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Original scientific paper

Impacts of Duty Belts and Load Placement on Police Officers: A Systematic Review

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Abstract: Background. Law enforcement officers (LEOs) wear duty belts to hold the specialised equipment required to complete their daily occupational tasks. The aim of this review was to identify, collect, and synthesize research investigating the impacts of duty belts and load placement on LEOs. Methods: A systematic review, registered with the Open Science Framework, was conducted following the Preferred Reporting Items for Systematic Reviews guidelines. Five databases were searched (PubMed, Embase, CINAHL, SPORTDiscus, and Web of Science) with identified studies considered against eligibility criteria. Included studies were critically appraised by two reviewers independently using the Joanna Briggs Institute checklist or the Mixed Method Appraisal Tool. Results: Ten studies (mean appraisal score = 79.8%; Kappa agreement = 0.73) informed the review revealing two main emerging themes; occupational impacts (task performance, vehicle duties, and weapon draw time), and movement impacts (balance, gait, and jump-based movements). Nine studies found duty belts and equipment loads, regardless of placement, negatively impacted LEO occupational tasks and movements in general. There were some differences in the nature of the impacts (e.g., areas of pressure with different systems). One study found no differences in performance between hip versus thigh holsters. Conclusions: The evidence suggests that LEO duty belts, their attachments, and the loads imparted by their equipment have a negative impact on performance of occupational tasks as well as officer movement, increasing

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injury potential. There were some differences in impacts based on load placement warranting consideration and further research.

Keywords: law enforcement, load carriage, accoutrements belt, load bearing vest, duty loads, occupational health, back injury, injury prevention.

INTRODUCTION

Law enforcement officers (LEOs) are responsible for taking action in challenging circumstances to maintain order in society and to serve and protect civilians (Dempsey et al., 2013). As a result, LEOs must be able to respond to situations that include physical altercations with another person, restraining and detaining offenders (especially those that resist arrest), engaging in driving vehicles, foot pursuits, mounting and scaling obstacles of varying heights, and providing aid to victims in the form of pushing, pulling, or dragging individuals or objects (Anderson & Plecas, 2000; Bonneau & Brown, 1995; Marins et al., 2019; Plecas et al., 2011; Ramstrand et al., 2016). These situations can be unpredictable and arise within a moment's notice (Campbell et al., 2013). Due to these ever-evolving situations that LEOs face, there is a continuous demand to add and bear more equipment, thus increasing the loads they carry (White, 2018). To accommodate the requirement to carry this load, equipment such as load bearing vests, thigh or hip holsters, and duty belts are worn and utilized (Larsen et al., 2019; Larsen et al., 2016; Ramstrand et al., 2016).

Duty belts hold vital pieces of specialized equipment LEOs require to complete their daily occupational tasks (Baran et al., 2018; Larsen et al., 2016; Sax van der Weyden et al., 2023). The equipment or 'appointments' attached to these belts, which are often made from reinforced nylon, include items such as a radio, handcuffs, a torch, a primary weapon, spare magazines, a taser, a baton, and OC spray (Baran et al., 2018; Larsen et al., 2019; Ramstrand et al., 2016; Wiley et al., 2020). The total load carried on a LEO inclusive of a duty belt, ancillary equipment, and body armor can range from 3.5 kg to 16.27 kg (Baran et al., 2018; Dempsey et al., 2013; Kasović et al., 2020; Larsen et al., 2016; Sax van der Weyden et al., 2023). One reason for this variability in weight may stem from geographical location or local area command requirements (Baran et al., 2018; Dempsey et al., 2013; Kasović et al., 2020; Larsen et al., 2019; Ramaj Jewett et al., 2023; Wiley et al., 2020). Often, while the physical size of officers is variable, the weight of necessary equipment loaded onto the duty belt is constant (within departments) (Baran et al., 2018). As a result, anatomically smaller officers carry greater relative load weights when compared with that of their larger counterparts (Baran et al., 2018). Additionally, when travelling in a vehicle, LEOs will orientate attachments anteriorly (forward) and laterally (to the sides) on the duty belt to improve comfort in their seats which themselves are often restricted by the officer's equipment (Larsen et al., 2019; Larsen et al., 2016; Ramstrand et al., 2016). For LEOs with a smaller waist, this gives less available space anteriorly, resulting in the alternative mounting of equipment posteriorly, which can cause discomfort during longer shifts (Larsen et al., 2016). Due to the evolving nature of equipment needs (e.g., edged weapon detectors, iPads, etc.), there is an increased requirement to affix loads to the LEO's load carriage system; this in turn can lead to greater risk of impacts associated with load carriage (Lewinski et al., 2015). Impacts can be inclusive of decreased overall comfort, poor appointment accessibility (e.g. draw time of primary weapon), reduced mobility, reduced physical and general task performance (e.g., reduced power, increased victim drag times, slower obstacle course negotiation times), and increased musculoskeletal injury risk (Campbell et al., 2013; Martin et al., 2023).

It is evident that specialized equipment is required for officer protection and safety, however this increased protection may result in decreased physical outputs and altered biomechanics, which of themselves present as risks to officers (Dempsey et al., 2013; Lewinski et al., 2015; Shim et al., 2023). Performance metrics inclusive of speed, acceleration, strength, power, mobility, VO_{2max}, heart rate, and rate of perceived exertion have all been found to be negatively impacted when officers wear their occupational equipment (Dempsey et al., 2013; Marins et al., 2019; Marins et al., 2020). For example, in their study of 47 (male n = 39; female n = 8) police officers performing a vertical jump assessment (as a measure of power) with and without their duty belt and appointments (9.57 ± .94 kg), Wiley et al. (2020) found that jump heights were significantly lower (-5.87 ± 2.75 cm, $p \leq 0.001$) when wearing load. This loss of power performance has been supported in further research which expanded to include measures of change of direction speed and acceleration (Kukic et al., 2023). In their study, Kukic et al. (2023) found significantly poorer performance ($p < 0.001$) in 63 police officer students (male n = 39, female n = 24) across a 300-yard shuttle run, an Illinois agility test, and a 10 m sprint. Measures of power are often associated with occupational task performance in police officers; thus, it is not surprising that load carriage induced reductions in power translate to poorer occupational task performance. For example, in their study of 13 male highway patrol officers completing their Occupational Physical Ability Test consisting of seven occupational tasks, Marins et al. (2020) reported that time to completion increased from 118.3 (± 11.0) seconds to 125.9 (± 13.8) seconds ($p < 0.01$) when officers wore their specialized equipment (5.2 kg versus 12.0 kg).

Apart from impacts on performance, wearing of occupational loads can also lead to pain, discomfort, and injury for police officers (Ramstrand & Larsen, 2012). In a study of 4,158 active-duty police officers, a Swedish work survey found police duty belts were the most strongly associated variable in relation to discomfort and multi-site pain (Larsen et al., 2018). Likewise, a study by Ramstrand and Larsen (2012) concluded that police duty belts were a major contributor to low back pain (LBP) in police officers. Of note, work by Hua et al. (2015) found that of officers reporting for physiotherapy treatment for LBP, more officers wore a hip holster as compared to a thigh holster on their duty belt. Thus, the placement of load around the body warrants consideration.

Considering the impacts of duty belts and load placement on these belts and around the body, Larsen et al. (2019) suggest the need to look for alternative load carriage options to help improve the musculoskeletal wellbeing of LEOs. Unfortunately, there appears to be controversy over which load position is optimal in terms of comfort and practicality (Holmes et al., 2013; Larsen et al., 2016; Ramstrand et al., 2016). Some evidence suggests no improvements from utilizing a load bearing vest over a standard duty belt after an initial adaptation period (Ramstrand et al., 2016). Conversely, the use of a thigh holster has been shown to improve comfort in vehicles (Ramaj Jewett et al., 2023). As such, the aim of this systematic review was to identify, collect, and synthesize research investigating the impacts of duty belts and their load placements on LEOs. The outcomes of this work will be used to inform future best practice and injury mitigation in LEOs required to wear duty belts.

METHODS

Experimental approach to the problem

A systematic review was conducted following the Preferred Reporting Items for Systematic reviews (PRISMA) (Aromataris et al., 2015). The project and protocol for this systematic review were registered with the Open Science Framework on the 06 October 2023 (https://doi.org/10.17605/OSF.IO/VJSB7), prior to data extraction being conducted.

Measurements and Procedures

Information sources and search strategy

Five key databases (PubMed, Embase [Elsevier], the Cumulative Index to Nursing and Allied Health Literature [CINAHL], SPORTDiscus, and Web of Science) were searched in September 2023, using dedicated search terms detailed in Table 1. The search terms were developed based off three key concepts (law enforcement, duty belt, and impact [Table 1]). For this review, impacts can be inclusive of mobility, appointment accessibility (e.g. draw time of primary weapon), overall comfort, musculoskeletal injuries, and physiological outcome measures (e.g., heart rate). Once preliminary search terms were developed, the PubMed Identifier (PMIDs) of seven key articles previously identified by the research team were entered into the Systematic Review Accelerator (SRA) Search Refinery tool (Clark, Glasziou, et al., 2020) to further optimize the terms and search phrases. Following finalization of the search terms, the search phrases were entered into a Polyglot search translator (Clark, Sanders, et al., 2020) to optimize the terms for the different databases. In addition to the database search, other literature sources were searched, inclusive of citations of included papers, pre-proof registers, and reports which were added to the PRISMA flow diagram.

Table 1. *Database and Relevant Search Terms*

Database	Search Terms
PubMed	(((police[Title/Abstract] OR sheriff[Title/Abstract] OR "Federal bureau of investigation"[Title/Abstract] OR deputy[Title/Abstract] OR officer*[Title/Abstract]) OR (police[MeSH])) **AND** ((equipment[Title/Abstract] OR belt[Title/Abstract] OR accoutrements[Title/Abstract] OR appointments[Title/Abstract] OR "load carriage system"[Title/Abstract] OR load[Title/Abstract]))) **AND** (injur*[Title/Abstract] OR pain[Title/Abstract] OR "lower back pain"[Title/Abstract] OR Impact[Title/Abstract] OR Mobility[Title/Abstract] OR agility[-Title/Abstract] OR power[Title/Abstract] OR gait[Title/Abstract] OR strength[-Title/Abstract] OR biomechanics[Title/Abstract] OR balance[Title/Abstract])

CINAHL	((((TI police OR AB police) OR (TI sheriff OR AB sheriff) OR (TI “Federal bureau of investigation” OR AB “Federal bureau of investigation”) OR (TI deputy OR AB deputy) OR (TI officer* OR AB officer*)) OR ((MH police+))) **AND** (((TI equipment OR AB equipment) OR (TI belt OR AB belt) OR (TI accoutrements OR AB accoutrements) OR (TI appointments OR AB appointments) OR (TI “load carriage system” OR AB “load carriage system”) OR (TI load OR AB load)))) **AND** ((TI injur* OR AB injur*) OR (TI pain OR AB pain) OR (TI “lower back pain” OR AB “lower back pain”) OR (TI Impact OR AB Impact) OR (TI Mobility OR AB Mobility) OR (TI agility OR AB agility) OR (TI power OR AB power) OR (TI gait OR AB gait) OR (TI strength OR AB strength) OR (TI biomechanics OR AB biomechanics) OR (TI balance OR AB balance))
SPORTDiscus	((((TI “police” OR AB “police”) OR (TI “sheriff” OR AB “sheriff”) OR (TI “Federal bureau of investigation” OR AB “Federal bureau of investigation”) OR (TI “deputy” OR AB “deputy”) OR (TI “officer*” OR AB “officer*”)) OR (DE “police”)) **AND** (((TI “equipment” OR AB “equipment”) OR (TI “belt” OR AB “belt”) OR (TI “accoutrements” OR AB “accoutrements”) OR (TI “appointments” OR AB “appointments”) OR (TI “load carriage system” OR AB “load carriage system”) OR (TI “load” OR AB “load”)))) **AND** ((TI “injur*” OR AB “injur*”) OR (TI “pain” OR AB “pain”) OR (TI “lower back pain” OR AB “lower back pain”) OR (TI “Impact” OR AB “Impact”) OR (TI “Mobility” OR AB “Mobility”) OR (TI “agility” OR AB “agility”) OR (TI “power” OR AB “power”) OR (TI “gait” OR AB “gait”) OR (TI “strength” OR AB “strength”) OR (TI “biomechanics” OR AB “biomechanics”) OR (TI “balance” OR AB “balance”))
Web of Science	(((MHpolice OR sheriff OR “Federal bureau of investigation” OR deputy OR officer*)) AND ((MHequipment OR belt OR accoutrements OR appointments OR “load carriage system” OR load))) AND (MHinjur* OR pain OR “lower back pain” OR MHImpact OR MHMobility OR agility OR power OR gait OR strength OR biomechanics OR balance)
Embase (Elsevier)	(police:ti,ab OR sheriff:ti,ab OR ‘federal bureau of investigation’:ti,ab OR deputy:ti,ab OR officer*:ti,ab OR ‘police’/exp OR ‘police’) AND (equipment:ti,ab OR belt:ti,ab OR accoutrements:ti,ab OR appointments:ti,ab OR ‘load carriage system’:ti,ab OR load:ti,ab) AND (injur*:ti,ab OR pain:ti,ab OR ‘lower back pain’:ti,ab OR impact:ti,ab OR mobility:ti,ab OR agility:ti,ab OR power:ti,ab OR gait:ti,ab OR strength:ti,ab OR biomechanics:ti,ab OR balance:ti,ab)

Eligibility criteria and selection process

Identified articles were compiled into an Endnote library (Clarivate Analytics, Bld 19133) and exported to the SRA (Clark, Glasziou, et al., 2020) for duplicate screening. Once duplicates were removed, the articles were screened by title and abstracts by two authors (CB & DH) independently to identify articles that were clearly not relevant. Any discrepancies were discussed and if adjudication was required, articles in question were reviewed by a third author (NB) who provided the final decision. The remaining articles were retrieved in full text. Following the retrieval, articles were screened against dedicated inclusion and exclusion criteria (Table 2). In this process, articles were excluded if they pertained to a military police or specialist police unit, as they are known to carry different equipment than the general duties police officers, and if a duty belt was not part of the load bearing ensemble studied. This process was conducted by three reviewers (CB, DH, NB) independently before being consolidated. The remaining studies were used to inform this review.

Table 2. *Eligibility Criteria Applied to Each Study*

Inclusion Criteria	Exclusion Criteria
• Peer review journal articles; • Articles published in English or translatable to English; • Populations were LEOs; • Study compared a load bearing system vs a duty belt, a duty belt vs a control, or a hip rig vs thigh rig; and • Reported the impacts of a duty belt	• Military Police or Specialist Police Unit; or • Studies not incorporating duty belts as part of the load bearing ensemble

Data collection process, item and synthesis

Data were extracted by two reviewers (DH & CB) independently using a data extraction table as the tool. The data collected and extracted into the table included the author(s), publication year, study's country of origin, the study's aims or purpose, information about the study population and its sample size, the methodology employed, the type of intervention studied, any comparators used, and the duration of the intervention. In addition, the measured outcomes, and key findings relevant to the review (inclusive of correlations, effect sizes, means, medians and standard deviations, delta values, and p-values) were collected for potential use in a meta-analysis if the data heterogeneity and nature of the data allowed. Additionally, efforts were made to contact the authors of these studies in cases where data were missing, or additional information was required. The table was calibrated by two reviewers (DH & CB) independently through collection and data extraction of a sample of the studies and verified by a further two reviewers (NB & RO). Once data were collected and extracted into the table, naturally emerging themes were used to synthesize the data with a primary focus being on equipment and variations.

Critical appraisal

All identified research studies informing this review were appraised for quality. Depending on the contents of the study, the appropriate Joanna Briggs Institute (JBI) review checklist was selected by the researchers, and the studies appraised independently by two reviewers (DH, CB). Studies with quantitative data were appraised by the appropriate JBI quantitative tools (Barker et al., 2023), while studies that contained both qualitative and quantitative data were appraised using the Mixed Method Appraisal Tool (MMAT) (Hong et al., 2018). To allow for easy appreciation of study quality, JBI and MMAT items were scored and summed with the result divided by the number of items applicable to the specific tool providing a percentage score. For both the JBI and MMAT, answers scored one point for a 'yes' answer and a zero for 'No', 'Unclear', 'Not Applicable' or 'Can't Tell' answers.

Statistical analyses

The level of agreement between the two reviewers was determined via a Cohen's kappa (k) analysis conducted using the statistical analyses, which were conducted using Social Package for Social Sciences (IBM, SPSS statistics, version 28.0.1.0). The level of agreement following that proposed by Viera and Garrett (2005), being < 0 'less than chance agreement', 0.01-0.20 'slight agreement', 0.21-0.40 'fair agreement', 0.41-0.60 'moderate agreement', 0.61-0.80 'substantial agreement', and 0.81-0.99 'almost perfect agreement'. A third reviewer (NB) was responsible for settling disputes in scores between the two reviewers (CB, DH). With no specific scoring system for the JBI and MMAT, a scoring system, previously described in the literature (Handler et al., 2010), was used to serve as a means of contextualizing the quality assessment, being; < 45.4% considered 'poor', between 45.4%-61% considered 'fair', and > 61% considered 'good' quality.

RESULTS

A PRISMA diagram detailing the results of the search, screening, and selection process is presented in Figure 1. The initial search through the five databases resulted in 2024 articles, of which 608 duplicates were removed. The remaining 1416 articles were screened by title and abstract, resulting in 1354 articles being excluded due to lack of relevance to the current review (e.g. the effects of military style ruck marching on lower extremity loading and muscular, physiological and perceived exertion in ROTC cadets (Earl-Boehm et al., 2020)). Sixty-two potential articles appropriate for the study remained and were sought for full text review to assess eligibility against the inclusion and exclusion criteria. The final number of studies to inform the review, drawn from the database searches, was nine (n = 9).

An initial search through other methods (e.g., citation searching, pre proof, and provided by subject matter expert) resulted in an additional 11 articles being identified. All 11 articles were sought for full text retrieval and assessed for eligibility against the inclusion and exclusion criteria. Ten of the 11 articles did not meet inclusion criteria, leaving one article remaining from other methods retrieval. In total, between the two sources (databases and other methods), ten articles were included to form the basis of this systematic review. Studies meeting the exclusion criteria for databases (n = 5), and other methods (n = 10) are detailed in the PRISMA flow diagram and in detail in Supplementary Table 1. Finally, the wide and varied range of load conditions and outcome measures used to inform key findings meant that the data heterogeneity did not allow for a meta-analysis.

Study characteristics

Of the ten studies informing this review, seven were of a Quasi-experimental design (Barker et al., 2023) while the remaining three were mixed methods studies (Hong et al., 2018). The research originated from five different countries, which include three studies from Australia (Campbell et al., 2013; Filtness et al., 2014; Wiley et al., 2020), three studies from Sweden (Larsen et al., 2019; Larsen et al., 2016; Ramstrand et al., 2016), two from

New Zealand (Dempsey et al., 2013, 2014), and one from the USA (Shim et al., 2023) and Brazil (Marins et al., 2019), respectively. The population of all included studies consisted of LEOs only. Population sizes across the ten studies were relatively small with the smallest population consisting of 13 officers (Marins et al., 2019), and the largest population consisting of 52 officers (Dempsey et al., 2013, 2014). In seven studies (Campbell et al., 2013; Dempsey et al., 2013, 2014; Filtness et al., 2014; Marins et al., 2019; Shim et al., 2023; Wiley et al., 2020), the participant demographics were biased in favor of males, with male representation ranging from 66% (Campbell et al., 2013) to 100% (Dempsey et al., 2013, 2014) of the study populations. One study (Larsen et al., 2016) had a larger female population, making up 52.7% of the population. Two studies (Larsen et al., 2019; Ramstrand et al., 2016) had an even split between male and female officers.

Nine of the ten studies (Dempsey et al., 2013, 2014; Filtness et al., 2014; Larsen et al., 2019; Larsen et al., 2016; Marins et al., 2019; Ramstrand et al., 2016; Shim et al., 2023; Wiley et al., 2020) reported on age with a range of 22 (Dempsey et al., 2013, 2014; Wiley et al., 2020) to 66 (Wiley et al., 2020) years of age. Six studies (Campbell et al., 2013; Filtness et al., 2014; Larsen et al., 2019; Larsen et al., 2016; Marins et al., 2019; Ramstrand et al., 2016) reported on years of service; the collective range spanned from 0.5 (Larsen et al., 2016) to 20 (Ramstrand et al., 2016) years. Of these six studies, one study reported differences between general duty and highway patrol officers (Filtness et al., 2014), and one study reported differences between male and female officers (Larsen et al., 2019).

All ten studies reported on participant height and weight which were recorded in centimeters (cm) and kilograms (kg). The range for height amongst nine studies (Dempsey et al., 2013, 2014; Filtness et al., 2014; Larsen et al., 2019; Larsen et al., 2016; Marins et al., 2019; Ramstrand et al., 2016; Shim et al., 2023; Wiley et al., 2020) within a single police population was 156.21 (Wiley et al., 2020) to 195.58 (Wiley et al., 2020) cm, while the weight was 51.71 (Wiley et al., 2020) to 154.59 (Wiley et al., 2020) kg. The study by Filtness et al. (2014) reported on the height and weight of general duties officers and highway patrol officers separately (general duties = 178.8 ± 6.4 cm and 87 ± 8.1kg; highway patrol = 180.5 ± 9.3 cm and 97.8 ± 22.7 kg respectively).

All but one study (Dempsey et al., 2013, 2014; Filtness et al., 2014; Larsen et al., 2019; Larsen et al., 2016; Marins et al., 2019; Ramstrand et al., 2016; Shim et al., 2023; Wiley et al., 2020) included an unloaded condition as their control group; and had at least one other condition loaded. Of those nine studies, four (Dempsey et al., 2013, 2014; Filtness et al., 2014; Wiley et al., 2020) had two conditions, four (Larsen et al., 2019; Larsen et al., 2016; Ramstrand et al., 2016; Shim et al., 2023) had three conditions, and one (Marins et al., 2019) had four conditions. The remaining paper by Campbell et al. (2013) utilized two different equipment conditions which consisted of a thigh holster and a hip mounted holster. Of the seven studies that reported equipment weights, all studies provided their data in kg (Dempsey et al., 2013, 2014; Larsen et al., 2019; Larsen et al., 2016; Marins et al., 2019; Shim et al., 2023; Wiley et al., 2020). The lowest weight range was 1.2 to 12kg (Marins et al., 2019) while the heaviest was 7.08 to 12.02 kg (Wiley et al., 2020).

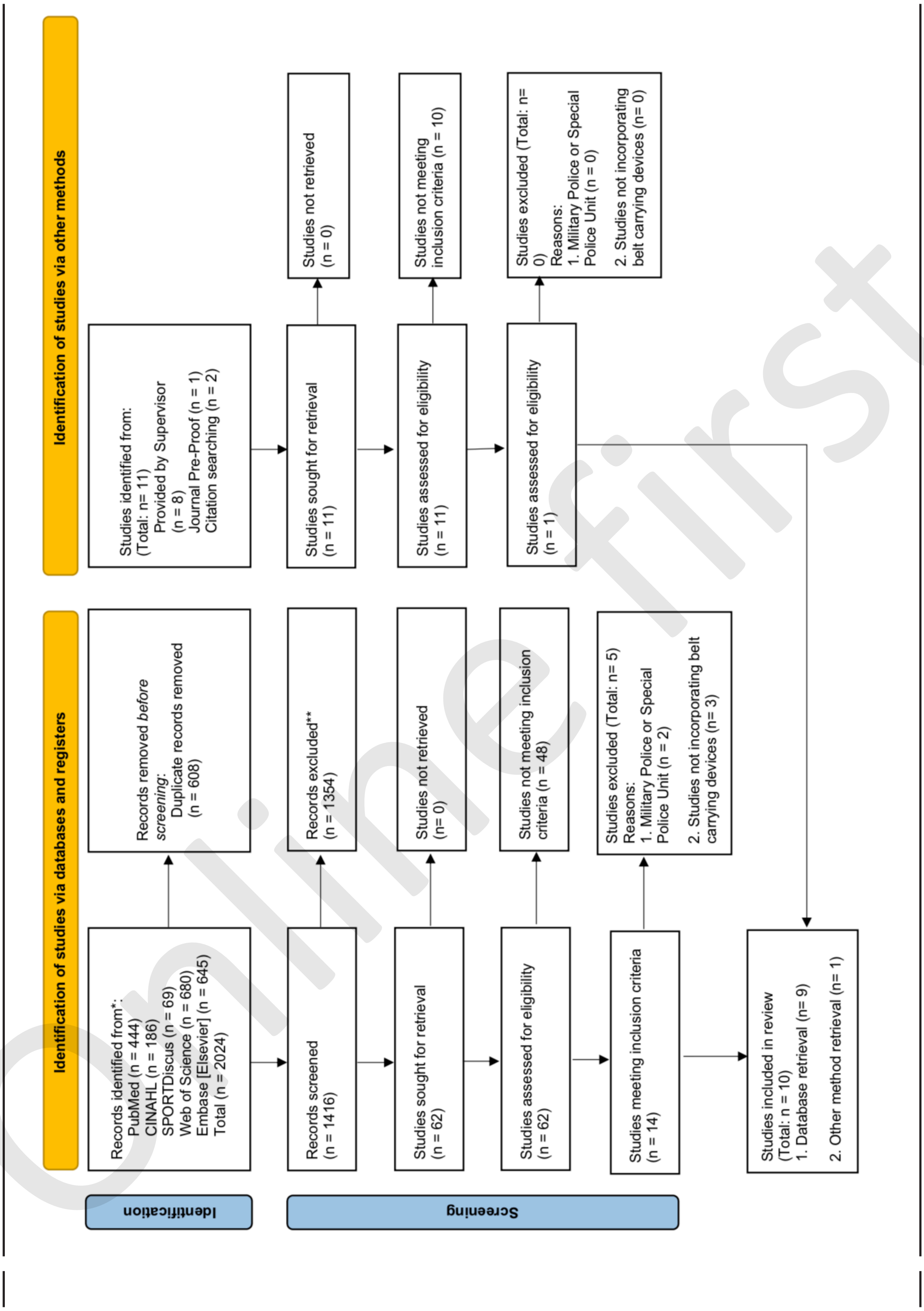

Figure 1. *PRISMA Diagram Detailing the Results of the Search, Screening, and Selection Process*

CRITICAL APPRAISAL

The overall averaged methodological quality of included studies was 71% or a grade of 'good' quality (Handler et al., 2010), ranging from 66% (Campbell et al., 2013; Dempsey et al., 2013; Shim et al., 2023) to 100% (Larsen et al., 2019). The initial level of agreement between the raters was k = 0.73 representing a 'substantial' level of agreement (Viera & Garrett, 2005). Following discussion with a third reviewer (NB), who acted as the adjudicator, the level of agreement was k = 1.0 with no discrepancies. There were no obvious and consistent questions of contention on the JBI Quasi-experimental checklist or MMAT between the two initial reviewers. The seven studies appraised by the JBI Quasi-experimental checklist generally scored poorly on Question 5 (Were there multiple measurements of the outcome both pre and post the intervention/exposure?) and Question 6 (Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analyzed?).

RESULTS OF THE INDIVIDUAL STUDIES AND THEMED SYNTHESIS

The results of each study included are presented in Table 3. The synthesis of these results revealed two emerging themes, being the following: 1) occupational outcome measures, and 2) movement-based impacts. Within each theme, emerging sub themes were identified being predictors of task performance, impact of load carriage in vehicles, and holster position under the occupational outcome measure theme and, balance, gait, jump based testing under the movement theme. The key findings relevant to each theme are discussed below.

OCCUPATIONAL OUTCOME MEASURES

A total of four studies (Campbell et al., 2013; Dempsey et al., 2013; Larsen et al., 2019; Marins et al., 2019) reported on measures relating to occupational outcome measures. From these studies, three sub themes emerged being the following: predictors of task performance (n = 2) (Dempsey et al., 2013; Marins et al., 2019), impacts of load carriage in vehicles (n = 3) (Dempsey et al., 2013; Filtness et al., 2014; Larsen et al., 2019), and weapon draw time (n = 1) (Campbell et al., 2013).

Predictors of task performance

Two studies reported on the impact of load carriage on occupational task performance. Marins et al. (2019) compared participants without personal protective equipment (NPPE) and with personal protective equipment (WPPE). The NPPE condition included a standard operating uniform (additional load = 1.5 kg), while the WPPE group wore a ballistic vest and nylon duty belt with appointments (additional load between 8.1 and 8.3 kg) (Marins et al., 2019). Their study found that performance in measures of agility / change of directions speed (Illinois Agility Test [IAT]), power (squat jump height, countermovement jump height and broad jump distance), upper body strength (flexed arm hang), trunk endurance (Biering Sorensen test), anaerobic power (Fletcher test), and aerobic power were all negatively impacted, as was performance on the OPAT, in the WPPE condition. Of note, relationships between the fitness measures and OPAT performance changed whether the participants wore NPPE or WPPE (see Table 3). For example, the correlation between OPAT and IAT changed from $r = 0.70$ ($p \leq 0.01$) in the NPPE condition to $r = 0.59$ ($p \leq 0.05$) in the WPPE condition. While relative and absolute VO_{2max} were not correlated with NPPE ($r = -0.24$ and $r = -0.28$ respectively), they were correlated with WPPE performance ($r = -0.71$ and $r = -0.68$, $p \leq 0.05$ respectively) (Marins et al., 2019). Dempsey et al. (2013) compared an unloaded group to a loaded group during a five-minute treadmill run. The unloaded groups wore just exercise shoes and clothing, while the loaded group were equipped with stab resistant body armor (SRBA) and a weight belt representative of a duty belt and appointments (7.65 ± 0.73 kg) (Dempsey et al., 2013). Heart rate, oxygen consumption, respiratory exchange ratio, and rating of perceived exertion were all found to increase significantly ($p < 0.001$) during the five-minute run when officers wore their duty belts and armor (Dempsey et al., 2013).

Impacts of load carriage in vehicles

Three studies (Dempsey et al., 2013; Filtness et al., 2014; Larsen et al., 2019) examined impacts of load carriage conditions on LEOs in their work vehicles. Larsen et al. (2019) compared median contact pressure of standard load carriage with alternate load carriage. Standard load carriage included a duty belt with appointments while the alternate load carriage had the same appointments attached to a load bearing vest (LBV) (Larsen et al., 2019). Median contact pressure in the right thigh ($p = 0.011$) and upper back ($p = 0.003$) increased from the standard load carriage condition to the alternate load carriage condition when seated ($p < 0.05$) (Larsen et al., 2019). Median contact pressure of the participants lower back was found to decrease from standard load carriage to alternative load carriage when seated ($p = 0.010$) (Larsen et al., 2019). Median contact area (cm^2) was shown to decrease in the left thigh ($p = 0.003$) and upper back ($p = 0.007$) region from standard load carriage condition to alternative load carriage condition (Larsen et al., 2019). While no statistical evaluation was done, it was noted that the contact pressures were lowest in each body region on the control condition as opposed to either load position.

The study by Larsen et al. (2019) also reported on subjective measure of vehicle discomfort as reported using the Automotive Seating Discomfort Questionnaire (ASDQ) scale. Standard load carriage conditions resulted in the greatest discomfort (36/100mm; IQR 14-52mm) when compared to the alternate load carriage system (Larsen et al., 2019). The highest levels of discomfort based on body regions were observed in the lower back (30.50/100mm; IQR 11-42) and the right and left pelvis regions (14.5/100 mm; IQR 0-34 mm, and 12/100 mm; IQR 1-32 mm, respectively) (Larsen et al., 2019). In a study comparing load placement and vehicle seats Filtness et al. (2014) assessed levels of discomfort between two different police vehicle seat types, being 'standard' and 'custom' and different equipment orientations, being duty belt with appointments (orientated to their personal preference with the prescribed placement of the firearm worn in a hip holster over the dominant hip) as compared to duty belt with appointments affixed to a load bearing vest (LBV condition) reported. The results found that police officers experienced significantly greater discomfort (average rating ≥ 3/10) when sitting in either a 'standard' or 'custom' police vehicle seat wearing their duty belt and appointments. Overall, the duty belt with appointments presented with greater overall discomfort as opposed to the LBV condition in both general duties ($F[1,13] = 5.64$, $p = 0.034$) and highway patrol ($F[1,10] = 12.20$, $p = 0.06$) (Filtness et al., 2014).

Dempsey et al. (2013) examined effects of duty belt, appointments, and SRBA (mean load = 7.65 kg ± 0.73), on an officer's ability to exit, pivot, and sprint 2.85 m from a low car seat. Their study found that the officer's requirement to wear duty loads significantly slowed their time to complete the task by a mean of 16% (change = +0.28 secs, $p < 0.001$) (Dempsey et al., 2013).

Holster position

A study by Campbell et al. (2013) compared firearm handling and draw times of the officer's side arm between a hip holster and thigh holster. Although there was a difference in holster position, no reported difference in weight between the two conditions was recorded. There were no significant differences in response time, fire position, variability, or draw success rate in their study. However, holster familiarity did impact the draw time success rate.

Movement-based impacts

Of the ten studies forming this review, six studies (Dempsey et al., 2013, 2014; Larsen et al., 2016; Ramstrand et al., 2016; Shim et al., 2023; Wiley et al., 2020) reported on movement-based measures. Three sub themes emerged: balance ($n = 2$) (Dempsey et al., 2013; Shim et al., 2023), gait ($n = 2$) (Larsen et al., 2016; Ramstrand et al., 2016), and jump based testing ($n = 2$) (Dempsey et al., 2014; Wiley et al., 2020).

Balance

Two studies (Dempsey et al., 2013; Shim et al., 2023) reported on measures of static balance. Dempsey et al. (2013) observed an increase in mean time off balance of 2.42s ($p < 0.001$) from unloaded to loaded groups during static balance testing. Unloaded groups wore exercise shoes and clothing while the loaded groups wore SRBA, duty belt and appointments (7.65 ± 0.73 kg) (Dempsey et al., 2013). The static balance testing comprised of a timed balance task on a stabilometer while facing lateral excursions for 30 s (Dempsey et al., 2013). Shim et al. (2023) compared three groups; 'no equipment' (standard uniform), 'tactical vest', and 'duty belt'. The authors found the 'duty belt' group had poorer balance ($p = 0.001$) in mean scores for the 'eyes closed perturbed surface' condition (0.45 ± 0.03), when compared with the 'tactical vest' group (0.57 ± 0.04) during static balance testing but better performance in the 'eyes closed stable surface condition' (0.36 ± 0.02 versus 0.35 ± 0.03, respectively, $p = 0.001$). This balance assessment involved officers standing on a Bertec posturography plate for 10s to measure CoP to determine postural sway in eight conditions with only the two mentioned conditions significantly different (Shim et al., 2023).

Gait

Two studies (Larsen et al., 2016; Ramstrand et al., 2016) found statistically significant changes in gait related to duty belt load carriage. While there were no significant differences in temporospatial parameters (i.e., velocity, stride length, width and frequency), Larsen et al. (2016) did find a decrease in median trunk rotation (p = 0.017) in both load conditions (standard load carriage and alternate load carriage) when compared with the control. Standard load carriage was classified as body armor and standard issue duty belt while the alternate load carriage configuration had load transferred from a belt to a load bearing vest and the holster moved to the thigh. The condition had officers wear standard issue boots and body armor only (Larsen et al., 2016). In addition, hip rotation and knee abduction / adduction were greater on the right side (holster side) in both stance and swing phases in the alternate load carriage condition when compared to the standard condition. When compared to the control condition, sagittal and frontal plane peak moments during the stance phase of gait was significantly greater (p = 0.006) in hip abduction / adduction (left) in the standard load carriage configuration and significantly greater (p = 0.002) in knee flexion/extension (left) in the alternate load carriage configuration (Larsen et al., 2016). In both load conditions ankle dorsi/plantar flexion (left and right) were significantly greater (p < 0.017). Peak power during stance phase decreased in ankle dorsi/plantar flexion on the left in both conditions (p < 0.017), but on the right side only in the alternate load carriage condition (p = 0.026) (Larsen et al., 2016). The alternate load carriage configuration also yielded greater peak power (p = 0.018) in hip flexion/extension (left) when compared to the control condition.

Ramstrand et al. (2016) found that trunk flexion/extension, lateral bending, and rotation (as well as pelvic tilt) were reduced when subjects wore their load bearing and ballistic vest (p = 0.05 to <0.001) as compared to the standard belt and ballistic vest group and the control group. Hip abduction / adduction (right) was reduced when compared to the control group and hip abduction / adduction (left) was reduced when compared to the standard belt and vest group. Of note, in the study the load bearing vest and ballistic vest group did not wear a duty belt while the standard belt group wore a standard issue belt and a ballistic vest (no specific weight provided). The authors did clarify that while there were some significant reductions in range of motion with the load bearing and ballistic vest condition, these ranges still fell within the normal population range. In terms of maximum and minimum joint angles, the range of abduction and adduction of the arms was generally greater when wearing either load condition as was pelvic rotation. Maximum and minimum joint angles at the hip (flexion / extension, abduction, and internal rotation) were greater on the right side (holster side) in the load bearing and ballistic vest condition. Finally, minimum and maximum lateral bending of the trunk to the right in the load bearing and ballistic vest condition was greater when compared to the other conditions (-6.06 degrees from control and -3.94 degrees in duty belt and ballistic vest condition). This notable reduction (p < 0.001) is postulated by the authors to be due to all but one (17/18) of the participants holstering their sidearm on the right hip.

Jump based testing

Of the six studies reporting on movement, two (Dempsey et al., 2014; Wiley et al., 2020) reported on findings related to jump-based testing. Dempsey et al. (2014) showed changes in various physical parameters when transitioning from unloaded to loaded conditions. In the loaded condition, participants were fitted with SRBA and weight representative of a standard duty belt with accessories (mean = 7.65 ± 0.73) (Dempsey et al., 2014). In the loaded condition, mean vertical jump height decreased (-5.61 cm, p < 0.001) as did mean drop jump height (-5.34 cm $p < 0.001$), while drop jump ground contact time increased (+99 ms, $p < 0.001$) (Dempsey et al., 2014). Similarly, Wiley et al. (2020) found individuals in loaded conditions experienced a decrease in vertical jump height by 5.87cm ($p \leq 0.001$) and while the power-to-weight ratio also decreased (-5.01 W/kg, $p \leq 0.001$), peak anaerobic power output increased (+76.81W, $p \leq 0.001$) under loaded conditions (Wiley et al., 2020). Loaded conditions for this study included all equipment routinely worn on duty including uniform, duty belt, boots, weapon, handcuffs, and specialized equipment (9.57kg ± 0.94) (Wiley et al., 2020).

Table 3. *Extracted Data from Included Papers with Key Findings*

Authors	Testing Conditions [Equipment included – approximate weight]	Main Findings	Critical Appraisal Score (%)
Campbell et al. (2013)	1. Duty belt with hip holster 2. Duty belt with thigh holster	• No significant difference in response time • No significant difference in fire position • No significant difference in variability • No significant difference in draw success rate	66.67%
Dempsey et al. (2013)	1. Unloaded 2. Added Load [Fitted SRBA plus weight representative of a duty belt])	Unloaded compared with loaded • Mean time off balance (s) increased by 2.42 ($p < 0.001$) • Mean TTC Acceleration(s) increased by 0.28 ($p < 0.001$) • Mean number of chin ups completed decreased by 2.86 ($p < 0.001$) • Mean TTC Mobility(s) increased by 2.31 ($p < 0.001$) 5 min run results when loaded vs unloaded • Mean % HR max (b.min-1) increased by 6.40 ($p < 0.001$) • Mean % VO2max (L.min-1) increased by 9.00 ($p < 0.001$) • Mean % VO2max (ml.kg-1.min-1) increased by 2.80 ($p < 0.001$) • Mean RER (VCO2/VO2) increased by 0.11 ($p < 0.001$) • Mean RPE final increased by 3.60 ($p < 0.001$)	66.67%
Dempsey et al. (2014)	1. Unloaded 2. Loaded	Unloaded compared with loaded • Mean VJ height (cm) decreased by 5.61 ($p < 0.001$) • Mean DJ height (cm) decreased by 5.31 ($p < 0.001$) • DJ ground time (ms) increased by 99 ($p < 0.001$)	88.89%

Filtness et al. (2014)	1. Duty belt 2. LBV with weapon holster on belt	• Both GDs and HPs experienced clinically significant discomfort (average rating ≥ three) when sitting in the 'standard' seat wearing the 'belt' • Both GDs ($F[1,13] = 5.64$, $p = 0.034$) and HPs ($F[1,10] = 12.20$, $p = 0.06$) had significant main effect of appointments carriage showed more discomfort experienced with 'belt' than 'LBV'	70.59%
Larsen et al. (2019)	1. Unloaded Vs. 2. Standard Carriage [Body Armor & duty belt] Vs. 3. Alternative Carriage [Body Armor & LBV])	Discomfort recorded on ASDQ (Values are on a 100 mm scale with 100mm representing high discomfort) • Greatest discomfort: DB in standard LC condition (36 mm; IQR 14–52 mm) ($p < 0.05$) Body regions of reported discomfort with standard LC • Standard LC had the greatest level of discomfort in the LB (30.50 mm; IQR 11–42) ($p < 0.05$) • Right pelvis resulted in reported discomfort (14.5 mm; IQR 0–34 mm) ($p < 0.05$) • Left pelvis resulted in reported discomfort (12 mm; IQR 1–32 mm) ($p < 0.05$) Median contact pressure of standard LC compared with alternate LC conditions (IQR) • Median contact pressure (mmHg) of right thigh increased from standard LC to alternate LC by 3.90 ($p = 0.011$) • Median contact pressure (mmHg) of LB decreased by 2.60 ($p = 0.010$) • Median contact pressure (mmHg) of UB increased by 6.00 ($p = 0.003$) Median contact area of standard LC compared with alternate LC conditions (IQR) • Median contact area (cm^2) of left thigh decreased by 33.00 ($p = 0.003$) • Median contact area (cm^2) of UB decreased by 36.00 ($p = 0.007$)	100%
Larsen et al. (2016)	1. Unloaded 2. Body Armor, duty belt, & hip holster 3. LBV, duty belt and thigh holster	Difference in ROM of body segments (degrees) between standard load carriage and control • Median trunk rotation decreased by 1.22 ($p = 0.017$) Sagittal and frontal plane peak moments and powers during the stance phase Peak Moments (Nm/BW) • Hip ab/adduction (left) decreased by 0.01 ($p < 0.017$) • Ankle dorsi/plantar flex (left) decreased by 0.04 ($p < 0.017$) • Ankle dorsi/plantar flex (right) decreased by 0.11 ($p < 0.017$) Power (W/BW) • Ankle dorsi/plantar flex (left) decreased by 0.33 ($p < 0.017$)	77.78%

Marins et al. (2019)	Block 1 [no Weapon]: 1. Unloaded [NPPE] 2. Loaded [WPPE] Block 2 [with Weapon]: 3. Unloaded [NPPE] 4. Loaded [WPPE])	NPPE • Agility (IAT (s)) was (+) related to performance in the NPPE OPAT (s) ($r = 0.70$, $p \le 0.01$) • SLJ (cm) and NPPE OPAT performance (s) were (-) related ($r = -0.60$, $p \le 0.05$) • Height (cm) and NPPE OPAT performance were (-) related ($r = -0.48$, $p \le 0.05$) WPPE • Relative Aerobic power ($VO_{2max)}$) was (-) related to WPPE OPAT performance ($r = - 0.71$, $p \le 0.01$) • Absolute Aerobic power (VO_{2max}/kg/min) was (-) related to WPPE OPAT (s) performance ($r = -0.68$, $p \le 0.01$) • Lower limb power (SJ, CMJ) was (-) related to WPPE OPAT (s) performance ($r = -0.52$, $p \le 0.05$; $r = -0.52$, $p \le 0.05$) • Agility (IAT) was (+) related to performance in WPPE OPAT (s) performance ($r = 0.59$, $p \le 0.05$)	88.89%
Ramstrand et al. (2016)	1. Unloaded 2. Ballistic Protection Vest & Standard Issue Belt 3. Ballistic Protection Vest & LBV (occasion 1) 4. Ballistic Protection Vest & LBV (occasion 2)	ROM (deg) of major body segments: testing condition 1. vs testing condition 2. • Hip internal/external rotation (left) increased by 0.91 ($p < 0.05$) ROM (deg) of major body segments: testing condition 2. vs testing condition 3. • Trunk flexion/extension decreased by 0.08 ($p < 0.05$) • Trunk lateral bending decreased by 5.19 ($p < 0.05$) • Trunk rotation decreased by 3.73 ($p < 0.05$) • Pelvic tilt decreased by 3.16 ($p < 0.05$) • Hip abduction/adduction decreased by 1.47 ($p < 0.05$) ROM (deg) of joint angles (median values) • Lateral trunk bending (right) decreased from testing occasion 1 to testing occasion 3 by 6.06 ($p < 0.001$) • Lateral trunk bending (right) decreased from testing occasion 2 to testing occasion 3 by 3.94 ($p < 0.001$)	94.12%

Shim et al. (2023)	1. Tactical Vest 2. No Equipment 3. Utility Belt	• Center of pressure and limit of stability scores between groups • Group mean scores for eyes closed stable surface → Group 1 (tactical vest): 0.3528 ± 0.029 ($p = 0.001$) → Group 2 (no equipment): 0.33 ± 0.02 ($p = 0.001$) → Group 3 (utility belt): 0.36 ± 0.02 ($p = 0.001$) • Group mean scores for ECPS → Group 1 (tactical vest): 0.572 ± 0.039 ($p = 0.001$) → Group 2 (no equipment): 0.54 ± 0.04 ($p = 0.001$) → Group 3 (utility belt): 0.45 ± 0.03 ($p = 0.001$)	66.67%
Wiley et al. (2020)	1. Unloaded (uniform only) 2.Duty belt with all accoutrements	• Unloaded compared with loaded (VJ, PAPw, P:W) • Mean cohort VJ (cm) decreased by 5.87 ($p \leq 0.001$) • Mean cohort PAPw (W) increased by 76.81 ($p \leq 0.01$) • Mean cohort power to weight ratio (W/kg) decreased by 5.01 ($p \leq 0.001$)	77.78%

Legend: (-) = Negative(ly); + = Positive(ly); ASDQ = The Automobile Seating Discomfort Questionnaire; CMJ = Counter Movement Jump; DB = Duty Belt; deg = degrees; DJ = Drop Jump; Ext = External; GD = General Duty; HP = Highway Patrol; HR = Heart rate; IAT = Illinois Agility Test; Int = Internal; IQR = Inner Quartile Range; JBI = Joanna Briggs Institute; LB = Lower Back; LBV = Load Bearing Vest; LC = Load Carriage; MMAT = Mixed Methods Appraisal Tool; NPPE = Without Personal Protective Equipment; OPAT= Occupational Physical Ability Test; PAPw = Peak anaerobic power output; PPE = Personal Protective Equipment; RER = Respiratory Exchange Ratio; RPE = Rate Perceived Exertion (BERG 6-20); ROM =Range of Motion; s = Seconds; SLJ = Standing Long Jump; SRBA = Stab Resistant Body Armor; TTC = Time to Complete; UB = Upper Back; VO2 Max = Aerobic Power; VJ = Vertical Jump; WPPE = With Personal Protective Equipment.

DISCUSSION

The aim of this systematic review was to identify, collect, and synthesize research investigating the impacts of duty belts and their load placements on LEOs. Ten studies met the criteria to inform the review and were critically appraised, yielding a mean quality score of 79.8%, which constitutes a grade of 'good' quality. The trend of the volume of data presented in this review suggests that police officer duty belts and their associated loads can have a variety of negative impacts on the officer's ability to perform occupational tasks and movement. Further, where this load is placed, be it on the duty belt or the torso, can influence these impacts.

This review found that officer duty belts and their added loads can negatively affect a LEOs ability to perform occupational tasks. Measures of strength, power, and agility were reduced when officers wore their duty belts and specialized equipment, both in general and while conducting occupational tasks (Marins et al., 2019). Likewise, VO_{2max} (absolute and relative),%HRmax, rate of perceived exertion (RPE), and respiratory exchange ratios were all found to increase when officers wore their duty belts and equipment (Dempsey et al., 2013). Ehnes et al. (2020) conducted a study with a civilian population (who were comparable to those the police recruited) where they compared a similar unloaded and loaded condition (10.3 kg inclusive of: undergarments, concealable body armor, patrol uniform, duty belt with appointments). In that study, Ehnes et al. (2020) found duty belts and associated loads likewise negatively impacted $VO2_{peak}$, RPE, and peak power output. Interestingly, a study by Thomas et al. (2018) both supports and refutes the research in this review. In their study of simulated tactical tests with specialist police, Thomas et al. (2018) found no significant differences in relative heart rate or RPE. However, Thomas et al. (2018) did find reductions in task efficiency when performing climbing, agility, crawling, sprinting, and shooting, door breach, victim rescue tasks, as well as overall course time, when officer's wore their duty belts. These findings by Thomas et al. (2018) of reduced task performance are not unsurprising when noting the work by Kukic et al. (2023) who found that carrying loads as light as 5 kg can have a negative impact on police officer performance. Further, both Holewun and Lotens (1992) and Billing et al. (2015) suggest that for every 1 kg of load carried on the body, physical performance is reduced by approximately 1%. As police officers can wear and carry loads on their duty belts and bodies more than 5 kg (Baran et al., 2018; Lewinski et al., 2015), reductions in task performance are not unexpected. These impacts can be seen practically, where evidence presented in this review highlights the work of Marins et al. (2019) who found that VO_{2max} (relative and absolute) did not differ significantly when officers performed their OPAT dressed in their NPPE (1.5 kg load). However, there were significant differences when officers wore their ballistic vest and duty belt with appointments (8.1–8.3 kg) (Marins et al., 2019). These findings by Marins et al. (2019) emphasize the importance of aerobic fitness for LEOs who have to carry load, a requirement noted in wider policing (Robinson et al., 2018) and the military (Orr et al., 2021).

With the volume of evidence suggesting reductions in task performance associated with this occupational equipment, concerns are raised as reduced task performance may not only lead to injury (Moore, 2001) but even, at the extreme, loss of life. For example, duty belts and associated load weights can reduce police officer agility (Marins et al., 2019) and sprinting speeds (Lewinski et al., 2015), as well as their ability to exit, pivot, and accelerate from a low car seat (Dempsey et al., 2013). Unfortunately, in some countries, like the USA, LEOs are at risk of deliberate ambushes while in a vehicle (Werling et al., 2019). Thus, with the ability for an officer to move quickly to cover being reduced, their vulnerability to weapons fire is increased and, as such, their risk of being shot (Billing et al., 2015).

While the above represents an extreme, the risk of injury imparted by duty belts and their loads is present. The evidence in this review highlights the increased levels of discomfort reported by officers being associated with their worn duty belts while seated in vehicles. Larsen et al. (2019) and Filtness et al. (2014) utilized the ASDQ to evaluate LEO discomfort in vehicles, with the officers reporting that duty belts were the primary cause. These findings were supported by Gruevski et al. (2016) who found the duty belt and appointments were perceived as the most uncomfortable equipment worn by officers throughout an eight-hour shift. Further research found 88% of officers (n = 974), participating in a study on LEO vehicle and equipment design, reported pain and discomfort at the end of a shift, with these complaints again associated with the duty belt (Hsiao, 2023). Both studies investigating the areas of most discomfort associated with duty belts in this review identified the hips and lower back to be the most often reported bodily site of this discomfort

(Filtness et al., 2014; Larsen et al., 2019). These results (Filtness et al., 2014; Larsen et al., 2019), whilst reporting on discomfort, serve as a precursor to injury with discomfort a precursor to pain (Larsen et al., 2019). These associations are highlighted when the sites of discomfort reported by Larsen et al. (2019) and Filtness et al. (2014) are considered against the findings by Cardoso et al. (2017) who concluded that long durations seated in right sided configured vehicles (the side noted as having the greatest reduction is trunk lateral bending (Ramstrand et al., 2016)), contributed to lower back pain of LEOs.

It is important to consider the impacts of wearing duty belts on LEOs in vehicles as research suggests approximately half of an officer's shift is spent in a vehicle or performing other seated tasks such as paperwork (Cardoso et al., 2017; Hsiao, 2023). Officers who regularly spend long durations seated with excess weight around the waist, are postulated to experience cumulative spinal loading which is a known contributor to lower back pain (Cardoso et al., 2017). In addition, carrying appointments on the duty belt and resultant maladaptive ergonomic positions when seated in a police vehicle across police populations can increase lower back injury risk (Filtness et al., 2014; Larsen et al., 2019). Thus, when the additional load and poor driving posture is added to whole-body vibration, which is already a known cause of backpain in professions which include a lot of vehicle driving (e.g., cab and delivery drivers) (Pickard et al., 2022), it is not unsurprising that officers may suffer from a high amount of lower back injuries (Gyi & Porter, 1998; Jahani et al., 2002). This supposition is supported by Burton et al. (1996) who noted that officers who were exposed to either vibration or increased time wearing heavy body armor had an increased lower back injury incidence rate when compared to other officers.

Considering the findings by Larsen et al. (2019) and Filtness et al. (2014) as well as the broader research (Burton et al., 1996; Cardoso et al., 2017; Gyi & Porter, 1998; Jahani et al., 2002; Pickard et al., 2022), research exploring alternative mounting options of appointments for officers, especially when in vehicles, is warranted (Filtness et al., 2014; Larsen et al., 2019), especially given the findings of Larsen et al. (2019) who identified differences in vehicle seat contact pressure of LEOs depending on which configuration (duty belt with appointments versus duty belt with some appointments on a load bearing vest) they wore. Campbell et al. (2013), in their study comparing a hip or a thigh holster for the officer's sidearm, found no significant differences in response time, fire position, variability, or draw success rate in officers who wore their sidearm on their duty belt at the hip or on their thigh. As such, for officers who spend long periods in a vehicle, wearing a load bearing vest may reduce seat contact pressure in the lower back (although potentially increase pressure in the upper back) while using a thigh holster attached to their duty belt may improve comfort in the seat while not negatively impacting marksmanship (Larsen et al., 2019). This supposition is partially supported by the findings of Hua et al. (2015) who observed fewer officers who wore a load bearing vest and thigh holster requiring physiotherapy treatment for lower back injuries.

Just as LEOs spend a significant amount of time in seated positions, they likewise can spend long periods standing (Anderson et al., 2001). The evidence presented in this review suggests that static standing balance was negatively impacted when LEOs wore their duty belt and affixed appointments (Dempsey et al., 2013; Shim et al., 2023). The degree to which balance is impacted may, however, depend on where the load is placed. For example, with loads of over 9 kg (noting the standard LEO load of around 10kg (Baran et al., 2018), Park et al. (2014) found that uneven distribution of an officer's load negatively impacted on their static body balance by increased postural sway and asymmetry of load bearing in the feet. It should be noted that the study by Park et al. (2014) was done with various load bearing vests and did not include a duty belt and, as such, it is not surprising that the findings align with research conducted in military personnel wearing packs (Orr et al., 2021; Taylor et al., 2016). These impacts warrant consideration as the lower limb injuries are a concern for LEOs with slips, trips and falls being a leading mechanism of injury (Lyons et al., 2021), a mechanism whose risk factors include poor balance and wearing equipment (Kong et al., 2013). Apart from impacting balance, military research also suggests that increased loads can impact the wearer's gait patterns (Orr et al., 2021; Taylor et al., 2016).

Two studies in this review reported significant changes to gait kinematics, notably at the hip, trunk, knees, and ankles when officers wore duty belts with or without load bearing vests (Larsen et al., 2016; Ramstrand et al., 2016). With a hip holster attached to a duty belt on the right side Ramstrand et al. (2016) found greater hip abduction / adduction to the right. Conversely, Larsen et al. (2016), although finding an increase in peak moments with hip abduction / adduction to the left with standard (hip holster), failed to find any significant differences in hip abduction / adduction (left or right) regardless of duty belt and load configuration. Larsen et al. (2016) also found greater hip rotation and knee abduction / adduction to the right in both stance and swing phases of gait, movement patterns associated with a circumduction movement pattern of the hip, when using a thigh holster as opposed to a hip holster (Larsen et al., 2016). This pattern would suggest that the movement pattern of the hip and knees were compensation for load on the right thigh. Further, while no significant differences were found between load conditions for spatiotemporal factors (e.g., stride length and frequency), trunk rotation was found to be greater in both studies (Larsen et al., 2016; Ramstrand et al., 2016) when compared to the conditions without duty belts and equipment with increases in peak moments and power increases at the ankle also noted (Larsen et al., 2016).

Previous literature suggests that this reported reduction of range of motion and peak moments (Larsen et al., 2016) may lead to further biomechanical alterations to gait patterns with the addition of further load (Kasovic et al., 2023; Walsh & Low, 2021). As such, it would not be unexpected that alterations in gait caused by duty belts may increase the risk of injury by these mechanisms. Finally, with foot patrols a critical task for general duties officers and many police officers in general (Mugari & Thabana, 2018), these impacts of duty belts and associated accoutrements on gait, can be expected to impact these officers on a daily basis throughout their occupational lifespan.

While impacts on gait are important, LEOs are often required to pursue suspects on foot, requiring them to jump over and negotiate various obstacles (e.g., a fence) (Marins et al., 2018; Silk et al., 2018). Both Dempsey et al. (2014) and Wiley et al. (2020) examined the impacts of duty belts and external loads on the outcomes of vertical jump performance. Both studies concluded the addition of duty belts resulted in a decreased jump height of LEOs (Dempsey et al., 2014; Wiley et al., 2020). While the vertical jump height decreased, lower leg power increased significantly in the group carrying additional load (Wiley et al., 2020). Thus, the officers worked harder but achieved less height in their jump, suggesting that the decreases of power performance (i.e., jump height) was a result of their equipment and not the officer's ability to generate power. When landing, Dempsey et al. (2014) found peak landing ground reaction forces were increased by up to 19% with the addition of the duty belts and loads. These findings by Dempsey et al. (2014) and Wiley et al. (2020) are comparable to a study within a firefighter population which found increases in vertical ground reaction forces and decreases in squat and countermovement jump height using force plate data (Miratsky et al., 2021) findings also identified in military populations (Birrell et al., 2007; Kinoshita, 1985; Lloyd & Cooke, 2000). These biomechanical alterations can lead to cumulative stresses which increases the risk of musculoskeletal injury (Birrell & Haslam, 2008; Knapik et al., 1992; Orr et al., 2021; Park et al., 2008; Polcyn et al., 2001) notably to the lower limbs (Lyons et al., 2021).

This study is limited by the low number of studies published within this area and by a language bias. Future research should, where possible, include searches of non-English databases (e.g. China National Knowledge Infrastructure) and include studies written in languages other than English to ensure a comprehensive understanding of the impacts of load placement on law enforcement officers. In addition, a comparison of equipment types and load distribution as well as profiling injuries caused by this load and equipment would be of value.

CONCLUSIONS

Based on the 'good' methodological quality of included studies informing this review, the volume of evidence suggests that LEO duty belts, their affixed equipment, and the loads imparted by their equipment have a negative impact on measures of strength, power, and agility both in general and while conducting occupational tasks with these impacts varying depending on load carriage configurations (e.g., lead bearing vests, hip versus thigh holsters, etc.). Consequently, this reduced performance increases the risk of injury to the LEO and can potentially lead to fatality in extreme situations (e.g., vehicle ambushes). General injury risk is increased by the negative impacts of this equipment on balance and changes to gait given slips, trips, and falls are a leading mechanism of injury in LEOs. Furthermore, with discomfort a precursor to injury, increased discomfort imparted by duty belts when officers were seated in vehicles raises concerns. Future research should be directed towards the belt design, impacts of duty belts and their associated appointments, as well as optimal equipment distribution given the limited research currently available.

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