152 - ERGONOMIC STUDY OF MANIPULATION OF BAGGAGE IN CARGO COMPARTMENT IN COMMERCIAL AIRPLANE - AIRBUS A-319

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1. INTRODUCTION

Ergonomic studies related to aviation have focused on improving the driver's commands and passenger's comfort (Antony and Keir, 2010; Dell, 1998; Vaz Junior, 2012; Mcfadden and Towell, 1999). However, only few studies have been focused on the manual transport of cargo related to the aircraft cargo hold when airplanes are on the ground (Dell, 1998; Korkmaz et al., 2006; Kuiper et al., 1999; Tapley and Riley, 2005). Even though this is not the focus of most of studies, this activity has caused a large number of injuries to workers every year (Dell, 1998; Vaz Junior, 2012; Tapley and Riley, 2005).

The National Safety Council of America committee in a study showed that only in US more than 300 back injuries were registered annually in the employees of this sector. Over 85% of these injuries can be directly related to the baggage loading. Every year, nearly 9% of the workers suffer some kind of back problem. However, the low investment in this activity is not penalizing only the workers, it is estimated that these injuries costs more than 10 million US dollars a year to airline companies (Vaz Junior, 2012).

Postures in the standing position with the trunk bent forward and bent knees adopted while handling materials have often been associated with the onset of back pain and musculoskeletal disorders. Baggage handlers, miners, carpenters, car mechanics and farm workers are some of the many professionals that use such postures (Splittstosser et al., 2007). Injuries and accidents are usually caused by multiple adverse factors and specific circumstances (Dempsey and Mathiassen, 2006).

The activities of airport services, in which musculoskeletal injuries are recurring and have well-defined characteristics, are directly related to biomechanical overload (Dempsey and Mathiassen, 2006; Tapley and Riley, 2005). Injuries arise from short-duration movements that can be repetitive or occasional such as movements of lifting, lowering, pulling or pushing a luggage volume in the aircraft cargo hold, as well as long-duration movements such as maintaining posture while waiting for a volume to be accommodated in the aircraft cargo hold (Vaz Junior, 2012).

The unloading of airplanes, whose activity requires reverse movements, can also cause injuries when the muscle capacity is exceeded. In loading and unloading activities, there is no weight standardization per volume and type of baggage, thus demonstrating the importance of establishing limits for handling baggage volumes in order to reduce overload in the musculoskeletal system (Korkmaz et al., 2006; Tapley and Riley, 2005).

One of the instruments to evaluate the limit load that could be handled by a single worker is the equation of the National Institute for Occupational Safety and Health-NIOSH (NIOSH, 1994). Thus, this study aimed to analyze the biomechanical overload on load manual lifting tasks performed by ramp operators in a cargo hold of a commercial aircraft Airbus A-319 through the application of NIOSH equation and of RULA method (Rapid Upper Limb Assessment).

2. MATERIALS AND METHODS

This is a case study characterized as an exploratory research. The method used in this study was based on the concepts of the NIOSH equation, a tool developed by the National Institute for Occupational Safety and Health-NIOSH (NIOSH, 1994), a federal agency of the U.S. Department of Labor, responsible for the development and application of health and safety standards at work. The equation is intended to determine the maximum load to be supported by the worker under unfavorable conditions. The method RULA (Rapid Upper Limb Assessment), developed by McAtamney and Corlett (1993) was also used to quickly assess the biomechanical load of work postures and determine which level of risk work postures offer for the development of musculoskeletal disorders.

2.1 Equation NIOSH

The NIOSH Lifting Equation is a tool used by occupational health and safety professionals to assess the manual material handling risks associated with lifting and lowering tasks in the workplace. This equation considers job task variables to determine safe lifting practices and guidelines (NIOSH, 1994).

The NIOSH survey equation is based on a multiplicative model that provides a weight for each of the six task variables. The weights are expressed as coefficients that serve to reduce the load constant, which is the maximum recommended weight to be lifted under ideal conditions. The Recommended Weight Limit (RWL) is the product of the equation and is defined as the weight that nearly all healthy workers could lift for a period of up to 8 hours per day without increasing their risk of work-related low back pain (NIOSH, 1994).

In addition, a Lifting Index (LI) is calculated to provide a relative estimate of the level of physical stress and MSD risk associated with the manual lifting tasks evaluated. RWL is obtained by the following equation:

$$RWL = 23 \times [25/H] \times [1 - 0.003(V-75)] \times [0.82 + (4.5/D)] \times [1 - (0.0032 \times A)] \times FFL \times HF$$

Where:

= Load Constant = 23Kg
Horizontal distance in centimeters between the position of hands at the beginning of the lifting vement and the midpoint on an imaginary line connecting both ankles.
Vertical distance in centimeters from hands in relation to the ground at the beginning of the lifting vement.
Vertical distance traveled from the beginning to the end of the lifting movement.
Rotation in degrees during load transportation.
. = Frequency Factor of Lifting.
= Handle Factor.

Each of the coefficients is established from the value of each variable found in the specific task (Figure 1): horizontal distance (H), vertical distance (V), vertical distance traveled by the load (D), angle of asymmetry (A), lifting frequency (F) and handle (H). Each factor can be calculated according to the equation previously shown (NIOSH, 1994).

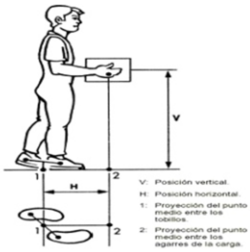

Figure 1: Graphical representation of variables H and V

Once the RWL is calculated for a given load lifting task, it is compared with the actual weight of the lifted load. This relationship provides the Lifting Index (LI), which determines if an activity presents risk of musculoskeletal injury and also quantifies this risk where :

LI = LW / RWL

LI = Load Weight (LW) / Recommended Weight Limit (RWL)

- **LI** less than 1.0 → safe condition → low risk of injury
- **LI** between 1.0 and 2.0 → unsafe condition → moderate risk of injury
- **LI** above 2.0 → unsafe condition → high risk of injury

2.2 Method RULA

The RULA (Rapid Upper Limb Assessment) method was developed to assess people exposed to postures that contribute to musculoskeletal disorders in the upper limbs. It uses observations adopted by upper limbs such as neck, back and arms, forearms and wrists. This method evaluates the posture and movements associated with sedentary tasks such as working with a computer (Mcatamney and Corlett, 1993). The main applications of the RULA method are:

- To evaluate musculoskeletal risks.
- To compare musculoskeletal effort between current and modified workplace design.
- To advise workers about musculoskeletal risks provided by different working postures.

The RULA action levels give you the urgency about the need to change how a person is working as a function of the degree of injury risk:

Action level	RULA score	Interpretation
1	1-2	The person is working in the best posture with no risk of injury fro their work posture.
2	3-4	The person is working in a posture that could present some risk of injury from their work posture, and this score most likely is th result of one part of the body being in a deviated and awkwar position, so this should be investigated and corrected.
3	5-6	The person is working in a poor posture with a risk of injury from their work posture, and the reasons for this need to be investigate and changed in the near future to prevent an injury.
4	**7+**	**The person is working in the worst posture with an immedia risk of injury from their work posture, and the reasons for this need to be investigated and changed immediately to preve an injury.**

When handling a heavy load or doing it incorrectly, mechanical moments are triggered in the spine area, mainly at the region of union of the L5/S1 vertebral segments, compression, torsion and shear forces, and it is considered that the compression of this disk is the main risk of low-back pain. Figure 2 shows an example of manual load lifting that provides overload in the L5/S1 region.

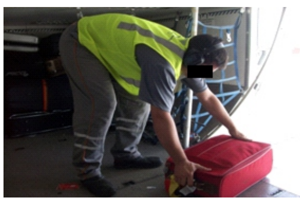

Figure 2: Manual load lifting - overload in the L5/S1 region

2.3 Procedures

A study was conducted to analyze the manual load lifting during baggage loading/unloading activities in the Airbus A-319 aircraft cargo hold, verifying through the application of the NIOSH equation, aspects such as frequency of activities, horizontal/vertical displacement and asymmetries while performing these activities. Two cases involving luggage loading and unloading activities were observed. Data collection was performed with a ramp operator during the period in which the aircraft was on the ground at the airport. Filming and photos of activities and workplace were made during the boarding and disembarkation of passengers, at which loading and unloading of baggage is performed at the aircraft cargo hold. The data allowed determining the Recommended Weight Limit (RWL), Lifting Index (LI) and analyze the posture of operators through the RULA method during baggage handling and if they offer some biomechanical risk for developing musculoskeletal disorders in upper limbs.

2.4 Work situation - observed aspects

It was found that the working day was 8 hours, with a break of 1 hour for meal. The workplace showed a cart with the baggage, positioned 60 cm above the ground at the entrance of the cargo hold of the aircraft for the loading/unloading activities. The operator works on foot all the time. Each bag weighted approximately 15 kg. It was also observed that there are no accessories for mechanized lifting of bags (conveyor belts). The lifting method was fully manual. Two activities were analyzed in the workplace studied.

2.5 Analysis of the activity 1 (loading baggage)

Activity 1 consisted in catching the luggage from the cart and putting them into of the cargo hold of the aircraft (Figure 3). The operator performed 8 lifts per minute and moved the trunk at an angle of 90°. The distance from him to the work plan was 30cm. The baggage was displaced 60 cm vertically between the soil and the amount of baggage.

Origin Destination

Figure 3: Operator catching the luggage from the ground at the entrance of the cargo hold of the aircraft and placing it at the bottom of the compartment

2.6 Analysis of the activity 2 (unloading baggage)

Activity 2 consisted of removing the baggage from of the cargo hold of the aircraft and putting them on the ground near the entrance to the aircraft cargo hold to be put on the cart (Figure 4). The operator performed 8 lifts per minute and moved the trunk at an angle of 90°. The distance from him to the work plan was 30cm. The baggage was displaced 60 cm vertically between the soil and the amount of baggage.

Origin Destination

Figure 4: Removing the bags and placing them at the entrance of the cargo hold of the aircraft

3. RESULTS

Table 1 shows the variables related to activities (1 and 2) and the values of coefficients of the NIOSH equation.

Table 1: Variables of the activties 1 and 2 and its coefficients

Variable	Activities	Coefficient of activities	
Load (kg)	15		
H (cm)	40	CH = 25 / H	0,625
V (cm)	20	CV = 1 - 0,003(V-75)	1,18
D (cm)	60	CD = 0,82 + 4,5/D	0,8575
A (degrees)	90°	CA = 1 - 0,0032ª	0,712
F (lifting /minute)	8	CF (frequency)	0,27
Grip	regular	CM (grip)	0,95

(Research data, 2017)

From the reference values, the Recommended Weight Limit (RWL) was determined by the product of seven variables described in the equation below:

RWL = 23 x [25/H] x [1 - 0.003(V-75)] x [0.82 + (4.5/D)] x [1 - (0.0032 x A)] x FFL x FP

Applying the NIOSH equation with coefficients of table 1, RWL was obtained for activities 1 and 2:

Where:

RWL = 23 x [25/40] x [1 – 0.003 x (20 - 75)] x [0.82 + (4.5/60)] x [1 - (0.0032 x 90)] x 0.27 x 0.95

RWL = 2.73

With RWL of activities 1 and 2, it was possible to obtain the Lifting Index (LI) with its respective risk classification for the activities analyzed:

Where:

LI = Load Weight (kg) / RWL

LI = 15 / 2.73

LI = 5.49

Risk Classification using the NIOSH Lifting Index (LI):

- **LI** < 1 ⟶ Low Risk
- 1 < **LI** < 2 ⟶ Moderate Risk
- **LI > 2** ⟶ **High Risk**

Table 2 shows the application of the RULA spreadsheet for activities 1 and 2 with the following partial scores of tables A, B and C and the final score.

Table 2: Score of RULA worksheet for activities 1 and 2

POSTURES	SCORES	SCORE FINAL
Table A	3	7
Table B	8	↓
Table C	7	(*Investigate and change immediately*)

(Research data, 2017)

4. DISCUSSION

Exposure to manual materials handling (MMH) activities is considered to be an important contributor to the etiology of back disorders (Kuiper et al., 1999; Dempsey and Mathiassen, 2006).

Stooped, restricted, kneeling, and other awkward postures adopted during manual materials handling have frequently been associated with low back pain (LBP) onset, for example, in the baggages handlers inside cargo hold (Splittstosser et al., 2007).

According to the risk classification using the NIOSH Lifting Index, it was possible to identify the degree of risk of activities 1 and 2 and rank them high risk, because the LI was higher than two. In this context, this type of activity is considered unacceptable from the ergonomic standpoint (Dell, 1998; Vaz Junior, 2012; Kuiper et al., 1999; Tapley and Riley, 2005; Splittstosser et al., 2007) and its redesigning is required (Korkmaz et al., 2006; Kuiper et al., 1999, Dempsey and Mathiassen, 2006, Schmidt et al., 2016).

Musculoskeletal back pain and disorder has been linked to work involving lifting and forceful movements. Shoulder musculoskeletal disorders (MSDs) have been associated with work postures and repetitive work, and more specifically with lifting with one or two hands (10kg), lifting at or above shoulder level (9kg) as well as pushing/pulling baggage (Antony and Keir, 2010; Korkmaz et al., 2006).

In order to evaluate the biomechanical risk in manual load lifting activities in ramp operators, the RULA spreadsheet was used, which assessed the level of exposure to risk factors and whether or not there was a need for research and change the work activities analyzed (Table 2).

One airline industry job that requires repetitive manual handling of heavy materials is that of airline baggage handler (Dell, 1998; Vaz Junior, 2012; Mcfadden and Towell, 1999, Korkmaz et al., 2006; Kuiper et al., 1999; Tapley and Riley, 2005). Surveys of airline safety professionals and baggage handlers revealed that one in 12 baggage handlers suffers a back injury each year (Korkmaz et al., 2006).

5. CONCLUSION

In the loading and unloading activities of the cargo hold of the aircraft, the operator works most of the time standing and bent forward forming an angle of approximately 90° between trunk and lower limbs (the maximum height inside the airplane cargo hold is 1.24m), performing flexion, rotation and lateral bending movements of the spine, in addition to elevation and abduction movements of the upper limbs and flexion of hip and knees.

Short-duration repetitive or occasional movements (lifting, lowering, pushing or pulling) and long-duration movements (maintaining posture) while handling or waiting for a load to be moved from the cart to the aircraft cargo hold.

These biomechanical factors observed and analyzed using NIOSH and RULA methods allowed generating values that indicated that the loading and unloading activities are of high biomechanical risk both in relation to the manual load lifting activity and to the postures used for baggage management, which may cause health problems to ramp operators.

Thus, the redesigning of the activities analyzed is recommended, including factors such as rotation of activities.

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Ergonomic studies related to commercial aviation have focused on improvements related to drivers' commands and cockpit. However, a small number of studies are devoted to the handling of airline baggage related to the aircraft cargo hold.

Thus, this study aimed to analyze the biomechanical overload on load manual lifting tasks performed by ramp operators in a cargo hold of a commercial aircraft Airbus A-319 through the application of NIOSH equation and of RULA method. Were analyzed two activities involving loading baggage (activity 1) and unloading baggage (activity 2), with photos and filming both activities during boarding and disembark of passengers. The biomechanical overload observed and ergonomically analyzed in this study with application of NIOSH and RULA methods, allowed generate values (NIOSH Lifting Index=5,49 and RULA final score=7) that show that the baggage loading and unloading brings a high biomechanical risk in both activities and also to the postures used during baggage handling, which may cause problems health to the ramp operators, especially the region of the lumbar spine and shoulders.

Keywords: Load handling, civil aviation, ergonomics, aircraft, baggage.

SOMMAIRE

Les études ergonomiques liées à l'aviation commerciale ont mis l'accent sur les améliorations liées aux commandes et au poste de pilotage. Cependant, un petit nombre d'études sont consacrées au traitement des bagages des compagnies aériennes liées à la soute à cargaison. Ainsi, cette étude visait à analyser les surcharges biomécaniques à charge manuelle effectuées par les opérateurs de rampe dans une soute d'un avion commercial Airbus A-319 grâce à l'application de l'équation NIOSH et de la méthode RULA. Ont été analysés deux activités impliquant le chargement des bagages (activité 1) et le déchargement des bagages (activité 2), avec des photos et filmer les deux activités lors de l'embarquement et du débarquement des passagers. La surcharge biomécanique observée et analysée ergonomiquement dans cette étude avec application des méthodes NIOSH et RULA a permis de générer des valeurs (NIOSH Lifting Index = 5,49 et RULA score final = 7) qui montrent que le chargement et le déchargement des bagages entraînent un risque biomécanique élevé. les deux activités et aussi les postures utilisées lors de la manipulation des bagages, ce qui peut causer des problèmes de santé aux opérateurs de la rampe, en particulier la région de la colonne vertébrale lombaire et des épaules.

Mots clés: Manutention de charges, aviation civile, ergonomie, avion, bagages.

RESUMEN

Los estudios ergonómicos relacionados con la aviación comercial se han centrado en las mejoras relacionadas con los mandos y la cabina de pilotos. Sin embargo, una pequeña cantidad de estudios se dedican al manejo del equipaje de la aerolínea relacionado con la bodega de carga del avión. Por lo tanto, este estudio tuvo como objetivo analizar la sobrecarga biomecánica en tareas de carga manual de carga realizadas por operadores de rampa en una bodega de carga de un avión comercial Airbus A-319 mediante la aplicación de la ecuación de NIOSH y del método RULA. Se analizaron dos actividades que involucran carga de equipaje (actividad 1) y descarga de equipaje (actividad 2), con fotos y filmación de ambas actividades durante el embarque y desembarque de pasajeros. La sobrecarga biomecánica observada y analizada ergonómicamente en este estudio con la aplicación de los métodos NIOSH y RULA, permitió generar valores (NIOSH Lifting Index = 5,49 y RULA final score = 7) que muestran que la carga y descarga de equipaje trae un alto riesgo biomecánico en ambas actividades y también las posturas utilizadas durante el manejo del equipaje, que pueden causar problemas de salud a los operadores de la rampa, especialmente a la región de la columna lumbar y los hombros.

Palabras claves: Manejo de carga, aviación civil, ergonomía, aeronave, equipaje.

RESUMO

Estudos ergonômicos relacionados à aviação comercial se concentraram em melhorias relacionadas aos comandos dos motoristas e ao cockpit. No entanto, um pequeno número de estudos são dedicados ao manuseio de bagagem aérea relacionada com a carga da aeronave. Assim, este estudo teve como objetivo analisar a sobrecarga biomecânica em tarefas de elevação manual de carga realizadas por operadores de rampa em uma base de carga de uma aeronave comercial Airbus A-319 através da aplicação da equação NIOSH e do método RULA. Foram analisadas duas atividades envolvendo carga de bagagem (atividade 1) e descarga de bagagem (atividade 2), com fotos e filmagem de ambas as atividades durante o embarque e desembarque de passageiros. A sobrecarga biomecânica observada e ergonomicamente analisada neste estudo com aplicação de métodos NIOSH e RULA, permitiu gerar valores (índice de elevação NIOSH = 5,49 e pontuação final RULA = 7) que mostram que o carregamento e a descarga de bagagens trazem alto risco biomecânico ambas as atividades e também as posturas utilizadas no manuseio de bagagem, o que pode causar problemas de saúde para os operadores da rampa, especialmente a região da coluna lombar e os ombros.

Palavras Chaves: Manipulação de carga, aviação civil, ergonomia, aeronave, bagagem.

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