Biomechanics and Ergonomics of Human Lifting Devices

The Raizer Chair is a portable lifting device designed to lift fallen people. The Raizer Chair is battery operated and designed to be assembled around the fallen person and operated by a single assistant. The Raizer Chair has been noted to be faster and easier for lifting people than the Mangar Elk (**E**mergency **L**ifting **C**ushion). The Mangar Elk is a portable lifting cushion that has its own battery powered compressor. When placed under the fallen person, the cushion is inflated by the compressor and with support from an assistant will lift the fallen person. The Mangar Elk has been well established as a lifting device in UK ambulance services. An alternative to the Mangar Elk is available in the form of the Mangar Eagle (the **E**mergency **AG**ile **L**ifting **E**quipment). The Mangar Eagle is designed to both sit up and lift a fallen person, whilst protecting carers from injury sustained through repetitive lifting.

To understand the influence of use of the lifting devices on both the operators and the people being lifted, an analysis was completed using a combination of instructional videos created by the manufacturer, 2D and 3D motion analysis of healthy volunteers. The analysis provides an ergonomical and biomechanical assessment of the operation of the equipment for all three devices. Three stages of use have been considered: 1) Assisting a patient on to the lifting device 2.) Operating the lifting device and 3.) movement of the patient on the lifting device.

The REBA (Rapid Entire Body Assessment) is scientifically validated process used to provide a risk assessment score following an ergonomical examination. The assessor will provide a score for each of the following body regions: wrists, forearms, elbows, shoulders, neck, trunk, back, legs and knees. These scores are used to calculate an overall score, providing a relative risk of musculoskeletal disorder (MSD) developing, as indicated below:

Score	Level of MSD Risk
1	negligible risk, no action required
2-3	low risk, change may be needed
4-7	medium risk, further investigation, change soon
8-10	high risk, investigate and implement change
11+	very high risk, implement change

Figure 1. REBA scoring to indicate relative musculoskeletal disorder (MSD) risk

Method – assessing ergonomics of positioning patient into lifting device

To ensure that the assessment of the ergonomics during positioning of the person being lifted follows the manufacturer recommendations, an instructional video for the Mangar Elk was obtained from mangarhealth.com/us and an instructional video on how to use the Raizer Chair from Felgains Ltd were utilised. REBA scores were scored at the most ergonomically demanding positions for each lifting device. The Mangar Elk instructional video demonstrates two methods of placing the cushion underneath the person being lifted, namely manually assisting the person being placed onto the cushion or using a sliding sheet to slide them onto the cushion. There are two distinct ergonomically demanding positions for manually assisting the person being lifted onto the cushion, which is to firstly sit the patient upright and then to assist the patient onto the cushion, so a REBA score has been determined for each of these positions (figure 1). A single REBA score has been determined for using the sliding sheet to position onto the Mangar Elk cushion (figure 2 (left)) and a single score for assisting rolling a patient onto the Mangar Eagle cushion (figure 2 (right)). Likewise, a single score has been determined for positioning the Raizer chair (figure 3) as there is just one method to apply this device.

Figure 1.
Mangar Elk, manually assisting method (left) - Sitting patient up. REBA score: 6
How To Transfer A Patient Onto The Mangar ELK (mangarhealth.com)
Mangar Elk, manually assisting method (right) - positioning patient into cushion. REBA score: 8
How To Transfer A Patient Onto The Mangar ELK (mangarhealth.com)

Figure 2.
Mangar Elk, sliding sheet method (left). REBA score (estimating neck flexion and using left person): 9
How To Transfer A Patient Onto The Mangar ELK (mangarhealth.com)
Mangar Eagle, assisting roll method (right). REBA score 4
How to lift a fallen person on the Mangar Eagle (Mangar Health YouTube channel)

Figure 3.
REBA score: 5
https://youtu.be/Jd1JTODyv8Y

Table 1: Results Comparison

Device	REBA Score	Risk Level
Mangar Elk manually assisting method		
- Sitting patient up	6	Medium Risk
- Positioning patient into cushion.	8	High Risk
Mangar Elk sliding sheet method	9	High Risk
Mangar Eagle manually assisting method	4	Medium Risk
Raizer Chair positioning equipment around patient	5	Medium Risk

Method – assessing ergonomics of operation by trained personnel without prompting/guidance

Eight volunteer participants were assessed. The selection criteria required each participant being either a paramedic or a student paramedic and having completed manual handling training required for Anglia Ruskin University's BSc in paramedic science course.; ensuring familiarity of manual handling techniques and correct use of lifting equipment. The aim for this section was to assess trained personnel without prompt or advice to identify any variances in ergonomics amongst the participants in this process. A REBA scoring was provided for three distinct positions for all three devices: the starting position (referred to as 'position 1'), a midway lifting position (referred to as 'position 2') and the final position (referred to as 'position 3'). Position 2 was determined for the same point for each device to ensure standardisation for each participant assessed. All three devices were measured twice for each participant and for each position the higher REBA score was taken.

Results

The average REBA score for all eight participants in each position was calculated, providing a risk stratification based on the MSD risk levels as show in 'Figure 1'. The results are shown in 'Table 2' below.

		Raizer score			Eagle score			Elk score	
Position	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Mean	6.2	1.8	1	3.5	4.1	1.7	5.6	4.9	2.5
Risk	**Med**	**Neg**	**Neg**	**Low**	**Med**	**Neg**	**Med**	**Med**	**Low**

Table 2 REBA scores for each of the lifting devices in three manual handler positions: the starting position (position 1), midway lifting position (position 2) and the final position (position 3).

The lowest risks were associated with the Raizer Chair, having two negligible risks associated with positions two and three and a medium risk for position one. The risks associated with the Mangar Eagle were negligible, low score and one medium respectively for each position (1,2 and 3). The risks associated with position one risk were lower for the Mangar Eagle than the Raizer Chair. However, the increased risk was a consequence of the manual handler only needing to place a hand on the shoulders for support in position 1 for the Mangar Eagle, whereas for the Raizer Chair the manual handler was required to support the participant's head. The REBA score risk can therefore be mitigated if the head rest for the Raizer Chair is utilised (note that the head rest is extra piece of equipment that is sold separately). In the instance that there is no need to support someone's head during the lifting process the associated REBA score would be negligible, therefore resulting in a negligible risk associated with Raizer Chair use in any of the three positions assessed. The highest overall risk associated with manual handler positions was the Mangar Elk, with two medium and one low risk positions identified. Although using the same inflatable cushion method as that of the Mangar Eagle, the Eagle is much larger and more supportive of the person being lifted. The Mangar Elk required the manual handler to support the person being lifted the whole time. It was noted that there was consistent feedback from persons being lifted that they felt less stable on the Elk compared to the other two devices.

To compare the user experience of being lifted by the Raizer Chair and Mangar Elk, an analysis was completed within the Biomechanical Laboratory at Anglia Ruskin University. Eight participants without any form of musculoskeletal conditions were recruited to act as both representative manual handlers and people being lifted. During the lifting process data was collected simultaneously from 8 3D motion capture cameras (Vicon, Oxford UK), a 2D Camera Samsung (Galaxy tab A7); during and following data collection the participants were asked to provide verbal feedback on how stable they felt on the lifting device and how smooth the lifting movement felt. The 3D motion analysis data was used to monitor the path of the upward trajectory of the participant lifted and the 2D data was used to complete the Rapid Entire Body Ergonomic (REBA) analysis. The combined data provides an overview on the movement that occurred, how the movement was perceived by the participant being lifted and the risk of musculoskeletal disorders associated with specific tasks within a job.

The vertical trajectory of the participants shoulders which is being lifted on the Raizer chair and the Mangar Elk are presented below in figure 1.

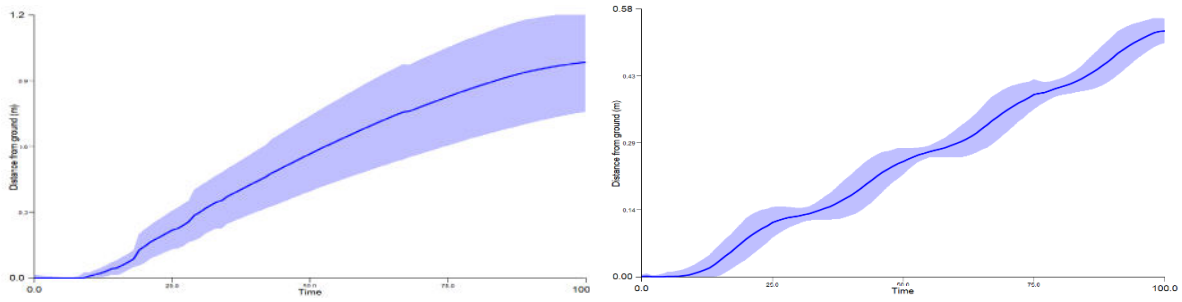

Figure 4. vertical movement of participants shoulders when being lifted by the Raizer Chair (left) and Elk vertical movement (right). The central bold line represents the average movement and the shaded area represents the standard deviation of the movement. The horizontal axis displays normalised duration of movement representing a percentage of the movement completed.

Figure 4 displays the distance travelled by the participant's shoulders during lifting, the distance from the ground is normalised to the initial position, the increased variation visible in the Raizer Chair figure is a result of the change in position from horizontal to vertical which incorporates the differences in height of the participants. As the starting position of the Mangar Elk is a seated position, the variances in participant height are accounted for at this stage. The average time for a participant to be fully lifted by the equipment was 31 seconds for the Raizer Chair and 1 minute and 7 seconds for the Mangar Elk.

The initial movement of the Raizer Chair is primarily a change in the alignment of the legs, therefore initially there is little change in height. Once the Raizer Chair's legs bases gain a significant grip on the ground a progressive, smooth vertical movement is observed, slowing down gradually until maximum height has been reached. Figure 1 (right), contrastingly, shows four distinct periods of pause, followed by a progressive vertical raise. This reflects each four sections of the inflatable cushion having a lag time due to the manual handler needing to press a separate button to inflate each cushion and the time taken to begin inflating each cushion section as air enters. The process results in an interrupted movement which is not as smooth, compared to the Raizer. The feedback from the participants being lifted mirrors that observed in the pattern of the vertical trajectory, with the perception that the Raizer Chair is faster, more stable and the movement was smoother. Feedback regarding the Mangar Elk is that the participant felt more vulnerable and required the support of a manual hander, the lifting process was less stable and prone small movements in varying directions due to the inflating process.

An alternative to the Mangar Elk is available in the form of the Mangar Eagle (the **E**mergency **AG**ile **L**ifting **E**quipment). The Mangar Eagle is designed to both sit up and lift a fallen person, whilst protecting carers from injury sustained through repetitive lifting. To facilitate lifting from a laying position rather than a seated position, the Eagle is larger than the Elk; consequently, the Eagle takes longer to inflate – an average of 2 minutes and 25 seconds. The trajectory of the participant's vertical shoulder movement is displayed in figure 5 below.

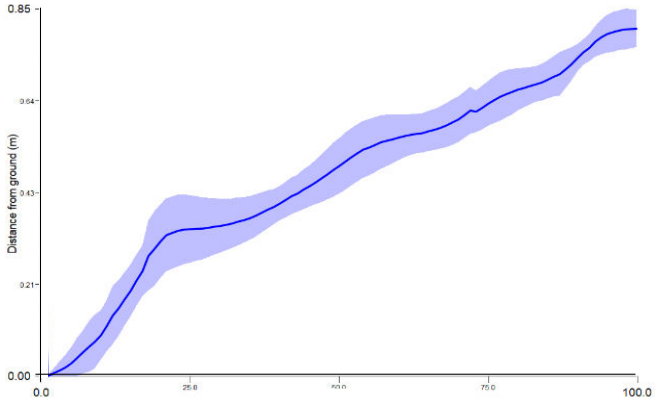

Figure 5. vertical movement of participants shoulders when being lifted by the Mangar Eagle. The central bold line represents the average movement and the shaded area represents the standard deviation of the movement. The horizontal axis displays normalised duration of movement representing a percentage of the movement completed.

The initial vertical movement displayed in figure two represents the Eagle changing a participant from a laying to a seated position. Please note that the manufacturer's guidance recommends that the section of the Mangar Eagle responsible for this movement is not fully inflated, therefore at this stage the person being lifted could be considered a partially upright posture. The process of moving from a laying position to a partially upright posture is approximately equivalent to 25% of the total lift time. During the remaining 75% of the lift a staggered upward movement is completed similar to that observed during use of the Mangar Elk.

Feedback from participants on the Mangar Eagle was that the Eagle felt more secure than the Mangar Elk, though not as study/secure as the Raizer Chair. The movement was perceived to be less smooth than either the Mangar Elk or the Raizer Chair. The increased size of the cushion sections results in inflation of the unloaded areas first (sections without body parts resting on them), until the internal pressure increases to the point at which bodyweight can be lifted. Even very small differences in the position of the person being lifted, for example closer to the left or right side, can result in small leans to one direction of the other. Likewise, as the primary loadbearing section of the Eagle is central, cushion inflation typically occurs in front and behind the participant before the hips are raised. The design the Eagle is such that the back rest is attached behind the participant, therefore if the initial partial raise is completed to either full inflation or past the approximate halfway point; the subsequent cushion inflations can create a small 'rocking movement' as the backrest is lifted before the hips of the person being lifted.

Despite the participants noting the differences in the movements that occurred during the lifting process, due to the larger size of the Mangar Eagle, the reclined position and the participant's back being in constant contact with the Eagle, the participants felt more secure on the Eagle than they did on the Mangar Elk. However, as the Raizer Chair does not inflate, has a more solid feel, a smoother movement and the lift is completed substantially faster, all participants preferred the Raizer Chair to both the Mangar Eagle and the Elk. It was also noted that the Raizer Chair did not require to be recharged at any point while assessing the participants, whereas the battery powered compressor used for the Mangar Elk and Mangar Eagle required frequent recharging between participant use.

Summary/Key Points

Tables 1 and 2 indicate that the process of setting up and positioning someone for lifting for the Mangar Elk and Mangar Eagle presents a greater risk level than that of the Raizer Chair.

However, the following important points should be noted:

1. No analysis completed for the positioning or lifting process were classified as 'very high risk'.
2. The REBA analysis does not account for the frequency at which the person analysed is in the position assessed. Therefore, if the lifting device is not used frequently, a 'high risk' position is unlikely to cause musculoskeletal problems/conditions.
3. The analysis of the Raizer Chair did not utilise the head support attachment. If the head support attachment was utilised, all REBA risk assessments would have been classed as 'negligible'.
4. The frequency and environment which the lifting equipment is used within is likely to be quite unique to different users, therefore a trained Health and Safety professional should complete a risk assessment before use.
5. Due to the ergonomic demands of the lifting devices, users should complete manual handling training before using the devices.