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Always watchful of your arrival and departure, baggage handlers wait to serve you: How baggage handling in an airport can entail in biomechanical risks

Proyecto de investigación

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A B S T R A C T

Baggage handling is a high risk job that presents awkward postures, overexertion and repetition in their activities. Ergonomic studies have used biomechanical and psychophysical approaches to evaluate the level of risk of MSDs in baggage handlers. Most of the studies target the activities in the aircraft baggage compartment. The objective of this study was to determine the risk level of MSDs in baggage handlers of the Quito airport through the application of biomechanical risk factors identification tools, in order to propose control strategies that could reduce the mentioned risk. The study analyzed the manual handling activities performed in the baggage tunnel. Four activities were identified and 95 baggage handlers of the Quito airport were evaluated using the RULA. Also, the Maximum Acceptable Weight of Lift (MAWL) was applied to determine the lift capacity of baggage handlers in the Quito airport. The RULA analysis determined a total score of 7, Action Level 4, for each of the activities evaluated, for the 100% of the baggage handlers. The activities performed by TAME and ANDES were found to be equal, but their lifting frequencies were not. On the other hand, the MAWL for the population of male baggage handlers in the Quito airport was determined to be 7 kg, which compared to the actual average weight of the bags lifted is much lower. Therefore, this study determined that baggage handling activities performed in the baggage tunnel present a high risk of developing an upper MSD, and work conditions should be changed immediately. Finally, administrative and engineering controls were proposed in order to reduce the biomechanical risk level that result from baggage handling activities.

1. Introduction

When traveling by airplane, almost everyone wants to take a full bag to be confortable in their destination, and they may wish that the airline would allow them to carry heavier bags so they could bring more belongings. What they are not aware is that the airline industry has high rates of work-related injuries in the US private industry, mainly because their workers handle heavy baggage (Korkmaz et al., 2006). The rates of back and shoulder injuries, presented by the US Bureau of Labor Statistics, are five times the rates for these injuries of the entire private industry as a whole (Korkmaz et al., 2006; Rud, 2011; Tafazzol et al., 2015). Also, back injuries of airport personnel are greater than nurses, coal mining and other occupations with high incidence rates (Korkmaz et al., 2006; Tafazzol et al., 2015) . Back and shoulder injuries have been highly associated with manual material handling (MMH), and are only two of the musculoskeletal disorders that are caused by such activities that include lift, push, pull, and hold movements (Putz-Anderson, 1988;Tafazzol et al., 2015). Musculoskeletal disorders (MSDs) refer to injuries that affect tendons, nerves, muscles and joints (Punnett and Wegman, 2004). These disorders related to work, degenerate and produce inflammation in the areas mentioned and cause absenteeism and health issues in workers (Punnet and Wegman, 2004; Fernandez et al, 2008).

MSDs are the consequence of the presence of ergonomic risk factors and a combination of them. The three principal risk factors associated with MSDs are overexertion (related with heavy lifting), repetition and awkward postures (Korkmaz et al., 2006; Riley, 2005; Rud, 2011; Tafazzol et al., 2015; Fernandez et al, 2008). Both injuries stated before, and combinations of the presented risk factors, are included in the job of an airplane baggage handler (Rückert et al., 1992). Therefore, most of the incidence rates of the airline industry are because of the presence of risk factors in ground handling services, that include ramp services and baggage services, specifically, baggage handling (Dell, 1998).

Usually, baggage handlers are employed either by handling companies that provide these services to airlines, or airlines that provide this themselves (Bergsten et al., 2015a). In the Quito airport EMSA and ANDES are the two main handling companies that provide baggage handling services, but also TAME, a national airline, has its own baggage handling service for domestic and international flights. The overall baggage handling system in Quito airport is similar to others; for example the one stated by Bergsten, Mathiassen & Vingård (2015) and Lenior (2012), in which the bags checked by the passengers are transported by a conveyor belt, to a Computerized Tomography (CT) scanner and to a sorting area. In the sorting area, baggage handlers take the bags from the conveyor and place them on a cart or container called Unit Loading Device (ULD) that is taken to the airplane (Bergsten et al., 2015a; Lenior, 2012). After that, the baggage handlers load the bags into the airplane baggage compartment (Pikaar and Asselbergs, 2010). When unloading the airplane, the system is the same but runs in reverse (Bergsten et al., 2015a).

As it can be seen, baggage handlers are the principal subjects in the sorting area (also called baggage room or baggage tunnel), tarmac, and in the aircraft baggage compartment. The main tasks of a baggage handler include sorting, loading and unloading baggage, flight cargo and mail. These tasks include activities like pushing and pulling bags, pushing and pulling loaded trailers, stacking bags inside a narrow compartment, loading and unloading containers, lifting baggage on and off conveyors, and transferring bags (Bergsten et al., 2015a; Dell, 1998). From all of them, baggage handler's main activity is lifting heavy luggage causing lower back MSDs to be more prevalent in them (Tafazzol et al., 2015). Because of the risk they face, Geoff Dell (1997, 1998) researched the causes and prevention of airline baggage handlers back issues. A survey was taken by 156 baggage handlers from two ground handling companies and ten airlines all over the world, and it was determined that on average one in twelve baggage handlers suffers low back problem per year (Dell, 1997, 1998). Also, it is estimated that these injuries cost, in average to every company that was surveyed, about $1.25 million per year (Dell, 1998; Korkmaz et al., 2006). To get this estimate Dell (1997) found that MSDs in baggage handlers cost 15 airlines and a ground handling company $21 million per year from 1992 to 1994.

High costs and high incidence rate among baggage handlers has switched the attention from improvements related to cockpit and drivers commands towards the ergonomic improvement of the baggage handling system (Amaral et al, 2014; Dell, 1998). Several studies have determined that two variables that influence two of the principal risk factors, overexertion and posture, are the weight of the baggage and the design of the workspace (Pikaar and Asselbergs, 2010; Riley, 2005; Rückert et al., 1992; Rud, 2011; Thomas et al., 1995). The space or surroundings where a job is taken care of is called workspace, and it can affect either positively or in a negative way the productivity and health of a worker (Lešková, 2014). The workspace of a baggage handler includes mainly three parts that are the conveyor in the baggage room, the ULD, and the aircraft baggage compartment.

Thomas, van Baar & van der Stee (1995) determined the significance of three aspects of the design of a conveyor in the influence of the postures and workload of baggage handlers that end up in injuries. The three aspects were height, angle and velocity of the conveyor at Schiphol airport (Thomas et al., 1995). The experiment tested 107 baggage handlers and 18 combination of heights angles and velocities, concluding that the three examined factors directly influence the postures adopted thought the job (Thomas et al., 1995). Finally, Thomas, van Baar & van der Stee (1995) recommended a height of 65 cm for the conveyor, which adds up to 86 cm when the angle is 25 degrees and the depth is 1 meter, and a speed of 0.48 m/s to improve the postures taken during baggage handling.

The ULD, or the cart where the bags are loaded after they are unloaded from the conveyor, is another element of the workspace that influences the posture of the baggage handler (Thomas et al., 1995). Usually ergonomic analysis of baggage handlers end up in design proposals for ULD that would accommodate the population of handlers in a way that they wouldn't have to crouch or reach too high, and adopt an awkward position in order to load and unload the luggage (Rud, 2011).

On the other hand, the aircraft baggage compartment is a height-restricted workspace that forces handlers to adopt awkward postures in order to load and unload the luggage (Rückert et al., 1992). From all of the workplaces where the baggage handler has to perform its task, the aircraft baggage compartment was determined to be the most likely to cause back injuries (Dell, 1998). In the same study, Dell (1998) found that pushing and stacking bags inside the narrow compartment are the activities that handlers perceived had greater MSD risk.

The other variable influencing the presence of risk factors was the weight of the bag. The heavier the bag that has to be lifted, the greater the stress in the L5/S1 vertebral joint (Tafazzol et al., 2015). About 80% of the bags lifted by baggage handlers are heavier than what ergonomic guidelines recommend (Pikaar and Asselbergs, 2010). Several studies describe the average weight of luggage handled in baggage handling activities. Liu & Tseng (2006) found that the average luggage weight was 13.7 kg and ranged from 4.8 kg to 33.3 kg. Pikaar (2010) found that at long haul flights, 15% of the bags weight less than 15 kg, 18% between 15-19 kg, and 66% exceed 19 kg, with an overall average of 22 kg. Finally, the European Aviation Safety Agency (EASA) with NEA performed a survey for Standar Weights of Baggage in 2009 with 22,353 observations and concluded that the average weight is 16.7 kg for checked in bags around the world, 19.6 kg and 19.2 kg for male and female luggage departed from South America, and 18.5 kg and 19.1 kg for baggage arriving to South America (Berdowski et al., 2009).

Since the MSD risks presented in baggage handlers are imminent, their tasks have started to be evaluated and analyzed in the three principal approaches to evaluate manual handling: epidemiological, biomechanical, and psychophysical (Rückert et al., 1992). Epidemiological studies aim to find the body segments and regions affected or where most complains occur because of the practice of certain tasks (Fernandez et al, 2008 ;Rückert et al., 1992). Studies determined that the most affected region was the low back followed by the shoulders; being low back pain and shoulder pain the principal injuries among baggage handlers (Bergsten et al., 2015b; Punnett and Wegman, 2004; Rückert et al., 1992; Tafazzol et al., 2015). To do so, Bergsten, Mathiassen & Vingård (2015) and Tafazzol et al (2015) used the Standarized Nordic Questionnarie (NMQ). The first ones had a response of 525 handlers from which 70% reported low back pain and 60% shoulder pain; and the second ones had a response from 209 baggage handlers from which more than 53% were in risk of pain. Also, Rückert, Rohmert & Pressel (1992) used a standardized questionnaire that was not specified. Finally, Liu &Tseng (2006) used, in the first part of their research, a field survey answered by 500 baggage handler that determined, in contrast to most authors, that 44% of workers had MSDs on wrists, 36% on the lower back and 32% on shoulders.

The biomechanical approach is the study of the forces that act over the musculoskeletal system when a job is being executed, and the study of the necessary measures to reduce these forces (Fernandez et al, 2008). Biomechanical studies determine, scientifically, the presence of risk factors, or the risk level of MSD that the subject is exposed to; with the use of an analysis of the body postures, lifting techniques and forces needed to perform the task (Fernandez et al, 2008 ;Rud, 2011). Every study determined that baggage handlers have a high risk level of facing an MSD, and determined, in some cases, that job conditions should be changed immediately, other are just recommended to be changed, and other should be analyzed in more detail. Tafazzol et al (2015) used the Revised National Institute for Occupational Safety and Health (NIOSH) Lifting equation and the University of Michigan´s 3D Static Strenght Prediction Program (3DSSPP) (to confirm the NIOSH results), and concluded that handlers lifted load heavier than the accepted limit, and that the spinal compression forces (L4-L5 disk), in fact, exceeded the

NIOSH recommended 3400N limit in the postures adopted. The Recommended Weight Limit (RWL) was 9.03 kg, and only 2.2% of workers had the Lifting Index (LI) lower than 1, which means they were in the safe zone, 34.88% with a LI lower than 2 and 76.1% with a LI lower than 3 (Tafazzol et al., 2015). It is important to remark that for ideal lifting conditions, the weight limit shouldn´t exceed 23 kg, but the NIOSH equation uses a model that provides variables that decrease the weight limit for not ideal conditions (Liu and Tseng, 2006; Pikaar and Asselbergs, 2010). Coelho da Silva et al (2014) also used the NIOSH equation to evaluate the limit load that could be handled in two activities, loading and unloading the aircraft compartment, of baggage handlers. It was found a RWL of 2.73kg and a LI of 5.49 placing both activities as high risk (Coelho da Silva et al, 2014). The same authors also analyzed both activities using the Rapid Upper Limb Assessment (RULA) and obtained a final score of 7 as a result, which determined that both tasks should be investigated and immediate changes on the workstations were needed (Coelho da Silva et al, 2014). Liu and Tseng (2006) in addition to using the NIOSH equation, that found a LI of 2.08 for activities in the sorting room, applied the eight channels posture measurement system (Biometric DataLINK, UK) and concluded that the flexion angles in the lower back were greater when lifting from a level surface and when the size of the bag was bigger. Also, in a research paper form the University of Wisconsin-Stout, Rud (2011) conducted the RULA, the Rapid Entire Body Assesment (REBA), and the NIOSH equation to determine the risk level of the tasks, and the lifting capacity respectively. The results were a score of 7 for the RULA, a score of 9 for the REBA and a LI higher than 2, which determined that the working conditions had to be changed immediately (Rud, 2011). The reason RULA and REBA were used was because RULA focused on the muscular effort associated with posture, force and repetition that creates muscle fatigue in the upper limbs, while REBA focused on the entire body and on flexion and extension (Rud, 2011). Finally, one of the most recent studies in baggage handling performed by Dell (2007) determined a weight limit of 6 kg using the NIOSH equation, and Culvenor in 2007 stated that a reduction of the weight limit should go as 10 kg or under (The Ergonomics Society Conference, 2008).

Psychophysical approaches have been widely used to determine the capacity of manual material handling for a population (Córdova et al., 2009). The way of quantifying this capacity is by measuring the acceptable weight limits (Córdova et al., 2009). The Maximum Acceptable Weight of Lift (MAWL) proposed by Snook and Ciriello used this psychophysical approach to calculate the lifting capacity of a population, for certain circumstances of the task (Córdova et al., 2009; Fernandez et al, 2008). Since every population is different, Córdova et al. (2009) measured the capacity of manual material handling for Chilean workers by determining, experimentally, the MAWL. In order to do so, they used the proposed guidelines from Snook and Ciriello, the Borg CR-10 scale to measure the perception, and the 3DSSPP (Córdova et al., 2009). The experiment resulted in a MAWL 25% lower for Chilean Workers than the one recommended for Americans (Córdova et al., 2009).

Because of the adverse work conditions in baggage handling multiple studies have focused on determining the solutions or controls that reduce the risk level of suffering a MSD (Korkmaz et al., 2006). It is said that reducing the weight of the luggage might be the most effective method to reduce the MSD risk, but airlines have refused to reduce the 23 kg weight limit because of the commercial disadvantage this initiative represents (Dell, 1998). Some airlines tried this, leading to a negative response from clients, and a competitive disadvantage against other airlines. Other solution asked the passengers to re-pack heavy bags into another, but ended up in upset passengers (Dell, 1998). Providing categorical information of luggage weight, such as warning tags to heavy bags, and an alternative stowing method in which bags are stored upright on their short side, are administrative controls evaluated for their capacity to reduce risk factors by Korkmaz et al (2006). The study used experimental design to relate both variables with the dependent variable measured with Electromyographic (EMG) data (Korkmaz et al., 2006). Providing warning tags on heavy bags was not significant while the method of tipping bags upright was; this meant that the alternative method proved to reduce the overall spinal loads (Korkmaz et al., 2006). Proving that placing warning tags on bags was not significant doesn´t mean it is not useful and should not be used; categorical information can help baggage handlers to identify heavy bags, call for help when lifting them, and place them in the lower layers of the ULD (Korkmaz et al., 2006). Dell (1998) also concluded in its survey that the most popular administrative control proposed by baggage handlers was the "heavy" tags on luggage. Other administrative controls proposed by multiple authors were: training sessions for handlers on proper lifting techniques that are monitored by supervisors throughout the activities, loosening up and stretching exercises, a routing medical checkup and physiotherapy, job and task rotation, and better equipment maintenance (Dell, 1998; Rückert et al., 1992; Rud, 2011). In average 90% of baggage handlers felt that lifting techniques training should improve (Dell, 1998). Finally using a "back belt" as protective equipment has been proposed in several studies to help stabilize and limit the back from twisting (Dell, 1998; Korkmaz et al., 2006; Rud, 2011). This one has created controversy since some authors have suggested that there was no ergonomic justification to use it (Fernández et al, 2008). The efficacy of the use of weight lifting belt in relation to reduction of lumbar injury was evaluated, and proven not to be significant (Reddell et al., 1992). Also, results indicated that 58% of the baggage handlers stopped using the belt before 8 months, and that the risk of lumbar injury increased when not wearing a belt following a period of wearing the belt (Reddell et al., 1992).

In the other hand, engineering controls have been proven to significantly improve job conditions, but are much more expensive (Pikaar and Asselbergs, 2010). An engineering control implemented inside the aircraft baggage compartment is the Sliding Carpet System, also called Telair, which reduces the movement of luggage along the length of the plane (Dell, 2007; Korkmaz et al., 2006). Also, to improve the conditions inside the aircraft devices such as the RTT Longreach, Rampsnake and Powerstow have been implemented (The Ergonomics Society Conference, 2008). Lenior (2012) described a project where human factors and ergonomics played an important role. It consisted in proposing designs that could reduce the need of manual handling, and described how semi-automated loading and automated loading could help ground handling companies to reduce the risk of MSDs (Lenior, 2012). A semi-automated design to help loading a ULD proposed by Pikaar and Asselbergs (2010) was the Extended Belt Loader (EBL) which reduces the risk of injury significantly and consists of a sort of arm shaped conveyor that extends into the ULD. Also, redesigns in the height angle and velocity of the conveyor, and a redesign of the height of the ULD were explained before. Finally, mechanical lifting aids have been also proposed; there have been designed devices such as the ErGobag that reduce manual handling but usually present many limitations (Dell, 1998; Pikaar and Asselbergs, 2010).

To sum up, baggage handling is a high risk job that presents awkward postures, overexertion and repetition in their activities, being the first two stated the principals. Ergonomic studies had used biomechanical and psychophysical approaches to evaluate the level of risk of MSDs in baggage handlers, which ended up in solutions and controls that had been proven to reduce this risk level, improve the work environment, and help save money to airlines and ground handling companies. Most of the studies among baggage handlers target the activities in the aircraft baggage compartment, but Dell (1998) found that other workplaces that can cause back injuries are outside the aircraft where activities such as loading and unloading the ULD and lifting the bags from the conveyors are performed. Because little or nothing had been done in Ecuador, specifically in the airport of Quito; the following study intends to determine the risk level of MSDs in baggage handlers of the Quito airport through the application of biomechanical risk factors identification tools, in order to propose control strategies that could reduce the mentioned risk. Specifically, RULA was the biomechanical risk factor identification tool applied, and the Maximum Acceptable Weight of Lift (MAWL) was applied to determine the lift capacity of baggage handlers in the Quito airport since its conditions are different. To conclude, the workspace selected for the analysis was the baggage room, also called sorting area or baggage tunnel in the Quito airport.

2. Method

2.1. Stages

Human Factors and Ergonomics research can usually be classified in three types: descriptive, experimental and evaluation studies (Sanders & McCormick, 1993). The present study falls in the descriptive category and in a certain way in the evaluation one because it intended to characterize a population against certain attributes, and evaluate the risk of the population when performing their activities (Sanders & McCormick, 1993). The research was divided into five stages suggested by Wickens, Lee, Liu, & Gordon-Becker, S. (1998). The five stages were:

- Define the problem: The potential risk of MSD in baggage handlers in the Quito airport was identified because there is the presence of two of the principal biomechanical risk factors that are: overexertion when having to lift luggage and awkward postures resultant of their job. Literature review and observation helped to define the problem.
- Specify the plan: In this stage the entire research was planned. Literature review helped identify the ergonomic studies that have been done so far in the matter (baggage handling). The general objective of the research and the specific objectives that were accomplished throughout the study were determined in this stage. It was necessary to understand, in a general way, the processes inside the airport and the companies that serve in it. An important development in this stage was the election of the Maximum Acceptable Weight of Lift (MAWL) as the most appropriate tool to determine the lifting capacity of the baggage handlers, and the Rapid Upper Limb Assessment (RULA) as the most appropriate to evaluate the risk level of MSD related to biomechanical risk factors. For this election, it was necessary to understand the advantages and limitations of each tool. Finally, the data gathering and measuring plan that included the number of participants in the study and the method was determined.
- Conduct the study: The data gathering and measuring plan was conducted and the MAWL and RULA method were applied for the baggage handlers. Activities were identified infield and the results were gathered.
- Analyze the data: The results were presented for each of the participants an each activity in the case of RULA. The final score was analyzed and preliminary conclusions were made. The result of the lifting capacity for baggage handlers in the Quito airport was also presented and compared to the actual weight of bags that were being lifted.
- Draw conclusions: Control strategies were proposed in order to reduce the biomechanical risk level that result from baggage handling activities.

2.2. Evaluation and analysis ergonomic tools

2.2.1. Maximum Acceptable Weigh in Lift (MAWL)

The two most popular methods that determine the lifting capacity in MMH tasks are the Revised NIOSH equation developed by the National Institute of Occupational Safety and Health, and the Maximum Acceptable Weight of Lift (MAWL) proposed by Snook and Ciriello in 1991 (Fernandez et al., 2008). It has been proven that both methods have similar results and conclusions when evaluating a task, and are called “two faces of the same coin”, but depending on the conditions of the task and the objectives of the study one could present more advantages than the other (Fernandez et al., 2008). While the NIOSH is used when it is required to investigate the effects of variables (such as handles and asymmetry angle) in lifting risk, the MAWL is used when it is necessary to consider population characteristics such as gender and percentage of the population needed to accommodate (Fernandez et al., 2008; Snook and Ciriello, 1991; Tafazzol et al., 2015). Also, the NIOSH equation is used for one individual performing the task, while the MAWL can be applied to a percentage of a population, such as the baggage handlers in an airport (Fernandez et al., 2008; Snook and Ciriello, 1991). Because of the conditions and the objective of the study the MAWL method was selected. Also, the study later on will use the RULA method to analyze specifically the postures adopted in baggage handling.

The MAWL presented by Snook and Cieriello (1991) use a psychophysical approach, which means that studies the relationship between a physical stimuli and its human sensation, to determine the lifting capacity of a population (Córdova et al., 2009; Fernandez et al., 2008). The psychophysical approach has been justified by several authors because when it is applied to MMH tasks, it allows a reasonable simulation of industrial jobs, their results are reproducible, it has been used as a foundation to calculate recommended weight limits, and this weight limits in lifting are said to include biomechanical and physiological demands of the task (Córdova et al., 2009).

The method consists on determining the MAWL, for the conditions given in the task, by using the prediction tables of the maximum acceptable weight in lift that were originally obtained by Snook and Ciriello (1991) in a discrete and tabular manner (Fernandez et al., 2008; Snook and Ciriello, 1991).

Snook and Cieriello (1991) first developed the “Snook Tables” at the Liberty Mutual Research center. The tables consist of maximum acceptable weights for lifting, lowering, pushing, pulling and carrying tasks, which serve as guidelines to design MMH tasks (Snook and Ciriello, 1991). The MAWL given in the table depends on other task variables such as frequency, object width or height, and vertical distance (Córdova et al., 2009; Snook and Ciriello, 1991). The tables were developed experimentally using the psychophysical approach, in which the subject monitored his or her feelings of exertion or fatigue and adjusted the weight to an acceptable level, while the other task variables were controlled by the investigator (Córdova et al., 2009; Snook and Ciriello, 1991). To be more specific, the subjects were supposed to adjust the weight until it represents the maximum load that, according to their perception, they could lift continuously for a period of 8 hours without straining themselves, or becoming unusually weakened, overheated or out of breath (Snook and Ciriello, 1991). Each experiment was performed twice and the result of the acceptable weight of lift for each person was an average of the two runs if the weight difference of both was not greater than 15% (Córdova et al., 2009). Finally, the data collected from all the experiments was used to develop the tables.

In order to use the tables, variables such as frequency of lift, object width or height (meaning the horizontal distance between hands when grabbing the object), and vertical distance have to be determined(Middlesworth, 2014a; Snook and Ciriello, 1991). After the data of the task is gathered, it should be compared to the appropriate table. The tables are divided in 4 different tasks that are lifting, lowering, pushing, pulling and carrying (Snook and Ciriello, 1991). Also they are classified as for females or males, and depending on the range of origin of the lift. The table for the lifting task for males is presented in Appendix H. The ranges of origin of lift and the variables shown in the tables are the following:

- F – K = Floor to knuckle height
- K – S = Knuckle to shoulder height
- S – R = Shoulder to arm reach height
- MAWL = Maximum acceptable weight in lift (kg)
- Width = Width of the object (cm)
- Dist = Vertical distance traveled during lift (cm)
- %pop = Percentage of the population desirable to accommodate
- lnILP = Natural logarithm of the in-between lifting period

Finally, if the task specific data does not match exactly the values presented in the tables, the next highest value of the table should be selected for a more conservative result (Middlesworth, 2014a; Snook and Ciriello, 1991).

2.2.2. Rapid Upper Limb Assessment (RULA)

An assessment method developed for ergonomic investigations of workspaces and tasks that report work-related upper limb disorders or MSDs, is the Rapid Upper Limb Assesment (RULA) (Mcatamney and Corlett, 1993). RULA, developed by McAtamney and Corlett in 1993, evaluates the risk level of suffering an upper limb MSD related to the exposure of biomechanical risk factors present in a task (Fernandez et al., 2008; Mcatamney and Corlett, 1993). To provide this evaluation of the exposure to risk factors, RULA uses diagrams of body postures, three scoring tables and scale of action levels that serve as a guide to determine what to do with the resulted score (Fernandez et al., 2008; Mcatamney and Corlett, 1993; Middlesworth, 2014b). McAtamney and Corlett (1993) state that RULA is a posture, force and muscle assessment tool, with the main objective of identifying the muscular effort associated with the three principal risk factors that are awkward postures determined by the workspace and the load, overexertion, and repetition or static work; and may contribute to fatigue.

Because of its quick ability to determine risk, its quick application, and the lack of special equipment need to perform the assessment it has been widely used by investigators and employees (Mcatamney and Corlett, 1993; Rud, 2011). It requires the use of a single page worksheet, presented in the Appendix A.1., and a simple training in how to use the worksheet and in identifying each posture (Mcatamney and Corlett, 1993; Middlesworth, 2014b). Although some authors use software that helps to identify easily the angles adopted by the body in each posture (Rud, 2011). As it can be seen on the worksheet, the body was divided in two groups; group A that includes the upper arm (shoulder), lower arm, and wrists; and group B that includes the neck, trunk and legs (Mcatamney and Corlett, 1993). The evaluator should start by evaluating each body region of section A with the help of the diagrams presented in the worksheet, then add a muscle score or load score if needed, and finally enter a score for the entire group in Table A (Middlesworth, 2014b). Secondly, the investigator should perform the same steps for the body regions of section B, and enter a score for the entire group in table B (Middlesworth, 2014b). Finally, based on the scores obtained for each section, Table C is used to compile the risk factor variables which result in a single score that ranges from 1 to 7, and represents the risk level (Mcatamney and Corlett, 1993; Middlesworth, 2014b). The risk level obtained is classified into one of four categories that determine the level of action that has to be taken (Fernandez et al., 2008). The categories with their respective action level are listed below:

- Action level 1: Scores of 1 and 2 are considered acceptable and no action is required.
- Action level 2: Scores of 3 and 4 indicate that should be investigated in a deeper manner and changes in the conditions are required.
- Action level 3: Scores of 5 and 6 indicate that the workstation should be evaluated and changes are required as soon as possible.
- Action level 4: A score of 7 indicates that changes are required immediately in the work conditions and that the task should be investigated in a deeper manner (Fernandez et al., 2008; Mcatamney and Corlett, 1993).

It is important to state that the selection of the postures to be evaluated should be based on:

- The postures where the highest force loads occur (Middlesworth, 2014b).
- The most difficult postures or activities (Middlesworth, 2014b). (Awkward postures)
- The posture sustained for the longest period, or the most repetitive one (Middlesworth, 2014b).

2.3. Participants

In the Quito airport two ground handling companies provide handling and auxiliary services to most of the airlines. Also, TAME, an Ecuadorian airline has its own handling department that serves its domestic and international flights, except for the flight to JFK in New York that is handled by ANDES Airport Services. ANDES Airport Services is one of the major handling companies, and provides baggage handling services to KLM, LAN and TAME.

TAME had 64 handling operators assigned to different areas and tasks. For the international tunnel, they had 2 baggage handlers assigned for each of the 3 shifts of the day, as well as 2 baggage handlers assigned for the domestic baggage tunnel for each of the same three shifts. The assignments were in a certain manner rotative. The rotation of handlers was in their shifts and also in the task or workspace. These meant that a handler assigned to the domestic baggage tunnel for the morning shift could be assigned the following week to the same area but in a different shift, or to a different area; but typically there was already people selected to certain task and workspace where they performed better, meaning the rotation was more on shifts rather than on activities. From all of them, the selected ones were the assigned to the baggage tunnels for baggage handling tasks during the 5 week period of data gathering. There were a total of 35 baggage handlers assigned for baggage handling operations in the baggage tunnel during the 5 week period.

In the other hand, ANDES Airport Services has its personnel well defined in areas. There were 60 baggage handlers assigned to the baggage tunnels. From these, 30 baggage handlers were assigned for each day. In the same way as Tame, they serve three different shifts, but the handlers only rotate their shift from week to week. In contrast to the handling system of TAME, ANDES had a greater number of handlers which allowed them to assign 6 to 10 baggage handlers to serve in each major international flight; as it is for the service they provided to TAME in the flight to JFK and the service provided to KLM in their flight to Amsterdam.

A statistical method was used in order to determine the number of baggage handlers that had to be measured and analyzed in for the conclusions to be representative of the entire population (Montgomery, 2009). This meant that from the entire population a sample had been taken and the conclusions about the sample could be replicated for the entire population (Montgomery, 2009). The sample size was calculated using the formula for proportions of finite populations, because it determines if the subject of the sample presents a high risk level, with a chosen proportion (Montgomery, 2009). The used formula is presented below:

$$n = \frac{(N)\left(Z^{2}\frac{\alpha}{2}\right)(p)(1-p)}{(N-1)e^{2} + \left(Z^{2}\frac{\alpha}{2}\right)(p)(1-p)} \quad (1)$$

Where N is the size of the population, Z depends on the probability of the type 1 error, p is the probability of the subject to present a high risk level of MSD, and e is the maximum error permitted that refers to the distance or difference between the value of the estimate of the parameter p and the real value of the parameter p (Montgomery, 2009).

As seen before, there were 95 baggage handlers in the Quito Airport from TAME and ANDES Airport Services. With a confidence level of 95%, a “p” value of 0.5 since is the greatest value of doubt (Montgomery, 2009); and “e” of 5%, it was found that the sample size was of 77 baggage handlers.

$$n = \frac{(95)\left(1.96^{2}\right)(0.5)(1-0.5)}{(95-1)0.05^{2} + \left(1.96^{2}\right)(0.5)(1-0.5)} = 76.32 \approx 77 \quad (2)$$

Finally, 95 baggage handlers from both companies were evaluated during a five week period. This means that in order to evaluate a sample of the population, the period of time permitted the evaluation of the entire population, and therefore a more precise study. The observation, filming and evaluation of the subjects were performed in the following flights:

- KL751 to Amsterdam at 15:55 pm for KLM served by ANDES. Later on changed to 17:35 pm.
- EQ550 to New York JKF at 00:50 pm for TAME served by ANDES.
- EQ524 to Bogotá, Caracas at 00:50 pm of TAME operated by TAME.
- EQ550 to Habana at 00:50 pm of TAME operated by TAME.
- EQ562 to Ft. Lauderdale at 02:15 of TAME operated by TAME.
- EQ543 to Ezeiza at 16:30 pm of TAME operated by TAME.
- Domestic flights to Guayaquil, Cuenca and Manta after the arrival of EQ551 at 15:30pm. These are connection flights of the arriving baggage.
- International and domestic flights of TAME in the morning shift.

2.4. Equipment and software

The equipment used consisted of a video camera Go Pro Hero 4 and Contour HD, which have a reduced size and allowed the researcher to film without the need of a tripod. Also, the software Kinovea was used as a video player that helped analyzing the images in the software by measuring the angles adopted. For the MAWL analysis a tape measure was used to measure the vertical distance traveled by the object.

3. Procedures

The Quito airport was visited several times before the data collection to understand its baggage handling system, which is similar to others and was explained before in the introduction section. The following study focuses on the activities performed by baggage handlers of TAME for its domestic and international flights, and of ANDES in their flights for KLM and TAME. As explained before, baggage handling tasks are performed mainly in the tarmac, in the aircraft compartment, and in the baggage sorting room or baggage tunnel as they call it in the Quito airport. The tasks performed by baggage handlers in the Quito airport are shown in Table 1.

Table 1. - Baggage handling Tasks in the Quito airport (Own development).

Task	Area
Loading and unloading bags onto trailers	Baggage tunnel
Loading and unloading bags into containers	Baggage tunnel
Lifting baggage on and off conveyors	Baggage tunnel
Pushing and pulling loaded trailers	Baggage tunnel
Transferring bags from trailers to mobile belt	Tarmac
Taking bags to the revision area	Baggage tunnel
Assisting with wheel chairs to passengers	Baggage tunnel
Loading, unloading and stacking bags in a narrow compartment	Aircraft baggage compartment
Driving dollies and cars to carry trailers and containers	Tarmac
Auxiliary operations	Tarmac

Source: Own development

From the three areas and activities, shown in Table 1, the baggage tunnel and the activities performed in it were chosen to be analyzed. In this area the main tasks are classifying bags, and loading and unloading the ULD that will be taken to the aircraft. The reason for this election was that MMH task performed in this area are likely to cause back injuries (Dell, 1998). Dell (1998) obtained the following results on a surveyed taken by 156 baggage handlers from different airlines and handling companies: 107 participants responded that loading bags onto trailers in the baggage room is likely to cause back injuries, 104 handlers responded that loading containers in the baggage room, and 69 that lifting baggage on and off conveyors is likely to cause back injuries. Also, most of the previous ergonomic studies in baggage handling have focused on operations inside the aircraft baggage compartment, which has led to improvements in the working conditions of this area as it was seen during the first visits. For the case of the flights assisted by ANDES, the work conditions in the aircraft compartment has few MMH operations because almost everything has been automatized with the use of the FMC machine that places the ULD or containers inside the aircraft compartment. This means that most of the MMH activities are performed in the baggage room, and therefore the study analyses the manual activities in this workspace.

The processes analyzed were: "unloading and loading baggage off conveyors into containers", which is performed by ANDES in the international baggage tunnel; "unloading and loading baggage off conveyors onto trailers in the international baggage tunnel", and "unloading and loading baggage off conveyors onto trailers in the domestic baggage tunnel", performed by TAME. These three processes include some of the tasks presented in Table 1, and in order to understand them better a flowchart for each is presented in Appendix A, B and C respectively. It is important to note that for the flights operated by ANDES, there were 6 to 10 baggage handlers assigned to the international tunnel, while for the flights operated by TAME there were 2 baggage handlers assigned to the each baggage tunnel (international and domestic). Also, while for the load of trailers the baggage handler loaded the trailer from outside; for the case of containers, there was always a baggage handler inside the container receiving the baggage from another baggage handler positioned outside the container. As it can be seen the most manual and demanding tasks in these processes are lifting heavy luggage and placing them in the right place.

In order to evaluate the risk level of suffering an upper limb MSD related to the exposure of biomechanical risk factors in baggage handling, the RULA method was applied. The international and domestic baggage tunnel was visited in a period of 5 weeks during the three main shifts of the day, specifically to observe and film the operations of the flights presented in section 2.3. In the processes observed, 2 postures were evaluated for the activity "load into containers", performed by ANDES; and 3 postures for the "load onto trailers" performed by TAME. Each posture was named to identify them easily and compare the risk level presented in each.

The postures evaluated were the ones adopted when: "lifting bags while being outside or inside the container", "placing bags in its final position while being inside the container", "lifting bags from the floor", "placing bags onto the trailer", and "unloading baggage of conveyor". Since the postures adopted when lifting luggage are the same when lifting inside or outside the container, both were named as "lifting" during the analysis. Figure 1 and Figure 2 present images of each posture analyzed. The reason for this selection was that all of them represent the most repetitive movements and awkward or difficult postures, meaning the ones where the highest load occurs. Finally, 95 baggage handlers from which 35 were from TAME and 60 from ANDES were filmed. Each baggage handler was evaluated one time for each activity he performed. It is important to mention that some baggage did not perform every activity evaluated, but they were evaluated in at least once of the four postures presented. The activities were filmed during 2 to 3 minutes each, and were later analyzed using the RULA worksheet in which each body part was given a score that resulted in a final score (Mcatamney and Corlett, 1993). Also, the software Kinovea was used as a complement to analyze the postures adopted during the task by allowing the measure of angles of each body region in a certain image.

On the other hand, to determine the lifting capacity of the population of baggage handlers in the Quito airport the Maximum Acceptable Weight in Lift (MAWL) was applied. Two different scenarios were analyzed: the lifting capacity for the minimum vertical distance to place the bag, and for the maximum vertical distance where the bag can be placed. Both scenarios used the vertical distance, height or dimensions of the trailers, since they were greater than the dimension of the container. Both scenarios were analyzed since there is a range of height where the bags can be placed, and the MAWL was calculated for the minimum and maximum vertical distance traveled during the lift. In order to do so, the variables that influence the MAWL such as frequency of lift, baggage width (horizontal distance between hands), and vertical distance where the bag is placed, were measured. The 2 to 3 minute videos used to apply the RULA were used to calculate the frequency of lift for the case of the load of containers and the load of trailers. The variable "width" was determined by the regulations imposed by TAME, ANDES, KLM and most of the airlines as the maximum accepted height of the bag, since the bag is usually lifted with a hand placed on top, and the other on the bottom on the bag as it was shown in Figure 2 (c). Finally, a tape measure was used to measure the vertical distance traveled during the lift (container and trailer dimensions). For the case that the value did not match exactly, the next highest value of the table for lifting tasks developed by Snook & Ciriello in 1991 (Appendix H) was selected, and MAWL determined.

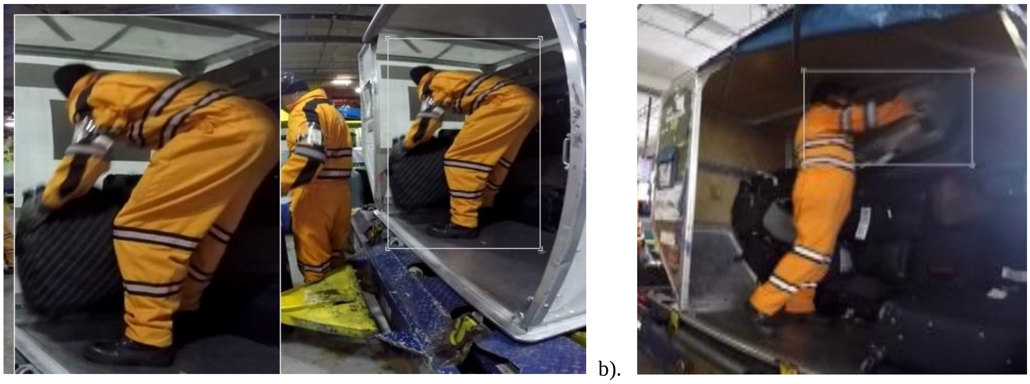
a).  b).

Fig. 1 - (a) Lift while inside; (b) Place while inside.

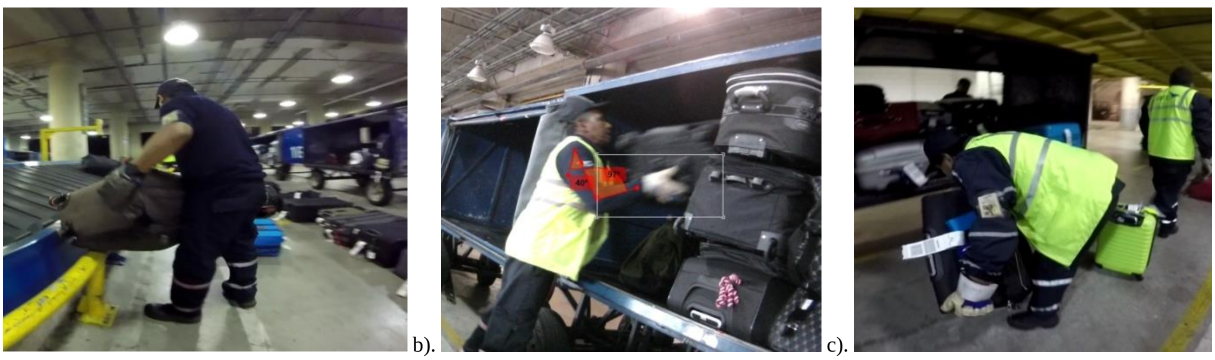
a).  b). c).

Fig. 2 - (a) Unload from conveyor; (b) Place; (c) Lift from the floor.

4. Results

To determine the lifting capacity of the population of baggage handlers the frequency of lift, object width or height (meaning the horizontal distance between hands when grabbing the object), and vertical distance were determined as explained before. The measures obtained are show in Table 2 for the case of the minimum vertical distance to place the bag, and for the case of the maximum o place the bag in the trailer.

Table 2 – MAWL variables measured.

Task	Range of origin of lift	Freq. of lift (lift/min)	ILP (seg)	Width (cm)	Dist. (cm)	% pop
Lifting to minimum height of trailer.	F-K	5.8	10.4	76	75	90
Lifting to maximum height on trailer.	K-S	5.8	10.4	76	75	90

Source: Own development

The width value of 76 cm presented in Table 4 was determined as the maximum height accepted by the airlines for a standard “large” bag (2015). It was found that bags should not exceed 158 cm including height, width and depth; and the standard measures for “large” luggage are 76 cm x48 cm x29cm (KLM, 2015; TAME Ep, 2015; LAN, 2015; AA, 2015). Also, the Distance (Dist. (cm)) values were determined by measuring the dimensions of the trailer presented in Appendix D. The minimum height is the distance from the floor to the surface of the trailer (loading height) was 75 cm and the range of lift was F-K. In the other hand, the maximum distance was the height of the roof of the trailer subtracted the depth of a large bag; this distance was 179 cm subtracted by 29 cm equivalent to a distance of 150 cm. The distance determined 75 cm from a K-S range of lift.

On the other hand, the frequency of lift was determined by counting the number of lifts per minute during each of the videos for the lifting activity. A total of 88 lift activities were obtained, from which 31 were performed by TAME and 57 by ANDES. The mean lifting frequency for ANDES was 5.8 (STD 1.8) lifts per minute, while for TAME was 5.0 (STD 1.3) lifts per minute. To statistically prove the difference of the mean lifting frequency between both companies, a two sample Mann-Whitney test was performed, because the lifting frequencies of TAME and ANDES, did not follow a normal distribution (Appendix E). It was proven that the medians of lifting frequency of the companies were significantly different and the null hypothesis about their equality was rejected (p-value < 0.05). The Mann-Whitney test is presented in Appendix E and shows that the loading of containers has a greater lifting frequency and therefore the lifting frequency used in the analysis was the mean frequency of ANDES (5.8 lifts per minute).

The lifting capacity for the population of male baggage handlers in the Quito airport, for each case analyzed is presented in Table 3.

Table 3 –MAWL in Kg for baggage handling in Quito (Snook and Ciriello, 1991)**.**

Case	MAWL (kg)
Lifting to minimum height of trailer.	7 kg
Lifting to maximum height on trailer	10 kg

Source: Own development

The RULA was applied to evaluate the risk level of suffering an upper limb MSD related to the exposure of biomechanical risk factors present in baggage handling (Mcatamney and Corlett, 1993). A total of 188 RULA analyses were performed, including in each one of them the completion of a RULA worksheet. This total amount is divided into the four activities analyzed. Table 4 presents the quantity of RULAs for each activity or posture analyzed.

Table 4 – Number of RULA analysis for each activity.

Activities	Number of RULA analysis
Lifting baggage	94
Unloading baggage from conveyor	21
Placing baggage	36
Placing baggage while being inside of the container	37
Total	188

Source: Own development

The score for each body part and for each group, meaning group A and B were determined. A total RULA score was obtained for each worksheet. The results of the total score and the action level obtained for each of the activities is presented in Figure 3.

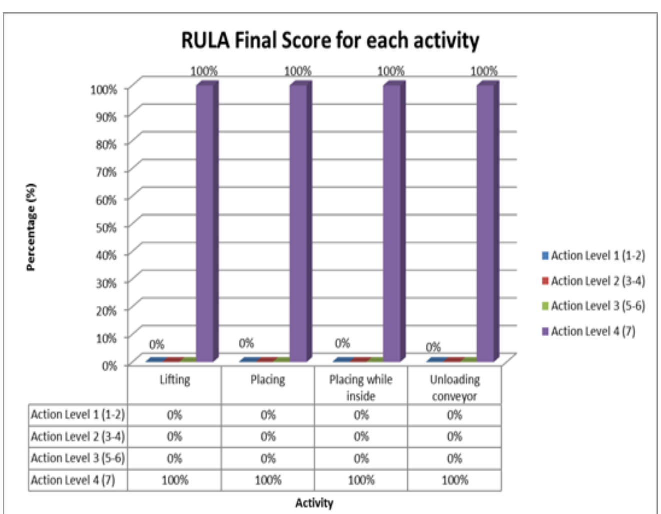


Fig. 3 – Percentage of handlers vs. Risk level Final Score for each activity. Source: Own development

As it can be seen, for each of the activities 100% of the baggage handlers evaluated present the highest possible total score (7) and fall in the Action level 4 (Mcatamney and Corlett, 1993). In order to understand better the reason for that high score and highlight the difference of the conditions of each task, the “wrist and arm score” (total score of group A) and the “neck, trunk and legs score” (total score of group B) are presented in Figures 4, 5 and 6. It is important to note that the scores for “wrist and arm” and “neck, trunk and legs” include each of them the muscle score and the force/load score. Because of the conditions of every task, the muscle score always added +1 since the activities were repetitive (> 4 lifts/min), as it was shown that the mean lifting frequency was 5.8 (STD 1.8) lifts per minute, with a maximum of 12 lifts per minute. Also, the force/load score added +3 every time to the group score since the activity was repetitive and more than 22 lbs. or 9kg were handled. This led to a minimum score of 4 for each group without considering the posture score for each body region.

Figure 4 presents the results of the “wrist and arm score and the “neck, trunk and legs score” individually for the 94 baggage handlers evaluated for the activity of lifting baggage.

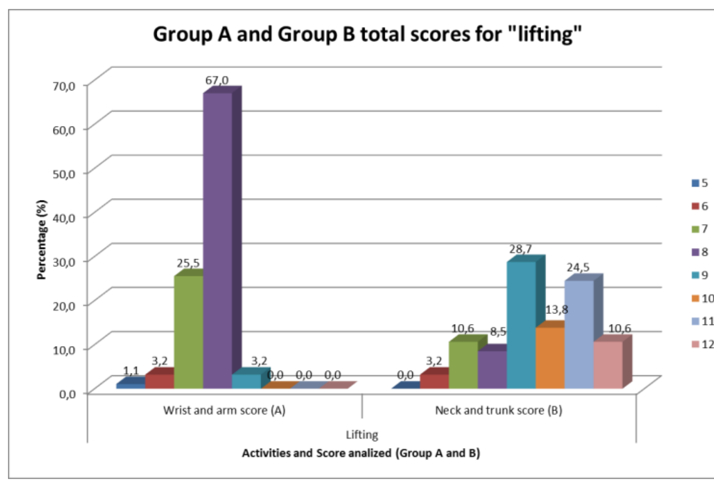


Fig. 4 – Percentage of handlers for every score obtained in group A and B. Source: Own development

In Figure 4, the scores obtained are presented in colours in the legend at the right of the graph. Group A resulted in higher scores than Group B. It can be seen that for Group B, 10.6% of the evaluated baggage handlers got a score of 12, 24.5% got a score of 11, 13.8% a score of 10 and 28.7% resulted in a score of 9; while for Group A, only 3.7% of the evaluated resulted in a score of 9, and there were no results higher than it.

On the other hand, Figure 5 presents the same results but for the 21 baggage handlers evaluated for the activity of unloading baggage from conveyor.

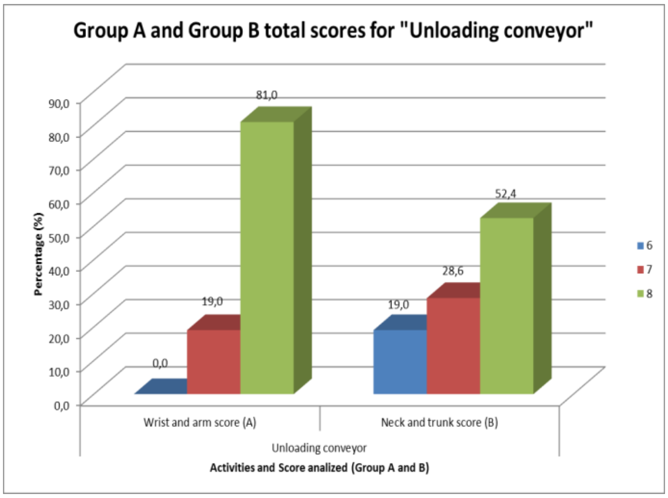


Fig. 5 – Percentage of handlers for every score obtained in group A and B. Source: Own development

In Figure 5, it can be seen that the results for both regions were quite similar. For Group A 81% of the evaluated got a score of 8 and 19% a score of 7, while for Group B 52.4% a score of 8 and 28.6% a score of 7. Finally, Figure 6 presents the results for both groups (A and B) for the activities of placing the bag into its final position and placing the bag while being inside of the container.

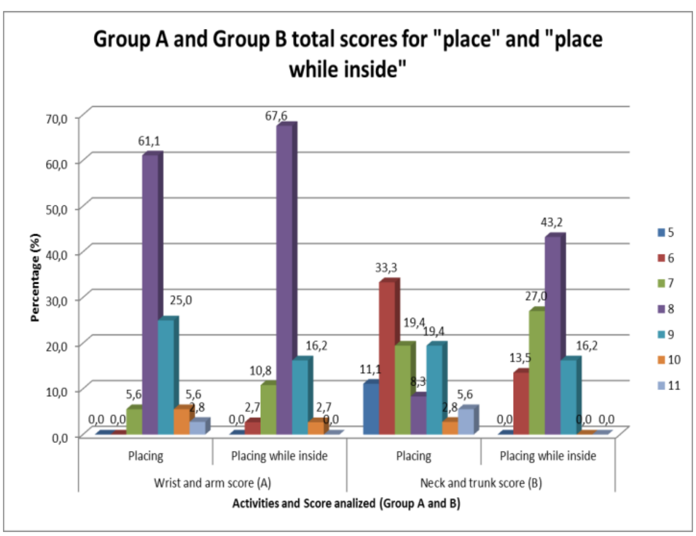


Fig. 6 – Percentage of handlers for every score obtained in group A and B. Source: Own development

As it can be seen, Figure 6 shows both activities analysed in the same graph to highlight the difference or similarities between them. It can be seen that the activity "pacing" shares similar results for Group A than the activity "Placing while inside". In the other hand, for Group B they are slightly different. The activity "place" had 5.6% of the evaluated with a score of 11 and 2.8% with a score of 10, while the activity "place while inside" did not reach those scores.

Also, to statistically find the activity that represents the highest risk of suffering a MSD for the body segments of Group A, an Analysis of Variance (ANOVA) followed by a Tukey test was performed (Montgomery, 2008). The model represented was an unbalanced design, since each of the treatments had a different number of observations ($N_{Placing} = 36$; $N_{PlacingInside} = 37$; $N_{conveyor} = 21$; $N_{lifting} = 94$) (Montgomery, 2008). The ANOVA proved that there exists a difference between the means of score levels of the activities; where in this case each activity represents a treatment (Montgomery, 2008). It resulted in the rejection of the null hypothesis in which all the activities had equal mean scores (p-value = 0.0 < 0.05), and it was concluded that at least one activity was different from the others (Appendix F). Then, the Tukey test compared the mean score between each pair of activities and determined the activities that present a different mean from the others (Montgomery, 2008). The activity "place" presented the highest mean score of 8.39 and was found statistically equal to the activity "place while inside" and different from the other two. Results of both, the ANOVA, its Residual Plots and the Tukey test are presented in Appendix F.

The same analysis was conducted to find the activity that represents the highest risk of suffering a MSD for the body segments of Group B. The ANOVA resulted in the rejection of the null hypothesis (p-value = 0.0 < 0.05), and concluded that at least one activity had a different mean score than the others (Appendix G). The Tukey test determined that the score for "lifting" 9.55 and was significantly different, and higher, than the other 3 which were equal between each other has a different mean score than the other 3 activities. Results are presented in Appendix G. Finally, Figure 7 summarizes the results obtained in the Tukey tests for Group A and Group B.

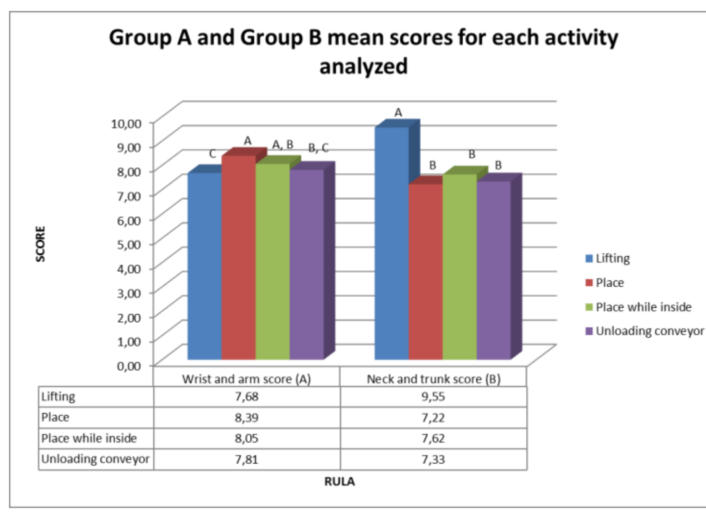


Fig. 7 – Mean risk scores obtained for each activity for Group A and Group B. Source: Own development

Figure 7 is divided into the results for Group A and Group B. It presents the mean risk score obtained for each one of the activities. The labels on top of every bar group the activities with an equal mean score, and show the activities that had a significant different mean score from the others.

5. Discussion

5.1. Maximum Acceptable Weight in Lift (MAWL)

The lifting capacity for the population of male baggage handlers in the Quito airport was determined to be 7 kg (Table 3). This value represents the "limit of weight" baggage handlers should be able to lift them, independently from the characteristics of the worker, so that there is a minimum risk of suffering a MSD (Fernandez et al., 2008; Snook and Ciriello, 1991). The MAWL of 7 kg represents the conditions of the lifting activity in baggage handling, meaning that variable such as the width of the object, the range of lift, and the frequency of lift are represented within the 7 kg (Table 2). It is important to consider that given these conditions, the task should be designed for a maximum weight of 7 kg, in order for the 90% of the population to work within "safe" conditions; and if it is wanted to accommodate a higher percentage of the population, then the MAWL should decrease (Fernandez et al., 2008; Snook and Ciriello, 1991). The result obtained of the MAWL was proven to be correct, by comparing it to the weight limit determined by Dell in 2007 using the NIOSH equation, that resulted to be quite similar (The Ergonomics Society Conference, 2008).

The MAWL determined, compared to the actual average weight of the bags lifted is much lower (Berdowski et al., 2009; Liu and Tseng, 2006; Pikaar and Asselbergs, 2010). In average the actual weight of checked bags is more than two times heavier than the MAWL of 7 kg recommended here. As it is known, the maximum weight accepted by airlines is, without an extra cost, 23 kg, meaning that a single bag could easily reach three times the suggested weight limit for baggage handling activities. Finally, when lifting a heavier object than the suggested weight limit (7 Kg), the compressive load is higher than 3400N recommended by NIOSH as the limit for lifting heavy objects (Korkmaz et al., 2006). Therefore, lifting activities performed by baggage handlers in the baggage tunnel present a high risk of developing a MSD related to the biomechanical risk factor "force", and the conditions of the task should be changed immediately.

5.2. Rapid Upper Limb Assessment (RULA)

The RULA analysis determined a total score of 7 for each of the activities evaluated, for the 100% of the baggage handlers. The entire population of baggage handlers evaluated for each activity had a Total RULA Score that falls in the Action level 4, meaning that there is a high risk of suffering an upper MSD in every activity, it implies that the work conditions should be changed immediately and the tasks should be investigated in a profound manner (Figure 3) (Fernandez et al., 2008; Mcatamney and Corlett, 1993).

The "Wrist and Arm Score" that represents the body region A, and the "Neck, Trunk and Leg Score" represented by Group B, were presented to find the regions most affected for each activity. For the activity "lifting" the body segments in Group B, such as the neck and trunk (lower back) are affected in a greater manner than the ones of Group A (Figure 4). The main reason for this was that the activity forced the baggage handler to bend his trunk (lower back), more than 60 degrees in order to lift the bag from the floor. Also most of the times the handler extended his neck back to look up and balance, which resulted in a high score (Mcatamney and Corlett, 1993). On the other hand, for the activity "unloading conveyor", both body segments of Group A and Group B are affected in a similar way (Figure 5). In this activity, having to extend the arm to reach for the bag produced higher scores for Group A, specifically the upper and lower arm. Finally, the activities "placing" and "placing while inside" both affect the body segments of group A, specifically the arms and shoulders, in a greater manner, than those of group B. The position or posture of the body segments of Group A, for both activities, was similar (Figure 6). In both activities, placing and placing while inside, the trunk position was not significantly bent. This means that body regions of Group B were not affected as in Group A. A difference found between both activities, placing and placing while inside, was that for the first one the operator extended his neck back when placing the bag, while for the second one, he was unable to do so because he was in a limited height workspace.

An ANOVA and a Tukey test were performed for the results for each group, and determined the activity with the highest risk mean score, and the activities that were equal in terms of risk scores. The activity "lifting" was determined to be the one (from all of them) that presents the highest risk. Specifically, this activity has a higher risk level for the body segments of Group B, which implies that that it presents a higher risk of suffering an injury in the lower back. Also, it was determined that the activity "placing" was statistically equal to the activity "placing while inside" for the scores of Group A and Group B. This implies that there is no difference of risk between TAME and ANDES, since the activity "placing while inside" was only performed by ANDES and the activity "placing" was only performed by TAME. Also, both activities present a higher risk, than the others, of suffering an injury in the shoulders and arms.

Finally, baggage handling includes a combination of the activities of lifting and placing, meaning that it could easily end up in MSD or injuries in the shoulders, lower back, neck and wrists. Epidemiologic studies presented in the introduction section showed that the body parts mentioned are the regions that usually suffer injuries in baggage handlers, meaning that the results of the RULA are coherent, and that the conditions in baggage handling should be changed immediately.

5.3. Frequency of lift between companies.

The frequency of lift determined that the lifting and placing activities were repetitive (lifting frequency > 4 lifts/minute), and therefore could present a high risk level when analyzed by a biomechanical method (Mcatamney and Corlett, 1993). It was determined that the mean lifting frequency of ANDES, was greater than TAME. Also, it is interesting to note that ANDES has a higher lifting frequency than TAME even though they had about 6 – 10 handlers assigned for each flight while TAME only had 2. This means that having more handlers may not reduce the lifting frequency during the lifting period. This interesting result can be explained by comparing the procedures of loading containers and loading trailers, in which for the first case the lifting period is lower than from the second case, and therefore the lifting frequency increased. To sum up, TAME baggage handlers lift bags during a longer period with a smaller lifting frequency, while ANDES baggage handlers lift luggage during a smaller period with a higher lifting frequency. The result does not prove that ANDES employees have a higher risk, because the baggage handlers of TAME have to lift a greater amount of bags since the entire flight is operated only by 2 handlers, while ANDES is able to divide the total amount of bags for the 6 -10 handlers assigned. In fact, having to lift more bags will produce greater overexertion and therefore a higher risk of MSD.

5.4. Administrative and engineering controls recommended.

Reducing the weights of the bags handled by baggage handlers might be the most effective method to reduce the exposure to risks (Dell, 1998). Some initiatives have tried to reduce the weight limit imposed by airlines, but there has been resistance to them, since airlines do not wish to upset passengers, become less competitive than others, or because it is hard to restrict the weight from incoming bags from other airports (Riley, 2005). In fact, around the year 2000 the weight limit used to be 32 kg, but the OSHA formed an alliance with the airlines and got to reduce this limit to 23 kg as it is today; making it hard to reduce it even more (Riley, 2005). Therefore, administrative and engineering controls aim to improve other conditions of baggage handling tasks, in order to reduce the risk of injury. These will be described ahead.

Administrative controls can be adopted without the need of an expensive investment. For this case an alternative stowing method and providing categorical information, such as heavy warnings tags in bags are recommended. The actual stowing method in the Quito airport for the load of containers and trailers consists in laying bags flat and stacking them in several layers inside the container. The stowing method proposed consists in placing the bags to be stored upright on their short sides (like books on a shelf) in order to reduce the number of layers, and therefore the number of lifts. Figure 8 presents the stowing method. Also, an important element of the proposed method is that the bags stored upright (first layer) have to be the heaviest bags, and they will be slid into place instead of having to lift them; while on the other hand, the lighter bags will be placed on top of this first layer. Providing categorical information in bags was also recommended as a complement to the stowing method, since it allows the security personal and baggage handlers to identify the heavier bags and determine the bag storage location. Also, the categorical information helps the baggage handlers identify a heavy bag and ask for help to lift it. A study used muscle activity using EMG and an experimental design used to relate the variables of stowing method and categorical information to this muscle activity (Korkmaz et al., 2006). In the proposed stowing method, developed by Korkmaz et al (2006), was proven to significantly reduce the overall spinal loads and therefore reduce the risk of low back injury in airline baggage handlers (Korkmaz et al., 2006). On the other hand, providing categorical information, such as weigh class ID tags, was not found to significantly reduce spinal loads, but that does not mean it is not useful (Korkmaz et al., 2006). In contrast, it is recommended to use categorical information as a complement for the proposed stowing method, and because it was observed that in the Quito airport, baggage handlers often misjudged small suitcases with great weight and surprised them when they tried to lift them. Every bag in the Quito airport has a tag with information in it, it is recommended that the tag should include a red sign that says "heavy" when the bag weights more than 21 kg, a yellow sign for weights between 10 – 21 kg, and a green sign for bags that weight less than 10 kg.

Fig. 8 – Proposed stowing method. Source: (Korkmaz et al., 2006)

Another administrative control proposed is a training program about lifting techniques that is performed two times a year in order to remember the baggage handlers how to lift bags properly and reduce the risk of injury. Previous studies demonstrated that baggage handlers think that training programs can reduce the risk level of the task (Dell, 1998; Tafazzol et al., 2015). The most important advice to reduce back injury is to avoid or minimize severe torso flexion (Gallagher, 2005). Lifting in a flexed posture, such as in the activity "lifting" analyzed leads to rapid fatigue failure of spinal tissue and therefore it should be minimized by squatting and using the legs in order to lift and learning this in the training program (Gallagher, 2005). The training program must include loosening up and stretching exercises that should be performed by baggage handlers in an obligatory manner at the beginning and at the end of the shift, and should be monitored by the handling supervisors or security personnel. Also, similar to the training program it is recommended that two routine medical checkups should be implemented to verify if the baggage handlers presents an injury, and in the case that he does it includes physiotherapy sessions. Another common solution that reduces the exposure to lifting activities in baggage handling is job rotation. ANDES baggage handlers are assign only to handling activities, meaning that they do not rotate tasks but only shifts, and therefore it is recommended that they should rotate tasks also. Finally, this study determined that TAME needs to assign more baggage handlers to serve each baggage tunnel. Having only 2 baggage handlers for each tunnel represents that in comparison to ANDES, TAME baggage handlers lift as much as 5 times the number of bags that a baggage handler from ANDES does. This results in periods with less rest that end up in a quicker develop of localized muscle fatigue and therefore a higher risk of injury (Gallagher, 2005). Assigning more baggage handlers should decrease the frequency of periods in which bags are lifted.

Finally, an engineering control recommended is the re-design of the trailer where bags are placed, into a new one that is lowered. Ergonomic guidelines for Manual Material Handling recommend that objects that are lifted should be placed in the "power zone", that ranges from above the knees to below the shoulders (Osha et al., 2007). Therefore, to accommodate 95% of the baggage handlers of the Quito airport, Ecuadorian male mestizos, the loading height (distance from the floor to the surface) should be 57 cm instead of 75 cm. To calculate the mentioned value, a data base of anthropometric measures (knee height) of Ecuadorian mestizos was used (Lema, 2012). Another engineering control is the redesign of the conveyor to its recommended height, inclination angle and speed (Thomas et al., 1995). Since the Quito airport already has an inclined conveyor it is recommended to only calibrate its speed to 0.48 m/s to improve the working conditions (Thomas et al., 1995). Also, semi-automated and automated loading devices have been proposed to be included in the baggage tunnel, but its implementation is no easy since it requires a redesign of the complete baggage system (Lenior, 2012). Those devices are the Extended Belt Loader (EBL) that consists of a sort of arm shaped conveyor that extends into the ULD (Pikaar and Asselbergs, 2010). Lastly, vacuum lifting assist devices, such as the Vaculex TP or the Vacucobra, should be implemented in the baggage tunnel by the Quito airport and it will significantly reduce the MSD risk level of any baggage handler in the airport.

6. Conclusions

The present study determined the risk level of MSDs in baggage handlers of the Quito airport through the application of biomechanical risk factors identification tools. The activities performed by baggage handlers in the Quito airport were determined. From all of them, the activities performed in the baggage tunnel, which include "lifting", "placing", placing while inside" and "unloading conveyor", were analyzed because all of them represent the most repetitive movements and awkward postures. The lifting capacity (MAWL) for the population of male baggage handlers in the Quito airport was determined to be 7 kg, which compared to the actual average weight of the bags lifted is much lower, concluding that baggage handling lifting activities have a high risk of developing a MSD related to the biomechanical risk factor "force". It was also concluded that the activities in baggage handling are repetitive (lifting frequency > 4 lifts/minute). A comparison between the lifting frequency of ANDES and the lifting frequency of TAME determined that ANDES baggage handlers have a higher lifting frequency. But it does not conclude that those baggage handlers had a greater risk. The baggage handlers of TAME lift as much as 5 times the number of bags that a baggage handler from ANDES and therefore more personnel of TAME should be assigned to the baggage tunnels.

The RULA analysis determined that for each of the activities evaluated the 100% of the baggage handlers presented the highest possible risk level. It concluded that there is a high risk of suffering an upper MSD in every activity, and implies that the work conditions should be changed immediately. An analysis of the scores obtained for Group A and Group B determined that the activity "lifting" is the riskiest and affects in a greater manner the lower back, while the activities "placing" and "placing while inside" were found to be statistically equal and affect the shoulders and arms of the baggage handler. Finally, from all the administrative controls, an alternative stowing method and providing categorical information, such as heavy warnings tags in bags, were recommended to significantly reduce the risk of low back injury without the need of a costly investment. Also, a redesign of the trailer was proposed, which includes a lowered height design to accommodate 95% of the baggage handlers of the Quito airport, which are Ecuadorian male mestizos.

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Appendix A. Unloading bags from conveyors and loading them into containers in the baggage room

A.1. Unloading and loading baggage off conveyors into containers in the baggage room flowchart

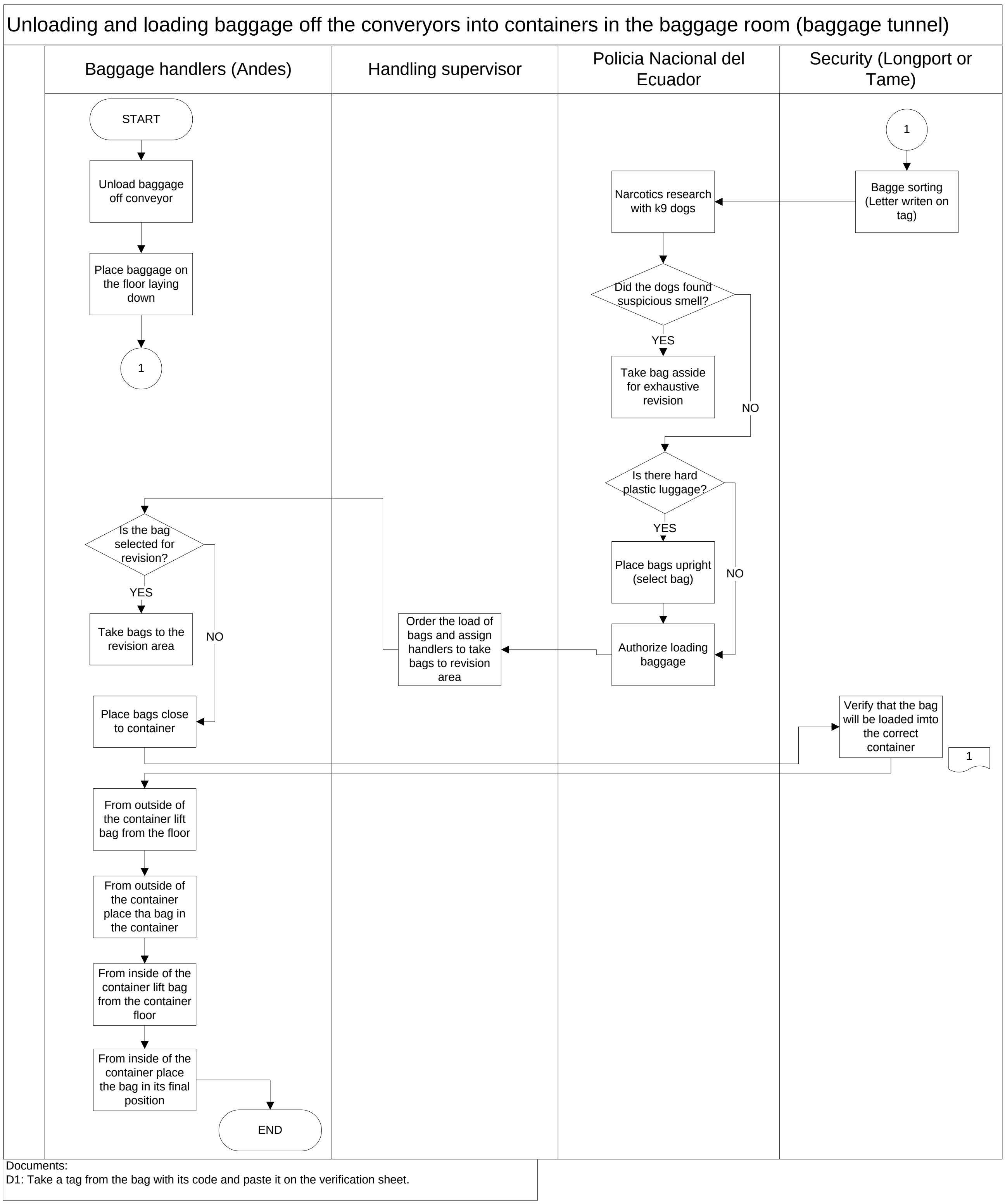

Fig. 9 – Unloading bags from conveyors and loading them into containers in the baggage room. Source: Own development

Appendix B. Unloading bags from conveyors and loading them onto trailers in the international baggage room.

B.1. Unloading and loading baggage off conveyors onto trailers in the international baggage room flowchart

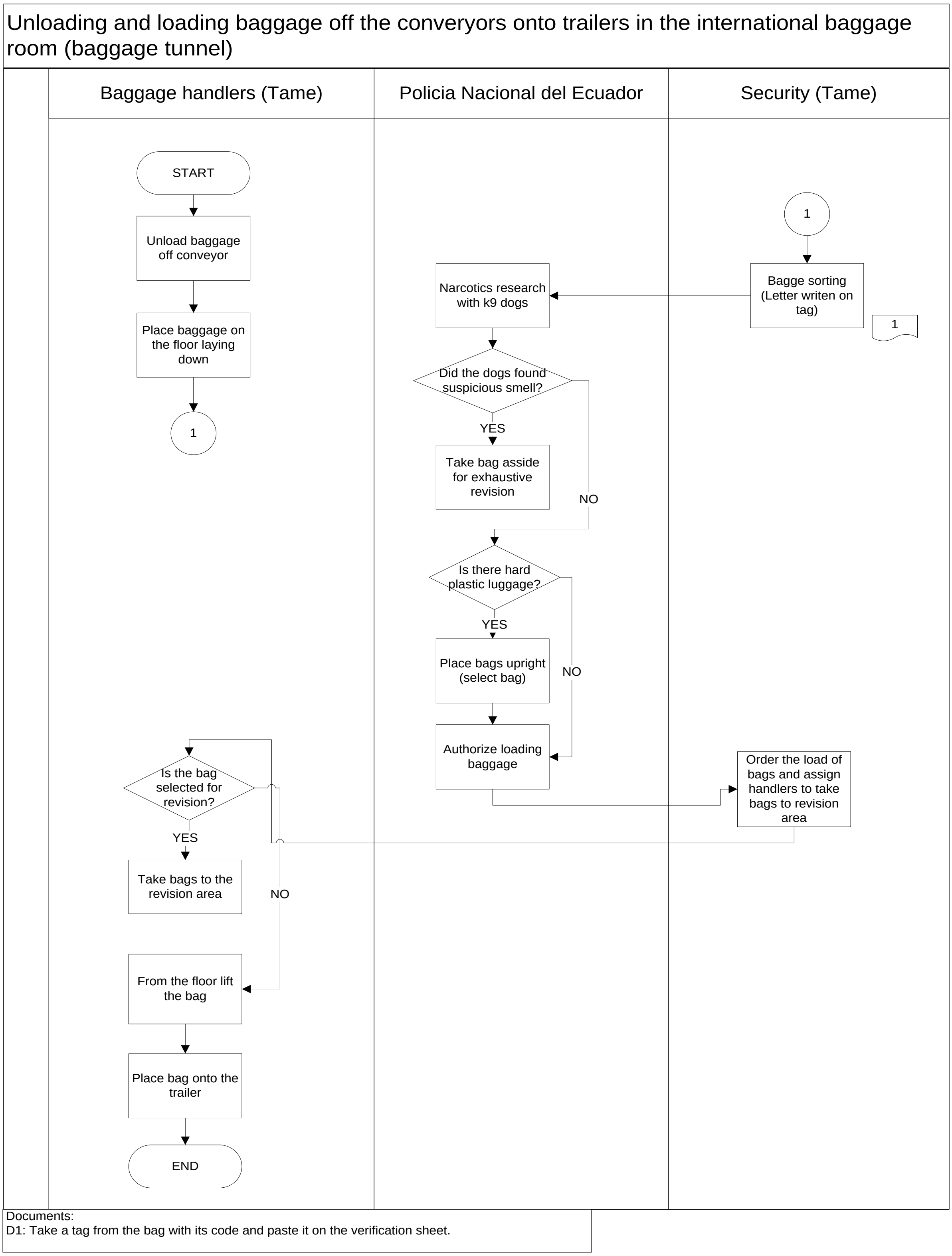

Fig. 10 – Unloading bags from conveyors and loading them onto trailers in the international baggage room. Source: Own development

Appendix C. Unloading bags from conveyors conveyors and loading them onto trailers in the domestic baggage room

C.1. Unloading and loading baggage off conveyors onto trailers in the domestic baggage room flowchart

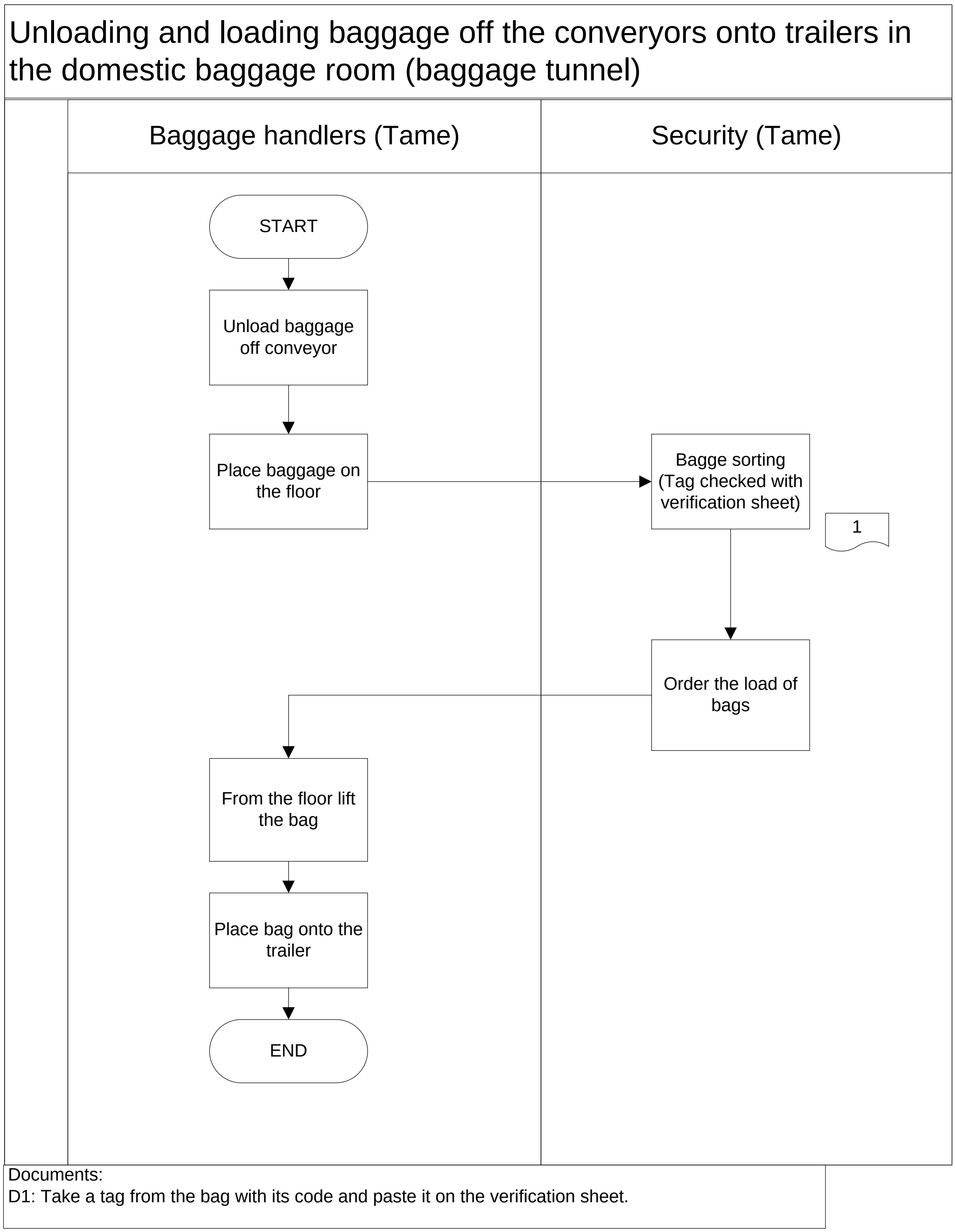

Fig. 11 – Unloading bags from conveyors and loading them onto trailers in the domestic baggage room. Source: Own development

Appendix D. Trailer used in the Quito airport to transport bags to the aircraft.

D.1. Trailer where luggage is loaded and its dimensions

Fig. 12 - Trailer used by the airlines and ground handling companies in the Quito airport.

Appendix E. Two sample Mann-Whitney test for the difference in the mean lifting frequency of each company.

E.1. Anderson Darling normality tests for the lifting frequencies data of each company.

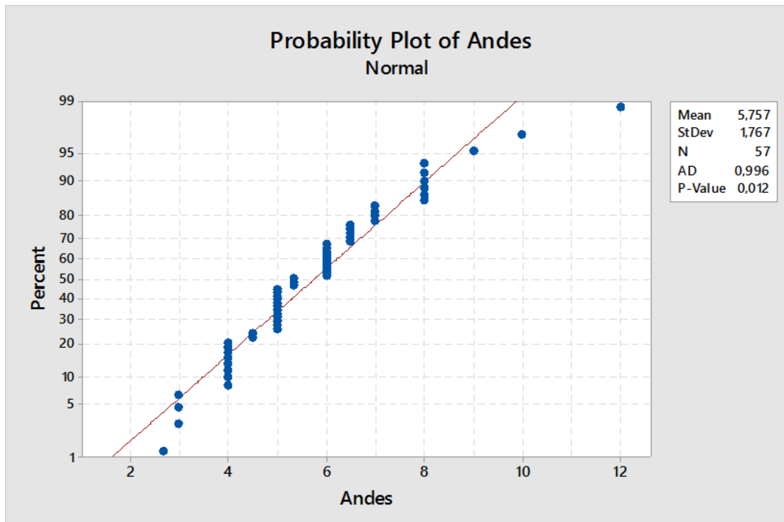

Fig. 13 – Probability Plot of the Anderson Darling test to prove the normality of the lifting frequencies of ANDES. Source: Own development

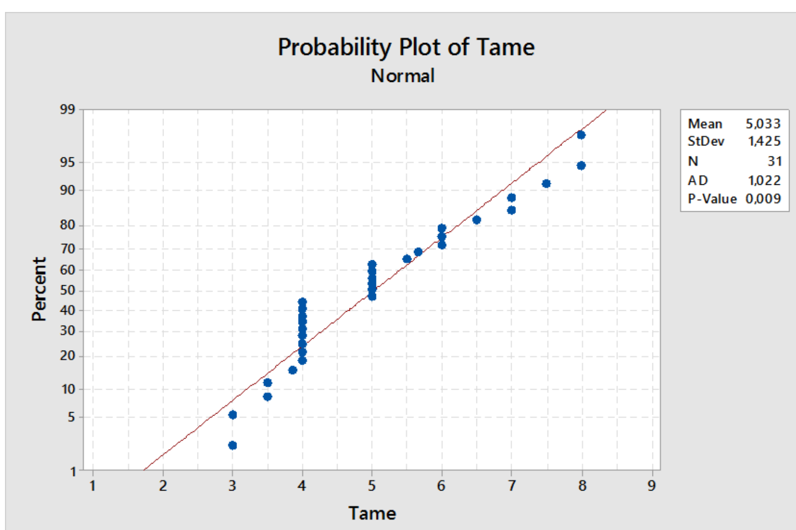

Fig. 14 – Probability Plot of the Anderson Darling test to prove the normality of the lifting frequencies of TAME. Source: Own development

E.2. Two sample Mann-Whitney test for the mean difference of the lifting frequency.

Mann-Whitney Test and CI: Andes. Tame

```
        N  Median
Andes  57   5,333
Tame   31   5,000


Point estimate for η1 - η2 is 1,000
95,1 Percent CI for η1 - η2 is (0,000.1,333)
W = 2767,5
Test of η1 = η2 vs η1 ≠ η2 is significant at 0,0441
The test is significant at 0,0419 (adjusted for ties)
```

Fig. 15 – Results of the two sample Mann-Whitney test for the difference of the mean lifting frequencies. Source: Own development

Two-Sample T-Test and CI: Lift freq. Company

```
Two-sample T for Lift freq

Company   N  Mean  StDev  SE Mean
Andes    57  5,76   1,77     0,23
Tame     31  5,03   1,43     0,26


Difference = μ (Andes) - μ (Tame)
Estimate for difference:  0,724
95% CI for difference:  (0,033. 1,415)
T-Test of difference = 0 (vs ≠): T-Value = 2,09  P-Value = 0,040  DF = 73
```

Fig. 16 – Results of the two sample t test for the difference of the mean lifting frequencies. Source: Own development.

Appendix F. ANOVA and Tukey test for the mean risk scores obtained in Group A.

F.1. ANOVA test to prove the difference of mean risk level between activities for the body regions of Group A.

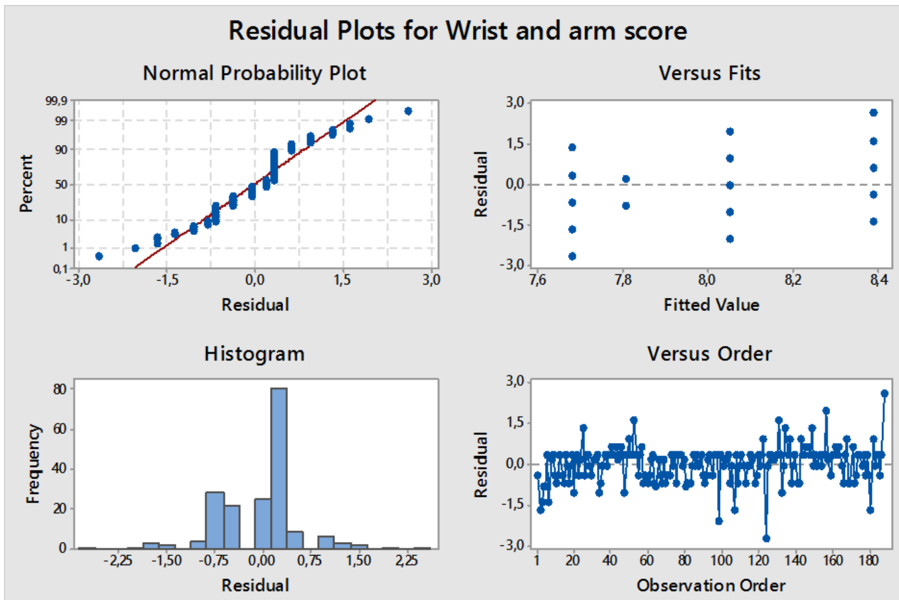

Fig. 17 – Residual Plots for Wrist and arm scores (Group A). Source: Own development

```
Factor Information

Factor     Levels  Values
Actividad       4  Carrusel. Colocar. Colocaradentro. Levantar


Analysis of Variance

Source      DF  Adj SS  Adj MS  F-Value  P-Value
Actividad    3   14,17  4,7218    10,58    0,000
Error      184   82,11  0,4463
Total      187   96,28


Model Summary

       S    R-sq  R-sq(adj)  R-sq(pred)
0,668024  14,71%     13,32%      11,10%
```

Fig. 18 – ANOVA results for the Wrist and arm score vs. the activities. Source: Own development

F.2. Tukey test to determine the activities that have a different mean Wrist and arm score (Group A).

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Actividad	N	Mean	Grouping
Colocar	36	8,389	A
Colocaradentro	37	8,054	A B
Carrusel	21	7,8095	B C
Levantar	94	7,6809	C

Means that do not share a letter are significantly different.

Fig. 19 – Tukey Pairwise comparisons between the mean score of Group A fof each activity. The Comparisons summarize the results of the entire test by grouping the activities that share an statistically equal mean, and showing the ones that don't. Therefore, p-values and statistics are not presented. Source: Own development

Appendix G. ANOVA and Tukey test for the mean risk scores obtained in Group B.

G.1. ANOVA test to prove the difference of mean risk level between activities for the body regions of Group B

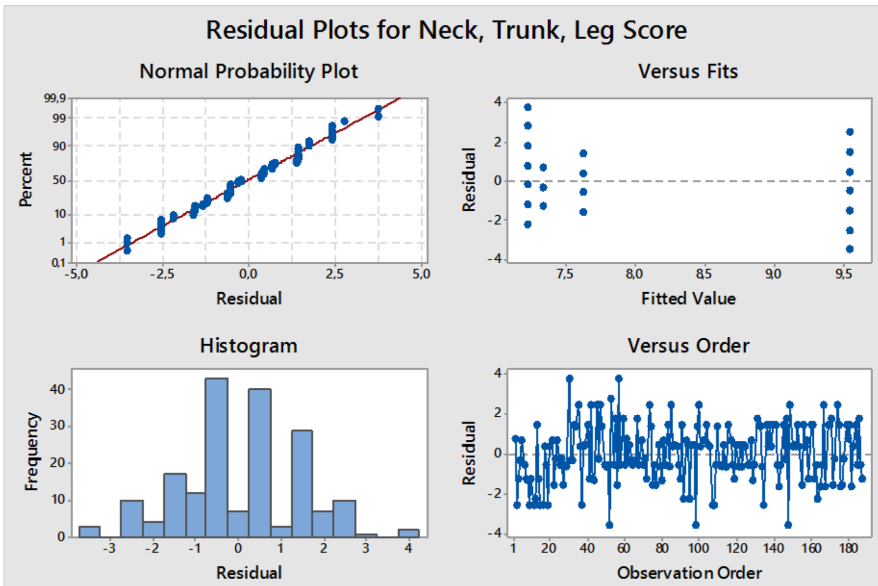

Fig. 20 – Residual Plots for Neck, Trunk and Leg score (Group B). Source: Own development

```
Factor Information

Factor      Levels  Values
Actividad        4  Carrusel. Colocar. Colocaradentro. Levantar


Analysis of Variance

Source      DF  Adj SS  Adj MS  F-Value  P-Value
Actividad    3   220,1  73,363    35,26    0,000
Error      184   382,8   2,081
Total      187   602,9


Model Summary

      S    R-sq  R-sq(adj)  R-sq(pred)
1,44242  36,50%     35,47%      34,19%
```

Fig. 21 – ANOVA results for the Neck, Trunk and Leg score (Group B) vs. the activities. Source: Own development

G.2. Tukey test to determine the activities that have a different mean Trunk, Neck and Legs (Group B).

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Actividad	N	Mean	Grouping
Levantar	94	9,553	A
Colocaradentro	37	7,622	B
Carrusel	21	7,333	B
Colocar	36	7,222	B

Means that do not share a letter are significantly different.

Fig. 22 – Tukey Pairwise comparisons between the mean score of Group B fof each activity. The Comparisons summarize the results of the entire test by grouping the activities that share an statistically equal mean, and showing the ones that don't. Therefore, p-values and statistics are not presented. Source: Own development

Appendix H. Maximum Acceptable Wight in Lift prediction table for Males (kg) in lifting tasks (Ciriello and Snook, 1999; Snook and Ciriello, 1991)**.**

Maximum Acceptable Weight of Lift for Males (kg)

Width	Distance	Percent	Floor level to knuckle height, One lift every: 5 s	9 s	14 s	1 min	2 min	5 min	30 min	8 h	Knuckle height to shoulder height, One lift every: 5 s	9 s	14 s	1 min	2 min	5 min	30 min	8 h	Shoulder height to arm reach, One lift every: 5 s	9 s	14 s	1 min	2 min	5 min	30 min	8 h
		90	*6*	7	9	11	13	14	14	17	8	10	12	13	14	14	16	17	6	8	9	10	10	11	12	13
		75	*9*	11	13	16	19	20	21	24	10	14	16	18	18	19	21	23	8	10	12	14	14	14	16	17
	76	50	*12*	*15*	17	22	25	27	28	32	13	17	20	22	23	24	26	29	10	13	15	17	17	18	20	22
		25	*15*	*18*	*21*	28	31	34	35	41	16	*21*	*24*	27	27	28	32	35	11	16	18	21	21	22	24	27
		10	*18*	*22*	*25*	33	37	40	41	48	*19*	*24*	*28*	31	32	33	37	40	*14*	18	21	24	24	25	28	31
		90	6	8	9	12	13	15	15	17	8	11	13	15	15	16	18	19	6	8	9	12	12	12	14	15
		75	*9*	11	13	17	19	21	22	25	11	15	17	20	20	21	23	25	8	11	12	15	15	16	18	20
75	51	50	*13*	15	18	23	26	28	29	34	14	19	21	25	25	26	29	32	10	14	16	19	20	20	23	25
		25	*16*	*19*	22	29	33	35	36	42	*17*	*23*	26	30	31	32	36	39	13	17	19	23	24	25	27	30
		10	*19*	*22*	*26*	34	38	42	43	50	*20*	*26*	*30*	35	36	37	41	45	*15*	19	22	27	27	29	32	35
		90	8	9	11	13	15	16	17	20	10	13	15	18	18	19	21	23	7	10	11	14	14	14	16	18
		75	*11*	13	15	19	22	24	24	28	13	17	20	23	24	25	27	30	10	13	15	18	18	19	21	23
	25	50	*15*	18	21	26	29	32	33	38	17	22	25	30	30	31	35	38	12	16	19	23	23	24	27	29
		25	*18*	*22*	26	33	37	40	41	48	*20*	*27*	*30*	36	36	38	42	46	15	20	22	28	28	29	32	35
		10	*22*	*26*	*31*	38	44	47	49	57	*23*	*31*	*35*	42	42	44	49	53	*17*	*23*	26	32	32	34	38	41
		90	7	8	10	13	15	16	17	20	8	10	12	13	14	14	16	17	7	9	10	12	12	13	14	16
		75	*10*	12	14	19	22	24	24	28	10	14	16	18	18	19	21	23	9	11	13	16	16	17	19	21
	76	50	*14*	*16*	19	26	29	32	33	38	13	17	20	22	23	24	26	29	11	15	17	20	21	21	24	26
		25	*17*	*20*	*24*	33	37	40	41	48	16	21	24	27	27	28	32	35	13	18	20	25	25	26	29	31
		10	*20*	*24*	*28*	38	43	47	48	57	*19*	*24*	*28*	31	32	33	37	40	*15*	*21*	23	28	29	30	33	36
		90	7	9	10	14	16	17	18	20	8	11	13	15	15	16	18	19	7	9	11	14	14	14	16	18
		75	10	13	15	20	23	25	25	30	11	15	17	20	20	21	23	25	9	12	14	18	18	19	21	23
49	51	50	*14*	17	20	27	30	33	34	40	14	19	21	25	25	26	29	32	12	15	18	23	23	24	27	29
		25	*18*	*21*	25	34	38	42	43	50	17	23	26	30	31	32	36	39	14	19	21	28	28	29	32	35
		10	*21*	*25*	*29*	40	45	49	50	59	*20*	*26*	*30*	35	36	37	41	45	*16*	*22*	25	32	32	34	37	41
		90	8	10	12	16	18	19	20	23	10	13	15	18	18	19	21	23	9	11	12	16	16	17	19	21
		75	12	15	17	23	26	28	29	33	13	17	20	23	24	25	27	30	11	14	16	21	21	22	25	27
	25	50	*16*	20	23	30	34	37	38	45	17	22	25	30	30	31	35	38	14	18	21	27	27	28	32	35
		25	*21*	*25*	29	38	43	47	48	56	*20*	*27*	30	36	36	38	42	46	16	22	25	33	33	34	38	42
		10	*24*	*29*	*34*	45	51	56	57	67	*23*	*31*	*35*	42	42	44	49	53	*19*	*25*	*29*	38	38	40	44	48
		90	8	10	11	15	17	19	19	23	8	11	13	15	15	16	18	19	8	10	12	14	14	15	16	18
		75	*12*	14	17	22	25	28	28	33	11	15	17	20	20	21	23	25	10	14	16	18	19	19	24	24
	76	50	*16*	*19*	22	30	34	37	38	44	14	19	21	25	25	26	29	32	13	17	20	23	24	25	27	30
		25	*20*	*24*	*28*	37	42	47	47	55	17	*23*	26	30	31	32	36	39	*16*	*21*	24	28	29	30	33	36
		10	*24*	*29*	*33*	44	50	54	56	65	*20*	*26*	*30*	35	36	37	41	45	*18*	*24*	*28*	33	33	34	38	42
		90	9	10	12	16	18	20	20	24	9	12	14	17	17	18	20	22	8	11	13	16	16	17	18	20
		75	*12*	15	18	23	26	28	29	34	12	16	18	22	23	23	26	29	11	14	17	21	21	22	24	26
34	51	50	*17*	20	24	31	35	38	39	46	15	20	23	28	29	30	33	36	14	18	21	26	27	28	31	34
		25	*21*	*25*	*30*	39	44	48	49	57	18	24	27	34	35	36	40	44	*17*	22	25	32	32	33	37	41
		10	*25*	*30*	*35*	46	52	57	58	68	*21*	*28*	*32*	40	40	42	46	51	*19*	*26*	*29*	37	37	39	43	47
		90	10	12	14	18	20	22	23	27	11	14	16	20	20	21	23	26	10	13	15	19	19	19	22	24
		75	*15*	18	21	26	30	32	33	38	14	18	21	26	27	28	31	34	13	17	20	24	25	26	29	31
	25	50	*20*	24	28	35	40	43	44	52	18	23	27	33	34	35	39	43	16	22	25	31	31	33	36	40
		25	*26*	*30*	*35*	44	50	54	55	65	*21*	*28*	32	40	41	42	47	52	*20*	*26*	*30*	37	38	39	44	46
		10	*29*	*35*	*41*	52	59	64	66	76	*25*	*33*	*37*	47	47	49	55	60	*23*	*30*	*35*	43	44	45	51	55

Note:

1. Width is dimension away from body in cm
2. Distance is vertical lift in cm
3. Percent pertains to industrial population
4. Italicized values exceed 8 hr physiological criteria

Fig. 23 – Maximum Aceptable Wight in Lift prediction table for Males. (Ciriello and Snook, 1999)

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