Title: What are the Interventions Affecting Manual Handling Injuries in Frontline Pre-hospital Clinicians?

Abstract

Background and purpose: A literature review to investigate the effects of manual handling interventions and equipment on musculoskeletal (MSK) injuries and disorders in pre-hospital clinicians.

Methods: The search included articles published in CINAHL Plus, AMED, MEDLINE, Academic Search Complete, PubMED, Scopus, Science Direct, Web of Science, PEDro, Cochrane and PsycINFO. There was no date limit set for the search, and a grey literature search was also conducted.

Results: The review included 10 studies that investigated a variety of manual handling equipment: powered loading stretchers, lifting straps, slip preventers and binder-lift attachments. No interventions such as manual handling, strength or ergonomic training was found. Despite the varied quality of studies, all were included due to the lack of research available in this topic and the original topic of this review.

Discussion: Overall, powered stretchers and loading systems were directly correlated to lower MSK injuries, with the other pieces of equipment such as lifting straps being related to a lower risk of MSK injury. The poor ergonomics of ambulance design and equipment placement were also linked to a higher risk of MSK injury. Current research is severely limited in this area and future studies should include multi-variate interventions to modulate MSK injuries and the risk thereof in this high-risk group of clinicians.

1. Introduction

Musculoskeletal disorders (MSDs) are a major contributor to disability and poor health worldwide. The Global Burden of Disease (GBD) 2019 data shows that 1.71 billion people suffer from MSDs, with this overall burden leading to 149 million Years Lived with Disability (YLDs) – the biggest contributor overall (IHME, 2020). Secondary data analyses of the GBD study have highlighted occupational risk as a significant contributor, higher than tobacco use or elevated BMI (Liu et al., 2022). What is more, other analyses have observed a significant increase in the YLDs from 77 million to 103 million between 2000 and 2015, postulating a significant correlation between GDP per capita and MSD disability-adjusted life years, with the highest proportion in Europe and the Americas (Sebbag et al., 2019). In the UK, a significant report by Versus Arthritis highlighted that almost 32% of the UK population suffer from MSDs – 20.3 million people (Versus Arthritis, 2021). Further, the Office for Health Improvement and Disparities (OHID) reported that in 2018, 17.1% of adults reported a long-term MSD, increasing from 15.4% in 2015 (OHID, 2022). The overall impact is significant, with 10.5% of all sickness absence in the UK due to MSDs contributing to the highest sickness absence rate and working days lost in recent years – 185.6 million working days lost and 2.6% total working hours lost across the UK (ONS, 2023). A report by the Health and Safety Executive (HSE) observed the causes of MSDs in workers and presented that 740/100,000 workers reported Manual Handling as a key factor (HSE, 2022). Furthermore, heavy lifting and material manipulation factored at 28% and 19% of all work-related MSDs (HSE, 2022). Healthcare workers have been historically documented to suffer from MSDs: prevalence ranges from 65.8% (Karaham et al, 2009) and 43-78% (Shaikh et al., 2021) with reports of low back, neck and shoulder pain being the leading site and nursing the highest reported profession. Notably, a qualitative study highlighted that nursing respondents found risk factors relating to their injuries were unanticipated sudden movements or falls by patients, lifting or transferring patients, repetitive tasks and bending/twisting (Yasobant and Rajkumar, 2014). Despite the paucity of primary research in paramedicine, Coffey et al. (2016) investigated the physical demands and found that: stretcher loading or unloading, carrying equipment and pushing/pulling the stretcher were the most physically demanding tasks; and that paramedics may lift/raise/lower the stretcher almost 40 times in a shift. This combination of repetitive tasks, lifting and pushing/pulling are all high-risk factors for injuries in the paramedic profession. In Australia, Roberts et al. (2014) found that paramedics had a 13 times higher risk of lower back injury that nurse professionals. Despite similar studies not being carried out in the UK, the NHS Staff Survey presents clear data: 42.7% of Ambulance Service responders report MSK problems compared to the 30.2% National Average; what is more, 64.9% of Ambulance Service responders also presented to work despite not feeling well enough to do so, compared to the 56.6% average (NHS Staff Survey, 2023). In 2016, the HSE has given guidance for employers to review working conditions and environments and help employees with an ergonomic approach to manual handling: adapting environments, providing adequate equipment and manual handling courses – with profession-specific approaches being recommended, depending on the tasks and environment required (HSE, 2016). Previous studies in this field have highlighted how inter-disciplinary Manual Handling training may be beneficial to decrease injuries (Garzillo et al., 2020). Another recent literature review considering MSDs in healthcare workers overall observed how providing equipment and training, enabling peer-to-peer coaching and promoting ergonomics have all been observed to reduce manual handling injuries (Wåhlin et al., 2021). Within the paramedic context, there has been limited research and no literature review to summarise the evidence base in this area to date.

2. <u>Methods</u>

The author utilised sections of the Cochrane Book for Systematic Review of Interventions (2022) for the research question formulation and initial literature search phases, later assessing, analysing and reporting on the data pool. Due to this piece of work being carried out by one researcher, it did not meet the inclusion criteria for a systematic review, but a high level of transparency is provided. A PICO approach (Table 1) was initially used to structure the research question and list the inclusion and exclusion criteria (Eriksen and Frandsen, 2018).

Table 1. PICO approach

Population or problem	Ambulance personnel or trainees
Intervention	Workplace manual handling interventions or equipment
Comparison	Any or none
Outcome	MSK symptoms, injury, symptoms, work status, absenteeism, presenteeism.

The literature search sought to retrieve all articles without time limits. The strategy initially sought to explore EMBASE, Web of Science and Google Scholar due to the 98.3% recall rate of this combination as demonstrated by Bramer et al. (2017). However, this list expanded in to the final 11 databases due to a lack of access (EMBASE) and un-reproducible searches (Google Scholar): CINAHL Plus, AMED, MEDLINE, Academic Search Complete, PubMED, Scopus, Science Direct, Web of Science, PEDro, Cochrane and PsycINFO. (Appendix A). Grey literature search included Google Scholar and websites such as the Health and Safety Executive, Institution of Occupational Safety and Health, British Safety Council, and the European Agency for Health & Safety at Work. The Boolean Operator 'AND/OR', acronyms, wild cards and alternative spellings were all utilised. Due to the limited results of initial searches, the operator 'NOT' was excluded in the final iteration.

a. Selection of studies: Eligibility criteria

Inclusion Criteria

The primary criterion was the population tested forming part of the ambulance service – with paramedics, emergency medical technicians (EMTs), fire-fighters and medical co-responders and other associated professionals including students. Participant's age ranged between 18 and 64 (OECD, 2023) and all genders were included. Interventions associated with manual handling training, equipment could be conducted in individual studies, at group or service level with no limitations on the

MSD presentation or duration. There had been no previous reviews of the literature, hence a time limit was not set.

Exclusion Criteria

Primarily not included in the review were studies concerning non-ambulance professionals or patients. Studies which did not evaluate an intervention or did not observe the MSK injury or risk were also not included. Reports, guidelines, policies, opinion pieces, editorials and recommendations were also not included in this review. A summary of the above can be found in Table 2.

Table 2 – Inclusion and Exclusion Criteria

Participant Inclusion Criteria	**Participant Exclusion Criteria**
Working age (18 to 64)	Non-ambulance service personnel
Ambulance service personnel, EMTs, fire-fighter co-responders or students	No intervention evaluated
Work-related MSDs, MSK symptoms or risk of MSK injury	No MSK injury or risk evaluated
Individual, group or service-level interventions	Reports, guidelines, policies, opinion pieces, editorials and recommendations
Interventions focused on managing MSD risk or injuries	
Primary research, audits and literature reviews	

b. Outcome

The review's intended outcomes were to identify the interventions or equipment, evaluate the effect and subsequent participant self-reported MSK state, symptoms, pain severity, presenteeism or sickness absence at service-level post intervention or introduction of equipment.

c. Data Collection

The identified studies were initially collated at Title and Abstract level, with duplicates being removed at this stage. Following this, the Rayyan web app was utilised to streamline the Study Selection process (Ouzzani et al, 2016). The individual study characteristics included design, country, participant details, intervention type, outcome measures and results.

d. Risk of bias assessment

Critical appraisal is an essential skill to inform decision-making in clinical contexts (Mhaskar et al., 2009). However, many published critical appraisal tools show great variability in application, context and guidelines – this limits the generalisation of one critical appraisal tool and emphasises a study-specific approach (Katrak et al., 2004). Despite the lack of a consensus, research has shown that the Clinical Appraisal Toolkit (CAT) developed by Moralejo, Ogunremi and Dunn (2017) can be promising for Healthcare professions. However, a more recent review of the available pool of critical appraisal tools by Ma et al. (2020) did not include it, but highlighted how the Scottish Intercollegiate Guidelines Network (SIGN) can be used for a variety of studies – including cohort studies and RCTs. Therefore, the SIGN checklists and explanation sheets were used for this review – specifically the Cohort Study and Literature Review tools. The overall assessment of the 'reliability' and 'strength' of the papers is rated with grades of '(+) acceptable', '(++) high quality', '(-) low quality', or '(0)' unacceptable/reject'.

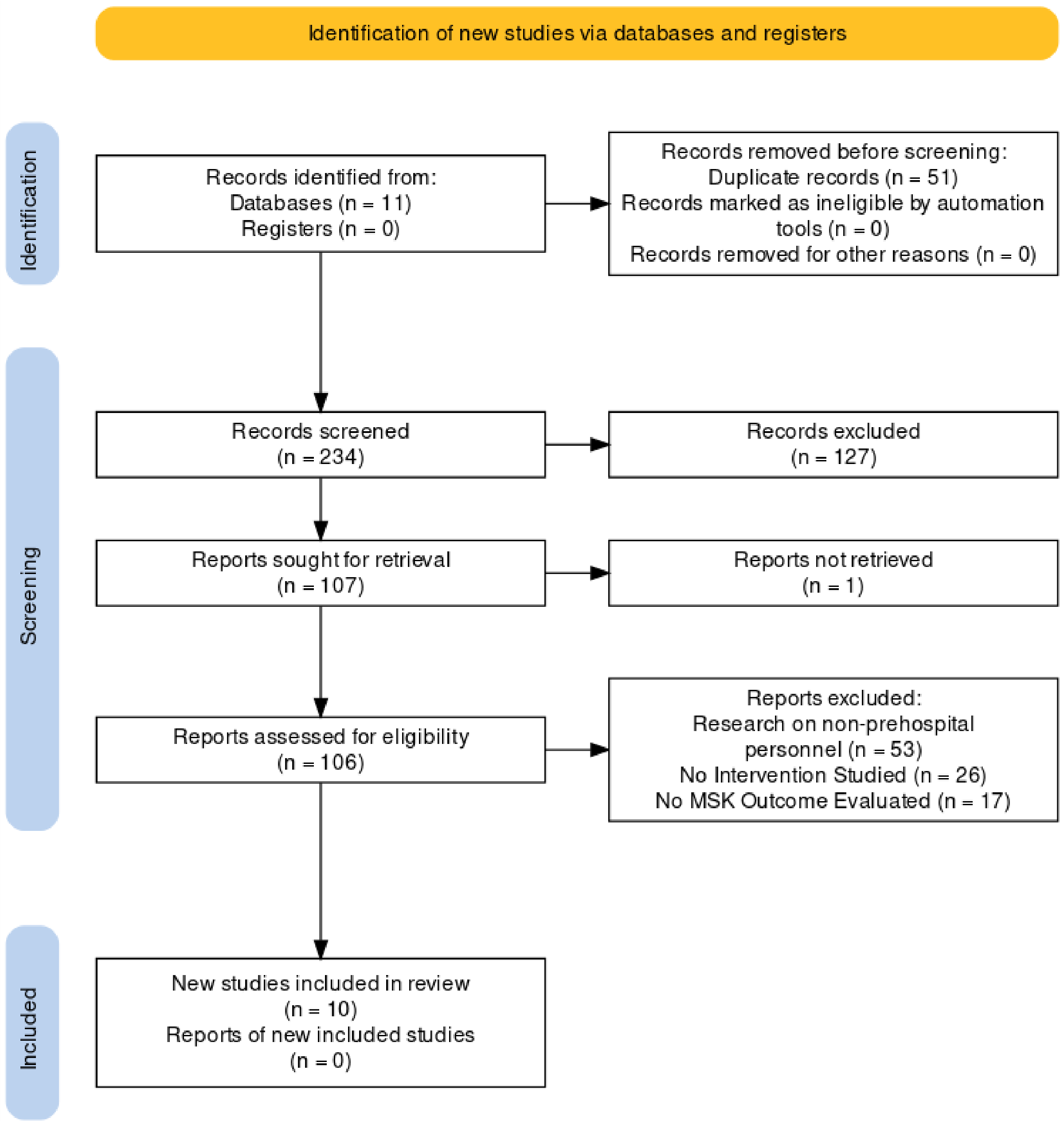
3. Results

a. Selection of Studies.

The search identified a total of 285 references: 17 references from CINAHL Plus, AMED and MEDLINE, 8 from Academic Search Complete, 24 from PubMed, 166 from Scopus, 31 from Science Direct, 35 from Web of Science, 1 from PEDro, 1 from the Cochrane Library and 2 from PsycINFO. 51 duplicates were removed and 234 references remained. The titles and abstracts were reviewed and a total of 107 records were sought for full-text reading, with only one not being able to be retrieved. The large pool of references removed were due to studying clinical and patient MSK injuries, and evaluating training or interventions related to patient care. Out of the 106 articles following full-text reading, only 10 were included in the review due to others not meeting the inclusion and exclusion criteria. A hand searching of the reference list was also undertaken, with no further satisfactory papers being found.

Ultimately, the search identified 10 final studies to be included in the review. A PRISMA Diagram summarising this can be found in Figure 1.

Figure 1 – PRISMA Diagram (Haddaway et al., 2022)



b. Study Characteristics

Four of the studies were conducted in Canada, three in the United States, one in Sweden, one in Israel and one study was fully digitalised. 6 of the studies followed a primary intervention cohort study approach, with two being retrospective cohort studies based on available data, one simulated cohort study and a systematic review. All studies had been granted ethical approval from their respective committees and had clear declarations of interest. Most cohort studies clearly declared their inclusion and exclusion criteria and the participant data. However, only three studies detailed the participants' ages, only four the participant's characteristics (weight, height) and only four the participants' work experience.

c. Quality Appraisal

The quality of evidence for each paper was assessed using the SIGN appraisal tool for Cohort Studies and Literature Reviews. 6 studies were found to be 'Acceptable' and 4 studies to be of 'High Quality'. Despite the lack of randomisation, studies demonstrated comparable cohorts amongst intervention groups in terms of age. Some studies went further and stated the height and weight of participants and even of the manikin or actors used in the interventions, yet this was not the case for all papers. Drop-out rates were minimal throughout, with only one participant dropping out of the Karlsson et al. (2016) study overall. Patient outcomes were analysed in all cases with clearly published statistical data and confidence intervals, though exposure levels were only assessed more than once in three cases. A summary of this evaluation can be found in Table 3 (Appendix B).

d. Outcomes Observed

The outcomes studied in this review varied from Spinal Loading and Biomechanical Exposure to calculating Trunk rotation and joint angles with one study (Harari et al., 2020) including the Rapid Entire Body Assessment (REBA) score of the participants during the study. Other studies explored the number of occupational injuries pre and post intervention. One study measured EMG Muscle activation (Xu et al., 2021) and another observed Heart Rate (HR) and salivatory cortisol levels (Karlsson et al., 2016). The literature review by Du et al. (2019) was included due to having an effective summary of the general ergonomic design features of EMS equipment and the results from the 'patient handling' or 'patient transport' were not included in this review. Lastly, one particular study (Potvin and Potvin, 2019) dealt with a simulated intervention with a cohort of only 3 participants based on the percentile weights and heights of ambulance staff and presented simulated data only. This was included to the need for simulation-based prehospital research due to the lack of evidence, both in this workplace-level based interventions and in patient-facing studies (Söderholm et al., 2019). A brief summary of the included articles' characteristics and results can be found in Table 4 (Appendix C).

4. <u>Results and Discussion</u>

a. Powered Stretchers and their effect

In total, three studies directly observed the effect of ambulance service stretchers, cots and loading systems, with one being a work simulation study with a virtual simulation. Furthermore, two retrospective cohort studies explored how introducing powered stretchers lowered occupational injuries in the respective services.

Prairie et al. (2015) carried out a cohort study with 58 active-duty participants in a 78% to 22% male to female ratio, recording 34 day and 24-night work shifts and their respective field loading of hydraulic stretchers (Stryker) into ambulances. With the use of a dynamometer and the stretcher's measurements, calculations estimating the moment arms applied throughout the lifts were also carried out (Prairie et al., 2015). With a total of 258 lifts observed, it was found that the average compression and shear forces applied to the L5/S1 were 3884 +/- 838 N and 549 =/- 101 N with over 71% exceeding the compression limit, but none exceeding the shear limit; it was also found that when solo lifting was carried out, the compression limit was always exceeded (Prairie et al., 2015). What is more, the results showed that other equipment loaded onto the stretcher accounted for between 0-14% of the lifting force, whereas the weight of the patient represented between 24-70% of the lifting force (Prairie et al., 2015). Despite this variety of lifts and data, the wide confidence intervals that are clearly stated limits it's use overall – yet still present an impactful picture of the demands of regular paramedic activities.

Armstrong et al. (2020) observed 20 active-duty participants with 13 males and 7 females with outlined experience and body composition across categories. The intervention had participants raise a manual stretcher (Ferno) onto a 75cm tall platform (approx. floor height of an ambulance), raising the handles from 50cm to

90cm. The lowering task had participants lowering the stretcher with its handles from 90cm to 50cm and the lifting task implied two participants lifting a rescue manikin on a scoop board (Ferno) – the manikin used weighed 75kg (Armstrong et al., 2020). The participants completed each task three times, switching roles as to being at the 'head' or 'foot' of the stretcher or scoop, respectively – these activities were recorded via three-dimensional motion capture and with in-ground force plates (Armstrong et al., 2020). The data showed that all activities exceeded mean peak compression of the spine as per the National Institute for Occupational Safety & Health (NIOSH) Guidelines, and all tasks except lowering the stretcher from the foot end also exceed the NIOSH maximum permissible limit; mean peak low AP shear force did not exceed 1000 N for any task; stretcher raising at the foot end and head end also had the highest probability of being a high-risk task, with lowering the stretcher having the lowest risk of all tasks studied (Armstrong et al., 2020). The risks were calculated based on the measured load, the exposure level of paramedics to these tasks and the measurements of the equipment used, employing the Lifting Fatigue Failure Tool (Armstrong et al., 2020). With a full presentation of data and the confidence intervals, this study proves valuable to this review with the small cohort size and short duration being a limiting factor.

Potvin and Potvin (2019) ran simulations with participants at 50kg (female), 72kg (female) and 125kg (male) lifting manual and powered stretchers (Stryker) with no patient, a patient of 125kg and a patient of 159kg. Measurements of weight and sizes of the manual and powered cots were performed live, before the data was inputted in a digital human model and simulation program. Three scenarios were postulated with a manual stretcher and loading (1), powered stretcher and manual loading (2), powered cot and loading (3), and with each being carried out by one or two of the simulated participants (Potvin and Potvin, 2019). The available data is extensive, but comparable figures to other studies can be obtained by observing the Lumbar Compression Force and Shear Force. For the tasks evaluated, single manual loading of an empty cot for the 50kg female participant showed a compression force of over 2,000 N, with the figures reaching up to 9,311 for the single 125kg male participant loading a manual cot solo with a 159kg patient (Potvin and Potvin, 2019). More data shows that with a 125kg patient, double lifting of a powered stretcher that has be manually loaded leads for lumbar compression forces of up to 5,304 N in the simulated 125kg male participant and of 2,809 N in the simulated 50kg female participant; however, the single operation of a fully powered (lifting and loading) stretcher shows a lumbar compression force of only 1,807 N in the simulated 50kg female participant and a shear force of 222 N (Potvin and Potvin, 2019). This study is unique in how it offers the opportunity for rare, yet possible, situations to be simulated: a high BMI patient having to be transported by a 50kg female or 72kg female crew is not uncommon in practice from the author's experience in this field. The dramatic reduction in estimated compression and shear forces with fully automated systems is however significant, though the digital simulation aspect of this study severely limits the value of the data.

Studnek et al. (2012) retrospectively evaluated data from 01/01/1999 and 31/12/2006 to the period between 01/01/2007 and 30/04/2008 after an urban EMS system introduced electrically powered hydraulic stretchers but not loading systems (Stryker) in December 2006. Overall, a damning 52.9 injuries per 100 Full Time Equivalents (FTE) across the almost 10 years of observation, with an injury rate of 61.1/100 FTE pre-intervention compared to 28.8/100 FTE with a RR of 0.43 following this (Studnek et al., 2012). There was significant decrease in all types of injuries from strain/sprains, back/neck/knee injuries, back injuries only and stretcher injuries only – with the latter reducing from 6.56/100 FTTE to 1.98/100 FTE post intervention (Studnek et al., 2012). This data is significant and provides good evidence for the use and implementation of powered stretchers, though the lack of a control group, the retrospective design and particularly the likelihood of other multi-faceted safety practices – as recognised by the authors – across the 10 years evaluated could have also influenced the results. This limits the reliability of this data, though the significant reduction is still notable.

Armstrong et al. (2017) also evaluated injury data from two paramedic services pre (four years) and post (one year) the implementation of both powered lifting and load stretcher systems (Stryker) in the Niagara Emergency Medical Service (NEMS), with the Hamilton Paramedic Service (HPS) being used as a control group with no powered stretcher or loading system. This study found that implementing powered stretchers significantly reduced MSDs and stretcher-related MSD incidents in the year of implementation and year after implementation; prior to implementation stretcher-related MSDs averaged 20/100 FTE and 17.9/100 FTE in the respective services, with figures lowering to 4.3/100 FTE in NEMS but raising to 24.6/100 FTE in HPS as the control group (Armstrong et al., 2017). Despite the retrospective nature of this study, the similarly staffed and demand-based services, the clear presentation of data and statistical interpretation strongly support the implementation of powered loading systems for significantly reducing MSDs (Armstrong et al., 2017).

b. Other lifting equipment and its impact

A further three studies explored the variety of other types of equipment that have been or could be introduced to frontline ambulance operations. Firstly, the same Armstrong et al. (2020) as above also observed how scoop lifting at the head end showed the highest resultant low back compression, the highest estimated cumulative damage per work shift and exposed paramedics to greatest peak AP shear.

Lavender et al. (2020) studied four devices during two-person lifting, exposing fourteen professional fire fighters - medical co-responders in the service area they operate in - with only one female participant and reported participant characteristics and patient weights – between 91 and 103kg. Initially, a focus group was carried out to identify priorities when dealing with realistic situations in patients' houses and what are the difficult manual handling operations during daily working activities (Lavender et al., 2020). Using EMG data and an optical motion capture system the researchers measured spinal loading and muscle use during: lifting a patient from a bathroom floor to a chair, from a recliner and from a simulated inflated seat without any equipment, with a Binder Lift (a device which envelops the patients' torso allowing for handles to be placed along their body) and with a Simple Strap (a strap that goes under the patient's armpits and along their upper back allowing for the hard plastic ends to be used to lift from either side of the patients' torso); the second lifting task explored raising a patient from supine on the floor with a standing position with no equipment, with a Binder lift, and both with or without a Slip Preventer - a fabric pouch with elongated ends that is placed over the patient's feet, with the ends being held on the floor by the paramedic team, therefore preventing feet slipping during lifting (Lavender et al., 2020). After a short instructional video, a total 18 lifts were performed for the first task (3 tasks x 3 types of equipment x 2 reps) and 8 for the second (2 types of equipment x 2 Slip Preventer usage x 2 reps) – the types of equipment, the participants and the sequence of lifts were randomised throughout the experiment (Lavender et al., 2020). Within the first batch of tests, L5/S1 anterior shear forces of over 1000 N were observed for lifting from the recliner and from the bathroom floor of up to 1700 N with no equipment- the use of the Simple Strap however reduced these figures to only 500 N for the first and 1100N for the latter (Lavender et al., 2020). What is more, peak L4/L5 spine compression forces were highest with no equipment at 7000 N and remained just below 6000 N for all other devices throughout the lifts; participants also subjectively rated that using the Simple Strap and binder lift made the task mostly ‘A Little Easier’ in all combinations during the first batch of testing (Lavender et al., 2020). Whilst the Slip Preventer did not affect results, the use of the Binder Lift when lifting a patient from supine to standing reduced L5/S1 anterior shear forces from 1500 N with no equipment to 1300 N (Lavender et al., 2020). Whilst the participant cohort is small and the tests limited in repetitions and scope, this study does provide some statistically significant data with clear indications that both the Binder Lift and the Simple Strap are both efficient ways of improving manual handling.

Xu et al. (2021) also explored the use of a strap (a textile strap that is placed under the patient’s shoulders, then bound at the front of the torso in order for it to be pulled on during lifting) in 15 participants – 13 males and 2 females with declared demographics – alongside three actor-patients – with weights between 64 and 68kg, in which a participant carried out a two-person lift alongside a researcher to minimise the risk of injury to participants and to provide instructions during the lift. EMG electrodes and motion capture sensors and cameras were used to evaluate lifting a patient from supine on the floor to standing using no equipment and the strap method, in 3 different environments – an open space, a hallway and a bathtub; this was repeated three times with a 2 min rest period between trials; later, participants were asked to subjectively rate the difficulty with a similar scale to Lavender et al. (2020) (Xu et al., 2021). Calibration of the EMG data followed a set pattern for all participants with detailed instructions for both placement and testing of Maximal Voluntary Contractions (MVCs) for biceps, erector spinae, latissimus dorsi (Xu et al., 2021). In the open environment, despite reduced torso, spinal, sacrum flexion and spine lateral bending, the %MVC used was raised by the strap from 12% to over 30% for Biceps and 20% to over 35% for Erector Spinae, though reducing from just under 25% to just over 10% for Latissimus Dorsi (Xu et al., 2021). Similar changes were observed in all other scenarios, with significant increases in %MVC in Biceps during Strap Lifting from both the hallway and bathtub, an increase in Erector Spinae use with Strap Lifting from the bathtub; in both scenarios, using the Strap decreased Latissimus Dorsi activation significantly – the highest reduction in the Hallway from 35% with no equipment to just under 10% using the Strap (Xu et al., 2021). Despite this exertion, using the strap was favoured between 'A Little Easier' or 'Much Easier' by most participants in all scenarios; with the logistics of using Strap favouring elbow and shoulder flexion and by engaging the body in a pulling motion, the authors postulate this may reduce overall passive tissue spinal load due to a reduction in flexion during movements (Xu et al, 2021). Despite the small cohort and small scale of the study, the clear presentation of data and clarity in outcomes allow for these results to be valuable for this review.

Karlsson et al. (2016) also explored the use of a lifting strap with 20 participants – 14 men and 6 women, with well-defined demographics – carrying a hand-held stretcher and a dummy (112 kg total) for 400m as a double team, switching positions at 200m over a flat terrain. On two different days, participants carried this with no equipment and with the use of a Shoulder Strap (a long textile strap that is placed in between the palm and stretcher handle, and the middle over the neck/shoulder area to provide further support from the torso during carrying) – the researchers then measured HR at every 15 seconds throughout the salivary cortisol collection times at 0, 15, 30, 45 and 60 minutes (Karlsson et al., 2016). For most participants, the use of shoulder straps not only reduced the total amount of salivary cortisol and peak HR, but also sped up the return to baseline resting HR and salivary cortisol in 18 out of 20 participants; the HR data suffers from very wide confidence intervals, yet the salivary cortisol data is clearly presented as being significant despite the wide variety in data – e.g. in Males, salivary cortisol peaked at 20.5 (12.4-31.2) nmol/L without the strap and at 15.7 (10.2-23.5) nmol/L with the strap (Karlsson et al, 2016). Despite this limitation and the small scale of the study, this paper provides a new perspective on the use of manual handling equipment that adds value to this review.

c. Ergonomics of lifting and equipment

The literature search found one small scale cohort study and the literature review concerning ergonomics and equipment placement within the prehospital environment.

Harari et al. (2020) approached 24 participants (12 males and 12 females with no declared demographic data and of which some were students), placed into 12 teams of two participants with each team performing two simulations of CPR lasting 10 minutes and comprising of the expected chest compressions, bag valve-mask ventilation, defibrillation and drug administration. The equipment consisted of an air-way bag, a medication bag, a monitor-defibrillator and an oxygen tank, in which the teams' working tactics in manoeuvring around a simulated bedroom, with a focus on equipment placement; these were observed with video cameras from multiple angles and estimated biomechanical loads using the equipment's weight and the recorded angles/distances over which the participants lifted them (Harari et al., 2020). What is more, the researches also calculated Rapid Entire Body Assessment scores using the video recordings to provide a risk of manual handling injuries; estimated peak compression forces were also estimated using a Digital Model of a female (1.63m, 63kg) and male (1.75m, 79kg) paramedic in which the simulated model pushed or pulled the bags with both hands whilst kneeling from 25cm and 90cm - as observed in the recordings (Harari et al., 2020). The peak compression forces on the L5/S1 from lifting the equipment bags whilst standing ranged from 3697 N to 4030 N, with peak compression during pushing/pulling ranging from 1901 N to 3673 N – these were directly correlated to the distanced inputted (Harari et al., 2020). On overage, paramedics lifted/pushed/pulled the equipment bags 2.3 times per simulation, with REBA scores averaging 8 (high risk of injury due to excessive trunk flexion, bending and twisting); this was mainly due to placement of the equipment away from the paramedic and the researchers postulate that CPR quality was also affected by poor bag placement due to increase effort, time spent to move equipment and paramedic sub-optimal positioning in relation to the patient (Harari et al., 2020). Overall, despite the small scale study and significant use of equations and digital models, as opposed to EMG or motion tracking cameras as used by other studies, this does provide an unique perspective to this review that has been widely known in the profession as an important risk for MSDs but never formally studied or reported.

Finally, Du et al. (2019) carried out a scoping literature review of the available peer-reviewed literature surrounding human factors and ergonomics in relation to ambulance and equipment design. The 10 papers relating to general design investigated a wide variety of issues: most ambulance designs do not allow for an 'evolution' of ergonomics of the equipment, as each individual ambulance trust will aim for individual efficiency and improvements; there is no consensus or overall 'best-practice' guideline for ergonomic and efficient ambulance or EMS equipment design (Du et al., 2019). Overall, this section of the review highlights the need for a set design and forward-thinking plan that has Human Factors and Ergonomics (HFE) at the forefront of both equipment and ambulance layout. Due to the overall poor reporting of this finding and overall low quality of the paper, this has limited value in this review.

d. Demographics and injury

Only three papers reported on the age of participants, without making clear links between outcomes or participant's age. Studies have previously shown that upper limb, lower limb, sciatica and 'highly disabling or severely limiting' MSD-related pain was much higher in the over 45 year old category; with back pain, disabling level of pain were 55% more prevalent at 50-59 (Coggon et al., 2013; Palmer and Goodson, 2015; Parsons et al., 2007). With a Freedom of Information Request by the Yorkshire Ambulance Service NHS Trust in 2018, we are aware the average age of Paramedics was 51.89 years in 2009 with a decreasing trend down to 42.58 years in 2018 (YAS, 2018). As Karlsson et al. (2016) declared mean ages in years of 41 (females) and 43 (males), with Armstrong et al. (2020) averaging 35 (females) and 38 (males) – the data found by these studies is applicable to the UK.

In terms of gender, 46% of all fully trained paramedics in the UK are women (NHS England, 2021). Only Harari et al. (2020) included a 50:50 female-male ratio, whereas other studies had double the number of male participants in nearly all cases. Cavallari et al. (2016) studied MSD symptoms in female and male active workers, and found that women had up to 50% higher prevalence of symptoms regardless of the tasks performed. A review by Biswas et al. (2022) found that women were at a higher risk of injury in health care, compared to men. However, no conclusions were drawn on differences in outcomes between genders by the papers in this review.

In terms of body composition, four had declared weights and heights for participants. Poston et al. (2011) found that 79% of career firefighters were found to have a BMI ≥ 25 kg/m, with over 33.5% ≥ 30 kg/m. Mansouri et al. (2021) investigated this and found that in night shifts greater energy intake, irregular meals and less physical activity all are factors that may lead to a weight gain overtime. In Lavender et al. (2020) participants had a mean BMI of 28.7; in Armstrong et al. (2020) females had an average BMI of 27 and males of 28.8; in Xu et al. (2021) participants had a mean BMI of 23.9; the simulated patients in Potvin and Potvin (2019) had a BMI of 22 and 27.9 for females and 35.4 for the male. Overall, the results demonstrate good applicability to the documented ambulance service population though the researchers do not correlate BMI with the studied outcomes. Despite this, a large scale retrospective analysis of over 44,000 sampled workers by Viester et al. (2013) found that high BMI was strongly associated with developing MSD symptoms, in particular in the lower back and limbs. What is more, it is postulated by Onyemaechi et al. (2016) that BMI is strongly related to increased lumbar angles during movements and lifting and therefore may expose workers to injuries during manual handling. Similar findings from the papers included in this review and particularly Potvin and Potvin (2019) showcase how a clinician's elevated BMI can increase lumbar angles and therefore lumbar compression and shear – linking this to a higher risk of MSK injury.

Another important implication related to manual handling injuries is the patient's weight. Whereas the studies researched have estimated patient weights ranging from 91-103kg (Lavender et al., 2020) and even up to 125kg and 159kg (Potvin and Potvin, 2019), some studies observed such as Xu et al (2021) only simulated patients between 64-68kg. This poses an interesting question as the Health Survey for England in 2021 shown that over 25.9% of adults in England are obese with average weights of 85.1kg for men and 71.8kg for women (NHS Digital, 2022). McClean et al. (2021) carried out a literature review of the risk this worryingly upwards trend of obesity may pose to healthcare organisations and postulated that high risk of injuries, high liability and financial risks are all issues relating to manual handling of obese patients services will have to address via training and appropriate equipment. Réminiac et al. (2014) illustrates a damning case report of an obese patient with a pre-hospital cardiac arrest that was made immensely difficult to manage due to a limited number of resources which, despite a return of circulation, eventually died in hospital; the authors propose that due to the lack of resources dispatched and limited equipment may have contributed to the patient's poor outcome. Progress in this field has been limited, with Swann (2022) summarising the current state of the evidence for pre-hospital practitioners regarding bariatric and obese patients, with a clear message that forward planning, appropriate staffing and availability of equipment are still key issues to be managed by service providers. Perhaps the findings from the NHS Staff Survey's worryingly high baseline of MSK injury rates in NHS workers are correlated with this rise in obesity, yet only form a greater body of evidence for actionable points for healthcare organisations to provide appropriate training and equipment.

e. Spinal Forces and Injury

Often quoted in the papers reviewed, the National Institute for Occupational Safety and Health conducted a study in 2005 of steel workers in which recordings and measurements were taken for data to be inputted into the NIOSH Lifting Equation; a recommendation of a maximum L5/S1 disc compression force of 3400 N during any single job activity was therefore created – with shear forces of up to 501 N being recorded but deemed safe for short periods of time (NIOSH, 2005). This equation and limit has been questioned, with recent papers such as Arjmand et al. (2015) observing that even recommended weight limits by NIOSH being lifted in the prescribed way by a computer model exceed 'safety' levels of 3400 N – therefore rendering the recommendation obsolete. Other studies observing back compression such as Abadi et al. (2016) observed that the size and weight of the load, alongside frequency of lifting affected back compression – with only one lift/minute of a small 5kg box from floor to knuckle height still generated 1001 N of force. Nelson and Hughes (2009) summarised the impact of biomechanical measures with clear links between both increased AP L5/S1 compression - as little as 1500N, but mostly related to cumulative load throughout shift work - and shear forces -which were unable to be isolated as an individual cause - being strongly linked to back injuries.

Despite the limits imposed and quoted by NIOSH, the studies demonstrated significantly elevated compression – up to 7000N AP compression at L5/S1 and shear forces of 1300N even with equipment in Lavender et al. (2020). Despite the lack of a 'gold standard' study, the overall results of manual handling in the prehospital environment are significant – considering the patient loads (up to 75kg) and heights (75cm) required during normal practice as studied by Armstrong et al. (2020). This long-term cumulative load implication is problematic as it regularly falls outside of the NIOSH and HSE recommendations for safe manual handling.

f. Biometrics and Injury

Karlsson et al. (2016) notably investigated salivary cortisol and HR variability during their intervention. Previous long-term observational studies in professional athletes have found that training at high-intensity (85-90% of max HR) and very high-intensity (≥90% of max HR) have been directly correlated with increasing injury during soccer matches (Owen et al., 2015). However, a study of over 500 workers found that HR variability had no link between MSK pain over the course of daily activities – including work, leisure and sleep; with 41% of the participants reportedly carrying and lifting for more than half of their work time, and a prevalence of single-site pain of 23% and multisite pain at 63%, this study can be related to the pre-hospital clinician population (Sato et al., 2018). What is more, Valera-Calero and Varol (2022) explored the correlation between salivary cortisol, chronic neck pain and physical activity in office workers: this study found that pain sensitivity and vigorous physical activity were directly correlated to salivary cortisol levels but not with disability or pain intensity. This casts doubts over the overall data provided by Karlsson et al. (2016), as the long-term implications of both their measured outcomes have not been shown to be linked to MSDs by other papers in this field.

g. Further evidence

With workers exposed to even two or more physical demands such as twisting/turning of the back for more of a quarter of the work day leading to a lower work ability (Skovlund et al., 2020) and physical work demands reducing working life expectancy by 3 years in women and 2 years in men (Pedersen et al., 2020), ambulance service personnel face a difficult future. A review by Sheridan (2019) further observed how pre-hospital practitioners show current levels of health and fitness below the general population despite having to undertake heavy physical work. With pre-employment physical capacity testing not being able to categorise risk of MSK injury after three years of employment (Jenkins et al., 2021), the solution to this problem seems to be complex. A thorough systematic review by Glykeria et al. (2018) highlighted how high-intensity strength exercise or an integrated health care plan can decrease MSD symptoms and pain, this has so far not been trialled in the ambulance service. However, a cluster RCT by Jakobsen et al. (2015) randomised hospital workers to different workplace or home based exercise programs with a clear prevention of deterioration in work ability in the workplace intervention branch of the study. Moreover, a recent systematic review by Sousa et al. (2023) observed how multi-faceted interventions with both training-handling devices and ergonomics education prevented work-related MSDs in nurses. A previous review by Wåhlin et al. (2021) observed how providing equipment and training, encouraging peer-to-peer coaching, engaging in ergonomics education and management-worker collaboration all promoted safer manual handling. So far, this has not been studied in pre-hospital clinicians.

5. Study Strengths and Limitations

A rigorous search of the literature available of this topic was carried out and was presented clearly by the author. The likelihood of publication bias was considered, but funding declarations and bias statements were provided for all studies – Potvin and Potvin (2019) in particular clearly presents the funding source as Stryker – the type of equipment used. However, due to the clear presentation of statistical data there is little room for misinterpretation by readers. Most of the studies also suffered from differences in participants, wide confidence intervals, undeclared demographics and lack of control groups – which limit the value of the data. Also, due to the wide confidence intervals and limited data sets, a meta-analysis was not performed. None of studies were conducted in the UK, with limits the application of this data, though the age of participants and work demands of in the pre-hospital environment are similar.

6. Conclusion

The studies listed above overwhelmingly demonstrate how regular paramedic activities such as lifting patients or moving equipment can lead to significant spinal loads. Though none of the cohort studies directly approached MSK injury risk, the implications from the wider literature link the high AP compression and shear loads to an increased risk of injuries. The use of equipment such as the Binder Lift or both types of lifting strap clearly show a reduction in the above loads, with a possible link overall to reducing body stress and risk of injury. What is more, the retrospective cohort studies show how power loading systems significantly reduce workplace injuries in paramedics. The studies show good applicability to the general paramedic population, even in the UK and can be readily applied to change policy and guidelines in UK Ambulance Service Trusts. Finally, further research is highly required to help ascertain the multi-factorial interventions which can help modify this significant risk of injury in paramedics.

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Appendix A

1. Words used for Search Strategy – with synonyms

Population: paramedic or ems or emergency medical service or prehospital or pre-hospital or ambulance or emergency medical technician or emt

Intervention: manual handling or moving and handling or patient handling or patient transfer or lifting or ergonomic* ; intervention or program or training or strateg* or education

Outcome: msk or musculoskeletal or muscular or skeletal; injury prevention or injury rate or injury incidence or sickness or absenteeism or presenteeism

2. Example Search – CINAHL Plus, AMED, MEDLINE

Monday, June 19, 2023 10:14:12 AM

#	Query	Limiters/Expanders	Last Run Via	Results
S6	S1 AND S2 AND S3 AND S4 AND S5	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL Plus;AMED - The Allied and Complementary Medicine Database;MEDLINE	15
S5	injury prevention or injury rate or injury incidence or sickness or absenteeism or presenteeism	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL Plus;AMED - The Allied and Complementary Medicine Database;MEDLINE	250,267
S4	msk or musculoskeletal or muscular or skeletal	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL Plus;AMED - The Allied and Complementary Medicine Database;MEDLINE	715,420
S3	intervention or program or training or strateg* or education	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL Plus;AMED - The Allied and Complementary Medicine Database;MEDLINE	7,197,800
S2	manual handling or moving and handling or patient handling or patient transfer or lifting or ergonomic*	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL Plus;AMED - The Allied and Complementary Medicine Database;MEDLINE	122,198
S1	paramedic or ems or emergency medical service or prehospital or pre-hospital or ambulance or emergency medical technician or emt	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL Plus;AMED - The Allied and Complementary Medicine Database;MEDLINE	188,277

Appendix B - SIGN Checklists

Cohort Studies

Authors	Appropriate and clearly focused question	Groups being studied selected from populations that are comparable in all respects	Indication of how many people asked to take part did so, in each group	Likelihood that some eligible subjects might have the outcome at the time of enrollment	Percentage of individuals or clusters that dropped out before the study completed	Comparison is made between full participants and those lost to follow up	The outcomes are clearly defined	The assesment of outcome is blind to exposure status	There is recognition that knowledge of exposure status could have influenced assement of outcome	The method of assesment of exposure is reliable	Evidence from other sources is used to demonstrate that the method of outcome assessment is valid and reliable	Exposure level or prognostic factor is assessed more than once	The main potential confounders are identified and taken into account	Have confidence intervals been provided?	How well was the study done to minimise the risk of bias or confounding?	Taking into account clinical considerations, your evaluation of the methodology used, and the statistical power of the study, do you think there is clear evidence of an association between exposure and outcome?	Are the results of this study directly applicable to the patient group targeted in this guideline?
Lavender et al. (2020)	Y	Y	N	N/A	None	Y	Y	N	Y	Y	Y	Y	N	Y	1	Y	Y
Prairie et al. (2016)	Y	Y	N	N/A	None	Y	Y	N	Y	Y	Y	Y	N	Y	1	Y	Y
Potvin and Potvin (2019)	Y	N/A	N/A	N/A	N/A	N/A	Y	N	N/A	Y	Y	N	Y	Y	2	Y	N
Studneck et al. (2012)	Y	Y	N/A	Y	N/A	N/A	Y	N/A	N/A	Y	Y	N	N	Y	1	Y	Y
Armstrong et al. (2017)	Y	Y	N/A	Y	N/A	N/A	Y	N/A	N/A	Y	Y	N	N	Y	1	Y	Y
Harari et al. (2020)	Y	Y	N	N/A	None	Y	Y	N	Y	Y	Y	N	N	Y	1	Y	Y
Armstrong et al. (2020)	Y	Y	N	N/A	None	Y	Y	N	Y	Y	Y	N	N	Y	2	Y	Y
Xu et al. (2021)	Y	Y	N	Y	None	Y	Y	N	Y	Y	Y	N	Y	Y	2	Y	Y
Karlsson et al. (2016)	Y	Y	Y	Y	1 participant	Y	Y	N	Y	Y	Y	Y	Y	Y	2	Y	Y

Literature Review

Authors	The research question is clearly defined and the inclusion/ exclusion criteria must be listed in the paper.	A comprehensive literature search is carried out	At least two people should have selected studies.	At least two people should have extracted data.	Grey/unpublished data was sought	The excluded studies are listed.	The relevant characteristics of the included studies are provided.	The scientific quality of the included studies was assessed and reported.	Was the scientific quality of the included studies used appropriately?	Appropriate methods are used to combine the individual study findings.	The likelihood of publication bias was assessed appropriately.	Conflicts of interest are declared.	What is your overall assessment of the methodological quality of this review?	Are the results of this study directly applicable to the patient group targeted by this guideline?
Du et al (2019)	Y	Y	N	N	Y	N	Y	Y	Y	Y	Y	Y	1	Y

Appendix C – Study Characteristics and Results

Authors	Country	Study Design	Sample Size (M and F)	Age in years (mean)	Height and Weight of participants (mean)	Experience of participants in years (mean)	Measuring tool used	Intervention studied, frequency, duration and length	Outcome Observed	Results
Lavender et al. (2020)	USA	Cohort Study	14 (13M, 1F)	Not reported	1.78m, 91kg	14.5	EMG and camera-tracking	Lifting from floor, recliner, inflated seat with no equipment, binder lift and simple strap; repeated with slip preventer; 26 lifts in total; actor patients 91-103kg in weight	Spinal loading during lifting.	Significant reduction in anterior shear loading, torso flexion and torso lateral flexion.
Prairie et al. (2016)	Canada	Cohort Study	58 (42M, 16F)	Not Reported	Not Reported	Not Reported	Camera-tracking	Field loading of hydraulic stretchers during 12hr day and 8hr night shifts; over 111 days	Compression and shear forces at L5/S1 and risk of injury and main variables that affect the above; hand load	Hand load, back saggital flexion, elbow flexion, paramedic's weight and shoulder elevation predict compression force
Potvin and Potvin (2019)	Digital model	Simulated Cohort Study	3 (2F, 1M)	N/A	5th Percentile F - 50.2kg, 1.497m; 50th Percentile F - 72.2kg, 1.619m; 95th Percentile M - 125.1kg, 1.882m	N/A	Software provided by system manufactures	Field loading of manual and powered stretchers over 3 simulated scenarios; simulated patient weights of 125kg and 159kg	Trunk rotation, knee flexion angle, hand force, lumbar compression; joint moments	Using multiple participants and powered loading systems reduces risks of injury.
Studneck et al. (2012)	USA	Retrospective Cohort Study	706	N/A	N/A	N/A	Software data analysis	Introduction of electrically powered stretchers since December 2006	Occupational injuries post new device	Significant reduction in relative incidence of injury pre and post-intervention
Armstrong et al. (2017)	Canada	Retrospective Cohort Study	574	N/A	N/A	N/A	Software data analysis	Introduction of electrically powered stretchers since April 2014	Occupational stretcher-related injuries post new device	Significant reduction in relative incidence of injury pre and post-intervention

Harari et al. (2020)	Israel	Cohort Study	24 (12F, 12M)	Not Reported	Not Reported	Students with at least 24 field shift experience	Digital force gauge, camera-tracking, REBA; later simulated digital data and software data analysis	Material handling during CPR and ergonomics over; 24 simulations of CPR lasting 10 minutes	Risk of developing MSDs during material handling - REBA scores and simulated peak compression forces	Clinician positioning around a patient can lead to postures with high risk of MSDs and excessive spinal loading.
Armstrong et al. (2020)	Canada	Cohort Study	20 (7F, 13M)	35 (F), 38 (M)	1.61m, 70.1kg (F) ; 1.74m, 87.1kg (M)	10.3 years (F); 13.9 years (M)	Camera-tracking; virtual simulation of lifting	Loading stretcher into ambulance, raising stretcher, lowering stretcher, lifting patient on a scoop from ground to waist height; 2-man lifts, 3 repetitions of each lift per participant; 75kg manikin as weight.	Biomechanical exposure at the low back; compression, AP shear force, peak saggital low back angle, estimated cumulative damage; if position during lifting influences above factors;	Lifting a scoop board from ground to waist showed highest peak low-back compression force, most severe peak low back angle; manual stretcher raising had the greatest estimated cumulative damage;
Xu et al. (2021)	USA	Cohort Study	15 (2F, 13M)	22	1.78m, 75.7kg	Not Reported	EMG and camera-tracking	Lifting from floor or bath, with or without the use of a strap over 3 lifts for each scenario and equipment; one participant with one investigator lifting; actor patients weighing between 64-68kg	EMG muscle activation, spine and knee posture, participant subjective rating of difficulty	Use of strap led to: reduction in trunk forward flexion, lateral bending and kneeling posture; reported ease of task; reduced biomechanical load on spinal tissues
Karlsson et al. (2016)	Sweden	Cohort Study	20 (6F, 14M)	41 (F), 43 (M)	Not Reported	17.4 (Nurses), 25.5 (Paramedics)	Heart Rate monitoring and salivary cortisol	Two participants arrying stretcher for 400m for 10 minutes on two different days; participants switched halfway through; second time with shoulder straps; 112kg total weight with stretcher.	Heart rate every 15s for 60 minutes and salivary cortisol at 15, 30, 45 and 60 minutes after carrying stretcher.	Shoulder straps led to a reduction in heart rate and salivary cortisol secretion and a quicker return to normal-resting heart rate.
Du et al (2019)	Canada	Systematic Review	48 papers	N/A	N/A	N/A	6-steps to Quality Intervention Development	Design features of patient compartments, EMS equipment	EMS personnel's performance or well-being	Current design and ergonomics are lacking in preventing injuries - a redesign of the workspace and workflow and system level is required.