

# Ergonomic Approach for Designing Water Therapy Handling Tool in a Veterinary Clinic

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**Abstract.** Praktek Dokter Hewan Bersama (PDHB) drh. Anton S.A.P has water therapy used for treating small animals up to 30 kg. Handling issues arose when paramedics treated larger animals, as the therapy activity triggered awkward postures that increased the risk of musculoskeletal disorders (MSDs) for the paramedics. This research aimed to design a handling aid for animals (patients) up to the size of a large dog. Based on direct observation and non-formal interviews with paramedics, the design process began with a Rapid Entire Body Assessment (REBA) to identify the ergonomic needs that would be used in the design process with Ergonomic Function Deployment. The selected design concept was the second concept (Ergonomic Semi-Electric Concept), where parts of the aid have an ergonomic shape and adjustable-sized equipment. Based on a simulation, the REBA evaluation of the design showed a decrease in the REBA score from 12 to 2.

## 1 Introduction

In addition to providing medical treatment for animals, PDHB drh. Anton S.A.P offers services such as hospitalization, therapy, animal grooming, and selling food that aids in animal recovery. One of the therapy services provided by the clinic is water therapy using a treadmill for animals up to the size of a large dog that suffer from musculoskeletal disorders (Muñoz et al., 2019). This therapy device is shaped like an aquarium and holds water at a height appropriate for the animal. However, due to its aquarium-like shape, the paramedics must manually lift the animals to place them inside the therapy device. Another activity performed in the water therapy room is drying the animals with a blower on a table next to the therapy device.

The problem identified is that paramedics have to bend down while performing their work due to the significant height difference between the floor and the entrance of the water therapy device, creating a non-ergonomic work area. This bending occurs when paramedics lift animals to place them into the water therapy device, which poses a potential risk of work-related injury, especially when lifting animals weighing more than 30 kg. If an animal weighs over 30 kg, the activity performed by the paramedics exceeds the recommended weight limit (RWL) of 23 kg. This situation affects the factors of being effective, comfortable, safe, healthy, and efficient.

## **2 Methodology**

### **2.1 Rapid Entire Body Assessment**

In this study, the chosen ergonomic assessment method is the Rapid Entire Body Assessment (REBA). The stages involved are identifying work postures based on observations and then conducting an ergonomic assessment of those postures using REBA. The resulting REBA score will serve as a justification for why this research was conducted and will be used as data in the design process.

#### *2.1.1 Posture Identification*

Based on the observations, the problem paramedics face is lifting patients as a whole. As an example, one of their activities is lifting a patient from the floor into the water therapy device. This poses a potential risk of hip injury, especially if the paramedic is dealing with a patient of a large and heavy species. The body parts that need to be identified include the neck, trunk, legs, upper arms, lower arms, and wrists. These six identified parts will be the data used to determine the REBA score in the next stage.

#### *2.1.2 Ergonomic Assessment*

Rapid Entire Body Assessment (REBA) is a work posture assessment method developed by (McAtamney & Hignett, 2004) to evaluate the risk of musculoskeletal disorders arising from work activities. REBA assesses the posture of the entire body (neck, back, legs, arms, wrists), force or load, and activity factors. It then generates a risk score categorized from very low to very high. This method is widely used in industries because it's practical, fast, and comprehensive, and it can help prioritize ergonomic improvement actions in the workplace.

### **2.2 Ergonomic Function Deployment (EFD)**

Ergonomic Function Deployment (EFD) is an extension of the Quality Function Deployment (QFD) method that incorporates ergonomic aspects—known as ENASE (Effective, Comfortable, Safe, Healthy, Efficient)—into the product design process to meet user needs ergonomically. This principle was introduced by (Damayanti, 2010) as a formal development of QFD with an ergonomic focus. The EFD method has become a crucial approach in ergonomics-based product design. From designing handling aids and work desks to furniture, EFD is used to reduce the risk of injury, improve comfort and efficiency, and provide scientific validity through statistical testing. The EFD implementation stages are as follows:

### 2.2.1 Identification of Ergonomic Needs

The description of the ENASE dimensions expected from the patient handling aid can be seen in Table 1.

**Table 1.** Ergonomic Requirements for Water Therapy

Dimension	Explanation
Efficient	The force applied to achieve a small goal is low, so the effort exerted when lifting a small animal is minimal.
Comfort	A condition where there is no mental burden caused by surrounding risks, so the equipment in the therapy room is universal and can be used by all paramedic therapists.
Safe	A work area condition free from risks, so the therapy room has an appropriate size and the equipment can help paramedics avoid danger.
Healthy	A work area that is safe from working conditions that can disrupt health, so the equipment used in the room is easy to use and good for health.
Effective	The achievement of the activity's target, so the therapy activity can be completed by the paramedics.

### 2.2.2 Planning Matrix

The Planning Matrix in this study has seven main elements: Importance Ergonomic Rating, Current Ergonomic Condition Score, Ergonomic Design Goal, Improvement Ratio, Ergonomic Point, Raw Weight, and Normalized Raw Weight. The element with a significant difference between this research and a typical Quality Function Deployment is the Current Ergonomic Condition Score. The data for this element is obtained from the REBA score, which is converted to a Likert scale as shown in Table 2 through Table 7.

**Table 2.** REBA Score Conversion

REBA Score	Risk Level	CECS	CECS Interpretation
1	1	5	Good
2-3	2	4	Fair
4-7	3	3	Moderate
8-10	4	2	Bad
11-15	5	1	Very bad

**Table 3.** Body Posture Combination Score Conversion

REBA Score	Likert	Explanation
1	5	Very safe
2	4	Safe
3-4	3	Fairly safe
5-6	2	Unsafe
7	1	Very unsafe

**Table 4.** Load/Force Score Conversion

REBA Score	Likert	Explanation
0	5	Very safe (light load/no load)
1	4	Safe (light load)
2	2	Less safe (heavy/unstable load)
3	1	Unsafe (heavy, unstable, and jerking load)

**Table 5.** Hand Posture Score Conversion

REBA Score	Likert	Explanation
1-2	5	Very safe
3	4	Safe
4-5	3	Fairly safe
6-7	2	Unsafe
8	1	Very unsafe

**Table 6.** Coupling Score Conversion

REBA Score	Likert	Explanation
0	5	Very safe (strong & stable grip)
1	3	Fairly safe
2	1	Unsafe (slippery, unstable)

**Table 7.** Activity Score Conversion

REBA Score	Likert	Explanation
0	5	Very safe (single frequency/low frequency)
1	4	Safe
2	3	Fairly safe

### 2.2.3 Identification of Technical Specifications

The identification of technical specifications is the stage of determining how to fulfill ergonomic needs by defining the parts of the tool to be designed. This stage also explains the definition of each required tool part.

### 2.2.4 Correlation Matrix

The correlation matrix is divided into two stages. The first is the relationship between ergonomic needs and the ergonomic dimensions of efficient, comfortable, safe, healthy, and effective. The second is the correlation between ergonomic needs (what) and technical specifications (how). The explanation of the symbols in the correlation matrix can be found in Table 8.

**Table 8.** Correlation Matrix Symbol Legend

Symbol	Relation Level	Weight / Score
●	Strong	9
○	Moderate	3
▲	Weak	1
	Not Related	0

### 2.2.5 Technical Matrix

The Technical Matrix, as its name suggests, is a matrix that determines the prioritized technical characteristics based on the largest normalized contribution value. The Technical Matrix uses data obtained from the planning matrix and compares it with the necessary technical characteristics of the aid to be created. It uses data from the Voice of the Ergonomic (VoE) relationship strength rating matrix (What) with the technical characteristics (How) and the Normalized Raw Weight from the planning matrix. There are three formulas for the technical matrix, as follows:

$$\text{Contribution per ergonomic needs} = \text{Normalized Raw Weight} \times n \text{ value} \quad (1)$$

$$\text{Contribution} = \Sigma \text{Contribution per ergonomic needs} \quad (2)$$

$$\text{Normalized Contribution} = \text{Contribution} / \Sigma \text{Contribution} \quad (3)$$

## 2.3 Design

Based on the data obtained from the House of Ergonomics, the next stage is design. This will involve developing concepts for a water therapy aid and selecting the best alternative to be the final concept.

### 2.3.1 Concept Development

Once the House of Ergonomics is complete, the next step is to develop concepts using a morphology chart. This tool is used to generate as many alternative solutions as possible for each primary function of a product. By breaking the product down into sub-functions and listing various solution principles, the team can explore a wider range of combinations. This prevents bias toward a single idea and opens up opportunities for innovation by combining solutions across different functions (Ulrich & Eppinger, 2011).

### 2.3.2 Concept Selection

#### a. Concept Screening (Pugh Method)

The purpose of concept screening is to filter a large number of initial concepts down to a few of the most promising candidates. This process uses a simple relative evaluation (+, 0, -) against key criteria, allowing the team to identify the strengths and weaknesses of each concept without overly detailed analysis. Screening helps save time by eliminating less viable ideas and retaining potential concepts for further evaluation (Ulrich & Eppinger, 2011).

#### b. Concept Scoring (Weighted Scoring)

The purpose of concept scoring is to perform a more detailed evaluation of the concepts that remain after the screening phase. By assigning weights to important criteria and conducting a quantitative assessment, the team can objectively compare candidates based on technical data, cost, and customer needs. The result is a final concept chosen systematically, with a transparent and accountable basis for the decision (Ulrich & Eppinger, 2011).

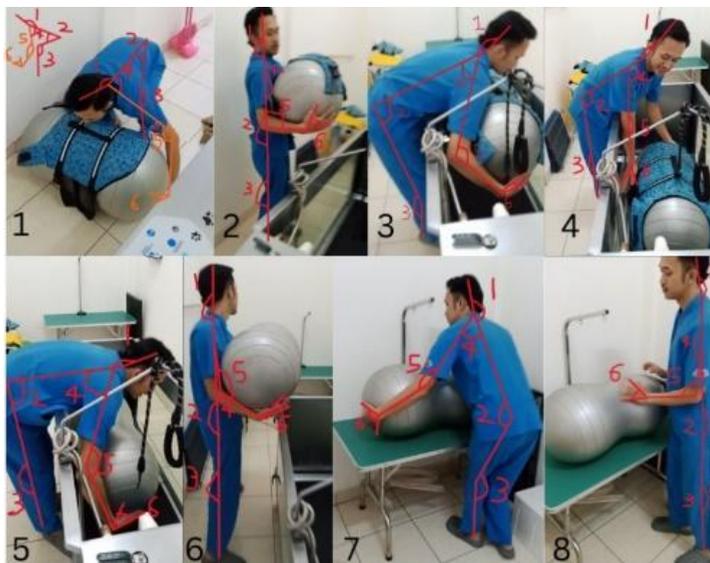
## 3 Results and Discussion

### 3.1 Ergonomic Assessment Water Therapy Session

The activities performed by the paramedics are divided into 8 sequential activities: lifting the patient from the floor, carrying the patient to the therapy device, placing the patient into the therapy device, giving the patient a therapy session, lifting the patient after the therapy session ends, carrying the patient to the drying table, placing the patient on the drying table, and drying the patient on the drying table. Images of the eight activities that have been analyzed can be seen in Figure 3. Based on the analysis of the work posture, each activity was assessed using REBA. Figure 4 shows the REBA worksheet for activity 1, and the summary of the REBA scores for the 8 activities can be seen in Table 9.

The use of REBA in this ergonomic assessment was to identify the musculoskeletal risks faced by paramedics during patient lifting activities. The assessment results in Table A show that the posture of the neck, torso, and legs contributes significantly to the high REBA score, which reflects a high level of work-related injury risk. These postural factors, when summarized, generally indicate a mismatch between the physical demands of the work and the capabilities of the human body, especially when lifting is done manually without the support of an aid. Therefore, these findings indicate the need for a patient handling aid to improve working conditions and lower the REBA score to a reduced risk level.

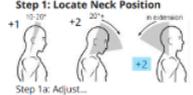
The use of this aid is expected to not only improve work posture but also to consider other important factors that support the effectiveness and efficiency of patient handling, which can be seen in Table 10.

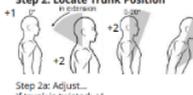


**Figure 4.** Eight Activities of Paramedics During a Therapy Session

**ERGONOMICS** REBA Employee Assessment Worksheet Task Name: \_\_\_\_\_ Date: \_\_\_\_\_

### A. Neck, Trunk and Leg Analysis

**Step 1: Locate Neck Position**  

 Neck Score: **2**

**Step 2: Locate Trunk Position**  

 Trunk Score: **4**

**Step 3: Legs**  

 Leg Score: **3**

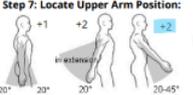
**Step 4: Look-up Posture Score in Table A**  
 Using values from steps 1-3 above, locate score in Table A.  
 Posture Score A: **7**

**Step 5: Add Force/Load Score**  
 If load < 11 lbs.: +0  
 If load 11 to 22 lbs.: +1  
 If load > 22 lbs.: +2  
 Adjust: If shock or rapid build up of force: add +1  
 Force / Load Score: **2**

**Step 6: Score A, Find Row in Table C**  
 Add values from steps 4 & 5 to obtain Score A.  
 Find Row in Table C.  
 Score A: **9**

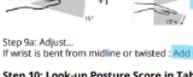
**Scoring**  
 1 = Negligible Risk  
 2-3 = Low Risk. Change may be needed.  
 4-7 = Medium Risk. Further Investigate. Change Soon.  
 8-10 = High Risk. Investigate and Implement Change  
 11 = Very High Risk. Implement Change

### B. Arm and Wrist Analysis

**Step 7: Locate Upper Arm Position:**  

 Upper Arm Score: **2**

**Step 8: Locate Lower Arm Position:**  

 Lower Arm Score: **2**

**Step 9: Locate Wrist Position:**  

 Wrist Score: **3**

**Step 10: Look-up Posture Score in Table B**  
 Using values from steps 7-9 above, locate score in Table B.  
 Posture Score B: **4**

**Step 11: Add Coupling Score**  
 Well fitting Handle and mid range power grip: **good: +0**  
 Acceptable but not ideal hand hold or coupling acceptable with another body part: **fair: +1**  
 Hand hold not acceptable but possible: **poor: +2**  
 No handles, awkward, unsafe with any body part, **Unacceptable: +3**  
 Coupling Score: **2**

**Step 12: Score B, Find Column in Table C**  
 Add values from steps 10 & 11 to obtain Score B. Find column in Table C and match with Score A in row from step 6 to obtain Table C Score.  
 Score B: **6**

**Step 13: Activity Score**  
 +11 or more body parts are held for longer than 1 minute (static)  
 +1 Repeated small range actions (more than 4x per minute)  
 +1 Action causes rapid large range changes in postures or unstable base

Table A Scores

	Neck		
Table A	1	2	3
Legs	1 2 3 4	1 2 3 4	1 2 3 4
Trunk	1 2 3 4	1 2 3 4	1 2 3 4
Posture	2 3 4 5	3 4 5 6	4 5 6 7
Score	4 3 5 6	7 5 6 7	8 6 7 8 9
5	4 6 7 8	6 7 8 9	7 8 9 9

Table B Scores

	Lower Arm	
Table B	1	2
Wrist	1 2 3 1 2 3	1 2 3
Upper Arm	2 1 2 3 2 3 4	4
Score	3 3 4 5 4 5 5	5
4	4 5 5 6 7	8
5	6 7 8 7 8 8	9
6	7 8 8 8 9 9	9

Table C Scores

Score A	Score B											
	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	1	2	3	3	4	5	6	7	7
2	1	1	2	2	3	4	4	5	6	6	7	7
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	6	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
6	6	6	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	9	10	10	11	11	11
8	8	8	8	9	10	10	10	10	10	11	11	11
9	9	9	9	10	10	10	10	11	11	11	12	12
10	10	10	10	10	11	11	11	12	12	12	12	12
11	11	11	11	11	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12

Table C Score: **10** + Activity Score: **1** = REBA Score: **11**

Original Worksheet Developed by Dr. Alan Hedge. Based on Technical note: Rapid Entire Body Assessment (REBA), Hignett, McAtamney, Applied Ergonomics 31 (2000) 201-205

Figure 5. REBA Worksheet Activity-1

**Table 9.** Recapitulation of REBA for Patient Handling

Activity Number	A						B						Table C	Activity Score	REBA Score
	Neck	Trunk	Leg	Table A	Load	Score A	Upper Arm	Lower Arm	Wrist	Table B	Coupling	Score B			
1	2	4	3	7	2	9	2	2	3	4	2	6	10	1	11
2	1	1	1	1	2	3	1	1	3	2	2	4	3	1	4
3	2	4	2	6	2	8	2	1	3	3	2	5	10	2	12
4	3	4	2	7	1	8	2	1	2	2	1	3	8	2	10
5	2	4	1	5	2	7	3	1	3	5	2	7	9	1	10
6	2	1	1	1	2	3	1	1	3	2	2	4	3	1	4
7	3	3	2	6	2	8	2	1	3	3	2	5	10	1	11
8	2	1	1	1	0	1	2	2	2	3	0	3	1	2	3

**Table 10.** Supporting Factors

Activity Number	Supporting Factors	Explanation
1, 3, 5, 7	Lifting energy used by paramedics	The energy exerted to lift the patient is not large, but a great deal of energy/force is required when lifting large patients. Awkward body postures require greater muscle energy consumption.
1,2,3,5,6,7	Patient lifting time	Efficient work time means paramedics are not forced to work quickly, which could potentially increase the risk of injury/accidents.
1-8	Paramedic posture during therapy sessions	Neutral working posture is very important for reducing the load on the spine, joints, and muscles, allowing paramedics to maintain their pace while providing their services.
1,2,3,5,6,7	Patient lifting process	Transport must be safe, smooth, and stable with the aid because there is a possibility that the patient may struggle.
1-7	Ease of handling patients when they struggle	When the patient is moving actively (struggling), extra control is needed without endangering the paramedic or the patient.
1,2,3,5,6,7	Reducing the potential for paramedic injury at work	Patient lifting and handling tasks are high-risk for lower back, shoulder, and wrist injuries.
1-8	Overall ease of patient handling	In general, the patient handling process must be controlled, safe, not require excessive force, and have a minimal risk of error.

All the supporting factors mentioned above contribute to the REBA score, both directly (through body posture and physical load) and indirectly (through the duration/frequency of the activity and the level of control over the work situation). Therefore, a reduction in the REBA score can be achieved by intervening in these elements through the design of an aid that supports neutral postures, reduces load, and controls the dynamics of the work. This can be seen in Table 11.

### 3.2 Ergonomic Function Deployment (EFD)

The results from the planning matrix, derived from the REBA scores, indicate that the primary ergonomic needs for patient handling focus on the paramedics' posture during therapy and the patient lifting process. These aspects have the highest priority due to their

largest relative weight. Additionally, factors like reducing the potential for injury and overall ease of patient handling are also significant priorities. Meanwhile, aspects such as the time it takes to lift the patient have a lower priority.

**Table 11.** Supporting Factors Relation with REBA Components

Supporting Factors	Contribution to REBA Components	Explanation
Lifting energy used by paramedics	A (Load), Activity Score	Energy required reflects the physical load → This is encoded in the Load/Force section (Section A) and affects the activity score if the load is handled repetitively or quickly.
Patient lifting time	Activity Score	Work duration and frequency → The longer or more frequent the task, the higher the activity score. Repetitive handling increases the risk score.
Paramedic posture during therapy sessions	A (Neck, Back, Legs) & B (Upper/Lower Arms, Wrist)	Body posture is directly assessed in REBA: neck, torso, legs (Section A), as well as upper arms, forearms, and wrists (Section B). The less neutral the posture, the higher the score.
Patient lifting process	A (Trunk, Legs), Activity Score	Transport involves movement and transfer, including pushing, pulling, and lifting. This motion affects posture and stability → impacting the torso and leg scores. If done repetitively or while walking, it will affect the activity score.
Ease of handling patients when they struggle	A (Load), Activity Score	A struggling patient creates a dynamic and unpredictable load → increasing risk and being assessed under Load/Force (A), as well as in the Activity Score as a rapid or uncontrolled movement.
Reducing the potential for paramedic injury at work	Overall final REBA score (A, B, and Activity Score)	The main goal of REBA is to map injury risk → If the design or procedure reduces the score in each section (A, B, and the activity score), the potential for injury also decreases.
Overall ease of patient handling	A and B in general	This ease of handling will impact the entire body posture during handling → The easier it is, the more neutral the posture → the lower the REBA score. It also reduces the speed/complexity of the activity, which can lead to a lower activity score.

These findings confirm that the design of the handling aid must be directed toward improving work posture, reducing physical strain, and increasing the long-term safety of paramedics. The planning matrix for the patient handling aid can be seen in Table 12.

The correlation matrix (Table 13) helps translate the paramedics' needs—such as reducing lifting energy, improving posture, reducing injury, and making patient handling easier—into the design's technical elements, such as the presence of a hoist, trolley, wheels, mesh design, device size, harness, wheel brakes, and handles. Fulfilling the paramedics' ergonomic needs in patient handling is heavily influenced by specific technical specifications, especially the hoist, adjustable design, harness, and device handles, which

have a strong correlation with reducing lifting energy, improving posture, and lowering the risk of work-related injury. Other technical features, such as the trolley, wheels, and mesh design, also play a role in supporting the ease of the lifting process and patient stability. Thus, this matrix confirms that the aid's design must prioritize a combination of these technical specifications to effectively address ergonomic needs and enhance the safety and comfort of both paramedics and patients.

**Table 12.** Planning Matrix Alat Bantu Handling Pasien

No.	Ergonomic Needs	IER	CECS	EDG	IR	EP	RW	NRW	Priority
1	Lifting energy used by paramedics	5	2	5	2,500	1,5	18,750	0,099	5
2	Patient lifting time	5	3	5	1,667	1,2	10,000	0,053	7
3	Paramedic posture during therapy sessions	5	1	5	5,000	1,5	37,500	0,197	1
4	Patient lifting process	5	1	5	5,000	1,5	37,500	0,197	2
5	Ease of handling patients when they struggle	5	2	5	2,500	1,5	18,750	0,099	6
6	Reducing the potential for paramedic injury at work	5	1	5	5,000	1,5	37,500	0,197	3
7	Overall ease of patient handling	5	1	5	5,000	1,2	30,000	0,158	4

**Table 13.** Correlation Matrix

Ergonomic Needs	Technical Specifications								Importance Ergonomic Rating	
	Hoist	Trolley	Wheels	Adjustable Design	Net Size	Net Design	Harness Design	Wheel Brakes		Handle of The Aid Device
Lifting energy used by paramedics	●	●								5
Patient lifting time			●	○						5
Paramedic posture during therapy sessions				●					●	5
Patient lifting process		○	○		●	●	●	○	○	5
Ease of handling patients when they struggle					○	●	●	○	●	5
Reducing the potential for paramedic injury at work					▲	●	●	▲		5
Overall ease of patient handling	●	●	●	●	○	●	●	●	●	5

The data obtained from the table above will be the input for the **technical matrix**. The results of the calculations can be seen in Table 14. At this stage, each ergonomic need is given a priority weight, which is then converted into a technical contribution to product design elements, such as the hoist, trolley, wheels, adjustable design, mesh size, mesh design, harness, wheel brakes, and handles of the aid. This matrix allows for the determination of the **normalized contribution** of each technical specification toward

fulfilling ergonomic needs, making it possible to identify which features should be prioritized in the design process.

Based on the technical matrix, the technical specifications with the largest contribution to fulfilling ergonomic needs are **harness design** and **wheel brakes**, followed by the **handle of the aid device** and **adjustable design**. All of these are closely related to increasing safety, reducing injuries, and improving the ease of patient handling. Meanwhile, elements like the trolley and wheels have a lower contribution. Thus, the design of the patient handling aid should focus more on developing an ergonomic harness system, reliable wheel brakes, and an adjustable design to effectively meet the ergonomic needs of paramedics during water therapy. The next step after obtaining the technical matrix data is to assemble the House of Ergonomics, which includes the relationships between each technical specification, as shown in Appendix A.

**Table 14.** Patient Handling Aid Technical Matrix

Ergonomic Needs	Technical Specifications									Normalized Raw Weight	Priority
	Hoist	Trolley	Wheels	Adjustable Design	Net Size	Net Design	Harness Design	Wheel Brakes	Handle of The Aid Device		
Lifting energy used by paramedics	9	9								0,888	5
Patient lifting time			9	3						0,474	7
Paramedic posture during therapy sessions								9		1,776	1
Patient lifting process		3	3		9	9	9	3	3	0,592	2
Ease of handling patients when they struggle					0,296	0,888	0,888	0,296	0,888		6
Reducing the potential for paramedic injury at work					1	9	9	1		0,197	3
Overall ease of patient handling	9	9	9	9	3	9	9	9	9	1,421	4
Contribution	1,421	1,421	1,421	1,421	0,474	1,421	1,421	1,421	1,421	2,309	
Normalized Contribution	0,071	0,089	0,076	0,103	0,084	0,179	0,179	0,077	0,143	2,309	
Priority	9	5	8	4	6	1	2	7	3		

### 3.3 Pengembangan konsep

Based on the **House of Ergonomics (HOE)** results, nine key components were identified as crucial for designing the patient handling aid: **hoist**, **trolley**, **adjustable design**, **net size**, **net design**, **harness design**, **wheel brakes**, **wheel balancer**, and **handle of the aid device**. Each of these components has several technical alternatives that can be used to meet ergonomic needs, as shown in Table 15. If all the alternatives are combined, it would theoretically create **1,363 design concepts** (the product of the number of alternatives for each component).

### 3.4 Concept Selection

Based on considerations of factors such as working environment conditions, facility limitations, and actual clinic needs, this study then filtered and developed **eight main concepts** that were most suitable for the current clinical conditions, as shown in Table 16. The screening process (Pugh) was conducted on the eight developed concepts (Table 17). Based on the screening results, the following was obtained:

- Leading concepts: Concept 2 (Semi-electric), Concept 3 (Full motorized), and Concept 4 (Hybrid), with a score of +7. These became the main candidates to proceed to the concept scoring stage.
- Potential concepts: Concept 6 (Electric hoist) and Concept 7 (Trolley + adjustable net), with a score of +6. These are still very good and are suitable for conditions with cost or environmental limitations.
- Intermediate concept: Concept 1 (Manual hydraulic), with a score of +3. However, it is only slightly better than manual, with limited improvement.
- Weak concepts: Concept 5 (Lightweight) (score -2) and Concept 8 (Ergonomic harness) (score +1). These are not strong enough as primary solutions and are more suitable as complementary or partial solutions.

**Table 15.** Alternatives for Each Technical Specifications

Technical Specifications	Alternative 1	Alternative 2	Alternative 3
Hoist	Manual	Electric	-
Trolley	Hand Trolley (hollow steel)	Intergrated Trolley (hollow steel)	Intergrated Trolley (hollow iron)
Wheels	Circle Caster	Ball Caster	-
Adjustable Design	Manual Hydraulic Jack	Electric Hydraulic Jack	Electric Motor
Net Size	Adjustable size	Fixed size	-
Net Design	Webbing Rope Model	Canvas Tarpaulin Model	-
Harness Design	Shoulder Model Harness	Adjustable nylon harness	8-shaped Model Harness
Wheel Brakes	Wheel Lock Brake	Total Lock Brake	-
Handle of The Aid Device	Standard	Ergonomic	-

Table 16. Spesifikasi Teknis Konsep Alat Bantu

Technical Specifications	C1 (Manual Hydraulic)	C2 (Ergonomic Semi-Electric)	C3 (Full Motorized)	C4 (Manual-Electric Hybrid)	C5 (Ergonomic Lightweight)	C6 (Electric Hoist)	C7 (Trolley + Adj. Net)	C8 (Ergonomic Harness)
Hoist	Manual	Electric	Electric	Manual + electric assist	Manual (lightweight design)	Manual	Electric	Electric
Trolley	Hand trolley (hollow steel)	Integrated trolley (hollow steel)	Integrated trolley (hollow iron)	Integrated trolley (lightweight steel)	Hand trolley (lightweight hollow steel)	Hand trolley (hollow steel)	Integrated trolley (hollow steel)	Integrated trolley (hollow iron)
Wheels	Circular casters	Circular casters	Ball casters	Ball casters + locking system	Circular casters with lock	Circular casters	Circular casters	Ball casters
Adjustable Design	Manual hydraulic jack	Electric hydraulic jack	Electric motor	Manual hydraulic jack + electric option	Mini manual hydraulic jack	Manual hydraulic jack	Electric hydraulic jack	Electric motor
Net Size	Fixed size	Adjustable size	Adjustable size	Adjustable size	Fixed size	Fixed size	Adjustable size	Adjustable size
Net Design	Webbing strap model	Canvas tarp model	Canvas tarp model	Webbing + canvas combination	Lightweight canvas tarp	Webbing strap model	Canvas tarp model	Canvas tarp model
Harness Design	Shoulder harness model	Adjustable nylon harness	8-shaped harness model	Adjustable nylon harness	8-shaped harness model	Shoulder harness model	Adjustable nylon harness	8-shaped harness model
Wheel Brakes	Live brake	Dead brake	Dead brake	Live brake + pedal lock	Simple live brake	Live brake	Dead brake	Dead brake
Aid Handles	Standard	Ergonomic	Standard	Ergonomic	Ergonomic + grip padding	Standard	Ergonomic	Standard

Table 17. Concept Screening

Criteria	Concept							
	C1 (Manual Hydraulic)	C2 (Semi-Electric)	C3 (Full Motorized)	C4 (Hybrid)	C5 (Lightweight)	C6 (Electric Hoist)	C7 (Trolley + adj. net)	C8 (Ergonomic Harness)
Lifting energy	+	+	+	+	0	+	+	0
Patient transport time	0	+	+	+	0	+	0	0
Paramedic posture during therapy session (REBA)	+	+	+	+	-	+	+	0
Patient transport process	+	+	+	+	0	+	+	0
Ease of handling the patient when they struggle	0	+	+	+	-	+	+	+
Reducing the potential for paramedic injury at work	0	+	+	+	0	+	+	0
Overall ease of patient handling	0	+	+	+	0	+	+	0
Total Score (+/0/-)	(+3)	(+7)	(+7)	(+7)	(+2)	(+6)	(+6)	(+1)

Based on the ergonomic needs, the Concept Scoring (weighted scoring) for the five concepts is as follows: Lifting energy - **0.20**; Patient transport time - **0.15**; Paramedic posture (REBA) - **0.20**; Patient transport process - **0.10**; Ease of handling the patient when they struggle - **0.15**; Reducing the potential for paramedic injury - **0.15**; Overall ease of patient handling - **0.05**. Scoring will be performed for the five concepts identified as leading and potential: C2, C3, C4, C6, and C7.

### a. Concept Scoring

Concept scoring was performed to evaluate the three concepts in more detail, using weighted criteria and quantitative assessment. This allowed the best concept to be selected objectively based on ergonomic data, technical specifications, and working environment conditions. The results of the concept scoring can be seen in Table 17. Based on the scoring results, the chosen patient handling aid concept is Concept 2, as it received the highest score.

Table 18. Scoring Matrix

Criteria	Weight	C2 (Semi-electric)	C3 (Full motorized)	C4 (Hybrid)	C6 (Electric Hoist)	C7 (Trolley + Adj. Net)
Lifting energy	0.20	4 (0.80)	5 (1.00)	4 (0.80)	5 (1.00)	3 (0.60)
Patient transport time	0.15	4 (0.60)	5 (0.75)	4 (0.60)	3 (0.45)	3 (0.45)
Paramedic posture during therapy session (REBA)	0.20	4 (0.80)	5 (1.00)	4 (0.80)	4 (0.80)	3 (0.60)
Patient transport process	0.10	4 (0.40)	5 (0.50)	4 (0.40)	3 (0.30)	3 (0.30)
Ease of handling the patient when they struggle	0.15	4 (0.60)	5 (0.75)	4 (0.60)	3 (0.45)	3 (0.45)
Reducing the potential for paramedic injury at work	0.15	4 (0.60)	5 (0.75)	4 (0.60)	4 (0.60)	3 (0.45)
Overall ease of patient handling	0.05	4 (0.20)	4 (0.20)	5 (0.25)	3 (0.15)	3 (0.15)
Total Score	1.00	4.00	4.95	4.05	3.75	3.00

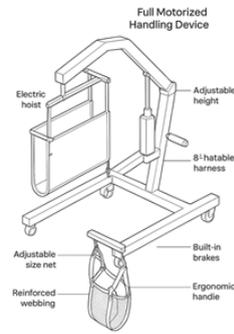
Based on the scoring results, the following was obtained:

- C3 (Full motorized) is the leading concept with the highest score (4.95), making it the most optimal in terms of ergonomics and efficiency.
- C4 (Hybrid) (4.05) and C2 (Semi-electric) (4.00) are equally competitive concepts. They are suitable choices if there are budget or energy limitations.
- C6 (Electric hoist) (3.75) is better than a manual system but not as good in terms of flexibility and ease of use.
- C7 (Trolley + adjustable net) (3.00) is a simple solution, but it is less effective at reducing physical load and the risk of injury.

Thus, C3 (Full motorized) obtained the highest score (4.95), proving to be the most effective at reducing lifting energy, improving posture (REBA), speeding up the process, and handling struggling patients. It's an ideal choice if the budget, maintenance, and electrical infrastructure are sufficient. C4 (Hybrid) and C2 (Semi-electric) showed very good performance, though slightly below C3. C4 excels in operational flexibility, as it can be operated manually without electricity, making it highly suitable for clinics with limited infrastructure that still want electrical capabilities when needed. C2 represents a balanced option between ergonomic performance and ease of implementation. Meanwhile, C6 (Electric hoist) and C7 (Trolley + adjustable net) received medium scores. C6 is effective at reducing the lifting load but is less flexible in the overall process, whereas C7 is a simple and relatively inexpensive mechanical solution, but it is less optimal for struggling patients or complex loads.

### 3.5 Designing the Patient Handling Aid

Based on the results of the concept development, the Patient Handling Aid was designed with reference to Concept 2. The patient handling aid was designed using the SolidWorks application, adhering to the size constraints of the therapy room and the existing therapy device. This patient handling aid, shown in Figure 6, consists of an electric hydraulic jack, an electric hoist, an integrated trolley made of hollow steel, locking wheel brakes, caster wheels, an adjustable-sized net with a canvas tarp material design, an adjustable nylon harness, and ergonomic handles for the aid.



**Figure 6.** Final Concept for a Patient Handling Aid

### 3.6 Design Evaluation

When the aid concept is used in the clinic, a simulation of the new paramedic activity will yield a REBA score, as shown in Table 18. Based on the table above, it can be seen that if the clinic uses the aid to lift patients during therapy sessions, it will reduce the potential for injury. This is because the REBA score for Activity 3, which was 12 before using the aid, can be reduced to a score of 2 with the aid's use. However, Activity 4 shows no significant change. This is because Activity 4 involves assisting the patient in walking during a therapy session, an activity that does not involve the newly designed aid.

**Table 19.** REBA Score Evaluation Before and After Using the Aid

Before Using Aid Device															
Activity Number	A						B						Table C	Activity Score	REBA Score
	Neck	Trunk	Leg	Table A	Load	Score A	Upper Arm	Lower Arm	Wrist	Table B	Coupling	Score B			
1	2	4	3	7	2	9	2	2	3	4	2	6	10	1	11
2	1	1	1	1	2	3	1	1	3	2	2	4	3	1	4
3	2	4	2	6	2	8	2	1	3	3	2	5	10	2	12
4	3	4	2	7	1	8	2	1	2	2	1	3	8	2	10
5	2	4	1	5	2	7	3	1	3	5	2	7	9	1	10
6	2	1	1	1	2	3	1	1	3	2	2	4	3	1	4
7	3	3	2	6	2	8	2	1	3	3	2	5	10	1	11
8	2	1	1	1	0	1	2	2	2	3	0	3	1	2	3
After Using Aid Device															
Activity Number	A						B						Table C	Activity Score	REBA Score
	Neck	Trunk	Leg	Table A	Load	Score A	Upper Arm	Lower Arm	Wrist	Table B	Coupling	Score B			
1	1	4	1	3	0	3	2	2	1	2	0	2	3	1	4
2	1	1	1	1	1	2	1	1	1	1	0	1	1	1	2
3	1	2	1	2	0	2	1	1	1	1	0	1	1	1	2
4	2	3	2	5	1	6	2	1	2	2	1	3	6	2	8
5	1	2	1	2	0	2	2	1	1	1	0	1	1	1	2
6	1	1	1	1	1	2	1	1	1	1	0	1	1	1	2
7	1	2	1	2	0	2	1	1	1	1	0	1	1	1	2
8	2	1	1	1	0	1	2	2	2	3	0	3	1	2	3

## 4 Conclusion

Based on the data collection, data processing, design of the aid, and analysis of its implementation, the following conclusions can be drawn from this study:

1. PDHB drh. Anton S.A.P has an ergonomic problem in its therapy work activities. An ergonomic assessment of the paramedics' activities yielded REBA scores that were mostly in the 10-12 range, which indicates that a change is urgently needed.
2. The REBA scores obtained by paramedics during therapy activities were proven to be significantly reduced when a re-simulation was performed with the designed patient handling aid. The scores after the simulation were mostly in the 2-4 range.
3. If the clinic uses the handling aid, they will benefit from better-maintained paramedic performance due to a lower potential for work-related injuries compared to when the clinic does not use the aid.
4. Effectiveness is achieved because therapy sessions can be completed with the aid. Comfort is gained through the ease it provides paramedics when carrying patients. Safety is achieved with the aid's ability to remain stable at one point. Health is attained because the aid reduces the lifting load on paramedics, and efficiency is reached as the effort paramedics put into lifting patients is minimized.

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## Appendix

### Appendix A

