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Ergonomic Risk Assessment of Baggage Handlers in Helipad Operations

Kennedy A. Osakwe Adakporia[1], Azizur Rahman[2], Dr. Folusho Alamina[3]

[1]RMIT University, Occupational Health & Safety/Ergonomics, School of PCPM, 124 La Trobe St, VIC 3000 Melbourne, Australia
Corresponding Author Email: *Kennedy.osakwe [at]rmit.edu.au*

[2]RMIT University, Occupational Health & Safety/Ergonomics, School of PCPM, 124 La Trobe St, VIC 3000 Melbourne, Australia
azizur.rahman [at]rmit.edu.au

[3]Industry Researcher in Occupational Health, SPDC, Port Harcourt, Nigeria
Email: folumine[at]gmail.com

Abstract: ***Baggage handlers' tasks in the aviation industry involve several M Handling (MH) activities with exposures to ergonomic risks and inherent potential for musculoskeletal disorders. Increased complaints of musculoskeletal disease among aviation workers, particularly baggage handlers in Warri Delta State in Nigeria, necessitated a detailed ergonomic risk assessment of their activities. Using modern tools such as ergonomic risk factors checklist, RULA (Rapid Upper Limb Assessment), Mital assessment, Dempsey and 3D Static Strength Prediction Program (3D SSPP); it was found that while the weight of the individual bag was acceptable to ergonomic limits, loaded carts of passenger's bag were too heavy to push or pull. As a remedial strategy, it will be efficient to use a tractor to move a loaded baggage cart. Alternatively, the cartwheel should be modified to reduce the friction grip on the floor during pushing or pulling. A procedural strategy for reducing the maximum allowable weight of each bag to less than 17kg and ensuring that passengers carry bags with handles to foster coupling. To further reduce the exposure to lifting bag loads into the helicopter boot, a mini-chain crane can be mounted on the cart and hoist bags into the boot of the helicopter.***

Keywords: Ergonomic risk factors checklist, RULA, Rapid Upper Limb Assessment, Mital assessment, Dempsey, 3D Static Strength Prediction Program, 3D SSPP

1. Background

Baggage handling is a critical aspect of the aviation industry in which the baggage handlers play a crucial role in the movement of personnel effects, goods and services. Increased complaints of musculoskeletal disease among baggage handlers in Warri Delta State have necessitated a detailed ergonomic risk assessment of their activities. In this project, baggage handler refers to an airport worker who loads or unloads baggage and/or cargo from passenger or client's 'checked-in' or from aircraft and safely secures same within the aircraft hold (Dell, 1998). In 2015, about 173, 700 baggage handlers were employed in the United States aviation industry (Lu et al., 2015); and 1, 400 in the Swedish aviation industry (Bergsten et al., 2015). The baggage handling process varies across aviation facilities and operations depending on the nature and type of terminal, security architecture and passenger traffic. Generally, the baggage handling process includes loading and off-loading customers' baggage on and off conveyors, containers, luggage trailers, aircraft baggage compartments, aircraft or helicopter booths, trolleys, baggage carts and collection carousels (Dell, 1998). While a typical high-end airport, such as an international and regional airport, manages baggage handling through the 'Baggage Handling System (BHS)' see Figure 1.

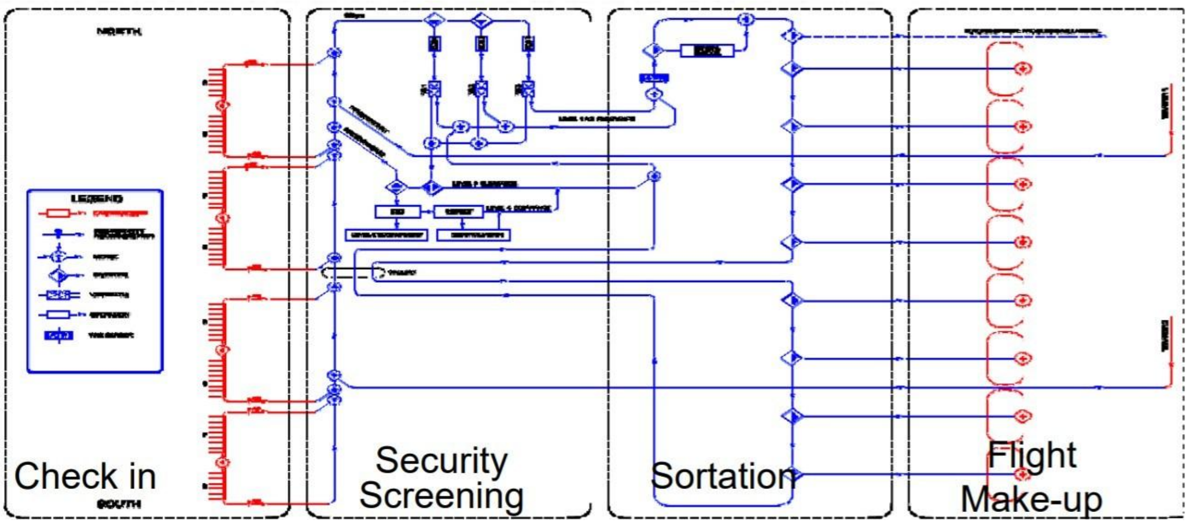

Figure 1: Baggage handling system BVHS

Smaller aviation facilities such as aerodromes, airstrips, helipads, helidecks, and some local airports manage baggage transfer via manual handling by the baggage handlers. In this study, baggage handling in a typical heliport, helipad and helideck is the primary focus. Beside loading and offloading of baggage's, handlers undertakes other ground handling activities, however the loading and offload facets poses the commonest ergonomic risk. Additionally, workers are exposed to environmental ergonomic factors such as noise from the aircrafts and mobile machinery, inclement weather, varying environmental temperature, varying illumination levels, varying wind speed and more. In this study, the principal focus is exposure to ergonomic and biomechanical factors from baggage handling. The process entails physical or manual handling of baggage's, characterized by lifting, lowering, pushing, reaching, pulling, sitting, twisting and holding of luggage (Tafazzol et al., 2016). It further involves awkward postures such as squatting, kneeling, bending and twisting. Researchers revealed that these kind of characteristics and postures requirement in the task constitute ergonomic risk factors with significant potential for musculoskeletal injuries when not controlled (Rahman et al., 2015). Generally, manual handling ergonomic risks include loading, pulling, pushing, stacking, lowering, transferring, carrying, holding, repetitive movement and awkward posture (Mikkelsen et al., 2016; Mikkelsen et al., 2019; Oxley et al., 2009; Thygesen et al., 2016).

The prevalence of Musculoskeletal injuries or disorders among baggage handlers is significant and has been reported in several studies. Musculoskeletal injuries are acute or chronic impacts to human musculoskeletal system involving the muscles, tendon, nerves and supporting structure (Rahman & Palaneeswaran, 2018). Generally, it is divided into Work Related Upper Limb Disorders, Low back pain and Repetitive Strain Injuries. Common complaints include upper back and knee aches, elbow, wrist and hip pain, low back pain, neck and shoulder pain and general body aches. Some reported musculoskeletal diagnosis includes back injuries, subacromial shoulder disorders, low back pain and strains (Møller et al., 2018). Literature abounds on the acute and chronic health disorders experienced by baggage handlers (Dell, 1998). These health disorders have been associated with the ergonomic risks and exposures integral to the baggage handling process. The UK HSE published in 2009 that baggage handlers are prone to Work Related Musculoskeletal Disorders of the neck, shoulder, low back and Knee (Oxley et al., 2009). Osteoarthritis of the knee (Mikkelsen et al., 2019), meniscal lesion and knee arthrosis (Mikkelsen et al., 2016), subacromial shoulder disorder (Thygesen et al., 2016) resulting from injury to the ligament, spasms of the lower back muscles, impingement of the spinal nerve roots, prolapsed disc and injury to the cartilages), pain in thelumbar spine region may originate from many different conditions. Injured ligaments, prolapsed discs, inflammation in the facet joints, muscle spasms, compression of spinal nerveroots, vertebral periosteum are just some of the causes of pain and impairment (Koblauch, 2016).

While several assessments have been undertaken on top-end airport operations with a significant amount of data, there is a paucity of data and information on the ergonomic assessment of baggage handlers in a corporate or in-house aviation setting involving helicopter operation in helidecks, helipads and heliports. This project aimed to assess and quantify ergonomic and biomechanical risks inherent in baggage handlers' activities in a corporate in-house aviation setting of a major conglomerate with widespread field locations.

2. Materials and Method

An investigative ergonomic assessment of baggage handling activities in a major organization's in-house corporate aviation setting was done. Aviation operations involve a daily airlift of personnel to and from several onshore and offshore field locations with helicopters from the main operating onshore base. There are 32 onshore helipads, 15 helidecks and 3 heliports locations in Warri Delta State in Nigeria. These heli-units (helidecks, helipads and heliports) are licensed by the ministry of aviation and manned by two baggage handlers each. A typical heli-unit consists of a check-in section with a check-in counter, weighing scale, baggage scanning machine, sorting area, waiting hall, luggage carts, briefing room, departure room, arrival hall with baggage holds and marked paths to heli-units. Generally, the baggage handling cycle starts from the check-in counter to the helicopter (aircraft) hold (boot) and from the boot (hold) to the baggage carousel (ramp) at the waiting bay.

Tools used in this assessment include an Ergonomic Risk Factor checklist (Table 1) used in a walk-through survey (Osakwe et al., 2020; Osakwe et al., 2021) to identify ergonomic risk factors inherent in baggage handlers' activities. A Rapid Upper Limb Assessment (RULA) (Figure 4) was used to quantify ergonomic risk factors of the upper extremity during baggage handling activities. RULA is an ergonomic survey tool used to quantify work-related upper limb ergonomic exposures (McAtamney & Corlett, 1993). This was used as a triageto identify where the highest risk lies and prioritise other tools that could be used to appraise high-risk factors. It analysed external load demand of the task by appraising the upper arm, lower arm, wrist, neck, and trunk. It further quantifies the risk by assigning numeric values used to calculate the grand score is compared with a risk matrix. To assess the acceptability of the luggage, the Mital table (Table 2, 3, 4, & 5) was used to calculate a corrected maximum acceptable load value for lifting and lowering baggages from the cart into the helicopter boot. This was used to assess lifting, lowering, pushing and pulling. Mital approach factors in the height of lift from origin to destination, gender (male in this instance), frequency of handling and values for correction factors. The Dempsey equation was used to assess the metabolic requirement for pushing and pulling the baggage cart. The compression force in the lower back was assessed using the 3D Static Strength Prediction Program (3DSSPP). This software package assesses and quantifies the compression in the lower back using ergonomic variables such as anthropometry (height, weight and gender of the baggage handlers), hand load, and trunk and neck posture. The software animation was also used to depict the picture of the baggage handlers during the manual handling process.

3. Result

Walk through survey revealed that the operations handle over 15 flights and over 35 passengers daily, the baggage handlers undertake daily task of loading baggage cart which they push for about 70 meters from the check-in baggage bay to the helipads parking lot and load into the helicopter's booth. Loading task involved lifting and lowering of passenger's bags into the baggage cart, pushing and pulling ofcart from check-in baggage bay through a 70m distance to helicopter parking lot, lifting of baggage's from the cart up above the knuckle height into the helicopter boot [see Figure 2] and pushing to anchor baggage's in the boot.

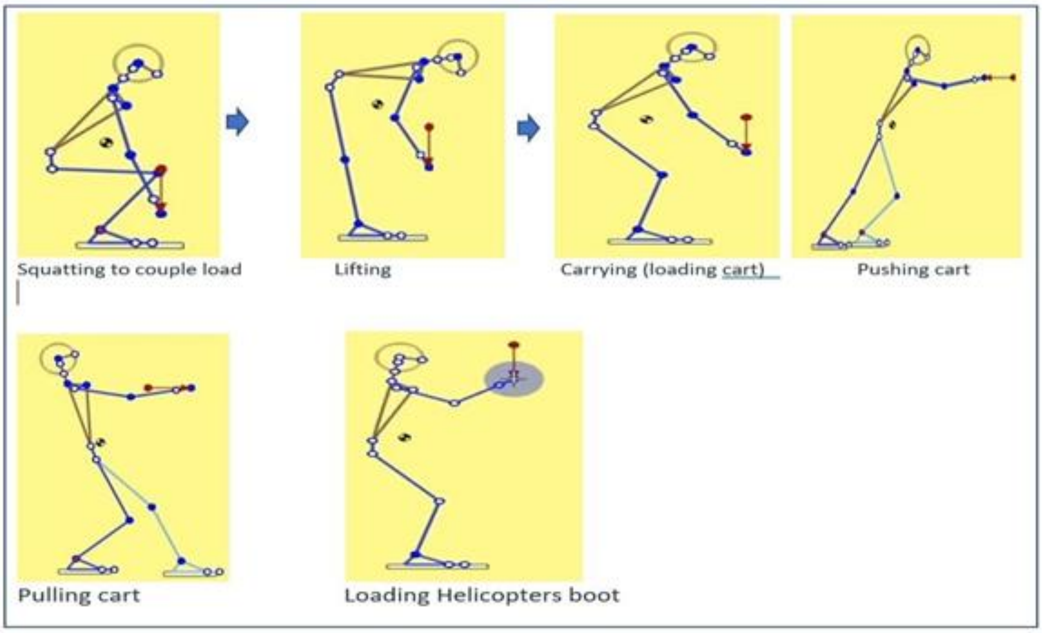

Figure 2: Worker's posture during activities

Layout: The facility is a small sized helipad with one runway, 2 hanger, 2 helipad parking lots, 1 check-in hall and counter, 1 briefing hall and several baggage cart (Figure 3 for details from Google earth). Direct photo snaps were not allowed.

Figure 3: Helipad Layout (Google Earth, 2022)

Ergonomic Risk Factors: Using the Jim Potvin Ergonomic Risk Factor Checklist (Armstrong et al., 2018), 20 risk factors were identified [see Table 1].

Table 1
Ergonomics Risk Factor Checklist
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Enter "1" in each grey box where the risk is present

Legs	**Standing**	
	- unevenly balanced on feet	
	- lifting with the legs	
	- prolonged standing	
	- prolonged knee bending	
	- required to use foot pedals	
	- knee(s) hyperextended	
	Sitting	
	- feet not supported	
	- knee clearance inadequate	
	- pressure under thighs	
	- required to use foot pedals	
	- seat pan size inadequate	
	- seat pan height not adjustable	
	- seat pan angle not adjustable	
	- seat pan does not rotate	
	Walking	
	- walk for long distances	1
	- pushing or pulling with force	1
	- pushing or pulling long distances	1
	- carrying loads	1
	- climbing stairs	
	- climbing a ladder	
Trunk	**Lifting or Lowering**	
	- heavy load	1
	- loads below knee knuckle height	
	- loads above shoulder height	1
	- long reaches	1
	- high frequencies	
	- poor coupling	1
	- spine twisting	
	- laterally bending the spine	
	- lifting/lowering with only one hand	
	Non-Neutral Spine Postures	
	- spine flexion	1
	- spine extension	
	- spine twisting	
	- spine lateral bending	
	- frequent motions	1
	- prolonged static postures	
	- whole body vibration exposure	

20 Risk Factors Identified

Neck	**Non-Neutral Postures**	
	- neck extension	
	- neck flexion	1
	- neck twisting	1
	- neck side beding	
	- wearing a head mounted display	
	- frequent motions	1
	- prolonged static postures	
Shoulder	**Non-Neutral Postures**	
	- shoulder flexion	1
	- shoulder abduction	
	- elbow above shoulder	
	- extreme internal rotation	
	- extreme external rotation	
	- shoulders raised/shrugged	1
	- heavy load in hand	
	- frequent motions	1
	- prolonged static postures	
Elbow & Forearm	**Non-Neutral Postures**	
	- elbow not near 90 degrees	1
	- contact pressure at elbow	
	- extreme forearm pronation posture	
	- extreme forearm supination posture	
	- forceful pronation or supination	
Hand & Wrist	**Forces**	
	- forceful power grip	
	- using a pinch grip	
	- hand exertion with deviated wrist	
	- wrist flexion or extension effort	
	- radial or ulnar deviation effort	1
	- contact pressure on wrist(s)	
	- contact stress on finger(s)	
	- high torque with power tool	
	- hand/arm vibration exposure	
	- unsupported tool used	
	Non-Neutral Postures	
	- grip span not optimal	
	- wrist flexed or extended	1
	- wrist radial or ulnar deviated	
	- repetitive finger movements	
	- repetitive wrist movements	1

NIOSH Lifting Equation Outputs:

Used to assess the recommended weight limit (RWL) i. e to assess whether the load handled by the baggage handlers are heavy for the task or not.

Quantitative data: Starting from 80 (V); Top of range (D) 180 CM; Reach (H) = 44; Frequency= 0.5 per min; Lateral displacement = 15; Duration = 8 hours; Coupling = Fair; Twist = 30; Correction Factors (lifting and carrying) - Working duration, Limited headroom, twisting, lateral bending, hand coupling, load clearance and heat stress. Distance rolled by cart = 70m; FMEA=9kg.

RWL = Table value x Working duration x Hand coupling X Lateral displacement x Asymmetry Lifting (twist).

RWL = 18 x 1.000 x 1.000 x 0.925 x 0.933 = 15.53kg

Maximum acceptable load = 17 kg corrected to 15.53kg

RULA grand severity score was 6 meaning it is a medium risk and should be investigated and reduced (see Figure 4).

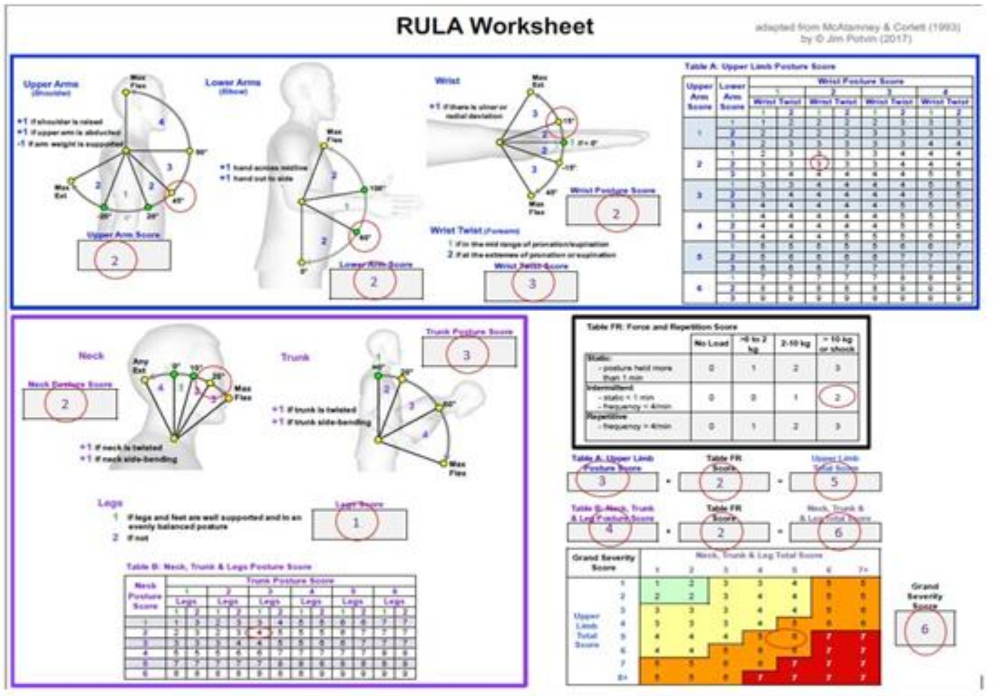

Figure 4: RULA Worksheet

Score	Level of MSD Risk
1-2	neglibible risk, no action required
3-4	low risk, change may be needed
5-6	medium risk, further investigation, change soon
6+	very high risk, implement change now

Mital values - The lowering and lifting values were 18 meaning acceptable as individual bags was 17kg but being quite close, more controls should be instituted.

The pushing and pulling values were 16 and 7 to initiate and sustain pushing respectively; 12 and 7 to initiate and sustain pulling respectively. Being that cumulative weight of the baggage cart was 119 (17 x 7) means that the baggage cart is too heavy to be pushed or rolled by one person.

Table 2

Mital: Lifting and Lowering Table

75% Capable (= 25th percentile) 2-handed RWLs

(Adapted from Mital, Nicholson & Ayoub, 1993; by Potvin, 2019)

Vertical Range (cm)		H (cm)	Frequency (per minute)							
Bottom of Range	Top of Range		0.002	0.033	0.2	1	4	8	12	16
132	183	58	20 / 11	18 / 9	15 / 9	15 / 8	12 / 8	9 / 6	8 / 5	6 / 4
		45	23 / 12	21 / 10	19 / 9	18 / 9	14 / 8	9 / 6	8 / 5	6 / 4
		37	26 / 14	24 / 12	22 / 11	21 / 11	17 / 9	9 / 7	8 / 7	8 / 7
80	183	58	22 / 13	20 / 11	18 / 10.5	17 / 9.5	15 / 8	8 / 6	8 / 6	6 / 5
		45	22 / 13	20 / 11	18 / 10.5	17 / 9.5	15 / 8	8 / 6	8 / 6	6 / 5
		37	24 / 15	22 / 12	20 / 11	19 / 10.5	16 / 10	8 / 7.5	8 / 7.5	7 / 7
	132	58	25 / 15	23 / 13	21 / 12	20 / 11	17 / 9	8 / 7	8 / 7	7 / 6
		45	25 / 15	23 / 13	21 / 12	20 / 11	17 / 9	8 / 7	8 / 7	7 / 6
		37	**27 / 17**	26 / 14	23 / 13	22 / 12	18 / 11	8 / 8.5	8 / 8.5	7 / 8
Floor	183	63	21 / 11	18 / 8	17 / 7	14 / 7	11 / 7	9 / 6	8 / 5	6 / 4.5
		50	24 / 12	21 / 9	21 / 7	16 / 7	12 / 7	9 / 6	9 / 5	7 / 4.5
		42	**27 / 14**	24 / 10	24 / 10	19 / 9	15 / 8	9 / 7	9 / 6	7 / 5
	132	63	22 / 12	20 / 9	19 / 8	14.5 / 7.5	12 / 7.5	10 / 6.5	9 / 6	7 / 5
		50	27 / 13	22.5 / 10	22.5 / 8	18 / 8	14 / 7.5	10 / 6.5	9 / 6	8 / 5
		42	**27 / 16**	26 / 11.5	25 / 11	21 / 10	16 / 9	10 / 8	9 / 6.5	8 / 5.5
	80	63	24 / 14	21 / 11	20 / 10	16 / 9	13 / 9	10.5 / 8	9 / 7	7 / 6
		50	**27 / 16**	24 / 12	24 / 10	19 / 10	14 / 9	10 / 8	10 / 7	9 / 6
		42	**27 / 19**	**27 / 14**	**27 / 13**	22 / 12	17 / 11	10 / 9	10 / 8	9.5 / 7

Values shown as Male/Female. For example: 20 / 11 means that the Male limit is 20 and the Female limit is 11

- Bolded values (shaded in blue) corrected based on the Biomechanical Criterion

- underlined values (shaded in red) corrected based on Physiological/Metabolic data in the literature

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Table 3

Mital: Pushing Table

75% Capable 2-Handed Maximum Acceptable Forces

(Adapted from Mital, Nicholson & Ayoub, 1993; by Potvin, 2008)

Dist. (m)	Height (cm)	Init or Sust	Frequency (pushes/min)							
			0.002	0.2	0.5	1	2.4	4	5	10
2.1	144 / 135	Init.	41 / 27	34 / 24		32 / 21			29 / 18	26 / 17
		Sust.	30 / 21	24 / 16		21 / 14			17 / 10	10 / 8
	95 / 89	Init.	44 / 27	36 / 24		34 / 21			31 / 16	26 / 17
		Sust.	31 / 19	25 / 15		22 / 13			18 / 9	11 / 7
	64 / 57	Init.	40 / 21	33 / 19		31 / 17			28 / 15	25 / 14
		Sust.	31 / 17	25 / 13		21 / 11			18 / 8	11 / 6
7.6	144 / 135	Init.	34 / 24	28 / 22		27 / 19		18 / 18		
		Sust.	25 / 16	20 / 12		17 / 11		8 / 7		
	95 / 89	Init.	39 / 25	32 / 22		30 / 20		21 / 17		
		Sust.	25 / 17	20 / 13		17 / 11		9 / 7		
	64 / 57	Init.	33 / 21	27 / 19		26 / 17		16 / 14		
		Sust.	24 / 15	19 / 12		17 / 10		9 / 7		
15.2	144 / 135	Init.	32 / 21	26 / 19		25 / 17	21 / 15			
		Sust.	22 / 13	18 / 10		15 / 8	9 / 6			
	95 / 89	Init.	36 / 21	30 / 19		28 / 17	24 / 14			
		Sust.	21 / 14	18 / 11		15 / 8	9 / 6			
	64 / 57	Init.	31 / 18	26 / 16		24 / 14	19 / 11			
		Sust.	21 / 13	17 / 10		14 / 8	9 / 6			
30.5	144 / 135	Init.	31 / 21	25 / 17		19 / 15				
		Sust.	21 / 12	16 / 9		9 / 6				
	95 / 89	Init.	35 / 21	28 / 18		21 / 15				
		Sust.	21 / 13	16 / 9		9 / 7				
	64 / 57	Init.	30 / 18	24 / 15		18 / 13				
		Sust.	20 / 12	15 / 8		9 / 6				
45.7	144 / 135	Init.	26 / 21	21 / 17		16 / 15				
		Sust.	18 / 11	13 / 8		8 / 6				
	95 / 89	Init.	30 / 21	24 / 18		18 / 15				
		Sust.	18 / 12	13 / 8		7 / 6				
	64 / 57	Init.	26 / 18	21 / 15		16 / 13				
		Sust.	17 / 11	12 / 8		7 / 6				
61	144 / 135	Init.	23 / 19	18 / 15	16 / 14					
		Sust.	15 / 9	11 / 6	7 / 4					
	95 / 89	Init.	26 / 19	21 / 16	18 / 15					
		Sust.	15 / 9	11 / 6	7 / 4					
	64 / 57	Init.	22 / 16	18 / 13	15 / 12					
		Sust.	14 / 8	10 / 6	7 / 4					

Values shown as Male/Female. For example: 41/27 means that the Male limit is 41 and the Female limit is 27
- underlined values (shaded in red) corrected based on Physiological/Metabolic data in the literature
- values refer to forces in kilograms
- Init. = Initiate, which is the force to get object started. Sust. = Sustain which is the force to keep object moving

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Table 4

Mital: Pulling Table

75% Capable 2-Handed Maximum Acceptable Forces

(Adapted from Mital, Nicholson & Ayoub, 1993; by Potvin, 2008)

Dist. (m)	Height (cm)	Init or Sust	Frequency (pulls/min)							
			0.002	0.2	0.5	1	2.4	4	5	10
2.1	144 / 135	Init.	28 / 26	23 / 23		22 / 20			19 / 19	17 / 16
		Sust.	23 / 20	19 / 15		16 / 13			13 / 10	10 / 7
	95 / 89	Init.	39 / 27	32 / 25		31 / 21			27 / 19	23 / 16
		Sust.	30 / 19	25 / 15		21 / 13			17 / 10	10 / 7
	64 / 57	Init.	44 / 28	37 / 26		34 / 22			30 / 20	27 / 17
		Sust.	32 / 18	26 / 13		23 / 12			19 / 9	11 / 6
7.6	144 / 135	Init.	26 / 24	21 / 21		20 / 19		14 / 14		
		Sust.	19 / 18	16 / 13		13 / 12		6 / 6		
	95 / 89	Init.	36 / 25	29 / 22		28 / 19		19 / 17		
		Sust.	25 / 17	20 / 13		17 / 11		9 / 7		
	64 / 57	Init.	40 / 26	33 / 23		31 / 20		21 / 17		
		Sust.	26 / 16	22 / 12		19 / 11		9 / 7		
15.2	144 / 135	Init.	24 / 20	20 / 18		19 / 16	16 / 12			
		Sust.	17 / 15	14 / 11		12 / 9	7 / 6			
	95 / 89	Init.	33 / 21	28 / 19		26 / 17	22 / 12			
		Sust.	22 / 14	18 / 11		15 / 9	9 / 6			
	64 / 57	Init.	38 / 22	31 / 20		29 / 17	24 / 13			
		Sust.	23 / 13	19 / 10		13 / 8	10 / 6			
30.5	144 / 135	Init.	23 / 20	19 / 17		14 / 14				
		Sust.	16 / 14	12 / 10		7 / 7				
	95 / 89	Init.	32 / 21	26 / 18		20 / 15				
		Sust.	21 / 13	16 / 9		10 / 7				
	64 / 57	Init.	36 / 22	29 / 18		22 / 16				
		Sust.	23 / 12	17 / 9		10 / 6				
45.7	144 / 135	Init.	20 / 20	16 / 17		12 / 12				
		Sust.	14 / 12	10 / 9		6 / 6				
	95 / 89	Init.	28 / 21	22 / 18		17 / 15				
		Sust.	18 / 12	13 / 9		8 / 6				
	64 / 57	Init.	31 / 22	25 / 18		19 / 16				
		Sust.	19 / 11	14 / 8		8 / 6				
61	144 / 135	Init.	17 / 17	14 / 14	12 / 12					
		Sust.	11 / 10	8 / 7	7 / 6					
	95 / 89	Init.	24 / 19	19 / 16	16 / 15					
		Sust.	15 / 9	11 / 7	7 / 5					
	64 / 57	Init.	27 / 20	21 / 16	19 / 15					
		Sust.	16 / 9	12 / 6	8 / 5					

Values shown as Male/Female. For example: 28/26 means that the Male limit is 28 and the Female limit is 26
- underlined values (shaded in red) corrected based on Physiological/Metabolic data in the literature
- values refer to forces in kilograms
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Table 5

Mital: Pushing Table

75% Capable 2-Handed Maximum Acceptable Forces

(Adapted from Mital, Nicholson & Ayoub, 1993; by Potvin, 2008)

Dist. (m)	Height (cm)	Init or Sust	Frequency (pushes/min)							
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	95 / 89	Init.	44 / 27	36 / 24		34 / 21			31 / 18	28 / 17
		Sust.	31 / 19	25 / 15		22 / 13			18 / 9	11 / 7
	64 / 57	Init.	40 / 21	33 / 19		31 / 17			28 / 15	25 / 14
		Sust.	31 / 17	25 / 13		21 / 11			18 / 8	11 / 6
7.6	144 / 135	Init.	34 / 24	28 / 22		27 / 19		18 / 18		
		Sust.	25 / 16	20 / 12		17 / 11		8 / 7		
	95 / 89	Init.	39 / 25	32 / 22		30 / 20		21 / 17		
		Sust.	25 / 17	20 / 13		17 / 11		9 / 7		
	64 / 57	Init.	33 / 21	27 / 19		26 / 17		16 / 14		
		Sust.	24 / 15	19 / 12		17 / 10		9 / 7		
15.2	144 / 135	Init.	32 / 21	26 / 19		25 / 17	21 / 15			
		Sust.	22 / 13	18 / 10		15 / 8	9 / 6			
	95 / 89	Init.	36 / 21	30 / 19		28 / 17	24 / 14			
		Sust.	21 / 14	18 / 11		15 / 8	9 / 6			
	64 / 57	Init.	31 / 18	26 / 16		24 / 14	19 / 11			
		Sust.	21 / 13	17 / 10		14 / 8	9 / 6			
30.5	144 / 135	Init.	31 / 21	25 / 17		19 / 15				
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61	144 / 135	Init.	23 / 19	18 / 15	16 / 14					
		Sust.	15 / 9	11 / 6	7 / 4					
	95 / 89	Init.	26 / 19	21 / 16	18 / 15					
		Sust.	15 / 9	11 / 6	7 / 4					
	64 / 57	Init.	22 / 16	18 / 13	15 / 12					
		Sust.	14 / 8	10 / 6	7 / 4					

Values shown as Male/Female. For example: 41/27 means that the Male limit is 41 and the Female limit is 27
- underlined values (shaded in red) corrected based on Physiological/Metabolic data in the literature
- values refer to forces in kilograms
- Init. = Initiate, which is the force to get object started. Sust. = Sustain which is the force to keep object moving

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Dempsey

This analyzed the activity of pushing and pulling of the cart from the check-in bay to the helicopter parking lot and quantified the metabolic energy requirement needed for pushing or pulling of the cart.

Pushing: E= 0.0048 [-1036.5+7.2 (BW) +60.0 (FREQ) +34.5 (FREQ) (DIS) +61.4 (FMEA)] E= 0.0048 [-1036.5+7.2 (31.84) +60.0 (0.2) +34.5 (0.2) (70) +61.4 (9)]
E= 0.0048 [-1036.5+ 229.2+ 12+ 483 + 552.6] E=0.0048 [240.3]
E=1.15kcal/min

Pulling: E= 0.0048 [-1205.9 +11.1 (BW) +46.6 (FREQ) +38.7 (FREQ) (DIS) +56.8 (FMEAS)] E= 0.0048 [-1205.9 +11.1 (31.84) +46.6 (0.2) +38.7 (0.2) (70) +56.8 (9)]
E= 0.0048 [-1205.9 +353.424+9.32+541.8+511.2]
E = 0.0048 [210.744] = 1.011kcal/min

3DSSPP - The compression on the spine (between L5/S1) is 139 according toJager & Lottman 1991, the average maximal spinal capacity is 5, 700. This implies the compression force within the lower back is acceptable (Figure 5, 6, 7).

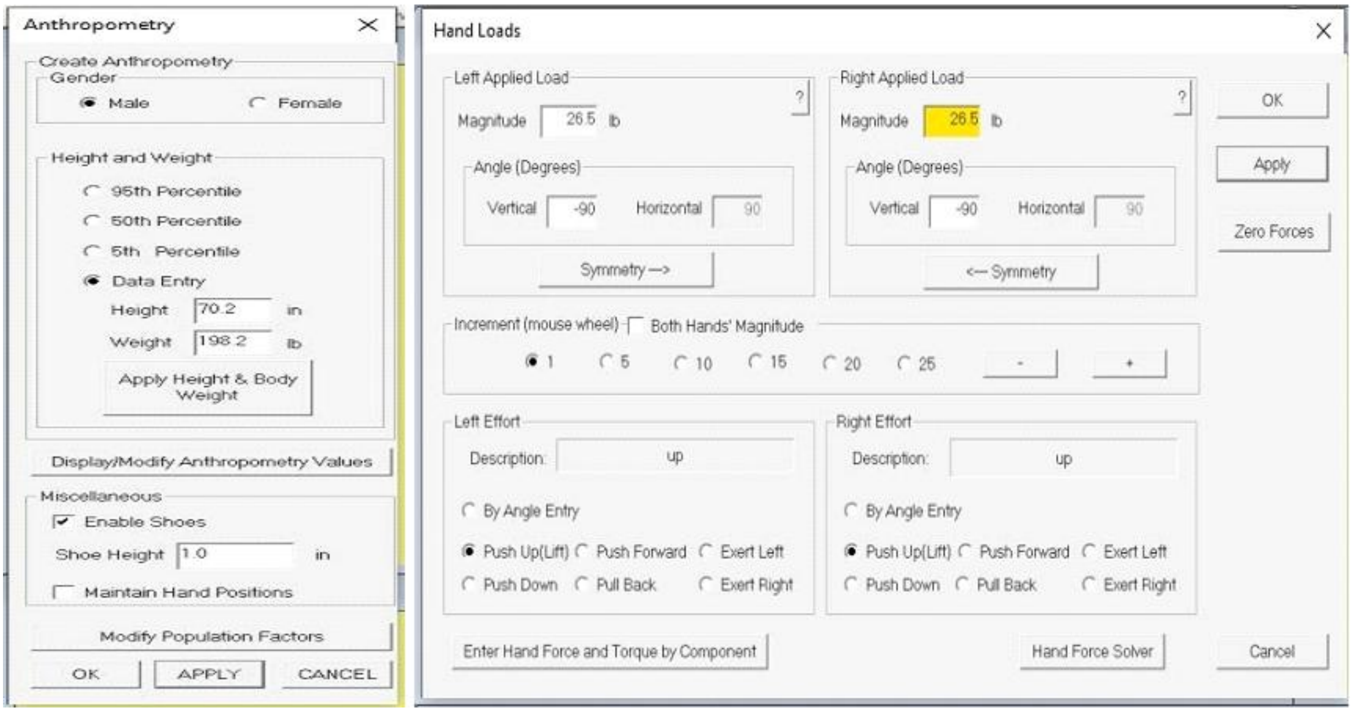

Figure 5: 3D Statistic Strength Prediction Program

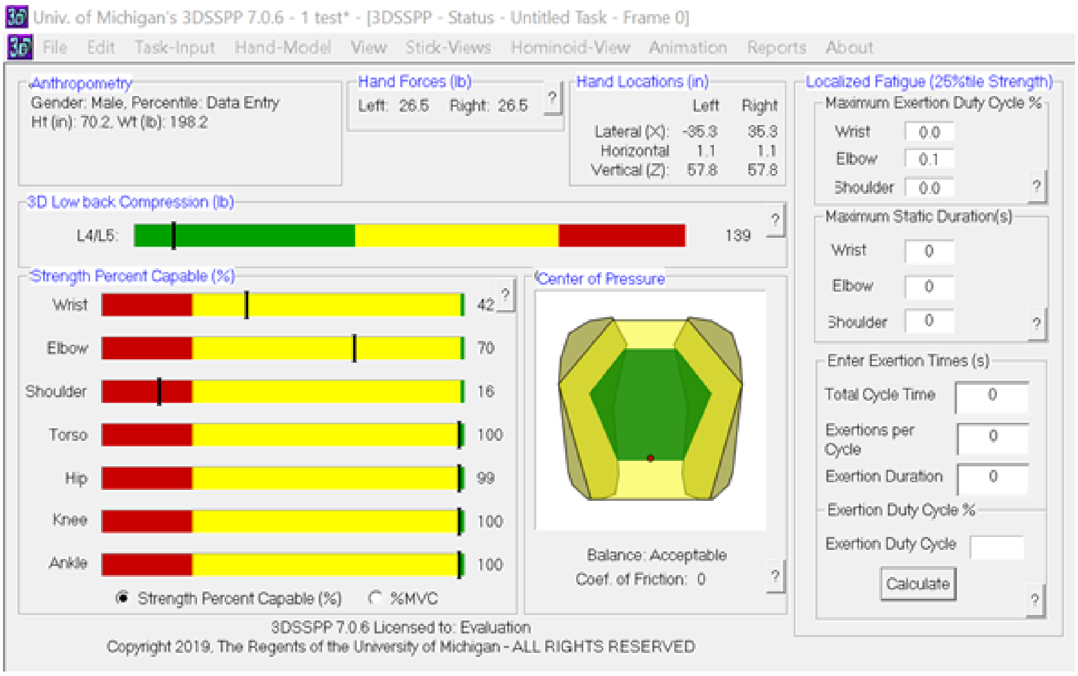

Figure 6: 3D Statistic Strength Prediction Program

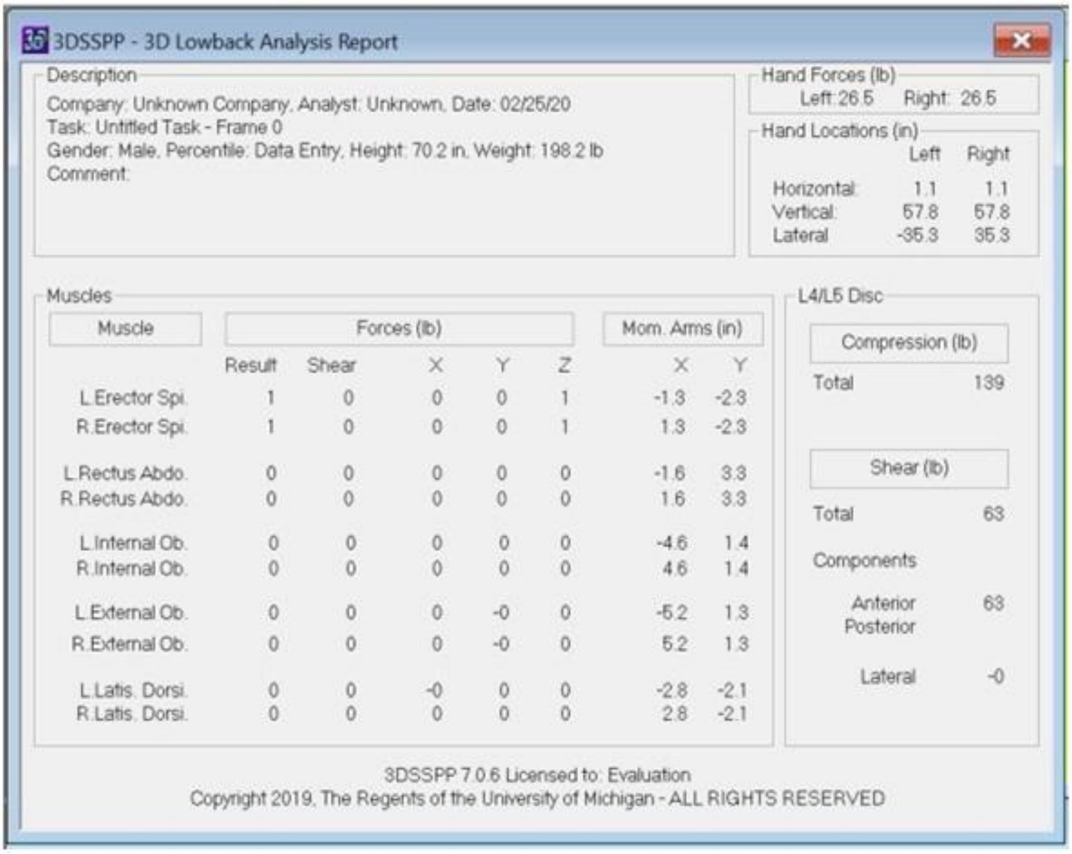

Figure 7: 3D Statistic Strength Prediction Program

4. Discussion

While ergonomic risk factors were amply identified in the whole process of handling baggage, a deeper dive revealed that passenger's baggage were within acceptable weight limit; spinal compression was within acceptable limit; and the cumulative cart weight was unacceptable for pulling and pushing. In view of the degree of manual ergonomic exposure vis-à-vis the force required to push and pull the entire load, the metabolic energy expended and required exertion can be minimized by using tractor to move a loaded baggage cart. Alternatively, if it must be pushed by manual handling, the wheel of the cart should be modified to reduce the friction grip on the floor during pushing or pulling. A procedural strategy for reducing the maximum allowable weight of each bags to be less than 17kg and further making sure that passengers carries bags with handle to foster coupling. To further reduce the exposure in lifting bags into the helicopter boot, a mini chain crane can be mounted on the cart and used to hoist bags into the boot of the helicopter.

5. Conclusion

Ergonomic risk factors found include awkward posture (squatting), lifting, carrying, pushing, pulling, reaching. Frequent motions, spine flexion, poor coupling, long reaches in the helicopter boot, heavy load, radial or ulnar deviation effort, wrist flexed or extended, elbow not near 90 degrees, shoulder with frequent motions, raided shoulders, shoulder flexion, walking for long distance, pushing and pulling of baggage cart, carrying of load and neck flexion.

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