Scheduled Airline - Ground Crew Operations Ergonomic Rulemaking Preliminary Scoping Assessment - Published Studies

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Purpose

This document summarizes published studies regarding work-related musculoskeletal disorders (WMSD) injuries, risk factors, and controls for airline baggage handling activities. These studies help inform the following preliminary scoping questions:

- Are there published studies for WMSD hazards in the industry/risk class?
  - Do they help to identify high-risk jobs or activities?
  - Do they identify solutions to risk factors? How successful are those solutions?
  - What is the strength of the evidence?

Studies - baggage handling and risk of WMSDs

Working as a baggage handler is a known risk for WMSDs and injuries. Several studies have found a high prevalence of symptoms and injuries among baggage handlers, with a dose-response association. Two of the studies found that baggage handlers experience symptoms and injuries at a younger age than the reference population of workers in other industries.

- A study of a large population of baggage handlers in Denmark (Bern, et al. 2013) found that they have higher rates of musculoskeletal symptoms in the lower back, neck, upper back, shoulders, elbows, wrists, and knees compared to a reference population. Symptoms increased linearly with an increase in years spent as a baggage handler. Further analysis of the same population of baggage handlers found an increased incidence of low back pain (Brauer, et al. 2019), subacromial shoulder disorders (Thygesen, et al. 2016), and knee osteoarthritis (Mikkelsen, et al. 2019) compared to the reference group. Incidence of these disorders also increased with more years of work as a baggage handler.

- A study out of Sweden (Bergsten, et al. 2017) found an increase in reports of shoulder pain when comparing pre-shift ratings to post-shift ratings. The increase was associated with the number of airplane handled in a shift. Another Swedish study (Bergsten, E.L. 2017) found a high prevalence of low back pain (70%) and shoulder pain (60%) in a survey of 525 baggage handlers.

Surveys – baggage handlers and WMSD symptoms

Most of the survey research has focused on musculoskeletal symptoms among baggage handlers (Stålhammar et al. 1986; HSE, 2009; Bergsten et al. 2015; Taffazol et al. 2014). All of the studies reported a high prevalence of symptoms, particularly for the low back (53% to 73% or respondents), knees (51% to 60%), and shoulders (43% to 60%).

The surveys also found evidence of the severity of symptoms. Baggage handlers in the Stålhammar et al. (1986) study reported absence from work due to symptoms - 37.8% for back pain, 17.1% for knee pain, and 54.3% for shoulder pain. Taffazol et al. (2014) found that 62% of those who reported pain had it wake them up from sleep, and 72% had absenteeism due to pain. The survey by Bergsten et al. (2015) found that psychosocial factors were associated with severity of pain, with work organization factors being more of a predictor than interpersonal relations.

Surveys – baggage handlers and WMSD risk factors and solutions

Dell (1998) surveyed baggage handlers to get their input on areas of greatest risk and potential solutions. Handling and stacking baggage in narrow-body aircraft was considered the most hazardous task by baggage handlers. Transferring baggage from the baggage cart directly into the aircraft, pushing and pulling loaded carts, and pushing loaded containers inside wide-body aircraft were also considered high-risk tasks. Developing in-plane baggage and cargo stacking systems was the most popular engineering control suggestion. Heavy bag tags, improved training, and better maintenance of equipment were popular administrative solutions offered by respondents.

Observational analysis – baggage handling posture and working techniques

Stålhammar et al. (1986) performed video analysis of postures and working techniques of 16 baggage handlers in the cargo hold. They found that lifting and throwing were most common during loading, which was more stressful than unloading because of the need to stack bags. Pulling and lifting were most common types of manual handling during unloading. Baggage handlers adopted stooped and rotated postures in 50% of transfers, positions that increase the risk for low back injury.

Observational analysis – novice and experienced baggage handlers using extendable belt loaders

Mostosi et al. (2022) did an observational analysis of experienced and novice baggage handlers using an extendable belt loader (EBL) in the cargo hold. They found that novice baggage handlers were likelier to reach out to pull bag towards them instead of letting the conveyor bring the bags to them, the method more commonly used by experienced handlers. They also found that experienced handlers were likelier to use the height adjustable feature on the EBL than novices.

Quantitative analysis – baggage handling WMSD risks

A number of studies involved a more quantitative approach to analyzing baggage handling risks. Researchers used a variety of methods that included muscle activity (EMG) and biomechanical analysis using laboratory mock ups (Stålhammar et al. 1986; Splittstoesser et al. 2007); and assessment of actual baggage handling using observational lifting analysis (Taffazol et al. 2014; Tapley and Riley, 2005), postural assessment with inclinometers (Wahlstrom et al. 2016), and biomechanical analysis (Taffazol et al. 2014; Koblauch, 2016).

The laboratory studies examined typical postures in a setup with low headroom to simulate baggage handling in a narrow-body aircraft. Stålhammar et al. (1986) examined three different postures - sitting,

squatting, and kneeling - and found that there was no clear winner for avoiding risk. Splittstoesser et al. (2007) looked at different bag weights and stack heights. Low back disc compression neared recommended limits, and anterior-posterior shear exceeded limits for heaviest weights (60 pounds) and highest destinations (31 inches). Compression exceeded recommended limits when heavier weights were combined with higher stack locations.

Both of the observational analyses (Taffazol et al. 2014; Tapley and Riley, 2005) found that many of the lifts assessed exceeded the recommended limits for the analysis tools they used. Taffazol et al. (2014) compared the results of analysis using the Revised National Institute of Occupational Safety and Health (NIOSH) Lifting Equation to a biomechanical analysis of low back spinal compression. They found that all of the lifts that exceeded the NIOSH recommended weight limit resulted in compressive forces above the threshold where disk damage can occur. Lifts that were more than three times the recommended weight limit were more than twice the damage threshold. Tapley and Riley (2005) found that lifting in the cargo hold was found to have a higher risk level than when standing upright. Risk of injury was high for bags over 40 pounds when lifting at the average observed frequency of one every six seconds during loading operations. Risk was also high for bags over 33 pounds when lifted once every four seconds, the average for unloading. Pushing and pulling baggage carts by one worker was acceptable when empty, but exceeded recommended limits when loaded.

Wahlstrom et al. (2016) recorded the percentage of time that baggage handlers worked with arms elevated more than 60 degrees (6% of shift) and with the trunk bent forward more than 60 degrees (2% of shift). Baggage handlers on the ramp spent more time in awkward postures than those in the make-up room.

Koblauch (2016) did a biomechanical and EMG assessment of baggage handlers in the make-up room, on the ramp, and in the cargo hold. The biomechanical model he used showed that low back compression force was significantly higher in the cargo hold compared to the other areas. Handling baggage in a stooped position resulted in the highest compression and shear forces. All of the baggage handling tasks he studied exceeded recommended limits for compression, and some were close to maximal vertebral tolerance. Shear forces did not exceed recommended limits in his model.

Research on engineering controls - extendable belt loaders

EBLs are in use in dozens of airports around the world, including the UK, Europe, Australia, New Zealand, Japan, Canada, and the United States. At SeaTac airport, Alaska Airlines pilot-tested an EBL as part of an ergonomics citation settlement agreement. The airline found that the EBL reduced the risk of injury and was well liked by baggage handlers. As a result, they purchased more EBLs and have reported a decrease in baggage handling injuries.

The Health and Safety Executive in the UK conducted a literature review (HSE, 2009) on baggage handling technology and found the following reported benefits of EBLs:

- Eliminated or reduced the need for a baggage handler at the hold door
- Reduced ratings of perceived exertion
- Improved working postures
- Decreased heart rate

- Reduced energy expenditure
- Reduced lifting

A study at Brussels South Charleroi Airport (Mostosi et al. 2022) found a 50% reduction in occupational accidents in the cargo hold following implementation of EBLs. The study also found the experienced baggage handlers were likelier to use the features of the EBLs more effectively, and they recommended improving training to help novice baggage handlers learn better work methods.

A NIOSH study (Lu and Werren, 2023) found the following benefits of using an EBL:

- The use of the EBL during unloading reduced the time spent lifting and pushing, and the number of lifts and pushes, while increasing time spent pulling and the number of pulls.
- Use of the EBL increased the number of pushes, while reducing lifts during loading.
- The EBL resulted in an additional two bags per minute during unloading, with no difference for loading.
- The total labor required when using the EBL is about half that without it.

Research on engineering controls - vacuum lifts

Vacuum lifts are also in use in dozens of airports, and research studies support their effectiveness at reducing risk of injury. Vacuum lifts support almost the entire weight of any load that they lift, so risk levels are reduced even when handling heavier objects.

One study (Lu et al. 2018) found that using vacuum lifts for baggage had the following benefits:

- Reduced low back spinal compressive forces by 39%; and
- Reduced low back anterior-posterior shear forces by 25%. A meaningful result of this study was that the compressive forces when using the vacuum lift were below the 3400 Newton (approximately 770 pound) threshold where disc damage can occur. Notably, the study used the airline industry average bag weight of 32 pounds, and found that peak compressive and shear forces approached the damage threshold when handled manually. Manually handling heavier bags would certainly exceed these thresholds, resulting in spinal disc damage.

Another study (NIOSH, 2014) compared use of a vacuum lift to manual handling and found:

- A 90% reduction in hand force;
- A 63% reduction in low back spinal compressive force; and
- An increased risk for low back injury when lifting bags that weighed 40 pounds or more, based on the Revised NIOSH Lifting Equation and biomechanical analysis.

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