Pairwise comparisons of the effect of duty belt on perceived ease of movement

	Condition	χ^2	a
Flexion	CON-FDB	-10.833	0.007
Hyperextension	CON-FDB	-11.167	0.002
Left lateral bend	CON-FDB	-10.167	0.012
Right lateral bend	CON-FDB	-11.833	0.003
	RDB-FDB	9.333	0.028
Left rotation	CON-FDB	-12.333	0.001
	FDB-RDB	8.667	0.036
Right rotation	CON-FDB	-12.333	0.001
	RDB-FDB	8.667	0.036

Note. adjusted significance level of $\alpha = .05$

Implications

To the best of our knowledge, this study is unique in providing information regarding officer's current duty belt configuration and their experiences related to discomfort issues with respect to their duty belt items. Furthermore, this study evaluates the effect of the reduced duty belt, on surface muscle activity taking into account officers' perceptions of discomfort and ease of movement. The overall results of this study suggest that the weight and bulk around the duty belt may impede the officers' mobility and reduce their flexibility. It may be that due to restricted movement, muscle activity decreased in the low back area particularly in the longissimus and multifidus muscles that are located right under the vest and duty belt. Additionally, officers' perceived discomfort in body areas and perceived ease of movement is further evidence that they feel more comfortable moving and conducting functional activities with less items around their waist. In terms of practical implications, these results might be of particular importance for interventions such as fitness training, aimed strengthening muscle activity and reducing musculoskeletal issues in the law enforcement community. In addition to that, a better understanding of discomfort issues and perceptions of officers, may be of importance to higher authorities in providing further options to their officers with respect to their duty gear. Also, the results of this study could guide functional apparel designers in developing ergonomic carriage methods for patrol officers. For example, designers can add more functional pockets to the outer vest or on the pants that could hold heavy duty gear items. The law enforcement community in the United States can use this information to seek better options in carriage methods, and even guide duty gear manufacturers in developing lighter and more ergonomic equipment. Methodological implications of this study are that the protocol for ease of movement could be used to evaluate range of motion of officer with duty belt conditions. Similarly, the functional activities yield clear EMG signals that could be used to assess other garment conditions that may affect muscle activity. Theoretical implication of this study is implementing a comfort model that identifies risk factors of musculoskeletal issues in law enforcement occupations. This model could be applied to further investigate the issue of musculoskeletal in law enforcement and even other similar occupations in other industries such as military, pilots, tractor and truck drives.

Limitations

It is acknowledged that the results of this study come from a laboratory setting. Thus, explaining the complex phenomenon of low back pain is not sufficient solely relying on laboratory testing. Due to low number of female participant volunteers, their perceptions were not fully understood compared to the perceptions of male officers.

There were some limitations due to the nature of the EMG test. First, there were only 8 electrodes to test muscle activity and certain muscles such as abdomen and external obliques were left out. Second, recording the rectus abdomini and external obliques would be interesting, however, the positioning of the electrodes against the vest, the higher fat content of the muscles would result in very low activation levels and would produce very low EMG signal. Third, officers were not blinded to the various duty belt conditions and they were subject to all three conditions on the same session. Finally, the last technical limitation was the amount of noise the surface EMG signals picked due to garment interaction with the electrodes. Electromyography testing requires minimal clothing but due to the nature of this study, a ballistic vest was included in all three levels of the treatment. Also, the nature of surface EMG electrodes is that they cannot detect muscle activity of deeper tissues that could have potentially been impacted by the duty belt. During the data collection, some peak values were observed that could not be eliminated by filtering and these peak values exceeded the peak values of the maximum voluntary isometric contraction test. These peak values were due to noise and rubbing of the ballistic vest against the electrodes. This lead to loss of data that could not be replaced.

Time was a limitation in this study and for that we were only able to test three conditions for the duty belt (control, reduced duty belt, and full duty belt). There needs to be fourth treatment that excluded the vest.

Caution must be taken in generalizing the data of this study as subjects were recruited from a small area in the South West of the United States. Officers in other states and urban cities may have different experiences with respect to duty gear carriage methods. In addition, the sample size was small. Also, gender was not taken into consideration due limited time in requiting participants.

Future Direction

It would be fruitful to investigate the effect of a full duty belt on muscle activity without a vest and have another control condition with no duty gear on the person. The results obtained from this study are limited in explaining the complex phenomenon of low back pain in officers. This study could be strengthened by further exploration of the duty gear conditions. For example, items were removed from the FDB with the intention of putting them in alternative locations such as pockets on the vest or on the pant. To fully understand the benefits of a RDB condition a load baring vest could be tested to compare with the current results.

The effect of a reduced duty belt needs to be tested in the field and this could only be possible with an external carriage system with extra pockets on the officer. This is an area that requires further research and preparation to address officers low back pain issues.

Although image perceptions were not the focus of this study, concerns regarding professional image and role status of officers were consistently brought up in this study and in our past preliminary research. Perceptions of image in the law enforcement is very strict nevertheless, it is not understood what the public perceives of a professional image of an officer and this area warrants research.

CHAPTER VI

Summary and Conclusion

Patrol officers' duties have changed over the past two decades requiring them to adopt new equipment onto their uniform increasing the total weight of the duty belt. The high incidences of low back pain among patrol officers have brought the attention of researchers to better understand the physical risk factors associate with low back pain. There appears to be little information regarding the effect of the duty belt on low back pain thus, questions are raised as to what carriage methods officers use and what their preferences are assuming that they could benefit from and alternative carriage methods. The overarching purpose of this study was to determine and evaluate an alternative duty belt for patrol officers by incorporating their experience and practices with their current duty gear into the decision-making process. It was assumed that a lighter weight duty belt would benefit officers' comfort needs with respect to duty gear. The long-term goal of this study was to address patrol officers' musculoskeletal issues particularly low back pain. It was expected that an alternative and lighter duty belt would show significant differences in muscle activity of the back and shoulder, perceived discomfort, and perceived ease of movement when compared to a baseline duty belt. A survey was administered at the State level to identify the current duty belt practices, discomfort issues associated with officers' duty belt items, and to investigate alternative carriage methods based on officers' inputs. First, results of the survey were used to determine a duty belt baseline (FDB) that carried all the equipment officers typically carry on a regular shift (keys, pepper spray, firearm, handcuffs 2 pairs, radio, TASER, baton, and extra magazines). Second, a reduced and lighter duty belt (RDB) was determined by removing most of the equipment off of the FDB and keeping only a baton and a TASER. The third condition included only a vest and no duty belt (CON).

A laboratory assessment was carried out on two separate sessions to assess the effect of the RDB on EMG activity of eight superficial muscles (RAD, LAD, RILIO, LILIO, RLONG, LLONG, RMUL, and LMUL). Right after the EMG testing, officers rated their perceived discomfort of various body regions. On a separate session, officers conducted mobility activities and rated their perceived ease of movement across all three duty belt conditions. Kruskal-Wallis test showed a significant duty belt effect on muscle activity. EMG amplitude was highest during the CON condition, followed by the FDB condition, and the lowest activity was observed wearing the RDB condition. This pattern was consistent for all the functional activities (lift, squat, lunge, and reach). For the perceived discomfort, there was no statistically significant effect of the duty belt on perceived discomfort. However, according to Kelly (1998) a difference of 9mm in the ratings is considered a clinically significant effect size. In other words, there was a small effect of the duty belt between the FDB and RDB for certain front areas (left and right hip, pelvis, and upper thigh) also certain back areas (lower back, left and right upper pelvis). Kruskal-Wallis test showed a significant duty belt effect for ratings of perceived ease of movement. The CON was rated as the easiest to move in, followed by the RDB, and the FDB was rated the most difficult to move in. Practical implications of this study is that, officers' comfort and movement could greatly improve by providing alternative duty gear carriage methods. Smaller duty gear items could be removed from the duty belt and placed in pockets. Heavier duty gear items such as the magazine and firearm could be carried on a thigh holster as another option. Future studies could enhance the knowledge regarding how an alternative duty belt could benefit with removed items relocated to the vest, pant pockets, and/or a thigh holster.

All the evidence in the laboratory assessment of the three duty belt conditions (CON, RDB, and FDB) demonstrate that EMG activity of the superficial back muscles were indeed affected by the duty belt. Even though muscle activation will change mainly due to functional tasks and regardless of the duty belt conditions, in the laboratory there was a unique pattern for change in muscle activity. For majority of the back muscles, EMG results yield higher activation for the CON condition, compared to the RDB and FDB conditions during squat, lift, lunge, and reach activities. Muscle activation was reduced slightly during the FDB condition and decreased a significant amount for the RDB condition. In other words, for majority of the cases, there was a significant difference between the CON and RDB. We predicted to see a significant duty belt effect between the RDB and FDB. This was only observed for the RLONG during lift activity and right reach, LONG muscle during the right lunge, and the RAD during squat. It is hard to believe that a duty belt in its fullest weight (3534 g) results with similar EMG activation as a condition with no duty belt (0 g). On the other hand, we anticipated to see a difference between CON and RDB however, EMG activation being too low in the RDB, was not expected. The result of a belt reducing back muscle activity is supported by previous research (Lander et al., 1990; McGill, 1991). One explanation is the effect of the duty belt and vest together; it is possible that the load from the belt was transferred to the vest and to the abdomen area but this was not possible to observe in this study. Another influencing factor was possibly the effect that time might have on muscle fatigue. We suspect that the actual reason behind the significant amount of reduction in EMG activation in the RDB condition was due to muscle fatigue which is consistent with previous findings where muscle activity was observed to reduce after an hour of repetitive task (Motmans, Tomlow, & Vissers, 2006; Warren, Appling, Oladehin, & Griffin, 2001)

Results from perceived discomfort related to body areas were not significantly affected by the duty belt conditions. However, it is clearly evident that there was more discomfort in the lower back (FDB = 23.45 mm, RDB = 11.55 mm), left upper pelvis (FDB = 18.91 mm, RDB = 8.36 mm), and right upper pelvis (FDB = 19.73 mm, RDB = 8.82). This may be due to the magazine being on the left side and firearm being on the right-hand side in the FDB condition. These areas were relieved from discomfort once the equipment was removed during the RDB condition. Given the reduced muscle activation during the RDB and FDB compared to CON, and increased perceived discomfort for different body areas, it is proposed that removing items from the duty belt and waist area increases mobility thus resulting in higher muscle activation and decrease in discomfort in the front and back body areas. This finding contrasts with the results of McKinnon et al. (2012) reporting that muscle activity reduced when a laptop was selected by the officer in their preferred location. The authors also reported an improvement in discomfort with a self-selected laptop location. Although, muscles of focus in this study were the back muscles and the focus of McKinnon et al. (2012) was the shoulder and arms, it is a appropriate to concluded that officers in both studies have improved discomfort when selecting the location for their own duty gear. Reduction of muscle activity during the RDB and FDB compared to the CON agrees with the results of Granata et al. (1997) and Lander et al. (1990)providing evidence that weight belts transfer motion from the back muscles to the pelvis and abdomen reducing muscle activity of the back.

There was a statistically significant effect of the duty belt treatment on perceived ease of movement. We hypothesize that the duty belt would affect the ratings for the RDB and FDB. This was supported only for the left and right rotation. Keeping in mind that officers spend prolonged hours seated in a patrol vehicle typing with a slight rotation to the right side, reducing the equipment in the duty belt may provide relief to officers while conducting occupational tasks. Ratings for the CON and RDB are low (1.4 – 1.8) and similar to the results of Barker et al. (2010). The sudden increase in ratings wearing the FDB are likely due to the bulk around the waist with the highest rating was reported for flexion and lateral bend to the right (3.22). It is possible that the firearm and magazine impeded the officer from these movements.

The increase in perceived discomfort and mobility, and the added weight of the duty belt combined with the time spent in awkward postures inside the vehicle may increase the risk of low back pain. Adding fuel to the speculation that extra bulk and weight around the waist could be a very influential factor with respect to low back pain in officers.

References

Adams, P. S., & Keyserling, W. (1996). Methods for assessing protective clothing effects on worker mobility. ASTM special technical publication(1237), 311-326.

Adams, P. S., & Keyserling, W. M. (1995). The effect of size and fabric weight of protective coveralls on range of gross body motions. American Industrial Hygiene Association, 56(4), 333-340.

Adams, P. S., Slocum, A. C., & Keyserling, W. (1994). A model for protective clothing effects on performance. International Journal of Clothing Science and Technology, 6(4), 6-16.

Andersson, G. B. J. (1999). Epidemiological features of chronic low-back pain. The lancet, 354(9178), 581-585.

ASTM. (2011). Standard practices for qualitatively evaluating the comfort, fit, function, and durability of protective ensembles and ensemble components (F1154-11).

Barker, J., & Black, C. (2009). Ballistic vests for police officers: using clothing comfort theory to analyse personal protective clothing. International Journal of Fashion Design, Technology and Education, 2(2-3), 59-69.

Barker, J., Black, C., & Cloud, R. (2010). Comfort comparison of ballistic vest panels for police officers. Journal of Textile and Apparel, Technology and Management, 6(3).

Barona-McRoberts, L. (2005). Petite women: fit and body shape analysis.

Bergen, M. E., Capjack, L., McConnan, L. G., & Richards, E. (1996). Design and evaluation of clothing for the neonate. Clothing and Textiles Research Journal, 14(4), 225-233.

Bigos, S. J., Battie, M. C., Spengler, D. M., Fisher, L. D., Fordyce, W. E., Hansson, T. H., . . . Wortley, M. D. (1991). A prospective study of work perceptions and psychosocial factors affecting the report of back injury. Spine, 16(1), 1-6.

Black, C., Grice, K., & Fowler, J. (2003). The evaluation of Hip Braces: A comparison of Comfort. Paper presented at the ITAA Savannah, GA.

Black, K. M., Lis, A., & Nordin, M. (2011). Association between sitting and occupational low back pain (lbp). Revista Ação Ergonômica, 1(3).

Blumenthal, D. (2001). Controlling health care expenditures. New England Journal of Medicine, 344(10), 766-769.

Boettcher, C. E., Ginn, K. A., & Cathers, I. (2008). Standard maximum isometric voluntary contraction tests for normalizing shoulder muscle EMG. Journal of Orthopaedic Research, 26(12), 1591-1597.

Bovenzi, M., & Zadini, A. (1992). Self-reported low back symptoms in urban bus drivers exposed to whole-body vibration. Spine, 17(9), 1048-1059.

Branson, D. H., & Sweeney, M. (1991) Conceptualization and measurement of clothing comfort: Toward a metatheroy. In S. B. Kaiser & M. L. Damhorst (Series Ed.). Critical linkages in textiles and clothing subject matter: Theory, Method and practice (ITAA Special Publication No. 4 ed., pp. 94-105): Monument, CO: International Textile and Apparel Association.

Brown, J. J., Wells, G. A., Trottier, A. J., Bonneau, J., & Ferris, B. (1998). Back pain in a large Canadian police force. Spine, 23(7), 821-827.

Burton, A. K., Tillotson, K. M., Symonds, T. L., Burke, C., & Mathewson, T. (1996). Occupational risk factors for the first- onset and subsequent course of low back trouble: A study of serving police officers. Spine, 21(22), 2612-2620.

Bye, E., & Hakala, L. (2005). Sailing apparel for women: A design development case study. Clothing and Textile Research Journal, 23, 45-55.

Cardoso, M., Girouard, M., McKinnon, C., Callaghan, J. P., & Albert, W. J. (2017). Quantifying the postural demands of patrol officers: a field study. International Journal of Occupational Safety and Ergonomics, 23(2), 185-197.

Carroll, K. E. (2001). Innovations and Improvisations: A study in specialized product development focused on business clothing for women with physical disabilities. Retrieved from http://theses.lib.vt.edu/theses/available/etd-02132002-140807/unrestricted/etd.pdf

Cassidy, J. D., Côté, P., Carroll, L. J., & Kristman, V. (2005). Incidence and course of low back pain episodes in the general population. Spine, 30(24), 2817-2823.

Chae, M. H., Black, C., & Heitmeyer, J. (2006). Pre- purchase and post- purchase satisfaction and fashion involvement of female tennis wear consumers. International Journal of Consumer Studies, 30(1), 25-33.

Chattaraman, V., & Rudd, N. A. (2006). Preferences for aesthetic attributes in clothing as a function of body image, body cathexis and body size. Clothing and Textiles Research Journal, 24(1), 46-61.

Chau, P. Y. (2012). Swimwear: Needs Assessment and Prototype Development for Special Needs Children. (Masters), Toronto, Canada: Ryerson University Press.

Cho, Y., Okada, N., Park, H., Takatera, M., Inui, S., & Shimizu, Y. (2005). An interactive body model for individual pattern making. International Journal of Clothing Science and Technology, 17(2), 91-99.

Cohn, J. (1988). Statistical power analysis for the behavioral sciences.

Czarnecki, F., & Janowitz, I. (2003). Ergonomics and safety in law enforcement. Clinics In Occupational and Environmental Medicine, 3, 399-418.

Dawes, J. J., Orr, R. M., Flores, R. R., Lockie, R. G., Kornhauser, C., & Holmes, R. (2017). A physical fitness profile of state highway patrol officers by gender and age. Annals of occupational and environmental medicine, 29(1), 16.

De Looze, M. P., Kuijt-Evers, L. F., & Van DieËN, J. (2003). Sitting comfort and discomfort and the relationships with objective measures. Ergonomics, 46(10), 985-997.

DeJonge, J. O. (1984). Forward: The design process. In Watkins, S. M. Clothing: The portable environment (pp. vii-xi). Ames, IA: Iowa State University.

Dempsey, P. C., Handcock, P. J., & Rehrer, N. J. (2013). Impact of police body armour and equipment on mobility. Applied Ergonomics, 44(6), 957-961.

Dolan, Kingma, I., De Looze, M. P., van Dieen, J. H., Toussaint, H. M., Baten, C. T. M., & Adams, M. A. (2001). An EMG technique for measuring spinal loading during asymmetric lifting. Clinical Biomechanics, 16, Supplement 1, S17-S24. doi:http://dx.doi.org/10.1016/S0268-0033(00)00097-8

Dolan, J. (2015). L.A. audits: Costly police, firefighter workers' comp claims avoidable. Los Angeles Times Retrieved from http://www.latimes.com/local/cityhall/la-me-injured-on-duty-20150327-story.html

Donnelly, C. J., Callaghan, J. P., & Durkin, J. L. (2009). The effect of an active lumbar system on the seating comfort of officers in police fleet vehicles. International Journal of Occupational Safety and Ergonomics, 15(3), 295-307.

Edmonds, J., & Laswson, G. (2001). The design of methods for carrying police equipment Contemporary Ergonomics Proceedings of the Ergonomic Societys Annual Conference.

Elder, S., Hennessy, E., & Kanagaki, G. (2010). Ergonomic evaluation of law enforcement chemical/biological (CB) personal protective equipment for the law enforcement advanced protection (LEAP) CB standards assessment. Retrieved from Natick, MA:

Espinoza, K. (2010). Egronomics and police duty belts: easing their load. Retrieved from http://americancityandcounty.com/law/ergonomics-and-police-duty-belts-easing-their-load

Fan, J., & Keighley, J. H. (1991). An investigation on the effects of body motion, clothing design and environmental conditions on the clothing thermal insulation by using a fabric manikin. International Journal of Clothing Science and Technology, 3(5), 6-13.

Fathallah, F. A., Marras, W. S., & Parnianpour, M. (1999). Regression Models for Predicting Peak and Continuous Three-Dimensional Spinal Loads during

Symmetric and Asymmetric Lifting Tasks. Human Factors: The Journal of the Human Factors and Ergonomics Society, 41(3), 373-388. doi:10.1518/001872099779611094

Federal Bureau of Investigation. (2011). Full-time law enfrocement employees. Retrieved from https://ucr.fbi.gov/crime-in-the-u.s/2011/crime-in-the-u.s.-2011/tables/table_74_full-time_law_enforcement_employees_by_population_group_percent_male_and_female_2011.xls

Filtness, A. J., Mitsopoulos-Rubens, E., & Rudin-Brown, C. M. (2014). Police officer in-vehicle discomfort: appointments carriage method and vehicle seat features. Applied Ergonomics, 45(4), 1247-1256.

Fourt, L., & Hollies, N. R. S. (1970). Clothing comfort and function. New York: Marcel Dekker

Fratto, G. M., Jones, M. R., & Cassill, N. L. (2006). An investigation of competitive pricing among apparel retailers and brands. Journal of Fashion Marketing and Management: An International Journal, 10(4), 387-404.

Gary Hart, L., Deyo, R. R., & Cherkin, D. C. (1995). Physician office visits for low back pain. Spine, 20(1), 11-19.

Granata, K. P., & Marras, W. S. (1993). An EMG-assisted model of loads on the lumbar spine during asymmetric trunk extensions. Journal of Biomechanics, 26(12), 1429-1438. doi:http://dx.doi.org/10.1016/0021-9290(93)90093-T

Granata, K. P., & Marras, W. S. (1995). An EMG-assisted model of trunk loading during free-dynamic lifting. Journal of Biomechanics, 28(11), 1309-1317. doi:http://dx.doi.org/10.1016/0021-9290(95)00003-Z

Granata, K. P., Marras, W. S., & Davis, K. G. (1997). Biomechanical assessment of lifting dynamics, muscle activity and spinal loads while using three different styles of lifting belt. Clinical Biomechanics, 12(2), 107-115.

Gyi, D. E., & Porter, J. M. (1998). Musculoskeletal problems and driving in police officers. Occupational Medicine, 48(3), 153-160.

Hatch, K. L. (1993). Textile Science. St. Paul, MN: West Publishing Company

Hildebrandt, V. H. (1995). Back pain in the working population: prevalence rates in Dutch trades and professions. Ergonomics, 38(6), 1283-1298.

Holmes, M. W. R., McKinnon, C. D., Dickerson, C. R., & Callaghan, J. P. (2013). The effects of police duty belt and seat design changes on lumbar spine posture, driver contact pressure and discomfort. Ergonomics, 56(1), 126-136.

Horridge, P. E., Caddel, D. K., & Simonton, J. L. (2002). Texas trooper uniforms: Assessment of fabrics, comfort, and wear. Family and Consumer Sciences Research Journal, 30(3), 350-381.

Hostens, I., & Ramon, H. (2005). Assessment of muscle fatigue in low level monotonous task performance during car driving. Journal of Electromyography and Kinesiology, 15(3), 266-274.

Huck, J., & Kim, Y. (1997). Coveralls for grass fire fighting. International Journal of Clothing Science and Technology, 9, 346-359.

Huck, J., Maganga, O., & Kim, Y. (1997). Protective overalls: Evaluation of garment design and fit. International Journal of Clothing Science and Technology, 9, 45-61.

Ilori, A., Li, Y., Mahesh, V., & Craig, B. (2017). Effect of Position: An Ergonomics Evaluation of Police's Wearable Equipment. In M. Soares, C. Falcão, & T. Z. Ahram (Eds.), Advances in Ergonomics Modeling, Usability & Special Populations: Proceedings of the AHFE 2016 International Conference on Ergonomics Modeling, Usability & Special Populations, July 27-31, 2016, Walt Disney World®, Florida, USA (pp. 199-207). Cham: Springer International Publishing.

Jahani, M. R., Motevalian, S. A., & Asgari, A. R. (2002). Musculoskeletal disabilities among police force personnel of the Islamic Republic of Iran. Military Medicine, 167(10), 850-852.

Katz, M. (2013). Equipment check: Tips for setting up your duty. Retrieved from https://www.policeone.com/police-products/duty-gear/articles/6100026-Equipment-check-Tips-for-setting-up-your-duty-belt/

Kelly, A. M. (1998). Does the clinically significant difference in visual analog scale pain scores vary with gender, age, or cause of pain? Academic Emergency Medicine, 5(11), 1086-1090.

Kim, J., & Farrell-Beck, J. (2003). Application of apparel design process in an experimental design course Paper presented at the ITAA, Savannah, GA.

Kirk, W., & Ibrahim, S. M. (1966). Fundamental relationship of fabric extensibility to anthropometric requirements and garment performance. Textile Research Journal, 36(1), 37-47.

Konrad, P. (2006). The ABC of EMG: A practical introduction to kinesiological electromyography. Retrieved from http://www.noraxon.com/wp-content/uploads/2014/12/ABC-EMG-ISBN.pdf

Kouprie, M., & Visser, F. S. (2009). A framework for empathy in design: stepping into and out of the user's life. Journal of Engineering Design, 20(5), 437-448.

Kreighbaum, E., & Barthels, K. M. (1996). Biomechanics: A qualitative approach for studying human movement (4 ed.). San Francisco, CA: Benjamin-Cummings Publishing Company.

Krenzer, G., Starr, C., & Branson, D. (2005). Excellence in design–Development of a sports bra prototype. Clothing & Textiles Research Journal, 23(2), 131-134.

Kumar, S., & Narayan, Y. (1999). Low back pain among RCMP officers: An investigation into vehicles, duty belts and boots. Retrieved from

Kumar, S., Narayan, Y., & Zedka, M. (1996). An electromyographic study of unresisted trunk rotation with normal velocity among healthy subjects. Spine, 21(13), 1500-1512.

Lamb, J. M., & Kallal, M. J. (1992). A conceptual framework for apparel design. Clothing and Textiles Research Journal, 10(2), 42-47.

Lander, J. E., Simonton, R. L., & Giacobbe, J. (1990). The effectiveness of weight-belts during the squat exercise. Medicine and science in sports and exercise, 22(1), 117-126.

Lawson, L., & Lorentzen, D. (1990). Selected sports bras: comparisons of comfort and support. Clothing and Textiles Research Journal, 8(4), 55-60.

Leigh, J. P., Markowitz, S. B., Fahs, M., Shin, C., & Landrigan, P. J. (1997). Occupational injury and illness in the United States: estimates of costs, morbidity, and mortality. Archives of Internal Medicine, 157(14), 1557-1568.

Li, Y., & Dai, D. X. (2006). Biomechanical engineering of textiles and clothing: Woodhead Publishing.

Luo, X., Pietrobon, R., Sun, S. X., Liu, G. G., & Hey, L. (2004). Estimates and patterns of direct health care expenditures among individuals with back pain in the United States. Spine, 29(1), 79-86.

Luttgens, K., & Hamilton, N. (1997). Kinesiology: Scientific basics of human motion (Ninth ed.). Dubuque, IA: Brown&Benchmark Publishers

Lyman-Clarke, L., Ashdown, S., Loker, S., & Schoenfelder, K. (2005). A comparison of visual analysis rating systems Paper presented at the International Textile and Apparel Association, Alexandria, VA.

Magnusson, M. L., Pope, M. H., Wilder, D. G., & Areskoug, B. (1996). Are occupational drivers at an increased risk for developing musculoskeletal disorders? Spine, 21(6), 710-717.

Maher, P. M., & Sontag, M. S. (1986). Insulative clothing for older women functioning at reduced household temperatures. Retrieved from

Manchikanti, L. (2000). Epidemiology of low back pain. Pain Physician, 3(2), 167-192.

Marras, W. S., & Granata, K. P. (1995). A biomechanical assessment and model of axial twisting in the thoracolumbar spine. Spine, 20(13), 1440-1451.

Marras, W. S., & Granata, K. P. (1997). Spine loading during trunk lateral bending motions. Journal of Biomechanics, 30(7), 697-703. doi:http://dx.doi.org/10.1016/S0021-9290(97)00010-9

McGill, S. M. (1991). Electromyographic activity of the abdominal and low back musculature during the generation of isometric and dynamic axial trunk torque:

Implications for lumbar mechanics. Journal of Orthopaedic Research, 9(1), 91-103. doi:10.1002/jor.1100090112

McGill, S. M. (1992). A myoelectrically based dynamic three-dimensional model to predict loads on lumbar spine tissues during lateral bending. Journal of Biomechanics, 25(4), 395-414.

McKinnon, C. D., Amy, S. A., Callaghan, J. P., & Dickerson, C. R. (2014). The effect of police cruiser restraint cage configuration on shoulder discomfort, muscular demands, upper limb postures, and task performance during simulated police patrol. Applied Ergonomics, 45(6), 1414-1421.

McKinnon, C. D., Callaghan, J. P., & Dickerson, C. R. (2011). Field quantification of physical exposures of police officers in vehicle operation. International Journal of Occupational Safety and Ergonomics, 17(1), 61-68.

McKinnon, C. D., Callaghan, J. P., & Dickerson, C. R. (2012). Evaluation of the influence of mobile data terminal location on physical exposures during simulated police patrol activities. Applied Ergonomics, 43(5), 859-867. doi:10.1016/j.apergo.2011.12.009

McRoberts, L. B. (2008). The design and assessment of a soft structural prototype for postural alignment. (Doctor of Philosophy Dissertation), Florida State University.

McRoberts, L. B., Black, C. M., & Cloud, R. M. (2015). Evaluation of a Prototype Soft-Structured Thoracic Posture Support Garment. Clothing and Textiles Research Journal, 0887302X15622571.

Mergl, C., Klendauer, M., Mangen, C., & Bubb, H. (2005). Predicting long term riding comfort in cars by contact forces between human and seat (2005-01-2690). Retrieved from http://papers.sae.org/2005-01-2690/

Mitchka, J., Black, C., Heitmeyer, J., & Cloud, R. M. (2009). Problem structure perceived dance practicewear needs of adult female dance students. Clothing and Textile Research Journal, 27, 31-44.

Motmans, R., Tomlow, S., & Vissers, D. (2006). Trunk muscle activity in different modes of carrying schoolbags. Ergonomics, 49(2), 127-138.

Movahed, M., Ohashi, J.-y., Kurustien, N., Izumi, H., & Kumashiro, M. (2011). Fatigue sensation, electromyographical and hemodynamic changes of low back muscles during repeated static contraction. European Journal of Applied Physiology, 111(3), 459-467.

Nakahashi, M., Morooka, H., Nakamura, N., Yamamoto, C., & Morooka, H. (2005). An analysis of waist-nipper factors that affect subjective feeling and physiological response-for the design of comfortable women's foundation garments. Sen'i Gakkaishi, 61(1), 6-12.

O'Brien, C., Blanchard, L. A., Cadarette, B. S., Endrusick, T. L., Xu, X., Berglund, L. G., . . . Hoyt, R. W. (2011). Methods of evaluating protective clothing relative to heat and cold stress: thermal manikin, biomedical modeling, and human testing. Journal of Occupational and Environmental Hygiene, 8(10), 588-599.

Park, H., Branson, D., Kim, S., Warren, A., Jacobson, B., Petrova, A., . . . Kamenidis, P. (2014). Effect of armor and carrying load on body balance and leg muscle function. Gait & Posture, 39(1), 430-435.

Pauly, J. E. (1966). An electromyographic analysis of certain movements and exercises. I. Some deep muscles of the back. Anatomy Record, 155(2), 223-234. doi:10.1002/ar.1091550209

Pontrelli, G. J. (1977). Partial analysis of comfort's gestalt. In N. R. S. Hollies & R. F. Goldman (Eds.), Clothing comfort: Interaction of thermal, ventilation, construction, and assessment factors (pp. 71-80). Ann Arbor, MI: Science Publlishers

Porter, J. M., & Gyi, D. E. (2002). The prevalence of musculoskeletal troubles among car drivers. Occupational Medicine, 52(1), 4-12.

Poulsen, K. B., Jensen, S. H., Bach, E., & Schostak, J. F. (2007). Using action research to improve health and the work environment for 3500 municipal bus drivers. Educational Action Research, 15(1), 75-106.

Ramstrand, N., & Larsen, L. B. (2012). Musculoskeletal injuries in the workplace: perceptions of Swedish police. International Journal of Police Science & Management, 14(4), 334-342.

Ramstrand, N., Zügner, R., Larsen, L. B., & Tranberg, R. (2016). Evaluation of load carriage systems used by active duty police officers: Relative effects on walking patterns and perceived comfort. Applied Ergonomics, 53, 36-43.

Rissanen, S., Jousela, I., Jeong, J.-R., & Rintamäki, H. (2008). Heat stress and bulkiness of chemical protective clothing impair performance of medical personnel in basic lifesaving tasks. Ergonomics, 51(7), 1011-1022.

Rutherford-Black, C., & Khan, S. (1995). Texas Tech bicycle patrol: Encounter with a uniform. Campus Law Enforcement Journal, 25(1), 26-28.

Sidberry, P. A. (2011). Effects of body shape on body cathexis and dress shape preferences of female consumers: A balancing perspective. Auburn University.

Slater, K. (1985). Human comfort (Vol. 1): Springfield, Ill., USA: CC Thomas.

Son, S. Y., Bakri, I., Muraki, S., & Tochihara, Y. (2014). Comparison of firefighters and non-firefighters and the test methods used regarding the effects of personal protective equipment on individual mobility. Applied Ergonomics, 45(4), 1019-1027. doi:10.1016/j.apergo.2013.12.006

Sontag, M. S. (1985). Comfort dimensions of actual and ideal insulative clothing for older women. Clothing and Textiles Research Journal, 4(1), 9-17.

Starr, C., Branson, D., Shehab, R., Farr, C., Ownbey, S., & Swinney, J. (2005). Biomechanical analysis of a prototype sports bra. Journal of Textile and Apparel, Technology and Management, 4(3), 1-14.

Starr, C., Branson, D. H., Ricord, D., & Peksoz, S. (2006). Child's Medical Support Garment Prototype, San Antonio, TX.

Stokes, B., & Black, C. (2012). Application of the Functional, Expressive and Aesthetic Consumer Needs Model: assessing the clothing needs of adolescent girls with disabilities. International Journal of Fashion Design, Technology and Education, 5(3), 179-186.

Stone, R. (2005). Sam Brown and beyond: A look at duty belts. Retrieved from https://www.policeone.com/police-products/duty-gear/articles/117535-Sam-Browne-and-beyond-A-look-at-duty-belts/

Stubbs, D., David, G., Woods, V., & Beards, S. (2008). Problems associated with police equipment carriage with body armour, including driving. Contemporary Ergonomics, 2008, 23.

Sullivan, C. S., & Shimizu, K. T. (1988). Epidemiological studies of work-related injuries among law enforcement personnel. Occupational Medicine, 38(1-2), 33-40.

The Free Dictionary By Farlex. (2016). Retrieved from http://medical-dictionary.thefreedictionary.com/biomechanical+assessment

Torén, A. (2001). Muscle activity and range of motion during active trunk rotation in a sitting posture. Applied Ergonomics, 32(6), 583-591.

U.S. Bureau of Labor Statistics. (2015). Number, incidence rate and madian days away from work for nonfatal occupational injuries and illnesses involving days away from work by selected worker occupation and ownership. Retrieved from http://www.bls.gov/news.release/osh2.nr0.htm

U.S. Bureau of Labor Statistics. (2016). Occupational outlook handbook: Police and detectives Retrieved from http://www.bls.gov/ooh/protective-service/police-and-detectives.htm

Warren, L. P., Appling, S., Oladehin, A., & Griffin, J. (2001). Effect of soft lumbar support belt on abdominal oblique muscle activity in nonimpaired adults during squat lifting. Journal of Orthopaedic & Sports Physical Therapy, 31(6), 316-323.

Wikström, B.-O. (1993). Effects from twisted postures and whole-body vibration during driving. International Journal of Industrial Ergonomics, 12(1-2), 61-75.

Wilder, D. G., Woodworth, B. B., Frymoyer, J. W., & Pope, M. H. (1982). Vibration and the human spine. Spine, 7(3), 243-254.

APPENDICES

APPENDIX A

PARTICIPANT COMMENTS

Summary of blog comments, personal interview, and literature findings

"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".

"Duty belts are restrictive and do not allow even deep breath - extended foot pursuit or traffic duty becomes quite tiring".

"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 [seat] *was softer and was not nearly as bad as the contoured seats of Crown Victoria".*

"Duty belts do not restrict flexibility (small subject) *Duty belts do interfere with flexibility* (large subject)*".*

"Removing some of the equipment form the duty belt will help" (Kumar & Narayan, 1999).

Narratives of officers, corresponding source, and issues

Issue	Source:	Narrative:
Duty Gear: Weight	Focus group	…in the long run I would need the weight to be supported off of my hips and off of my lower back because that's what's going to hurt me 15-20 years down the road. (Sam, 39)
Duty Gear: Adjust and resituate myself	Interview	…right here on my right kidney there's a pair of handcuffs there, right in the center of my back I keep my latex gloves, on the left of that there's flash light and so that does not allow you to sit in your natural posture whereas, if I move that flash light, handcuffs, rubber gloves to smaller pockets in this area [indicating cargo pockets], that allows me to sit in my natural posture… and that's hard on the back. (Brook, 47)
Duty Gear: Level of professionalism needs to be there	Focus group	This [police] department and this [campus] setting here, image is a huge factor, in this environment you have to show professionalism in all things and if you come across people, they're going look at that [load-bearing] vest and think that he's coming at us with everything he has…it [the load-bearing vest] shows aggressiveness. (Sam, 39) More aggressiveness (Roger, 38) [The group indicated agreement by nodding].
Vehicle Seat: Adjustability and upholstery	Interview	I don't like these seats they seem to be more satin top on them, you slide on the seat if it was just a cloth seat it's almost like you stick to it you don't slide as much but these have some kind of slick finish and you move around in the seat. (Brook, 47)
Vehicle Seat: Seat and gear interaction	Focus group	… all vehicle chairs, all office chairs are designed for a person which has the thin belt on, they aren't designed a for person with gear in between them so your back is shifted, your lumbar, your vertebra for all those hours that you are sitting in the car is shifted in a way that they normally wouldn't be so your vertebra is shifted your hips ride differently as you sit with a duty belt. (Corbin, 57)

APPENDIX B

QUESTIONNAIRE

Dear officer,

I am a Ph.D. student in Oklahoma State University and conducting a research study in developing a more comfortable duty belt for patrol officers. The purpose of this research is to better understand the comfort needs of officers when wearing a duty belt. Your response to this survey will be used to develop an ergonomic and lighter duty belt. There are no risks involved in taking this survey and your identity will not be linked to your responses.
Participants eligible to take this survey are officers who have at least 1 year of patrol experience in the last 10 years and above the age of 21. The questions in this survey refer to seated occupational tasks such as sitting in an office chair or patrol vehicle.

If you have questions about your rights as a research participant you may contact Dr. Hugh Crethar, IRB Chair, 219 Cordell North, Stillwater, OK 74078, 405-744-1676, irb@okstate.edu.

If you have any questions concerning the study, you may contact the following researchers:

Mercan Derafshi at (509) 592 8841, email to mercan@okstate.edu
Dr. Adriana Petrova at (405) 744 9574, email to adriana.petrova@okstate.edu

If you agree to take this survey click to this link:

https://okstateches.az1.qualtrics.com/SE/?SID=SV_57JmiKcqxDWQXC5

1. How long have you been a law enforcement officer?

    - o less than 3
    - o 3-10
    - o 11-15
    - o 16-20
    - o 20-30
    - o more than 30

2. What is your current shift?
    - o Day shift
    - o Evening shift
    - o Night shift
    - o Specialized unit

3. In which department are you currently employed? (Spell it out for example: Texas Department of Safety)

    ____

4. What is your current rank and position assignment?

____

5. Do you consider where you live to be urban or rural?
    - o Urban (over 50.000 population, Census, 2010)
    - o Rural (under 50.000 population, Census, 2010)

6. Which hand is your dominant hand?
    - o Right hand
    - o Left hand
    - o ambidextrous
7. What items do you carry on you? Please check all that apply and specify equipment not included in the list.
    - ☑ Hand cuffs (only 1 pair)
    - ☑ Hand cuffs (2nd pair)
    - ☑ Expandable baton
    - ☑ Pepper spray
    - ☑ TASER
    - ☑ Flash light
    - ☑ Radio
    - ☑ Firearm
    - ☑ Spare magazines
    - ☑ Cellphone

- ☑ Knife
- ☑ Keys
- ☑ Gloves
- ☑ note pad
- ☑ paperwork
- ☑ pen
- ☑ wallet
- ☑ extra firearm
- ☑ Extra knife

Other items:_______________
Other items:_______________
Other items:_______________

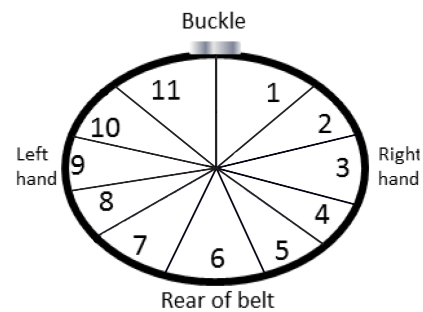
8. Which items does your department require?
____
9. Does your department provide wearing a tactical vest an option?
    - Yes, tactical vest is a given option
    - No, we are not allowed to use tactical vest
    - We are only allowed to use a duty belt
    - We use an alternative carriage method

10. What type of duty belt are you currently using?
    - Leather belt
    - Nylon belt
    - Other: _______________

11. Which items goes on the duty belt?
    - ☑ Hand cuffs (only 1 pair)
    - ☑ Hand cuffs (2nd pair)
    - ☑ Expandable baton
    - ☑ Pepper spray
    - ☑ TASER
    - ☑ Flash light
    - ☑ Radio
    - ☑ Firearm
    - ☑ Spare magazines
    - ☑ Cellphone
    - ☑ Knife
    - ☑ Keys
    - ☑ Gloves
    - ☑ note pad
    - ☑ paperwork
    - ☑ pen
    - ☑ wallet

☑ extra firearm
☑ Extra knife
Other items:_______________
Other items:_______________
Other items:_______________

12. Look at the image on the right and specify where you keep the equipment on your duty belt. Indicate your response by placing a number on the box next to the duty gear.



- Hand cuffs (only 1 pair) in Area ☐
- Hand cuffs (2nd pair) in Area ☐
- Expandable baton in Area ☐
- Pepper spray in Area ☐
- TASER in Area ☐
- Flash light in Area ☐
- Radio in Area ☐
- Firearm in Area ☐
- Spare magazines in Area ☐
- Cellphone in Area ☐
- Knife in Area ☐
- Keys in Area ☐
- Gloves in Area ☐
- Note pad
- Paperwork
- Pen
- Wallet
- Extra firearm
- Extra knife
- Other items:_______________
- Other items:_______________
- Other items:_______________

13. Please describe your agreement/disagreement level on the following statements.
    a. I like the appearance of high gloss leather belt.
    b. High gloss leather belt has a *business-like* appearance.
    c. It is uncomfortable to sit with the high gloss leather belt.
    d. I will sacrifice my comfort to have a uniform with *business-like* appearance.

14. My duty belt and items attached to it cause the following:

- Pain
- Pinching
- Pressure from tightness
- Digging into soft tissues
- Numbness
- None of the above
- Other:____________________

15. Please indicate which items cause these symptoms?
- ☑ Hand cuffs (only 1 pair)
- ☑ Hand cuffs (2nd pair)
- ☑ Expandable baton
- ☑ Pepper spray
- ☑ TASER
- ☑ Flash light
- ☑ Radio
- ☑ Firearm
- ☑ Spare magazines
- ☑ Cellphone
- ☑ Knife
- ☑ Keys
- ☑ Gloves
- Other items:_______________
- Other items:_______________
- Other items:_______________

16. In your opinion what items are best carried on the duty belt? Check all that apply and provide reasoning for each selection.

		Drop down menu
Hand cuffs	☑	Quick removable
Baton	☑	Ease of use
Pepper spray	☑	Can be accessed by either hand
TASER	☑	Retrieve with dominant hand
Flash light	☑	Retrieve with weak hand
Radio	☑	Other tactical reasons
Firearm	☑	Other reasons you can think of____________________

Spare Magazines	☑	Due to…
Cellphone	☑	Due to…
Knife	☑	Due to…
Keys	☑	Due to…
Keepers	☑	Due to…
Gloves	☑	Due to…
Other items	☑	Due to…

17. If you had the flexibility to move items around where would you put them other than the duty belt?

Hand cuffs	☑	Possible location
Baton	☑	Possible location
Pepper spray	☑	Possible location
TASER	☑	Possible location
Flash light	☑	Possible location
Radio	☑	Possible location
Firearm	☑	Possible location
Spare Magazines	☑	Possible location
Cellphone	☑	Possible location
Knife	☑	Possible location
Keys	☑	Possible location
Keepers	☑	Possible location
Gloves	☑	Possible location
Other items	☑	Possible location

18. Do any of the items on your duty belt;
    Inhibit the ability to stand
    Inhibit the ability to squat
    Inhibit the ability to sit

19. Do any of the times on your duty belt;
    Interfere with the car seat
    Interfere with the steering wheel
    Interfere with the seat belt
    Interfere with your hips
    Interfere with your arms
    Interfere with your thighs
    Interfere with your low back
    Interfere with your pants

Interfere with your shirt
Interfere with your ballistic vest.

20. If you could speak to a duty belt and holster manufacturer, what would you like them to know about your duty belt?
____
____

21. What is your present age in years?
____

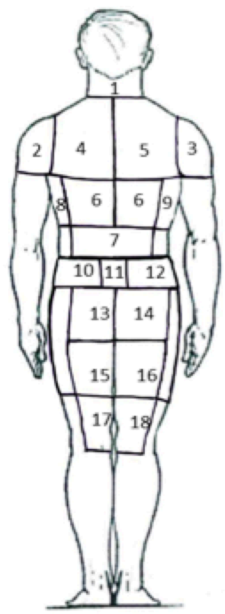
22. Please indicate your sex.
    - Male
    - Female
23. What is your height in feet and inches? ___________________________
24. What is your current weight in pounds? ____________________________
25. What is the highest level of education that you have completed?
    - Completed high school
    - Some college
    - Bachelor's Degree
    - Some graduate work
    - Graduate Degree
26. What is your race? (Census, 2010)
    - White
    - Black or African American
    - American Indian or Alaska Native
    - Asian
    - Native Hawaiian
    - Another Pacific Islander.
27. Please indicate your pant size by selecting the waist and length. _____x_____

APPENDIX C

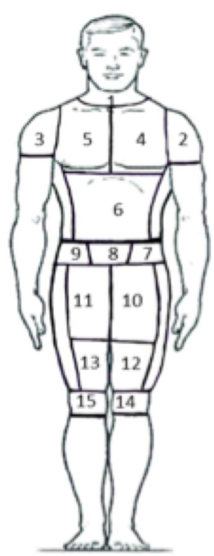
PERCEPTION QUESTIONS AND SCALES

Perceived discomfort on body addressed using Visual Analog Scale (VAS) adapted from Mergl, Klendauer, Mangen, and Bubb (2005).

Please indicate how the duty belt gear feels (<u>when completing the functional tasks)</u> by placing a dash.



Posterior Body Regions	No Discomfort	Extreme Discomfort
1. Neck		
2. (L) Shoulder		
3. (R) Shoulder		
4. (L) Upper back		
5. (R) Upper back		
6. Middle back		
7. Lower back		
8. (L) Side of body		
9. (R) Side of body		
10. (L) Upper pelvis		
11. Sacrum/tail bone		
12. (R) Upper pelvis		
13. (L) Buttocks		
14. (R) Buttocks		
15. (L) Upper thigh		
16. (R) Upper thigh		
17. (L) Lower Thigh		
18. (R) Lower thigh		
19. (L) Side of leg		
20. (R) Side of leg		



Anterior Body Regions	No Discomfort	Extreme Discomfort
1. Neck		
2. (L) Shoulder		
3. (R) Shoulder		
4. (L) Chest		
5. (R) Chest		
6. Abdomen		
7. (L) Hip		
8. Pelvis		
9. (R) Hip		
10. (L) Upper thigh		
11. (R) Upper thigh		
12. (L) Lower thigh		
13. (R) Lower thigh		
14. (L) Knee cap		
15. (R) Knee cap		

Perceived ease of movement adapted from ASTM F1154-11 protocol (ASTM, 2011).

	Extremely easy				Extremely difficult
	1	2	3	4	5
Trunk Flexion					
Turnk Hyperextention					
Turnk lateral left					
Trunk lateral right					
Trunk rotation left					
Trunk roation right					

APPENDIX D

IRB APPROVAL

Oklahoma State University Institutional Review Board

Date:	Wednesday, January 18, 2017	Protocol Expires:	5/11/2017
IRB Application No:	HE1522		
Proposal Title:	Design and Assessment of an Ergonomic Duty Belt: The Case of Law Enforcement Officers		
Reviewed and Processed as:	Expedited **Modification**		

Status Recommended by Reviewer(s) **Approved**

Principal Investigator(s):

Adriana Petrova 444 HES Stillwater, OK 74078	Aditya Jayadas 441 HS Stillwater, OK 74078	Semra Peksoz 440 HES Stillwater, OK 74078

The requested modification to this IRB protocol has been approved. Please note that the original expiration date of the protocol has not changed. The IRB office MUST be notified in writing when a project is complete. All approved projects are subject to monitoring by the IRB.

☐ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

The reviewer(s) had these comments:

Mod to 1) change title from "Empathic & Co-Design: Redesign of Duty Belts for Police Officers" to "Design and Assessment of an Ergonomic Duty Belt: The Case of Law Enforcement Officers", 2) add an online survey to establish the design criteria for the duty belt, 3) remove compensation for the lab study, 4) collect EMG data for eight muscles and 5) have subjects fill out questions on comfort and ease of movement after the completion of each session.

Signature :

Hugh Crethar, Chair, Institutional Review Board

Wednesday, January 18, 2017
Date

GLOSSARY

Biomechanical Assessment: "Static and dynamic examination and assessment of joint complexes (foot and ankle, knee, hips and spinal column) and their interrelationships, under both weight-bearing and non-weight-bearing conditions; made by clinical observation and quantification of: (1) the position of joint axes and the functional segments of the body; (2) the quality, range and direction of motion of joints and functional limb segments; and (3) observation, quantification and examination of limb function during gait and movement." (The Free Dictionary By Farlex, 2016).

Duty Gear: is referred to the equipment officers carry on their duty belt and/or on their uniform (magazines, pepper spray, firearm, TASER, expandable baton, hand cuffs, knife, keys, notepad, etc.)

Electromyography (EMG): technique for measuring the activation signal produced by skeletal

muscles (Wang, Stefano & Allen, 2006).

EMG signal: "a biomedical signal that measures electrical currents generated in muscles during its contraction representing neuromuscular activities" (Reaz, Hussain, & Mohd Yasin, 2006, p. 11).

Ergonomics: "designed to minimize physical effort and discomfort, and hence maximize efficiency". (The Free Dictionary By Farlex, 2016)

Extension/hyperextension: "Extension is the return movement from flexion. Hyperextension is a backward-downward movement in the sagittal plane." (Luttgens & Hamilton, 1997).

Flexion: "This is a forward-downward bending in the sagittal plane about a frontal-horizontal axis." (Luttgens & Hamilton, 1997).

Lateral Flexion: "This is a sideward bending in the frontal plane about a sagittal-horizontal axis." (Luttgens & Hamilton, 1997).

Law Enforcement Officers: Are all sworn police officers that are legally able to make an arrest. For brevity Law Enforcement Officers will be referred as officers in this study.

Low Back Pain: Is represented here by reported or examined ache, pain, stiffness, or discomfort in the lumbar spine (Bovenzi & Zadini, 1992). For brevity, Low Back Pain will be referred as back pain in this study.

Maximum Voluntary Isometric Contraction (MVIC) test: is a standardized, objective and sensitive tool for the measurement of muscle strength.

Mobility: is "the ease with which an articulation, or a series of articulations, is allowed to move before being restricted by the surrounding structures" (Kreighbaum & Barthels, 1996, p. 64).

Perceived Ease of Movement: "the ease with which an articulation, or a series of articulations, is allowed to move before being restricted by the surrounding structures" (Kreighbaum & Barthels, 1996, p. 64).

Perceived Discomfort: is the quantification of absence of comfort from the subject's perspective.

Rotation: "This is a rotary movement of the spine in the horizontal plane about a vertical axis." (Luttgens & Hamilton, 1997)

VITA

Mercan Haddad Derafshi

Candidate for the Degree of

Doctor of Philosophy

Thesis: ASSESSMENT OF AN ALTERNATIVE DUTY BELT: THE CASE OF LAW ENFORCEMENT OFFICERS

Major Field: Human Sciences: Design, Housing, and Merchandising

Biographical:

Education: Completed the requirements for the Doctor of Philosophy in Human Sciences at Oklahoma State University, Stillwater, Oklahoma July, 2017. Completed the requirements for the Master of Arts in Apparel, Merchandising, and Textiles at Washington State University/College of Agriculture, Pullman, Washington/U.S.A in 2013. Completed the requirements for the Bachelor of Science in Textile Engineering at Ege University/College of Engineering, Izmir/Turkey in 2008.

Experience: Instructor of record as a graduate teaching associate in The Department of Design, Housing, and Merchandising at Oklahoma State University (August 2016-May 2017). Graduate Teaching Associate at Oklahoma State University (August 2013 – May 2016) and Graduate Research Associate (August 2013 – May 2015) at Oklahoma State University, Graduate Teaching Associate (January 2011- December 2012) in The Department of Apparel, Merchandising, Design, and Textiles at Washington State University. Technical Design and Costumer Representative at Ozusta Tekstil LTD. Izmir/Turkey (September 2008 – July 2009). Internship in Hugo Boss Int. (June – August 2007).

Professional Memberships: International Textile and Apparel Association