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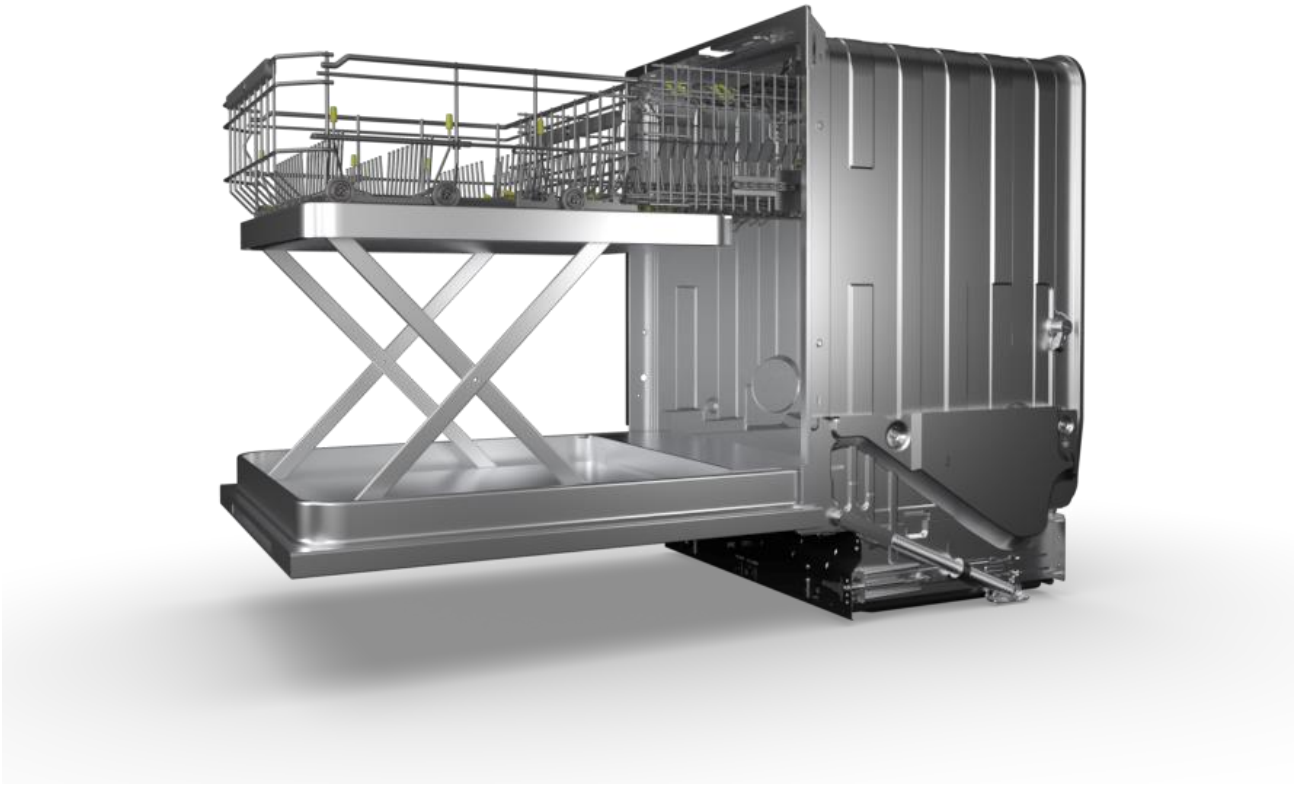

Lifting the Load: Optimizing Dishwasher Ergonomics Through User-Centered Design

Master's Thesis in Industrial Design Engineering

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Preface and acknowledgements

This master's thesis project was performed in the spring of 2025 at Chalmers University of technology at the department of Industrial and Materials Science, for the master program Industrial Design Engineering, in collaboration with ASKO. The supervisor as well as the examiner for this project was Lars-Ola Bligård. From ASKO, the supervisor was Mikael Johansson.

Firstly, we would like to thank Lars-Ola Bligård, the supervisor and examiner of the project. Lars-Ola have supported us in all parts of this project as well as helped us achieve our personal goals we set for the project.

Secondly, we would like to thank the people at ASKO, and our supervisor Mikael, for all their support in discussions about concept realization and prototyping the final concept. It has been an experience where we have had the ability to grow, learn and create an outcome that we are proud of.

Moreover, we would like to thank Lars-Olas colleagues at the department of Industrial and Materials Science, who have helped us with this project as well. Cecilia Berlin who helped with the user test setup and ergonomic assessments, Håkan Almius who helped with product renders and animations and Siw Eriksson who helped us combine user study tools to create our own method, a method we are proud to have included in this thesis.

Lastly, we would like to thank all participants in the user studies. We would like to thank the physio- and occupational therapists, the kitchen architect and dishwasher retailer, for participating in the interviews. We would like to thank the participants in the user tests, and we would like to thank the participants in our own method Letters. This thesis would not be possible without you.

Abstract

Dishwashers are a widely used appliance in modern homes, yet their design has seen limited ergonomic innovation in recent decades. Most models remain standing on the floor, requiring users to bend down repeatedly during loading and unloading dishware, leading to physical strain on the back. This study aims to improve the ergonomics of household dishwashers by developing user-centered design solutions, in collaboration with ASKO.

Through an iterative design process, the project used a range of methods to analyze the current situation regarding dishwasher ergonomics, gathering both numeric and qualitative data. The data was analyzed leading to the identification of pain points and user needs, and then the development of two ergonomic dishwasher solutions. A contemporary concept and a future concept.

The contemporary concept features a built-in scissors lift mechanism in the door, allowing the users to work at an ergonomically optimized height when loading and unloading the dishwasher, where both the upper and lower basket can be reached simultaneously.

The future concept features modular baskets that can be removed and moved to a better work height, such as the countertop, with handles for better grip. This concept is a holistic concept that blurs the line between the dishwasher and kitchen storage by providing the possibility to store the baskets directly in drawers and cupboards.

Both concepts aim to reduce bending, improve posture, and support usability. Ergonomic evaluations indicate improvements compared to ASKOs dishwashers today, with lower strain on the body in critical tasks when using a dishwasher.

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Introduction

1 Introduction

This project will investigate the ergonomic challenges of using a dishwasher, address these challenges and design a more ergonomic dishwasher solution in collaboration with ASKO. This chapter will introduce the project by giving a background to the subject, followed by the projects aim and objectives. The chapter will also present the project's demarcations as well as the report structure.

1.1 Background

For thousands of years, dishwashing was a manual task, performed by hand. This changed in 1886 when the first dishwasher was introduced to the market (Rosa, et al., 2012). This marked the beginning of a gradual evolution in dishwashing technology. Since then, dishwashers have become increasingly common in households. Today, dishwashers are in many homes considered a necessity. These machines are used daily by a wide range of individuals, from children who struggle to reach the upper baskets, to elderly users who may struggle to bend down to access the lower ones.

Since the invention of the dishwasher, the machines have become more standardized in size and format. A width of approximately 60 cm is common in households, typically integrated under the kitchen countertop. This standardization aligns with standard measurements of countertops, which make the installation more convenient. The more recent development of dishwashers has largely focused on digitalization, quality enhancements and energy optimization.

In recent decades, *user-centered design* and *design for accessibility* have become central values in product development across many industries. While dishwashers have followed this trend to some extent, particularly in terms of interface design and wash cycle customization, the physical ergonomics of dishwasher use have seen minimal progress. Most dishwashers are still installed at floor level, requiring users to bend down repeatedly, which may lead to discomfort and physical strain. Although the fixed dimensions and format of modern kitchens making it difficult to deviate from these standards, the lack of ergonomic innovation in this area represents a notable gap in product development.

In contrast, industrial dishwashers have seen significant advancements. In these professional work settings, dishwashers are considered essential work tools, and industrial kitchens are often designed to accommodate dishwashers at optimal working heights. This has enabled the development of more ergonomically adapted solutions that minimize physical and cognitive strain and support efficient workflows.

Despite these advancements in professional settings, there are still only a few household dishwashers on the market that prioritize ergonomic design. While some alternative concepts exist, they are not widely known nor adopted as standards solutions.

Given the shift toward inclusive and user-centered design in other areas of product development, there is a clear opportunity to explore how household dishwashers can evolve to better support user comfort, physical accessibility and ergonomic well-being.

1.2 Aim

The aim of this thesis is to enhance the physical ergonomics of household dishwashers. This, by creating a more user-centered and ergonomically optimized dishwasher experience that minimizes physical discomfort and improves usability. The focus will be on improving the ergonomics when the users interact with the dishwasher within daily use.

1.3 Objectives

1. Analyze the current ergonomic challenges of an ASKO dishwasher in everyday tasks.
2. Develop a redesigned dishwasher concept with enhanced ergonomic features.
3. Evaluate the final concept based on ergonomic performance.

1.4 Demarcations

This thesis will not address specific electric or mechanical functions or features in the current and developed dishwasher solution.

1.5 Report structure

Chapter 1, Introduction

The report begins with an introduction describing the background, aims, objectives and demarcations of the report.

Chapter 2, Final results

This chapter includes the result of this project and its objectives. This means that the current needs regarding ergonomics in use of household dishwashers, concepts created to meet these needs, and the evaluation of these concepts are presented here.

Chapter 3, Kitchen and dishwashers

This chapter introduces and explains the current situation in household kitchens and presents ASKO dishwashers.

Chapter 4, Ergonomics

This chapter presents the basic ergonomic theories that are of importance for this project. This chapter is divided into two parts; Physical ergonomics and Cognitive ergonomics.

Chapter 5, Methods

The methods used in this project are presented in this chapter.

Chapter 6, General description and procedures

This chapter includes the description of the project model, and its respective phases, on which the project is based.

Chapter 7, Project execution

In this chapter, the execution of the different phases in this project are explained.

Chapter 8, Results of Empathize phase

This chapter presents the results of the empathize phase, including results from pre-studies as well as the results from user studies.

Chapter 9, Results of Define phase

This chapter presents the results of the Define phase, including ergonomic assessments and KJ-analyses.

Chapter 10, Results of Ideate, Prototype and Evaluate phases

This chapter presents the results of the Ideate, Prototype and Evaluate phases, including idea generation, concept evaluations and prototyping.

Chapter 11, Results of final concept

This chapter presents the final concept, which resulted in a contemporary concept and a future concept.

Chapter 12, Discussion

This chapter will discuss the results in relation to theory, process and methods. The aims and objectives from the introduction chapter will be addressed and discussed. Thereafter the validation of results will be discussed, and finally sustainability and ethics of the project will be addressed.

Chapter 13, Future work

In this chapter, opportunities for future work are presented, such as user testing, further development and prototyping.

Chapter 14, Conclusion

This chapter presents the final conclusions of this master's thesis.

Final results

2 Final Results

This chapter includes the results of this project and its objectives, as can be read in chapter 1. This means that the current user needs regarding ergonomics in dishwashers, concepts created to meet these needs, and the evaluation of these concepts are presented here. For the complete results see chapter 8, 9, 10 and 11.

2.1 Results from user studies

The user studies included interviews, user tests and a new method for qualitative data collection, all focusing on ergonomic pain points in dishwasher use. These user studies, after thorough analysis, resulted in a list of user needs, consisting of insights phrased as requirements (see Appendix 6: Complete list of user needs).

The list of user needs included user needs from all parts of the user studies, the most urgent needs being the ones most frequently mentioned, observed throughout the study and most relevant for the scope. A selection of these urgent needs and sub-needs can be viewed in Figure 1: Urgent needs.

Figure 1: Urgent needs

These needs were thereafter at the center of ideation, concept generation and evaluation to develop concepts that meet these needs.

Furthermore, ergonomic assessments were carried out to investigate the ergonomics of the current ASKO dishwasher. These assessments were based on two ergonomic assessment methods: *PEPA* and *REBA* (see information about these methods in 5.2). The PEPA showed that the task of loading and unloading the dishwasher were the most straining tasks. Furthermore, the positions observed in the user tests received points ranging from 4 to 9 in the REBA worksheet, meaning medium to high-risk positions, with bending down to reach as the biggest cause for these points.

2.2 Final concepts

Following an iterative development process, two concepts were designed that met the user needs on an equal level. One of the concepts focuses on minimizing bending by adjusting the lower basket to a more favorable working height, thereby improving both visibility and overview. This concept also reduces cognitive load by presenting the baskets at the same height, side by side, providing the possibility to view and work with both baskets at the same time. The other concept focuses on minimizing bends by providing the possibility to remove individual baskets and place them at a good working height on the countertop, or store directly in kitchen storage. This provides the possibility for adjustability, good visibility and provides adequate grip and enhances the feeling of being effective by eliminating the need for completing a full unloading sequence. Both concepts are also adapted for critical users.

2.2.1 Scissors-lift integrated in the door

This concept features a built-in lifting function that changes how the users interact with the lower basket of the dishwasher (see Figure 2). The lifting function is inspired by the mechanics of a scissors lift, where the function is smoothly integrated into the dishwasher door. The user interacts with the solution by pressing a button, which initiates the elevation of the lower basket, elevating it to the same height as the upper basket, eliminating the need for bending.

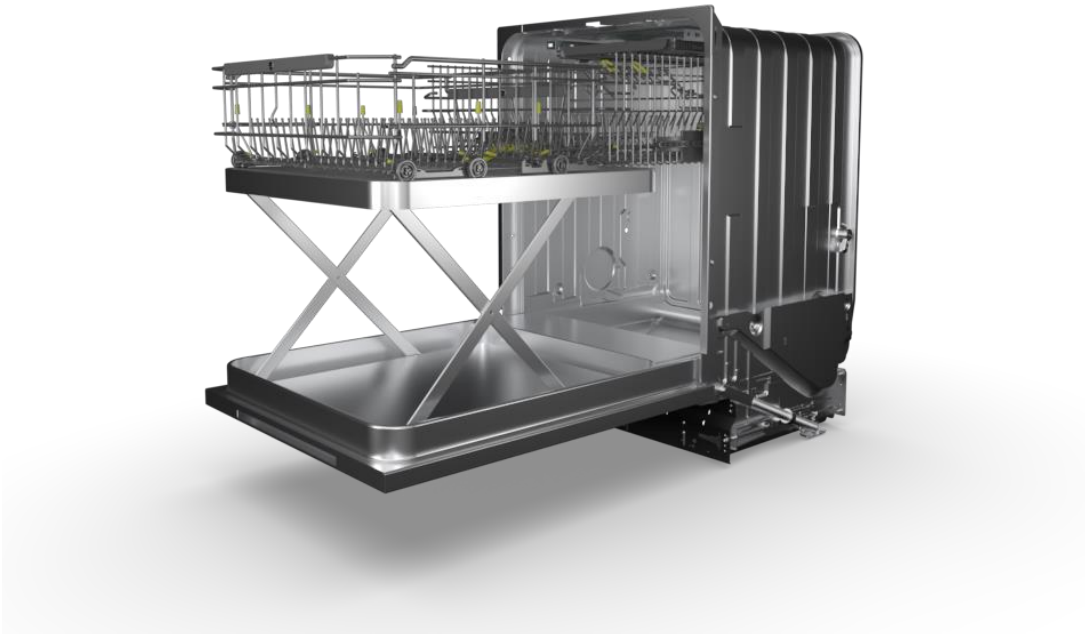

Figure 2: Scissors lift integrated in the door

In this concept the baskets are approximately 60 mm shorter in depth, to provide the possibility to work on the lower and upper basket at the same time (see Figure 3).

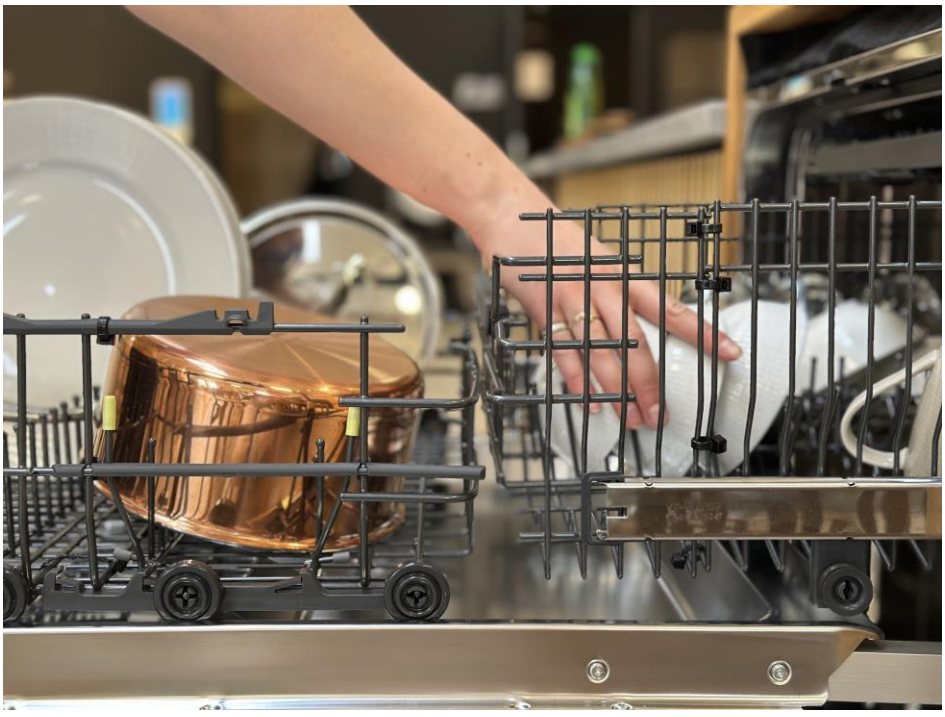

Figure 3: Upper and lower basket at the same height

The raised lower basket improves the visibility and enhances the sense of proximity. Aside from improving back ergonomics by reducing the need to bend, this concept also minimizes awkward postures by increasing proximity.

2.2.2 Modular baskets

The second concept is created with a holistic approach, redefining how the dishwasher functions in relation to kitchen storage. This concept blurs the line between storage and dishwasher baskets by introducing modular baskets. These baskets can easily be removed and placed at a comfortable working height (see Figure 4).

Figure 4: Modular baskets[1]

The baskets can also be placed straight into kitchen drawers and cupboards, shifting the process from unloading each individual dish, sorting, and storing it, to simply lifting out a few modular baskets and placing them directly onto shelves and in cabinets. The modular baskets therefore act as an extension of the dishwasher (see Figure 5).

[1] Picture published with permission from ASKO. Retrieved from ASKO (https://asko-shop.ch/products/dfi746u), edited by the authors.

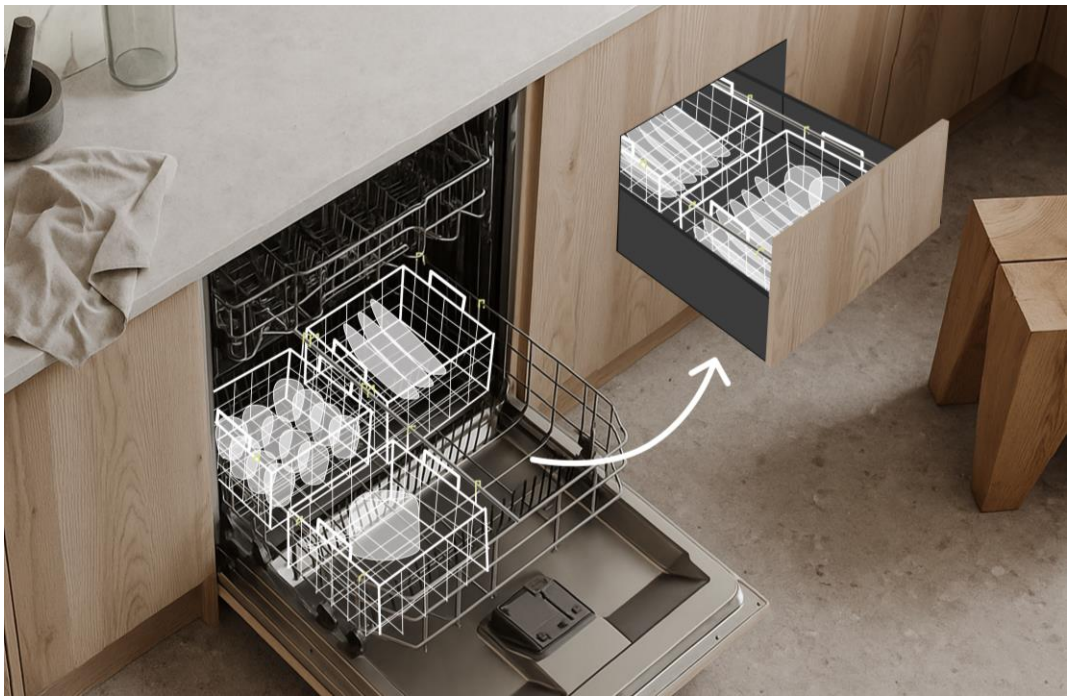

Figure 5: Store in cabinets[2]

In Figure 6, a suggestion of how the modular baskets could look are visualized. The modular baskets are designed so that the user can place the baskets correctly in the dishwasher, using hooks that hang on the rods of the original baskets.

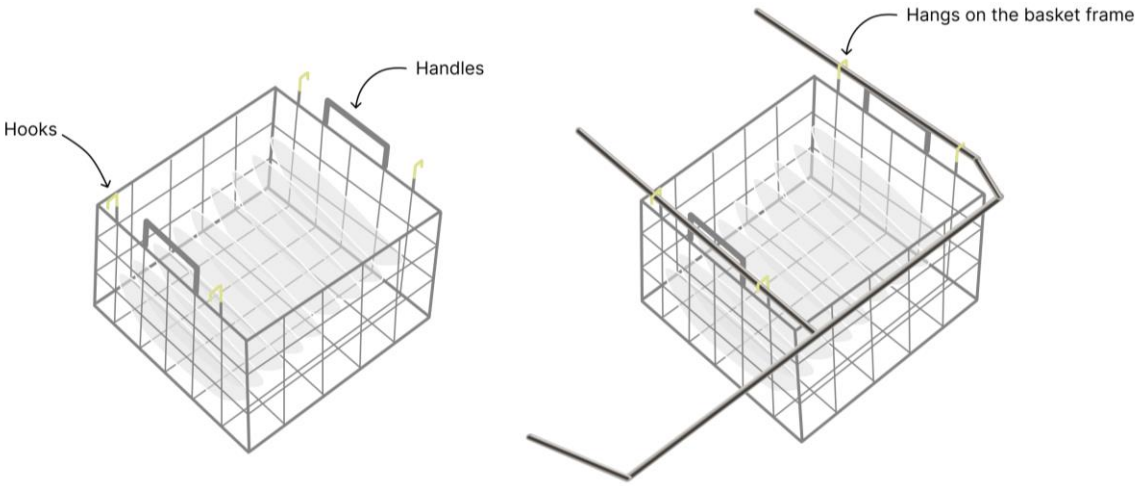

Figure 6: Modular baskets

[2] Picture published with permission from ASKO. Retrieved from ASKO (https://asko-shop.ch/products/dfi746u), edited by the authors.

In addition to simplifying the unloading sequence in terms of time, this concept also offers several ergonomic advantages when using the dishwasher. Firstly, since the user only needs to lift a few modular baskets instead of handling each plate or glass individually, fewer bends and rotations are required to perform the same task. Moreover, the modular baskets feature handles on each side, providing a more ergonomic grip compared to the pinch grip typically used when holding a small fork or the edge of a thin plate. Finally, placing the modular baskets on the countertop offers better visibility, which reduces cognitive load.

2.3 Final evaluation

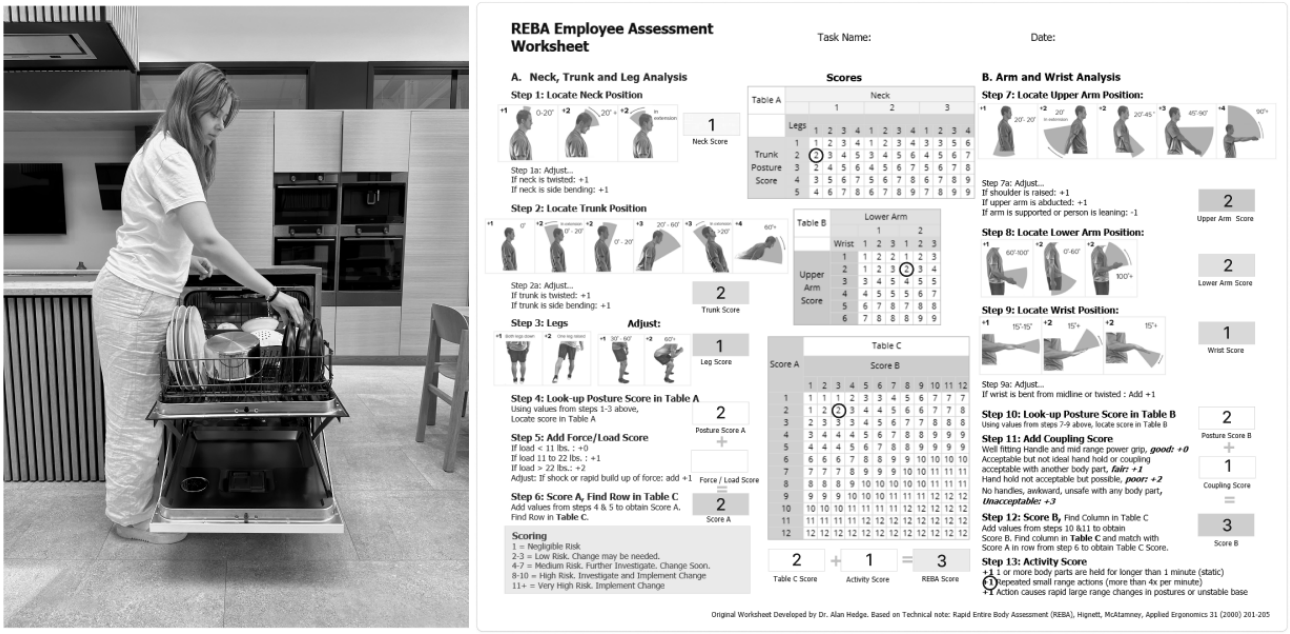

Figure 7: REBA of final concept[3]

The scissors lift concept received a score of 3, suggesting a low-risk position (see Figure 7). The main reason for these low points is the straight neck position, small trunk bend, steady posture on the legs and low extension of the arms and wrists. In this case, the person is also reaching for the plate furthest away from them, meaning that this concept would score even lower when grabbing plates closer to the body. This result suggests an ergonomic improvement in comparison to the ergonomic assessments performed on an ASKO dishwasher on floor height.

[3] REBA- worksheet recreated based on McAtamney, L., & Hignett, S. (2000). Rapid Entire Body Assessment (REBA). Applied Ergonomics, 31(2), 201–205. This source also applies to all subsequent REBA-related figures in this report.

The modular concept combined with the scissors-lift concept also shows an improvement in an estimated PEPA, with several improved aspects regarding, for example, the back and precision work among others. For the complete evaluation, see chapter 11.

Theoretical Framework

3 Kitchen and dishwashers

This chapter introduces and explains the current situation in household kitchens and presents ASKO dishwashers.

3.1 Kitchens today

Modern kitchen design prioritizes a layout that have an efficient workflow, often organized around the “work triangle” (Baden-Powell, 2005). The triangle is a concept that connects the sink, stove and refrigerator, the most used places in the kitchen. With this layout, unnecessary movements are minimized, which enhances functionality.

The work triangle is based on the typical work sequence used in the kitchen. *Store, wash, prepare, serve and eat.* Once the sequence is complete, there is a cleaning sequence; *clear, wash up.* During the activities of the sequence, some activities are repeated, for example the use of the dishwasher both during and after the first sequence.

Moreover, Baden-Powell states that the modern kitchens are based on key dimensions for ergonomic efficiency, which plays a crucial role in reducing strain and improving comfort. The ergonomic key dimensions are for example measurements of reach, vertical dimensions of cupboards and countertop, as well as space between counters. These dimensions are based on both men and women, where a sweet spot has been sought that suit both taller and shorter people.

For countertops, the standard heights are around 900 mm, a dimension that suits the average user for food preparations tasks. Appliances such as microwaves and ovens are more commonly installed at higher levels, around 1200 mm, to minimize back pain and provide a better overview. Dishwashers are available in several sizes, where the full-size models are about 600 mm wide x 850 mm deep.

3.2 ASKO dishwashers

ASKOs products are characterized by their durability in all their product categories. (ASKO Appliences, n.d.) Their dishwashers are built to last for 20 years. The durability and robustness can, for example, be observed by the amount of steel the dishwashers are produced in (see Figure 8). However, not only do the robust materials such as steel make ASKOs dishwashers durable, but they also present the design expression of a sturdy and reliable machine, that retains elegant and sleek. This minimalistic Scandinavian design is seen in all ASKO products.

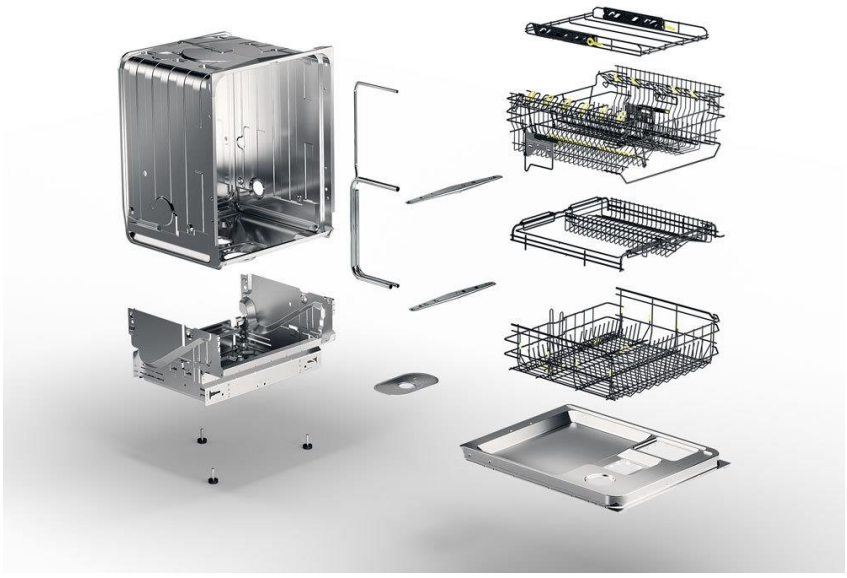

Figure 8: ASKO dishwasher 8 steel[4]

ASKO has in recent years focused on improving flexibility, the capacity of dishware, energy and water consumption. The biggest model of ASKO, XXL, has a capacity for washing 17 place settings (see Figure 9).

Figure 9: ASKO dishwasher[4]

[4] Picture published with permission from ASKO. Retrieved from ASKO (https://se.asko.com/kok/diskmaskiner/funktioner).

ASKO has developed various modular inserts when moving towards a more user-friendly and adaptable development. When there is an interaction with a part inside the machine, those parts are colored in a distinct yellow-green color (see Figure 10). This makes it easier for the user to know that there is a function to be used.

Figure 10: ASKO color cue[5]

3.3 Affecting the results

The information in this chapter has affected the results of this thesis by providing insights regarding raising the dishwasher, to provide a more ergonomic work position in the kitchen. This has in turn led to an improved working height in the final concepts. Moreover, the traditional work sequence in the kitchen has been investigated, and efforts have been made to optimize efficiency by the modular concept. Furthermore, information about standard heights and adapting the solution to both taller and shorter people has affected the result by hindering the final concept from resulting in a too high or too low working height.

Regarding the information about ASKO dishwashers, this has affected the results by mimicking the form language of ASKO into the final concepts. Color cues have also been added to the modular concept to parts that should indicate a function or interaction point, to serve as a help to the user. Lastly, the concepts have been using mostly steel as seen in the ASKO dishwashers today to stay consistent to the expression of durability.

[5] Picture published with permission from ASKO. Retrieved from ASKO (https://se.asko.com/dw60).

4 Ergonomics

This chapter presents the basic ergonomic theories that are of importance for this project. This chapter is divided into two parts: Physical ergonomics and Cognitive ergonomics.

4.1 Physical ergonomics

Physical stresses on the body can cause injury in tissues, organs, joints and muscles (Bohgard et al., 2009). The concept of *load* in physical ergonomics is related to physical stresses, which includes both static load and dynamic load. Static load entails long-term continuous load without any variation in force or muscle length, while dynamic load is the opposite, with changes in force or muscle length. Slightly higher static loads often result in impaired blood circulation and very often tiredness and pain. Lower static loads do not frequently cause any acute problems; however, all sorts of static load increase the risk for various types of illnesses of the joints and muscles in the long run. Dynamic work can also be seen as static from a physiological point of view even though there is movement involved. For example, when the force level applied to a curtain muscle remains the same, even though there is movement involved to complete the activity.

Bohgard explains that an emphasis has for a long time been on reducing the size of loads within the field of ergonomics. Thus, a long list of aids has been designed to reduce the effort needed to execute an activity, and as a result, working life today often includes prolonged low loads instead. It has become evident that the duration and frequency are essential in understanding how quickly fatigue and pain arise. In many cases, a person experiencing discomfort does not understand what the root of the cause is because the loads are so small. Furthermore, monotonous repetitive work is also of importance in physical ergonomics. This could lead to chronic pain and discomfort, similarly to a sudden high load, due to its repetitiveness.

It's also discussed by Bohgard that lumbago commonly is a result of unexpected load of the back in an unexpected direction. This is probably due to small displacements of the vertebrae in the back that in turn is due to insufficient preparation in stabilizing back muscles. The displacements are what causes pain. Epidemiological research shows frequent heavy lifting to be a risk factor in back problems where twisted or bent postures can increase these risks. Regardless of the work being “light”, prolonged twisting and flexing in the back often lead to back problems, both due to the load and the actual weight of the body itself.

When it comes to standing work it’s highly dependent on the height above the floor at which the work is carried out. With too high working height, the arms are kept in a high position resulting in a heavier static load, which is unbeneficial from an ergonomic standpoint. On the other hand, if the working height is too low, the body must be bent forward, and that increases load on the back as well as neck muscles.

According to Bohgard, as a result of the different possible causes, spontaneous emergence and passing of back pain, it is difficult to provide engineers with specific musculoskeletal ergonomic advice on designing products better suited. However, it's reasonable to conclude that a guideline would be to avoid working positions with deep and frequently repeated bends forward or a twisted bodily position.

Hands and wrists are critical parts of the human body for one to be able to execute various tasks (Berlin & Adams, 2017). The hand, wrist and arm together form a structure that is especially complex and sensitive to injury in physical work. An injury in this complex structure could severely hinder a human from executing a large range of activities.

Belin & Adams explain that hands are an important tool for gripping, with different functional positions depending on the amount of power and/or precision needed for a specific activity. The complex structures of the hand are not to be overloaded with unnecessary twisting and bending, instead, the hand should be as close to its resting position as possible. The resting position of the hand is when the wrist is straight, muscles are relaxed, and fingers are slightly curled. A few typical issues that could risk injury to the hand are repetitive tasks, high forces and incorrect grips.

4.2 Cognitive ergonomics

The human cognitive abilities are a combination of certain skills: experience, attention, pattern-recognition, ability to focus, association, memory and the ability to sort information into categories (Berlin & Adams, 2017). A well-designed work system, focused on improving cognitive ergonomics, can decrease the impact of fatigue by minimizing the ability to execute a task incorrectly. A more demanding task needs carefully designed cues in products that humans use.

According to Berlin & Adams the human cognitive processes are the handling of information. The combination of sensory stimuli, attention, perception, memory and interpretation, which combined result in a response, is what builds these processes or mental capabilities. When designing to support human mental capabilities there are some specific design principles aimed at supporting the capabilities *attention*, *perception* and *mental models*. Three of those principles are: Minimize time and effort for finding information, proximity (being close to the product, visibility and reachability) and legible displays.

4.3 Affecting the results

In this thesis the literature has affected the results in regard to exploring and establishing the cause of back-related ergonomic issues, hand and grip related ergonomic issues and cognitive related issues. It has also guided the execution of the ergonomic assessments conducted. Furthermore, a favorable working height and its effect on visibility, reachability and proximity, the importance of correct grips and well-designed work systems has been implemented in the final results.

Methods

5 Methods

The methods used in this project are presented below. The order in which the methods are presented is based on the five phases of this project: Empathize, Define, Ideate, Prototype and Evaluate. More about the phases can be viewed in chapter 6.1.

5.1 Methods of Empathize phase

This section presents the methods of the Empathize phase.

5.1.1 Functional analysis

A functional analysis is a method used to break down a product's functions (Johannesson, Persson, & Pettersson, 2018). The main function is the primary purpose of the product. This main function is divided into several sub-functions, which are necessary for the main function to work properly. Support functions are features that enhance usability and support the product's use but are not critical for the main function.

5.1.2 Semi-structured Interviews

A semi-structured interview is a qualitative data collection method combining open-ended questions with a pre-defined interview guide (Knox & Burkard, 2023). It is a method widely used to obtain participants' perspectives, opinions and experiences regarding a topic.

5.1.3 User based evaluation

A user-based evaluation is a usability method where users participate directly (Bastien, 2010). Users are invited to carry out typical tasks related to a specific product, while their behaviors during usage of the product are observed and recorded with the goal of identifying design flaws that cause issues. Once flaws in the products design have been identified, design recommendations can be proposed to improve ergonomic qualities of the specific product.

5.1.4 Letters

Letters are a method used for obtaining information from users in their home environment, using probes guiding the user to reflect on everyday tasks. This is a method combining *diary studies* and *cultural probes* to reach deeper thoughts from the participants. Instead of using a diary, the user receives letters to fill in by hand. See more information about the method letters in Appendix 2: Letters.

5.1.4.1 Diary studies

Diary studies is a research method used to keep log of the participants' thoughts, experiences and activities of a set time frame (Hanington & Martin, 2012). It is a useful tool for exploratory research, where the participants self-report their personal details. Diary studies can be more or less guided, depending on the context. The results are then analyzed by the researchers to understand habits and patterns. According to Hanington and Martin, diary studies are useful when the researcher wants to understand long-term habitual behaviors and user experiences across time. They allow participants to reflect and report in their own words, leading to rich, user-driven data.

5.1.4.2 Cultural probe

A cultural probe is a method where provocative materials are given to the participants, to help them reach thoughtful self-understanding about their lives, context, thoughts and interactions (Hanington & Martin, 2012). This method is often creative, varied and imaginative. In this method, any kind of material could be given to the participants, for example postcards or disposable cameras, to guide personal responses. The method is not intended to be formally analyzed, but rather to identify key patterns and themes that might emerge.

5.2 Methods of Define phase

This section presents the methods used in the Define phase.

5.2.1 KJ-analysis

The KJ-method is a method for qualitative data formulation and analysis (Scupin, 1997). Information relevant to the problems is written down on labels and each label contains only one concept, thought or opinion related to the problems. The labels are then grouped into "themes". Here, biases should not motivate the grouping into themes, rather feelings or intuition. When repeating this process, larger themes will emerge and when all labels have been assigned a team, the team is given a title. The themes can then be grouped into larger "families", helping to classify the data. When themes and/or families have been created, a chart will start to form by organizing the teams by occurrence and/or via arrows that indicate connections or contradictions. Finally, the chart is explained in writing or verbally, often developing new ideas surrounding the problems.

5.2.2 PEPA

PEPA is an analytic assessment method for ergonomics in relation to a specific product (C. Berlin, personal communication, January 29, 2025). With PEPA one can analyze the ergonomics in a specific

task related to a critical user, to identify what steps in the task that result in strain on the body. The PEPA-table consists of steps in the task on the X-axis which are established from an HTA. An HTA is a task breakdown method which analyses a task and divides it into sub-steps and subgoals. On the Y-axis there are different ergonomic themes (such as force and precision). The analyzer will then estimate the strain for the critical user to low, medium or high for every step in the task and every ergonomic theme.

5.2.3 REBA

REBA (Rapid Entire Body Assessment) is one of the most established methods for analyzing physical strain on the body (Bohgard, et al., 2009). Like the name suggests, this method focuses on the entire body. REBA also takes into consideration coupling effects, if the position of upper extremities is caused by gravity and if large dynamic changes of posture occur. The result from REBA is then connected to categories of action depending on the severity of the position, for example if measures must be taken or if it should be subject to further investigation.

5.2.4 List of requirements

A list of requirements is a structured method used to define all the necessary requirements a product must fulfill (Johannesson, Persson, & Pettersson, 2018). The list can be organized into various themes, for example functional requirements. For a specific requirement, it is often described and ranked in priority. Often, the requirement list is divided into requirements and wishes, where wishes do not need to be met for the product to function.

5.3 Methods of Ideate phase

In this section the methods of the Ideate phase are presented.

5.3.1 Brainstorming

Brainstorming is a method used for idea generation (Johannesson, Persson, & Pettersson, 2018). It is a creative and open method for exploring new ideas and solutions to problems. This method aims to explore as many ideas as possible, where quantity precedes the quality of the solutions.

5.3.2 Brainwriting

Brainwriting is a method used to come up with new ideas but is initiated individually and nonverbally (Tague, 2023). Participants write down ideas alone, to then be shared and added upon when a number of ideas have been produced. Brainwriting is used when a large range of ideas are

desired, when participation of the whole group is desired, to encourage equal participation and when ideas might be complex and require explanations.

5.3.3 6-3-5

6-3-5 is a creative method used for idea generation (Johannesson, Persson, & Pettersson, 2018). Firstly, all individuals sketch or write down several ideas that differ from each other, for a set time. After a few minutes, the ideas are passed along to the next participant. The timer will then start over, and each participant will be adding ideas to the already written ideas from the previous participant. This is to encourage collaboration and development of ideas.

5.4 Methods of Prototype phase

Below the methods of the Prototype phase are presented.

5.4.1 Mock-up

Physical mock-ups are an experimental way to test design decisions (Strobl, 2012). The level of fidelity in a physical mock-up can vary. Simple mock-ups can consist of easily obtained materials such as cardboard boxes or tape, where ideas can be quickly tested and manipulated. Simple mock-ups are both less expensive and less time consuming than detailed models.

5.4.2 Rapid prototyping

Rapid prototyping is a technique and method for immediate conversion of CAD models into physical prototypes (Kamrani & Abouel Nasr, 2010). It is done through slicing the model into multiple 2D layers and stacking them one layer at a time. This method is often used to reduce the time spent on product development cycles, to quickly assess concepts.

5.4.3 Traditional prototyping

Prototyping is a method for exploring, testing and communicating ideas (Bäumer, Stolterman, & Croon Fors, 2018). A traditional prototype is a physical or digital model that presents essential parts of a design. It helps improve communication, learning and decision-making in the design process. Depending on the design phase and the objectives, a prototype can be both high- and low fidelity.

5.5 Methods of Evaluate phase

Below, the methods of the Evaluate phase are presented.

5.5.1 Concept selection

Concept selections are done iteratively in the product development process and can be done in various ways (Ulrich & Eppinger, 2015). It's a process of narrowing concepts down and eliminating worse performing ones. Concept selection can be more or less structured and follow different methods. Common methods are Intuition, pros and cons, multivoting, or external decision. The concept selection can also be combining several aspects and be a mix of different methods.

5.5.2 Pugh matrix

The Pugh matrix is a decision-making tool used to evaluate and rank concepts by comparing them with a reference product (Johannesson, Persson, & Pettersson, 2018). Each concept is assessed based on whether it meets the requirements better (+), worse (-), or equally (0) compared to the reference. The scores are summed up, providing a clear ranking of concepts and identifying those most suitable for further development.

Process

6 General description and procedure

This chapter includes the description of the project model, and its respective phases, on which the project is based.

6.1 Project model

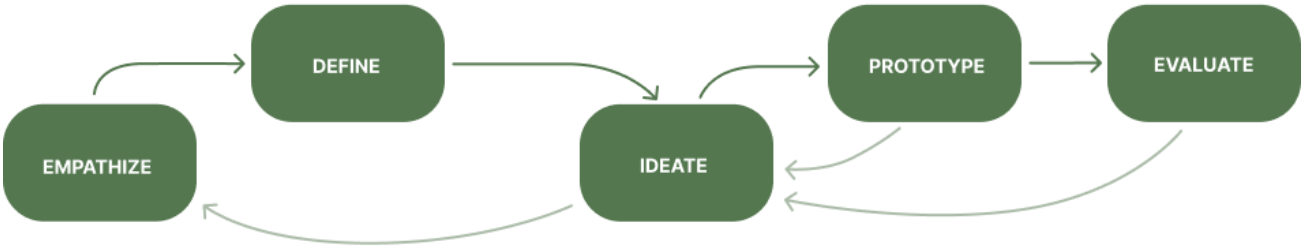

Figure 11: Project model

The process used in this project is a modification of the design thinking process, a non-linear product development process. This modified process includes five phases, with their respective goals and focus; Empathize, Define, Ideate, Prototype & Evaluate (see Figure 11). The difference from the design thinking process is that Evaluate replaces "Test". This is done because the evaluation of this project is essential, both in terms of ergonomic comparisons, but also for concept evaluations.

This project model was chosen based on several advantages. The design thinking process model places the user at the center, which is suitable for a project focused on ergonomics. This ensures that the final product isn't just technically sound, but also relevant, desirable and usable for the end user. Furthermore, it provides a structured but flexible framework, applicable to an iterative but goal-oriented project such as this thesis work. It allows for flexibility but also supports exploration without losing focus. This process model is also creative at its core, encouraging ideation beyond obvious solutions through exploration, increasing chances of innovative and meaningful end products. This encouragement also helps balance theory with practicality, for example with user testing and prototyping, further improving validation for real-world solutions, not only theory-based concepts.

In this project an iterative workflow is applied to guarantee that input from different phases won't be discarded, considered equally and to its fullest potential. Thus, methods can be repeated and overlap from one phase to another.

6.2 Description of phases

This section presents the goal, aims and contents of each phase in the order they are presented in the project model.

Emphasize

The emphasize phase aims to gather knowledge in the area of ergonomics, existing solutions and essential dishwasher functions to ensure a rigid foundation for the project. The aim is also to gather information regarding user needs in dishwasher use, preferences and ergonomic pain points to ensure a fair problem identification (see chapter 8 for the results of the Empathize phase).

Define

This phase aims to identify the needs and requirements for the end concept(s). This, by analyzing and summarizing the insights from the emphasize phase. With numerical data and qualitative insights, a list of user needs will be produced as a result of this phase (see chapter 9 for the results of the Define phase).

Ideate

The ideation phase will employ an iterative process with the aim of developing several concepts. The goal of this phase is to produce several ideas and solutions to the problems identified in the previous phase, it aims to refine ideas into concepts, and it also aims to try out ideas, discard, combine and develop iteratively against the list of user needs. This is to ensure that nothing important from the previous phase is missed and that all possibilities are explored (see chapter 10 for the results of the Ideate, Prototype and Evaluate phases).

Prototype

This phase aims to create solutions physically and thereby test ideas from the previous phases. By the end of this phase a better idea of the solutions' possibilities and limitations will be obtained, benefiting potential real-world implementation (see chapter 10 for the results of the Ideate, Prototype and Evaluate phases).

Evaluate

In the last phase, the concepts will be evaluated to know which concept to further develop and to validate the chosen concept. This phase is iterative and is present along with other phases. The aim

of the evaluation phase is to ensure that and investigate if the concepts meet the list of user needs set from previous phases, mainly in terms of ergonomic improvements (see chapter 10 for the results of the Ideate, Prototype and Evaluate phases).

7 Project execution

Below, the execution of the different phases in this project will be presented, using the phases explained previously as a guide. The project execution is presented in a chronological order and since the development process is iterative, some of the phases are explained together as they overlap.

7.1 Execution of Empathize phase

This section presents how the Empathize phase was executed, including pre-studies and user studies (see chapter 8 for the results of the Empathize phase).

7.1.1 Online and literature research

The project began with online and literature research to obtain knowledge of the current situation of ergonomics in dishwashers, how to best perform ergonomic assessments as well as carry out analyses of competitors ergonomic solutions. Databases that were used during this research phase were Chalmers library and AcessSience. Search engines such as Google Scholar was also used with search words such as “Ergonomic solutions in home appliances” and “Design solutions for dishwashers”. The aim was to find research on, and public solutions to similar ergonomic challenges, as well as dishwashers and the functions of these. Furthermore, the literature research also included gathering information on specific ergonomic assessment tools and methods from other studies and articles on ergonomics. The goal of this was to map out aspects of ergonomic issues to consider, as well as to get an understanding of the current solutions on the market.

7.1.2 Site visit and self-test

After finishing the online and literature research, a field trip to two showrooms was scheduled, to see some of the competitors’ solutions firsthand. One showroom exhibited an Electrolux Comfort-Lift, designed to raise the lower basket to a more comfortable working height. The lower basket is lifted with the help of a handle that unlocks the basket and spring that helps elevate the lower basket to the height of the upper basket. This, however, hinders the user from using the upper basket simultaneously and blocks the user from refilling salt.

The other showroom exhibited a Fisher & Paykel divided drawer dishwasher, that is designed for the purpose of making dishwashing more sustainable, running one of the two drawers at a time if the amount of dishware is lower than a full load. However, the design for sustainability in the Fisher & Paykel dishwasher is also beneficial for ergonomics, especially for the higher drawer. These two dishwashers were briefly examined mechanically, functionally and during the task of opening and pulling out the drawers to obtain an understanding of function, usability and ergonomic benefits.

7.1.3 Functional analysis

To ensure understanding of the different functions and sub-functions of a dishwasher a functional analysis was made. This was done with the knowledge attained from ASKO, combined with the information gathered from literature and online research.

7.1.4 Product breakdown

A product breakdown was carried out to get a better understanding of the different parts of the dishwasher relevant for the project. Two pictures of an ASKO dishwasher were used for labeling different parts of the dishwasher, one of a front view, and one of an exploded view. Information needed to label the different parts was obtained from the ASKO webpage.

7.1.5 Expert interviews

Semi-structured interviews were held, focusing on two professional categories: Ergonomic experts, such as physiotherapists, and dishwasher experts, such as kitchen architects. These interviews were held with the aim of creating a rigid knowledge base in these areas. All interviews were recorded and transcribed using Words' transcription tool. The transcribed material was then read through, and interesting opinions and experiences were marked, to be sorted into a KJ-analysis at a later stage.

7.1.5.1 Interview ergonomic experts

Two interviews were held around ergonomics. One interview with a physiotherapist and one with an occupational therapist. For these interviews an interview guide was created (see Appendix 1: Interview guides). During the interviews the interview guide was followed but with space for follow up questions, probing and skipping questions already answered previously. Themes such as working posture during dishwasher use, common user errors, bodily strain and possible improvements of dishwashers were discussed. The interview with the physiotherapist was held in an online meeting, lasting for about 30 minutes. The interview with the occupational therapist was held at their workplace, lasting for about 30 minutes.

7.1.5.2 Interview dishwasher experts

Two interviews were held around dishwashers. One with a kitchen architect and one with a kitchen appliance and dishwasher expert. For these interviews an interview guide was created similarly to the interviews with the ergonomic experts and the interviews were conducted in a similar way (see Appendix 1: Interview guides). However, the focus for the interviews with the dishwasher experts

were functionality, customer opinion, surrounding structure in the kitchen area and broader questions around ergonomics such as other ergonomic solutions in the home.

7.1.6 Letters

Since the method *Letters* is a combination of different methods, the process of forming the method began with a meeting with a lecturer within design and human factors to discuss aims, methodology outline and layout. Once these aspects were established, the creation of the layout of the letters began, resulting in five letters.

Each letter was based on different themes for the participant to fill out. The letters were created in Figma and were later labeled with day 1 through day 5 (see examples in Figure 12). All the letters can be viewed in Appendix 2: Letters. These letters were created for the purpose of obtaining deeper thoughts and experiences from the users regarding their lifetimes with their dishwashers. To do this, each letter has probing attributes and asks of the users to see themselves in different scenarios, and to write letters for different purposes.

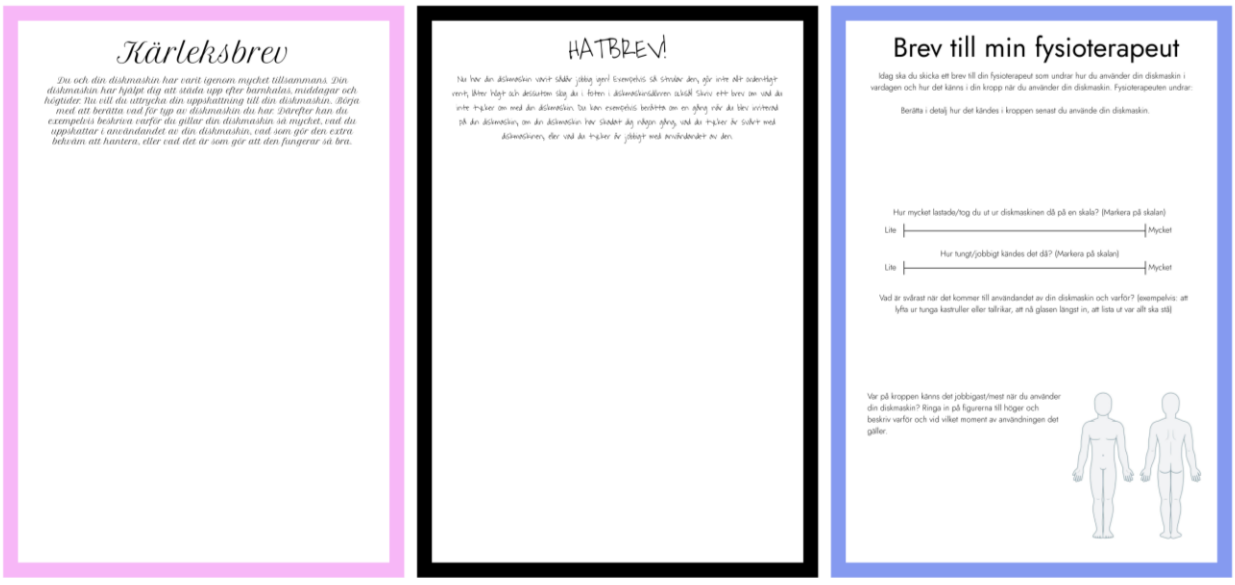

Figure 12: Letters

A pilot study was performed to establish the final layout of the letters as well as the contents to ensure that the information that was needed for the study was obtained. The pilot study was carried out with two participants. The pilot study had a duration of 4 days, and the filled-out letters were then analyzed regarding information gathered, which resulted in some changes in the final layout, such as changing the introduction of some of the letters to target specific information and rephrasing some questions for the same purpose.

The letter for day 1 was a “love letter”, where the participants were asked to describe what they like about their dishwasher.

The letter for day 2 was a “hate letter”, where the participants were asked to describe what they dislike about their dishwasher.

The letter for day 3 was a “letter to your physiotherapist” where the participants got to fill out where on the body they experience the most strain while using their dishwasher, what the hardest thing is when using their dishwasher and how much they had loaded or unloaded their dishwasher that specific day, in relation to how much strain they experienced in the body.

The letter for day 4 was an “excerpt from my diary” where the participants got to fill in a timeline explaining about times in their life where it was especially difficult to use their dishwasher, when the dishwasher potentially broke down or when they saw someone else having a difficult time when using the dishwasher.

The fifth and last letter was a “letter to Santa” where the participants were asked to describe their dream dishwasher, with no limitations. They were also able to add to their description with drawings.

These five letters were packaged in envelopes corresponding to each of the five days and they also came with an introduction (see Figure 13).

Figure 13: Letters in envelopes

The introduction thanked the participant for participating in the study and included an explanation of the context of the study in connection with this master thesis. It also explained the purpose of the study and that it was designed the way it was to allow them to reflect from different viewpoints. Furthermore, the introduction also encouraged them to open the letter in the morning, reflect during the day and answer in the afternoon or evening.

The letters were sent out to seven participants, aged approximately 40-80 years old with 5 women and 2 men, to be filled out in one week's time (see Figure 14). These participants were chosen based on their age (preferably over 30 years old to have some longer experience with dishwashers), and that they owned a dishwasher. To minimize potential bias from the participants, they were selected via indirect social connections, such as extended family acquaintances or friends-of-friends, rather than individuals with close personal ties with the authors.

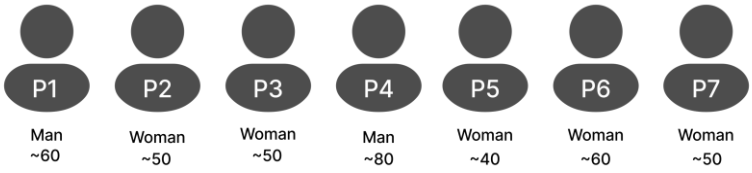

Figure 14: Participant selection Letters

After one week, the letters from the participants were collected, read and answers interesting for the study were marked and then categorized in a KJ-analysis.

7.1.7 User test

A pilot study was first performed for the user test to ensure that the information needed was obtained. The pilot study was carried out with one participant and one ergonomic researcher that observed the implementation of the test to later give feedback. The pilot study resulted in a few changes to the real user tests, such as filling the dishwasher half-full of dishware to guide the user on where to place dishes and to resemble a real situation.

Six user tests were conducted with three women and three men, ages ranging from 50-64 and heights from 161-185 cm (see Figure 15). These participants had been chosen based on their age (50+ to get input from users with longer experience with dishwashers), their height (to ensure representation of different heights in the study) and to preferably not have a background in ergonomics or product development (to not be colored by their previous knowledge). The selection of participants was carried out through contacting the Chalmers library and Chalmers administration and sending an open invite, and by contacting lecturers at Chalmers and asking if they wanted to participate.

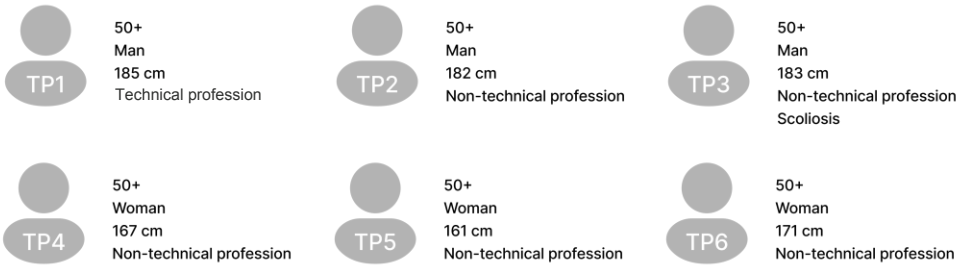

Figure 15: Participant selection User test

The user tests were carried out to get physical observations on the use of the dishwashers to later be able to conduct ergonomic assessments. The participants were invited to a 40-minute test where they were to use dishwashers and "think out loud" while doing so. The test procedure looked like this:

1. Open and load a dishwasher with the dishware available on the table
2. Add the dishwasher detergent and close the door
3. Open and unload the dishwasher and put the dishware on the table
4. Answer the first part of the survey
5. Open and load another dishwasher with the dishware available on the table
6. Add the dishwasher detergent and close the door
7. Open and unload the dishwasher and put the dishware on the table
8. Answer the second part of the survey
9. Final questions and short discussion

To ensure that the tests could be completed, the set-up included two dishwashers, one ASKO dishwasher on floor height, and one Gorenje dishwasher that was raised 35 cm of the floor using three EU pallets. The reason for having one raised dishwasher was because the information gathered from the literature and interviews pointed to that raising the height of the dishwasher could be beneficial for the users' work position. The participants also had dishware to be able to load and unload the dishwasher.

To be able to analyze the participants' work position during the tasks, the test was recorded with video and audio using two Go-Pros placed at two different angles.

In the middle and at the end the participants filled in a survey regarding how they rated the strain on the body during each task on each dishwasher on a scale from 1-6, 1 being "not straining at all" and 6 being "very straining". At the end of the survey the participants answered which one of the two dishwashers was the most straining overall. The test ended with a discussion regarding the overall feeling during the test and final thoughts. Only the audio was recorded for this part.

When the 6 tests were completed, all film and audio material were reviewed and notes were taken on observations regarding user behavior, work positions and the comments that the participants made during and after the test. The comments that the participants made during the tests and the

final discussions were sorted into a KJ-analysis at a later stage. The film material was reviewed once more to conduct ergonomic assessments.

7.2 Execution of Define phase

This section presents how the Define phase was executed, including ergonomic assessments and KJ-analyses (see chapter 9 for the results of the Define phase).

7.2.1 Ergonomic assessments

Ergonomic assessments were conducted to identify problematic areas within the tasks completed during the user tests. The methods used for this assessment were PEPA and REBA. PEPA was used to analytically identify ergonomic pain points in specific steps of the tasks, based on how the user handled the dishwasher. Thereafter, REBA was used to gather numeric data that would provide a ranked score accompanied by a suggestion of action. The REBA score would also enable a numeric comparison in the final evaluation. The combination of these ergonomic assessments reinforced the validation of the project outcome.

7.2.1.1 PEPA

The method PEPA was created for assessing ergonomics for a critical user. However, in the user tests three critical users were identified and therefore selected. The critical users chosen were the tallest, the shortest and one participant with scoliosis. Firstly, the video and audio materials were observed and analyzed, and an HTA was conducted to break down the steps of the task performed by the users. Thereafter, each step was observed, discussed, and finally evaluated on the scale “low physical effort, medium physical effort, or high physical effort”. To further understand the result, the complete tables were imported into Figma and further analyzed with comments, pictures and connections. Problems were grouped into themes to be a part of the merged KJ-analysis.

7.2.1.2 REBA

REBA was conducted on the most critical ergonomic positions found in the video materials and on positions frequently repeated among the participants. Each video was observed through two angles and paused where a critical position was observed. These still images were saved and later analyzed through a REBA worksheet.

Among the most critical ergonomic positions observed, deep bends were one of the most prominent positional issues among the participants, meaning that this position was a focus point in the REBA worksheets. This position was also compared between the two dishwashers used in the

user test. Lastly, raised shoulders, arms, positioning of legs/knees, neck extensions and twists of wrists were also observed.

7.2.2 KJ-analysis

The data from each study (interviews, letters, and user tests) was analyzed first separately, grouping common comments, quotes and observations together, into common themes and themes within themes. Then a merged KJ-analysis was created to understand the overall themes and what has been observed and mentioned in more than one study.

When the merged KJ analysis was done, connections between different themes were analyzed. The connections between the themes were drawn with dashed arrows, one-sided arrows and interconnected arrows, to separate the connections of something that could be a solution to a problem, something affecting something, and to themes affecting each other. From the data in the merged KJ-analysis as well as the connection between these, the categories and themes were translated into user needs.

7.2.3 List of user needs

The list of user needs created in this study was based on the data obtained from the merged KJ-analysis. The list was designed as a requirement list but does not include target values and hard values. The list is more focused on soft values within the user needs and wishes collected in the previous phase. The reason for the creation of the list of user needs was to be able to structure and highlight some of the large number of needs gathered throughout the study, and to be able to use as a basis for later decision making in the development process. The user needs were divided into needs and sub-needs. The needs stemmed from the larger common themes in the hierarchy of the KJ-analysis as well as the number of connections that had emerged for them. The sub-requirements stemmed from the smaller themes and opinions in the hierarchy and specified and defined the needs. The list was divided into functional, emotional, ergonomic and other requirements.

7.3 Execution of Ideate, prototype and evaluate phases

This section presents how the Ideate, Prototype and Evaluate phases were executed, including Ideation, prototyping and decision-making. Since these phases are iterative and overlap, the execution of them is presented together. This is to ensure a presentation of the execution that mirrors the true order in which it was done (see chapter 10 for the results of the Ideate, Prototype and Evaluate phases).

7.3.1 Ideation

During the ideation methods were used iteratively: Brainwriting, brainstorming and 6-3-5. The brainwriting and brainstorming sessions varied in being conducted individually and as a team. Furthermore, sketches, refinements and mockups were also made in an iterative manner, whereas sketching and refinements also varied in being conducted individually and as a team. Additionally, some of the sketches were also refined and visualized with higher fidelity using AI, for example by adding materials. Lastly, mockups were created.

The ideation started with brainstorming and brainwriting individually with the goal of producing as many ideas as possible (see Figure 16). Ideas varied in visuality, some being text, rough sketches, provisional sketches, and inspiration in combination with explanations. The individual ideation lasted for a few days, resulting in many ideas. These ideas were then brought forth in a discussion, where similar ideas were grouped together and thoughts, opinions and ideas of improvement were shared, and some ideas were developed further as a part of the brainwriting process.

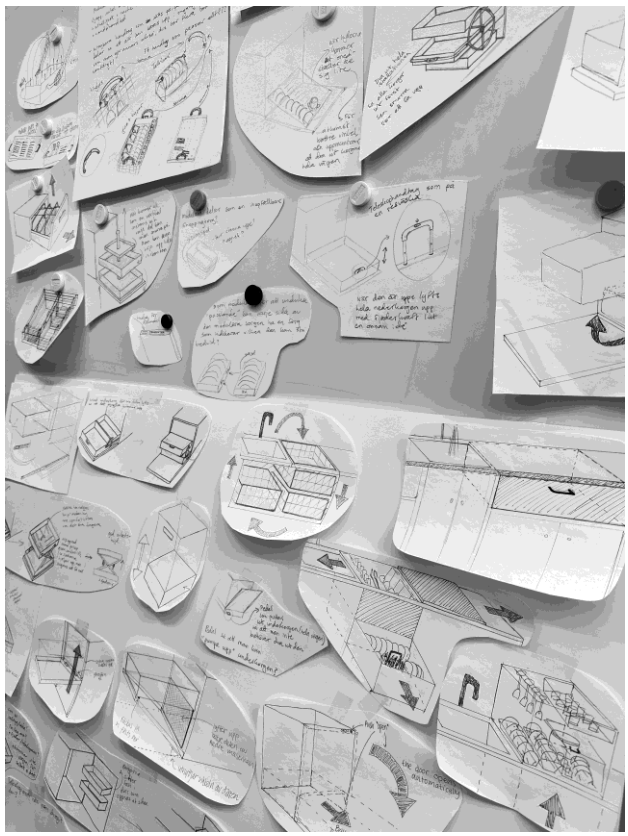

Figure 16: Ideation

When all ideas had been grouped and discussions had been held, a round of 6-3-5 was conducted. This was carried out in three rounds with three different groups of concepts of interest. The aim of using this method was to further add on to the number of ideas. A discussion was held after these

sessions and advantages, problems and unclarities regarding the ideas were raised. Thereafter, a list was made on possible further refinements of ideas as well as points of investigation, especially regarding mechanics and realizations.

Different mechanical solutions on the market were investigated and knowledge was gathered to be able to refine some of the concepts. After some refinements were made a discussion regarding the concepts was held with ASKO, where some concepts proved to be more interesting and feasible than others, subsequently eliminating a few concepts in a concept selection session. The concept selection that followed these discussions was based on both the discussed requirements and on intuition regarding the concepts overall potential. Furthermore, an external engineer with long experience in mechanics was also asked to take part in a discussion regarding how to realize these concepts, giving even more insight into possible construction plans.

When having ideated, explored feasibility and discussed with ASKO and the engineer, mockups were made on a few of the concepts that moved forward from the concept selection. The mockups were made to further understand and explore mechanics and how the concepts would work in the real world. This was done iteratively; creating mockups; sketching on a new variant; changing the mockup; gathering information to solve problems found; changing the mockups again.

Another discussion about the concepts was then held once more with ASKO. The aim of this discussion was to eliminate concepts that were not feasible and to obtain construction suggestions of prototypes for these concepts.

When the mockups were made, mechanics were sufficiently understood, and the concepts were on the same level of fidelity another selection had to be made. The aim of this selection was to evaluate the concepts against the list of user needs and as a result eliminate concepts accordingly.

7.3.2 Pugh matrix

To decide what concepts to continue with in the ideation phase, a Pugh matrix was created, with the user needs on the Y-axis and the concepts on the X-axis. Each concept was discussed against each of the user needs and scored either 0, if equal to the current ASKO dishwasher, “+” if it performed better, “- “if worse, and “?” if more investigation was needed to say. Each of the “+” were added and all the “- “ were subtracted from the total.

As a result of the Pugh matrix some concepts could be eliminated based on their score, leaving four concepts. However, more information was needed on a few of the concepts that had the same score but had “?” on some user needs. Therefore, two of the concepts were rapid prototyped to more fairly be compared in the table. Thereafter the summarization of the scores were updated again and decisions about what to further develop were made.

7.3.3 Rapid prototypes

When decisions were made based on the Pugh matrix, prototyping was initiated for three concepts. The aim of the prototyping was to test the functions, size and measurements and get an understanding of what it would look like in reality, to later be able to make decisions on what to further develop.

Catia V5 was used to model the prototypes and their respective parts. The parts were later exported as STL files and imported into PrusaSlicer to be positioned and sliced as preparation for 3D-printing. The prototypes were then 3D-printed and assembled.

With the functional prototypes, function, mechanics and strain on different components of the concepts could be investigated and based on these findings, decisions could be made regarding what concept to move forward with.

It was decided to combine three of the four remaining concepts, while also developing the fourth concept separately, resulting in two separate tracks for the final concept; A scissors lift concept and a modular baskets concept.

7.3.4 CAD

When the final concept had been chosen, modeling in Catia V5 was initiated for the final concept. The starting point of the modeling was a current ASKO dishwasher model. This model was used as reference and as a base for building the new parts. The final CAD file was then exported into VRED for final renderings and animations.

7.3.5 Visual prototype

Based on the CAD model of the scissors lift concept, a non-functional prototype in real scale was created. The goal of this prototype was to be able to execute ergonomic assessments on the concept, hence the prototype being created in 1:1 scale. To simplify and to be able to build it within the time frame, a decision was made to build it in a static position.

Firstly, the prototype was built using pine wood sticks and thin wooden sheets as a separate platform from the dishwasher, designed to be placed on top of the dishwasher door. In this prototype, the measurements of the height of the platform matched the measurements of the CAD model in the lifted position. But the width and length were over dimensioned, as well as the size of the scissor's arms, since the height was what mattered the most for the execution of the ergonomic assessment. To build the prototype, a band saw was used to cut the wooden parts to the correct size, and a drill, screwdriver and screws were used to attach the wooden sticks to the wooden sheet (see Figure 17 for a picture of the process).

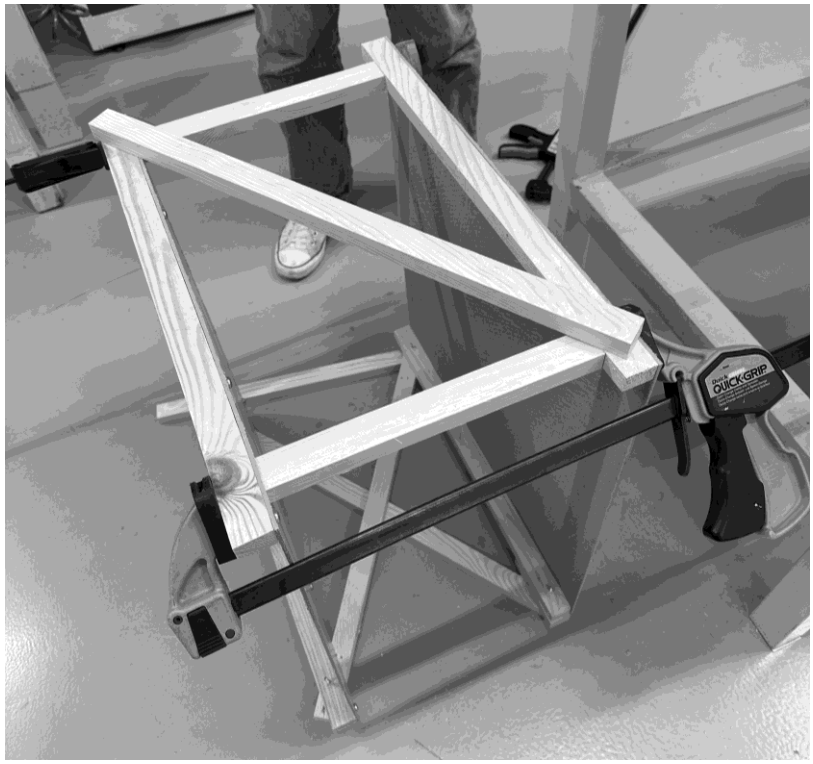

Figure 17: Process of first prototype

A decision was made to further refine the prototype and build it more closely to how the real product would look like. Similarly to the first prototype, this was built as a non-functional static prototype. In this final prototype, an inner dishwasher door was used as the upper platform, and 2 mm thick 25 mm wide aluminum flat profile lists were used as the scissor's arms. Since the aluminum profiles were a bit too unsteady, the profiles were stacked with two profiles, attached with double-sided tape, resulting in a thickness of 4mm. To attach the scissors lifts arms to the upper inner dishwasher door, 90-degree angled aluminum profiles were attached and bolted to the bottom of the inner dishwasher door. At the lower inner dishwasher door, attached to the machine, the arms were screwed directly into the steel. Before bolting, the holes were measured and predrilled.

When the scissors arms and upper platform were mounted, the prototype was unsteady in the X-direction. Therefore, an extra 90-degree aluminum profile was mounted between the back of the upper platform and into the dishwasher, to minimize movement.

Additionally, the modular basket concept was also prototyped, but with lower fidelity with the goal of testing size and weight (see Figure 18 and Figure 19).

Figure 18: Modular basket prototype for plates

Figure 19: Modular basket prototype for cups and glasses

These prototypes were created with already existing basket inserts with rods from another basket mounted on, to be able to place plates, cups and glasses and test the weight, size and stability.

7.3.6 Visualization of modular baskets

The modular basket concept was further visualized using Figma. Pictures from ASKO dishwashers were used as a base, edited with lines to sketch and present the concept of the modularity. A decision was made to not refine the visualizations further and leave it as a theoretical concept that could be combined with the scissors lift concept and as a subject for future work.

7.3.7 Ergonomic assessment REBA

With the refined static visual prototype of the scissors lift concept, pictures were taken to be analyzed with REBA. Since the limited time frame of the project, and the similarity to the raised dishwasher in the user tests, it was decided to not evaluate through a second user test, but to carry out self-tests for evaluation and validation purposes.

Results

8 Results of Emphasize phase

This chapter presents the results of the empathize phase, including results from pre-studies as well as the results from user studies.

8.1 Functional analysis

The results from the functional analysis are presented in a tree-diagram, presenting the main, sub and other functions (see Figure 20).

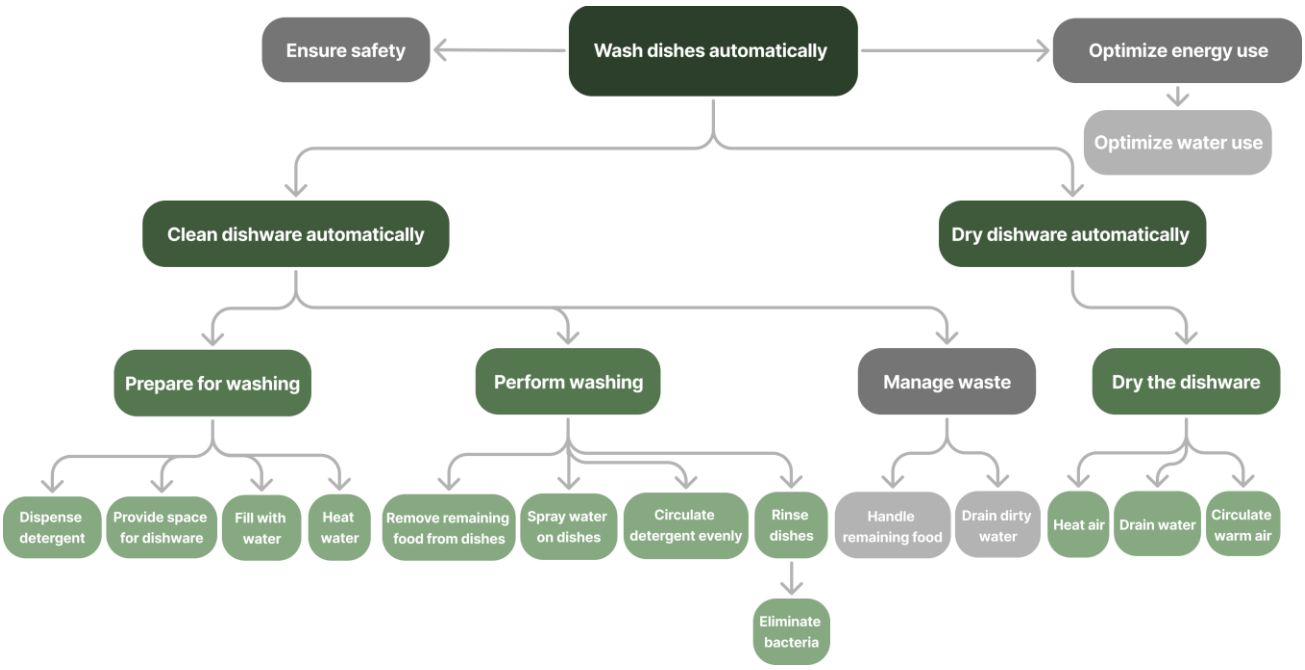

Figure 20: Functional analysis

The main function is “Wash dishes automatically” and this function is divided into “Clean dishware automatically and “Dry dishware automatically”. Furthermore, “Clean dishware automatically” is divided into “prepare for washing”, “perform washing” and “manage waste”.

8.2 Product breakdown

The product breakdown is presented in two separate views, one of which parts can be seen from the front view picture, and one from the exploded view picture. The most important parts of the dishwasher for this project are viewed (see Figure 21 and Figure 22).

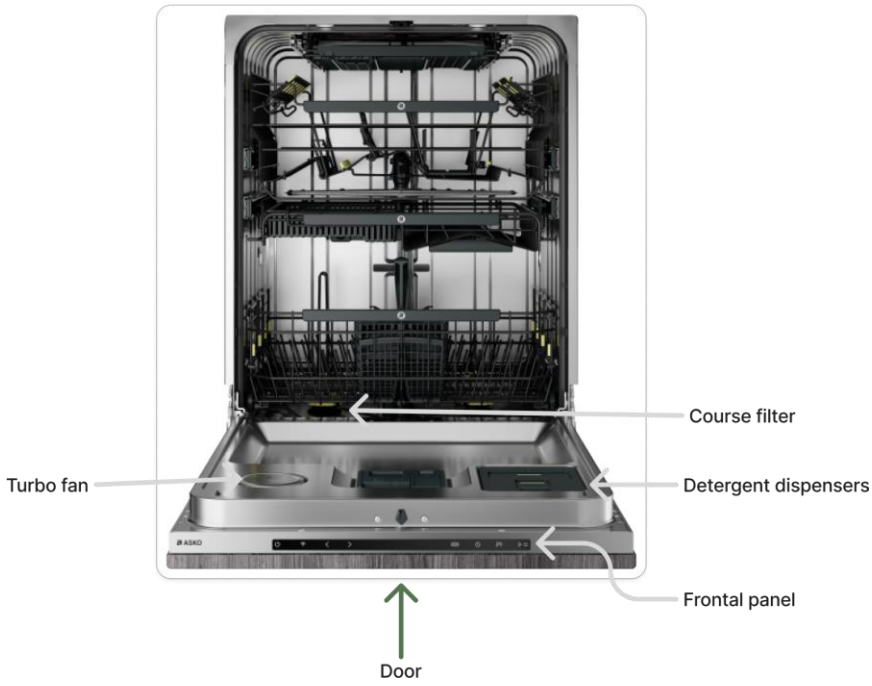

Figure 21: Product breakdown of dishwasher A[6]

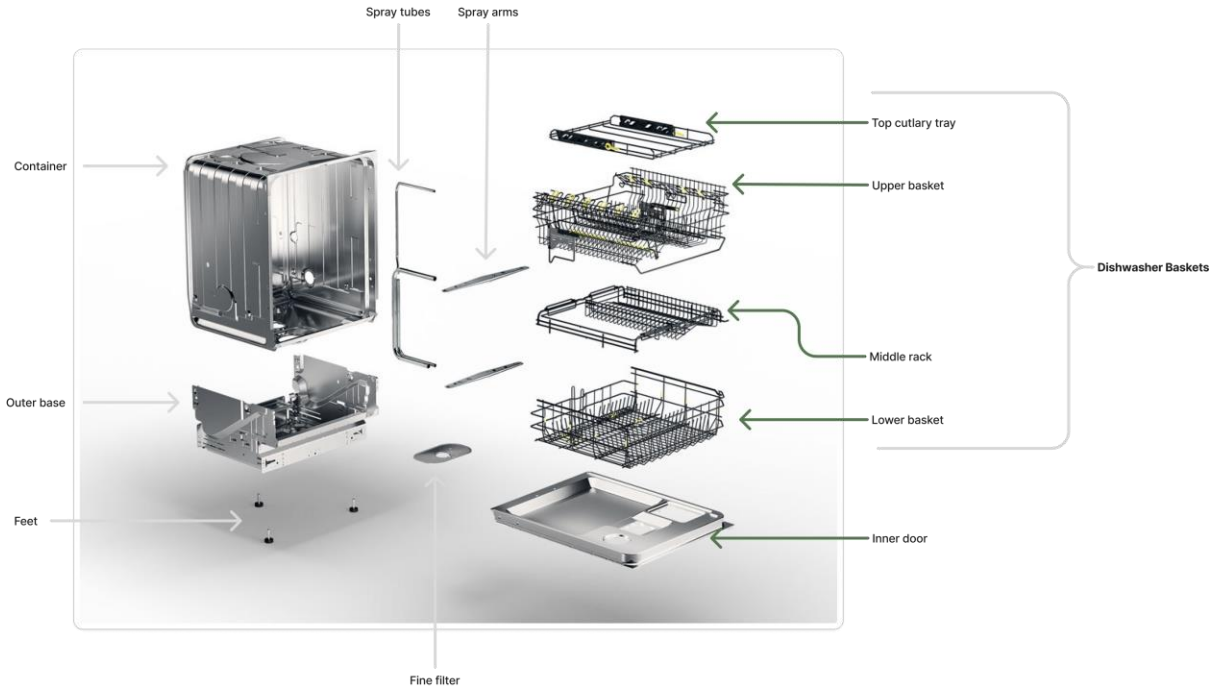

Figure 22: Product breakdown of dishwasher B[7]

[6] Picture published with permission from ASKO. Retrieved from ASKO (https://se.asko.com/produkter/kok/alla-diskmaskiner/fullintegrerade-diskmaskiner/DISHWASH-DW60-2-DFI544H-1-ASK/p/000000000000746022), edited by the authors.

[7] Picture published with permission from ASKO. Retrieved from ASKO (https://se.asko.com/kok/diskmaskiner/funktioner), edited by the authors.

8.3 Interviews results

The interviews resulted in two separate KJ-analyses, one for the ergonomic experts and one for the dishwasher experts. The KJ-analyses were done separately since the interview guides differed from each other.

8.3.1 Interviews ergonomic experts results

The KJ analysis from the interviews with the ergonomic experts resulted in several themes and themes within themes (see Figure 23).

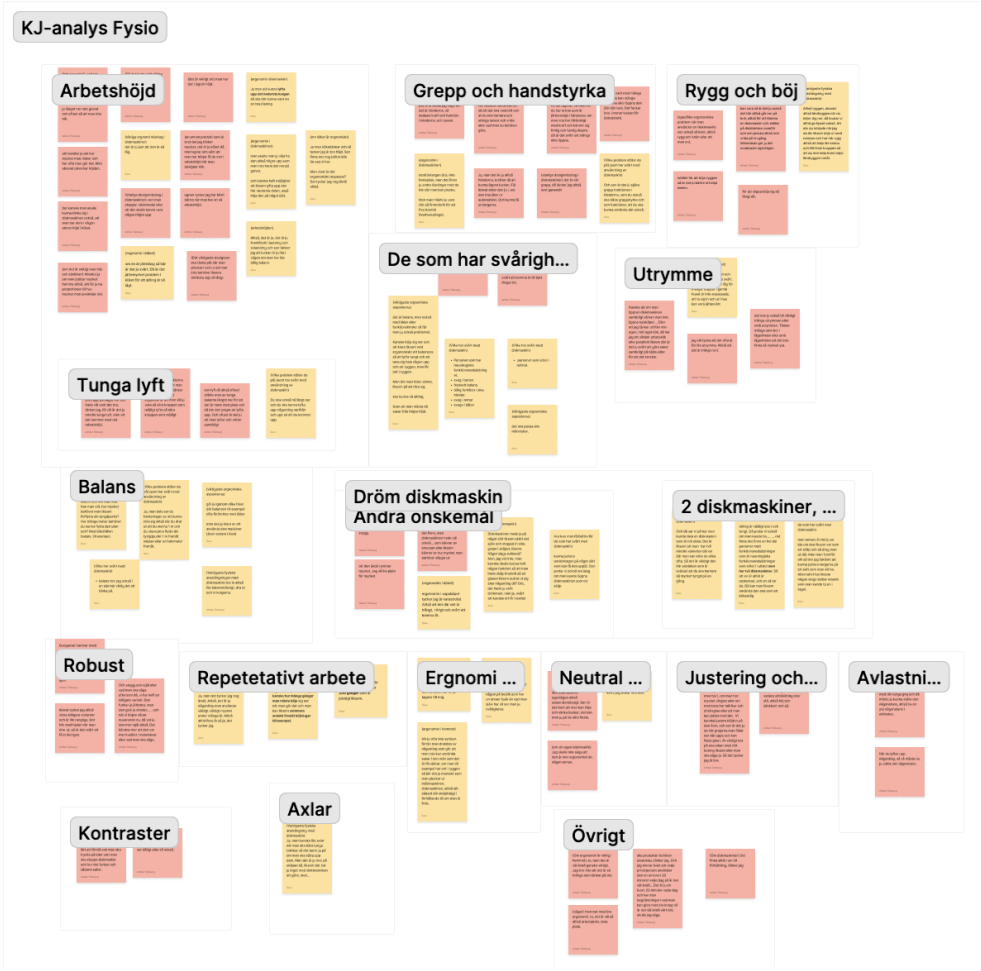

Figure 23: KJ-analysis Ergonomic Expert Interview

A few of the bigger themes were Working height, Grip & hand strength, Back & bends, Critical users and Balance. See Appendix 5: KJ-analysis themes for a complete account for all the themes.

From these interviews the general opinion was that the back is subjected to the most strain while loading and unloading the dishwasher and that the cause of this is an unfavorable working height and heavy lifts. Grip and hand strength were also important topics, where some tasks when using the dishwasher, such as opening the lid for detergent or gripping dishware, were especially straining. In these interviews critical users were also discussed, such as the elderly. These users would also have issues with balance when performing dishwasher related tasks. This is because of the low working height, deep bends and moving the center of gravity over the lower basket, trying to avoid hitting the dishwasher door and reaching the dishware. Additionally, robustness, space in and outside of the dishwasher, repetitive work and adjustment and adaptation were also discussed.

8.3.2 Interviews dishwasher experts results

The material from the interviews with the dishwasher experts was handled in the same way as the interviews with the ergonomic experts. Interesting opinions and experiences from the interviews were sorted into a KJ-analysis and several themes emerged, see Figure 24.

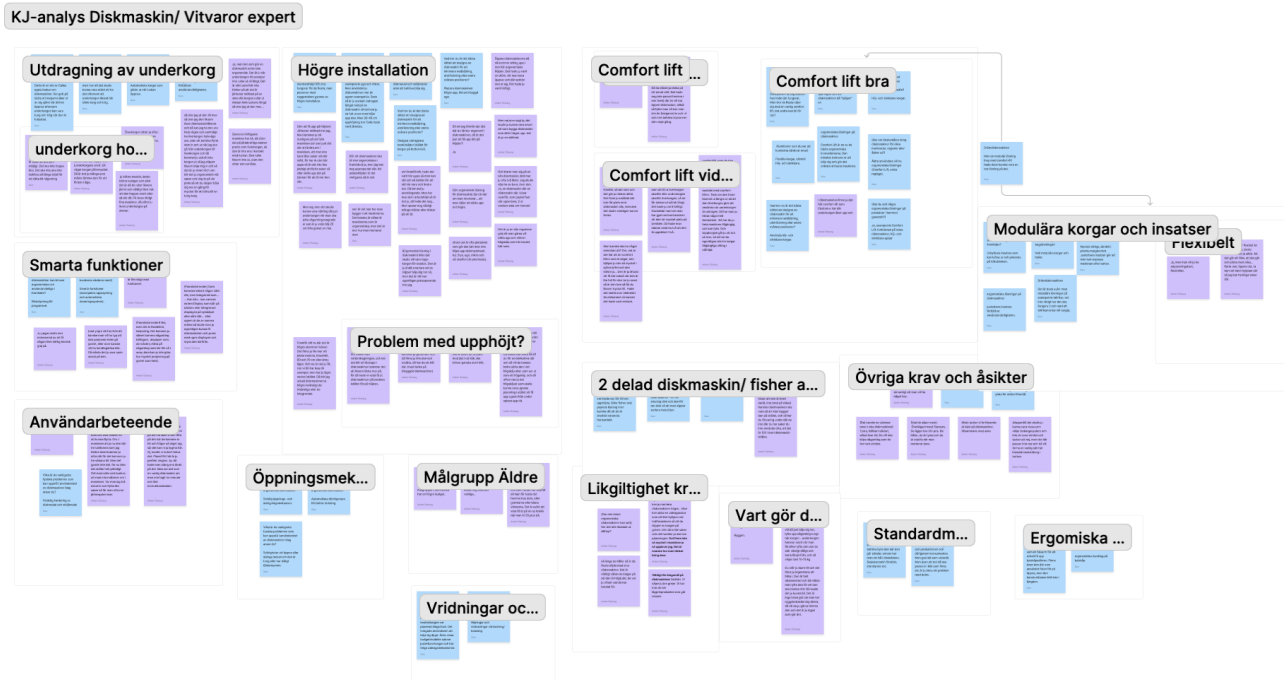

Figure 24: KJ-analysis: Dishwasher Expert interview

The biggest themes that emerged were for example High installation, Comfort Lift, Pulling out the lower basket, Modular baskets & inserts and smart functions. See Appendix 5: KJ-analysis themes for a complete account for all the themes.

In these interviews the most prominent opinions were regarding high installation, where it was agreed upon that dishwashers should be prioritized when raising appliances in the kitchen, since the dishwasher is used more often. Pulling out the lower basket and for it not to derail and run smoothly was also a reoccurring theme, where a derailing lower basket could potentially cause both frustration, pain and injury, especially because it's located at a very low height. Benefits and problems with the Electrolux Comfort Lift were also discussed, for example, that it provides a good working height, but it obstructs the use of the upper basket, forcing the user to only use one basket at a time. Modularity was also a topic where both benefits and problems arose. Many customers like modularity and it could improve the ergonomics, but if it becomes too modular, it becomes hard and troublesome to use and understand the dishwasher functions. Customers typically want something that is easy to use and that can be trusted for a long period of time, they do not want to read through the instructions a second time. Additionally smart functions, accessibility and the elderly were discussed.

8.4 Letters results

All letters were received from the participants about 2 weeks after they were sent out. The letters were opened, read through and interesting opinions and experiences were marked (see Figure 25 for examples of the filled in letters).

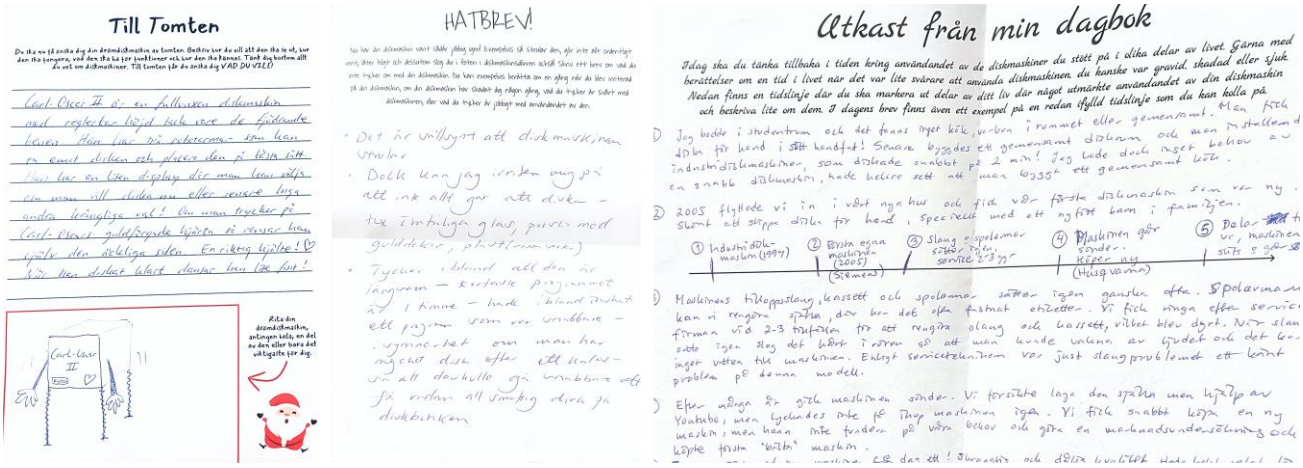

Figure 25: Results Letters

The marked quotes from the letters were then categorized in a KJ-analysis where themes and themes within themes emerged (see Figure 26).

Figure 26: KJ analysis Letters

From the KJ-analysis several themes emerged, a few of the biggest were User friendliness, Quality, Body, Base requirements and Packing. See Appendix 5: KJ-analysis themes for a complete account for all the themes and sub-themes.

From the letters it became evident that quality was one of the most important aspects for the users when it comes to dishwashers. Many of the issues explained in the letters were regarding the dishwasher breaking, baskets derailing displays getting fainter with time etc. The second largest theme from the letters was “body”. This theme is connected to the ergonomics of using a dishwasher. Many of the respondents explained that lumbago is a common issue when using the dishwasher, and that it stems from deep bends and repetitive work on a low working height. Some also explained that they would like to have the dishwasher at a better working height, especially the lower basket. Fingers and hands were also an issue for some respondents, where pain arose from broken handles or when grabbing dishware. Another important theme was “packing” where effective packing was largely discussed, the users want it to go as fast as possible when loading and unloading the dishwasher. Additionally, some base requirements were mentioned such as running quietly and cleaning thoroughly.

8.5 Summary of Results of Empathize phase

To summarize, the empathize phase resulted in a breakdown of the dishwashers’ various functions, a breakdown of its different components, as well as grouped recurring themes from both interviews and the Letters method. Key insights from this phase revealed that deep bends, grip and critical users are important factors when designing for ergonomic improvements. Moreover, insights regarding higher installations, robustness and existing ergonomic home appliance solutions emerged as recurring themes.

9 Results of Define phase

This chapter presents the results of the Define phase, including ergonomic assessments and KJ-analyses.

9.1 PEPA results

From the PEPAs one could observe what steps during the use of a dishwasher were the most straining and what ergonomic issue was the root of the problem. One could also observe the difference in strain in each step between the dishwasher on floor-height and the raised dishwasher (see Appendix 8: PEPA for all PEPAs).

The dishwasher on floor height demonstrated several issues, mostly regarding steps in relation to loading and unloading the dishwasher. Parts of the body most affected by this activity were the back for all participants, in combination with endurance when being in a bent position for a longer period. The PEPA also demonstrated instances of strain on legs and knees, in connection with trying to reach the lower basket. Furthermore, precision work, such as loading cutlery, was also on a higher level of strain, this was because the hit area was less than 10 millimeters (see Figure 27 for one PEPA on a dishwasher on floor height).

Physical Ergonomics Product Assessment	Steg 1: Öppna dörren	Steg 2: Dra ut underkorg	Steg 3: Dra ut överkorg	Steg 4: Ställ ner disk under korg	Steg 5: Ställ ner disk över korg	Steg 6: Placera bestick	Steg 7: Lägg in diskmedel	Steg 8: Stäng dörr	Steg 9: Dra ut full underkorg	Steg 10: Plocka ur disk ur underkorg	Steg 11: Dra ut full överkorg	Steg 12: Plocka ur överkorg	Steg 13: Plocka ur bestick
(1) Hantering (Hålla, Förflytta, Impuls, Fånga)	Impuls	förflytta	förflytta	förflytta	förflytta	förflytta	förflytta	Impuls	förflytta	förflytta	förflytta	förflytta	förflytta
(2) Styrka	l	l	l	l	l	l	l	l	l	l	l	l	l
(3) Precision	l	l	l	m	m	h	m	l	l	m	l	m	m
(4) Uthållighet	l	l	l	m	m	l	l	l	l	m	l	l	l
(5) Grepp	l	l	l	l	l	l	l	l	l	l	l	l	l
(6a) Nacke	l	l	l	l	l	l	l	l	l	l	l	l	l
(6b) Axlar/ Skuldror	l	l	l	l	l	l	l	l	l	l	l	l	l
(6c) Arm/ armbåge	l	l	l	l	l	l	l	l	l	l	l	l	l
(6d) Hand/ handled	l	l	l	l	l	l	l	l	l	l	l	l	l
(6e) Fingrar	l	l	l	l	l	l	l	l	l	l	l	l	l
(6f) Rygg	l	m	l	m	m	l	l	l	l	m	l	l	m
(6g) Ben/ knä	l	m	l	m	l	l	m	m	l	m	l	l	l
(6h) Fot/fotled	l	l	l	l	l	l	l	l	l	l	l	l	l
(7) Yttre omständigheter				Kladdig disk	Kladdig disk	Kladdig disk			Blött och varmt	Blött och varmt	Blött och varmt	Blött och varmt	Blött och varmt

Figure 27: PEPA TP3, Floor height

In this PEPA one can also view examples of positions that result in the yellow or red fields, such as bending down and bending both the knees and the back.

The PEPAs made for the raised dishwasher demonstrated overall lower strain on more fields in comparison to the PEPAs for the dishwasher on floor height (see Figure 28 for a PEPA on a raised dishwasher).

Physical Ergonomics Product Assessment	Steg 1: Öppna dörren	Steg 2: Dra ut underkorg	Steg 3: Dra ut överkorg	Steg 4: Ställ ner disk underkorg	Steg 5: Ställ ner disk över korg	Steg 6: Placera bestick	Steg 7: Lägg in diskmedel	Steg 8: Stäng dörr	Steg 9: Dra ut full underkorg	Steg 10:Plocka ur disk ur underkorg	Steg 11: Dra ut full överkorg	Steg 12: Plocka ur disk ur överkorg	Steg 13: Plocka ur bestick
(1) Hantering (Hålla, Förflytta, Impuls, Fånga)	förflytta	förflytta	förflytta	förflytta	förflytta	förflytta	förfltrra	förfölyyta	förflytta	förflytta	förflytta	förflytta	förflytta
(2) Styrka	l	l	l	l	l	l	l	l	l	l	l	l	l
(3) Precision	l	l	l	m	m	h	m	l	l	m	l	m	m
(4) Uthållighet	l	l	l	l	m	l	l	l	l	l	l	l	l
(5) Grepp	h	l	l	l	l	l	l	l	l	l	l	l	l
(6a) Nacke	l	l	l	l	l	l	l	l	l	l	l	l	l
(6b) Axlar/ Skuldror	l	l	l	l	l	l	l	l	l	l	l	l	l
(6c) Arm/ armbåge	l	l	l	l	l	l	l	l	l	l	l	l	l
(6d) Hand/ handled	l	l	l	l	l	l	l	l	l	l	l	l	l
(6e) Fingrar	m	l	l	l	l	l	l	l	l	l	l	l	l
(6f) Rygg	l	l	l	l	l	l	l	l	l	l	l	l	l
(6g) Ben/ knä	l	l	l	l	l	l	l	l	l	l	l	l	l
(6h) Fot/fotled	l	l	l	l	l	l	l	l	l	l	l	l	l
(7) Yttre omständigheter				Kladdig disk	Kladdig disk	Kladdig disk			Blött och varmt	Blött och varmt	Blött och varmt	Blött och varmt	Blött och varmt

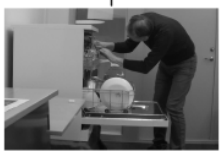

Figure 28: PEPA TP3, raised height

Here, the strain on the back, knees, legs and neck was much lower because of the raised height. This was true for all the participants. The yellow and red fields at the top in this PEPA represent precision work such as placing plates and cutlery on a small area. The precision work is generally the same for both dishwashers. However, there is one field for “opening the door” and “grip” that is red. The reason for this is that the participant didn’t see the handle, opening the door with force from the side, therefore there is also a yellow field for the same step but for “fingers” as well.

When comparing these two PEPAs one can observe that the PEPA for the raised dishwasher received about ten fields less than the PEPA for the dishwasher on floor height. Meaning that the raised dishwasher resulted in less strain overall. One could also observe that the most straining

steps in the sequence for the dishwasher on floor height, with four yellow fields, were step 4 and 10, loading dishware in the lower basket and unloading dishware from the lower basket (see Figure 29).

Physical Ergonomics Product Assessment (PEPA)	Steg 1: Öppna dörren	Steg 2: Dra ut underkorg	Steg 3: Dra ut överkorg	Steg 4: Ställ ner disk under korg	Steg 5: Ställ ner disk över korg	Steg 6: Placera bestick	Steg 7: Lägg in diskmedel	Steg 8: Stäng dörr	Steg 9: Dra ut full underkorg	Steg 10: Plocka ur disk ur underkorg	Steg 11: Dra ut full överkorg	Steg 12: Plocka ur överkorg	Steg 13: Plocka ur bestick
(1) Hantering (Hålla, Förflytta, Impuls, Fånga)	impuls	förflytta	förflytta	förflytta	förflytta	förflytta	förflytta	impuls	förflytta	förflytta	förflytta	förflytta	förflytta
(2) Styrka	l	l	l	l	l	l	l	l	l	l	l	l	l
(3) Precision	l	l	l	m	m	h	m	l	l	m	l	m	m
(4) Uthållighet	l	l	l	m	m	l	l	l	l	m	l	l	l
(5) Grepp	l	l	l	l	l	l	l	l	l	l	l	l	l
(6a) Nacke	l	l	l	l	l	l	l	l	l	l	l	l	l
(6b) Axlar/ Skuldror	l	l	l	l	l	l	l	l	l	l	l	l	l
(6c) Arm/ armbåge	l	l	l	l	l	l	l	l	l	l	l	l	l
(6d) Hand/ handled	l	l	l	l	l	l	l	l	l	l	l	l	l
(6e) Fingrar	l	l	l	l	l	l	l	l	l	l	l	l	l
(6f) Rygg	l	m	l	m	m	l	l	l	l	m	l	l	m
(6g) Ben/ knä	l	m	l	m	l	l	m	m	l	m	l	l	l
(6h) Fot/fotled	l	l	l	l	l	l	l	l	l	l	l	l	l
(7) Yttre omständigheter				Kladdig disk	Kladdig disk	Kladdig disk			Blött och varmt	Blött och varmt	Blött och varmt	Blött och varmt	Blött och varmt

Figure 29: PEPA, Floor height, most straining steps

Other straining steps with more than one yellow field were:

Step 2. Pull out lower basket

Step 5 Load upper basket

Step 6 Load cutlery

Step 7 Load detergent

Step 11. Unload cutlery

All the steps above except step 6 have issues when it comes to bending the back, meaning that bending the back could be a relevant problem area to work with. The precision work received both yellow and red fields on several steps in both PEPAs, meaning that this also could be a relevant field to work with.

From the PEPAs it could be observed that the raised dishwasher had fewer ergonomic issues in the different steps, however, there was a concern regarding shoulders for shorter people when handling the cutlery basket, since the entirety of the dishwasher was raised during the tests. As can be observed in Figure 30 the participant experiences raised shoulders, and raised upper arms, which was also commented on during the test, which are negative effects of raising the entirety of the dishwasher.

Physical Ergonomics Product Assessment	Steg 1: Öppna dörren	Steg 2: Dra ut underkorg	Steg 3: Dra ut överkorg	Steg 4: Ställ ner disk underkorg	Steg 5: Ställ ner disk över korg	Steg 6: Placera bestick	Steg 7: Lägg in diskmedel	Steg 8: Stäng dörr	Steg 9: Dra ut full underkorg	Steg 10:Plocka ur disk ur underkorg	Steg 11: Dra ut full överkorg	Steg 12: Plocka ur disk ur överkorg	Steg 13: Plocka ur bestick
(1) Hantering (Hålla, Förflytta, Impuls, Fånga)	förflytta	förflytta	förflytta	förflytta	förflytta	förflytta	förflytta	förflytta, impuls	förflytta	förflytta	förflytta	förflytta	förflytta
(2) Styrka	l	l	l	l	l	l	l	l	l	l	l	l	l
(3) Precision	l	l	l	m	m	h	m	l	l	m	l	m	m
(4) Uthållighet	l	l	l	l	l	m	l	l	l	l	l	l	l
(5) Grepp	l	l	l	l	l	l	l	l	l	l	l	l	l
(6a) Nacke	l	l	l	l	m	l	l	l	l	l	l	l	l
(6b) Axlar/ Skuldror	l	l	l	l	l	m	l	l	l	l	l	l	l
(6c) Arm/ armbåge	l	l	l	l	l	l	l	l	l	l	l	l	l
(6d) Hand/ handled	l	l	l	l	l	l	l	l	l	l	l	l	l
(6e) Fingrar	l	l	l	l	l	l	l	l	l	l	l	l	l
(6f) Rygg	l	l	l	l	l	l	l	l	l	l	l	l	l
(6g) Ben/ knä	l	l	l	l	l	l	l	l	l	l	l	l	l
(6h) Fot/fotled	l	l	l	l	l	l	l	l	l	l	l	l	l
(7) Yttre omständigheter				Kladdig disk	Kladdig disk	Kladdig disk			Blött och varmt	Blött och varmt	Blött och varmt	Blött och varmt	Blött och varmt

Figure 30: PEPA TP5, raised height

9.2 REBA Result

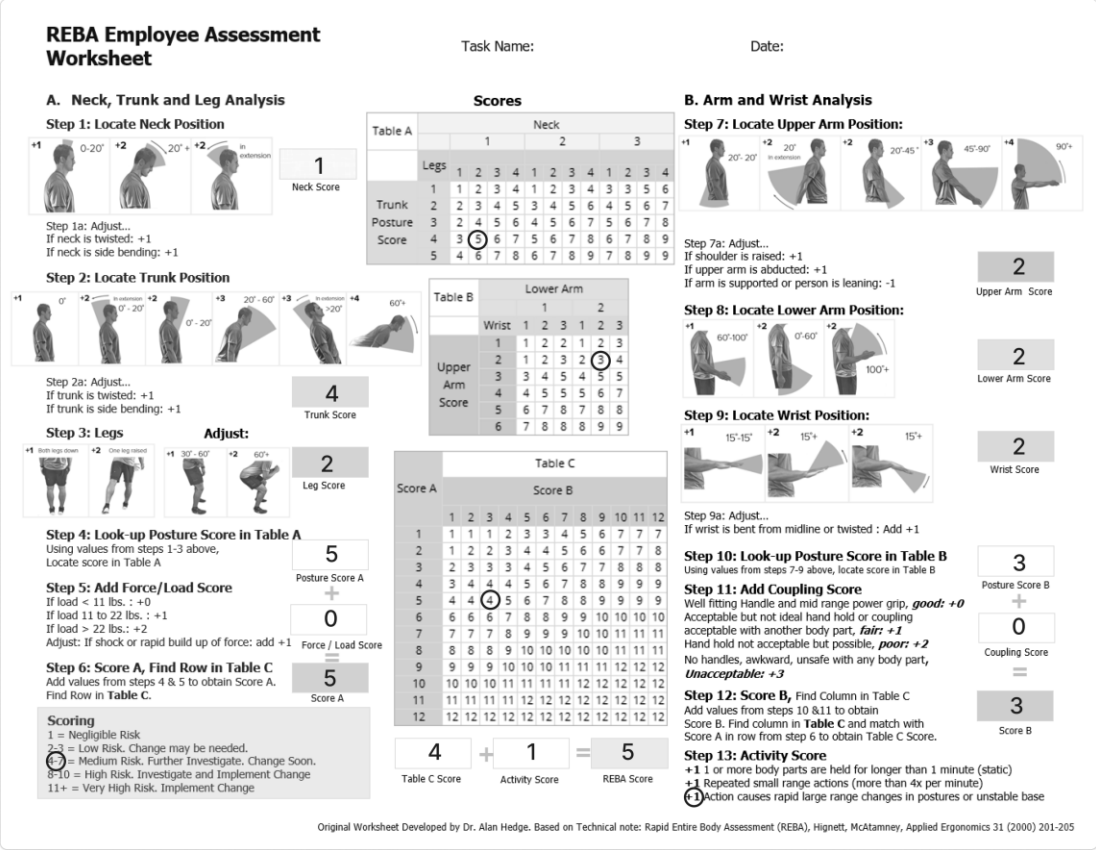

Figure 31: Reba worksheet

Fifteen REBAs were conducted. REBAs were conducted on all participants, at least two for each one. In Figure 31, an example of a filled in REBA worksheet can be viewed. The focus for the REBAs was the deepest bend on both the raised dishwasher and the dishwasher on floor height. The reason for this was that bending down was seen as the most problematic position in the PEPAs. Precision was also seen as a problem in the PEPAs, therefore some of the pictures taken to be included in the REBAs were a combination between precision work and bending down. Lastly, some extra REBAs were done on other awkward positions. In this section, still frames of some of the positions used in the REBAs will be presented and the belonging worksheet can be found in Appendix 7: REBA.

Figure 32: REBA 1

This first REBA (see Figure 32) is during the task of opening the door and about to pull out the lower basket on the dishwasher on floor height. This position received an overall score of 5, meaning medium risk. In this position, the trunk received the most points because of the deep bend. This bend also results in bending of the legs, resulting in extra points for legs as well. Furthermore, upper arms, lower arms and wrist also received points, but not as high as trunk, but these also stem from trying to reach down, extending arms for example.

Figure 33: REBA 2

This second REBA (see Figure 33) is during unloading of the lower basket on the raised dishwasher. This position received 3 points, meaning low risk. A clear improvement from the previous REBA. The main reason for this is that the bend isn't as deep. This means that both trunk and legs received lower points. One can also observe that points for extension of the upper arm are lower, which also is a result of the less deep bend and better reachability. Other points in this position are also overall low, but this position received two extra points for actions that result in large change movements and small change movements. Meaning that the participant is both grabbing several plates (small change movements) and moving away from the dishwasher to place them on a table (large change movements).

The points were generally higher for the dishwasher on floor height and lower for the raised dishwasher, however there were some instances where both received the same points (see Figure 34 and Figure 35)

Figure 34: REBA 3

In this instance (see Figure 34) the position that affects the points the most is once again the trunk, but not the legs. This is because this participant is shorter, meaning that they don't need to bend down as low as the previous participant, and therefore bends the legs a lower degree, resulting in lower points. However, this participant receives similar points as the previous participant when it

comes to upper and lower arms, again because they are trying to reach down, extending the arms. This participant also receives higher points on flexed and twisted wrist when grabbing an oven dish as well as points for large and small change movements.

Figure 35: REBA 4

When this participant uses the raised dishwasher (see Figure 35) they receive lower points for the trunk, but higher points for the neck and legs. The reason for the higher points for the neck is that it's twisted to be able to look into the dishwasher. Why it is twisted in this instance is because the participant hasn't pulled out the lower basket completely, resulting in lower visibility and reachability, a frequently observed problem in the user tests. The higher points for the legs are because this participant is leaning on one leg, leaning over to again be able to look into the dishwasher. Points for twisted and flexed wrist are also given here, as well as points for large and small change movements.

After doing the ergonomic assessments on the user tests it was evident that the activity of loading and unloading the lower basket was the biggest issue. This results in deep bends, affecting the back, legs and extension of arms. It was also evident that twisted and flexed wrists were issues in these activities, as well as small and large change movements and precision issues when handling dishware. Another observed problem was that the participants didn't pull out the basket fully, resulting in awkward positions when trying to see and reach.

These issues would be even more prominent in some cases (see Figure 36 and Figure 37).

Figure 36: REBA 5

In this case the participant sits down on their knees to load the lower basket on the dishwasher on floor height (see Figure 36). The reason for this is that this person has scoliosis and experience issues when bending down and staying in that position for longer periods of time. This demonstrates an important example of how people with different abilities approach the standard dishwasher on floor height. This position also creates new problems for the knees when standing on a hard surface such as the kitchen floor.

Figure 37: REBA 6

In this position one can observe an awkward position of the arm, wrist and a pinch grip (see Figure 37). This results in higher points for the upper arm, lower arm and wrist. Here, points for large and small change movements are also obtained. One thing also observed during the tests is that all participants grab several plates at the same time when unloading the dishwasher, resulting in uncomfortable grips.

With the problematic steps observed in the PEPAs in combination with the issues in working position observed in the REBAs, it could be determined that loading and unloading the lower basket were the biggest issues. Therefore, the focus forward was to try to minimize the deep bend and repetition of the bend to reach the lower basket. From the points received in the REBA it was also of interest to minimize small and large change movements, increase reachability and visibility to avoid awkward positions, improve grip when handling dishware and minimize precision work in these steps (steps 4 & 10 in the PEPA).

9.3 Questionnaire

The participants also answered a questionnaire during the user test. The questions were mainly focused on rating the level of strain after using each of the dishwashers. For example, the participants were asked to rate the strain they felt while unloading the lower basket from a scale on 1-6, 1 being no strain and 6 being high strain (see Figure 38 and Figure 39). (For complete review of all questionnaire answers, see Appendix 4: Questionnaire answers).

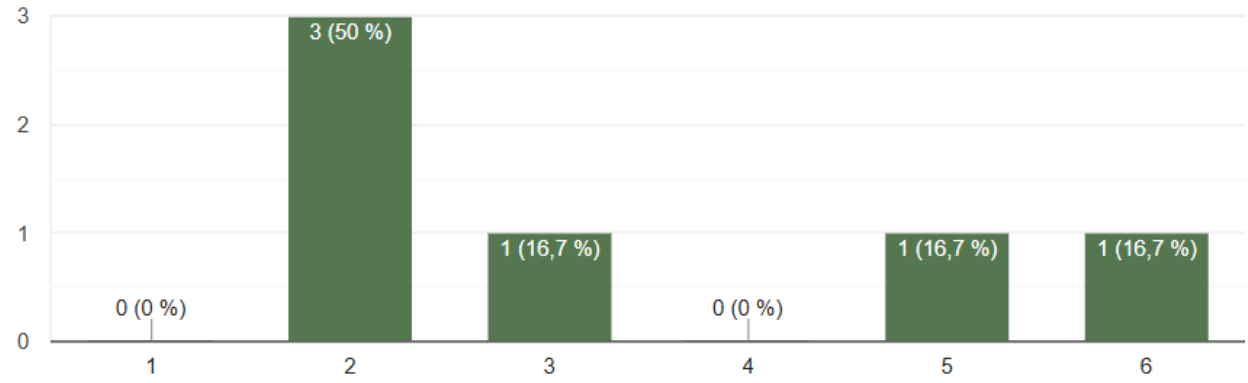

Figure 38: Questionnaire answers for loading the lower basket on the dishwasher on floor height

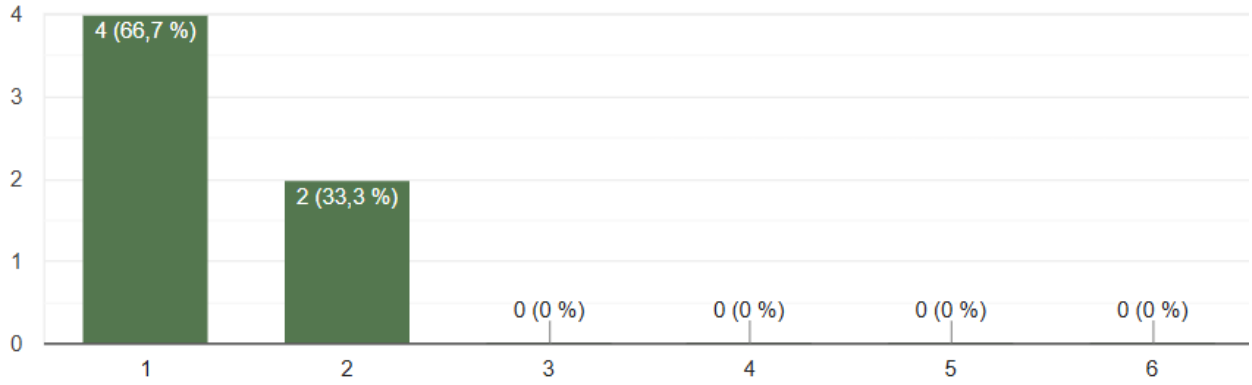

Figure 39: Questionnaire answers for loading the lower basket on the raised dishwasher

As can be viewed from the participants' answers, the dishwasher on floor level received higher ratings than the raised dishwasher, with as high as 6 points, suggesting uncomfortable and straining positions.

At the end of the questionnaire the participants were asked which one of the two dishwashers they felt was more straining and 100% answered that the dishwasher on floor height was the more straining. 100% also answered that it was in the lower back that they felt most strain, with quotes such as *"the back quickly became statically loaded, unpleasant working position".*

9.4 KJ analysis User test

To ensure that the participants' opinions and comments in the user test were a part of the analysis, a KJ-analysis was created for this purpose. In this KJ-analysis the observational notes taken from the

video material were also included as well as some of the still frame pictures taken for the ergonomic assessments (see Figure 40).

Figure 40: KJ analysis User test

Several themes and themes within themes emerged in this KJ-analysis, the biggest themes being Layout & space, Taking several things at once, Hassle and fuss, Cutlery basket, Deep bends, Dishwasher on floor (bad) and Raised dishwasher (good). See Appendix 5: KJ-analysis themes for a complete account for all the themes and sub-themes.

The comments and observational notes from the user tests showed a large consensus among the participants that the dishwasher on floor height felt worse ergonomically than the raised dishwasher. In connection to this, the participants mentioned lumbago and general pain and discomfort in the back as the biggest issues while using the dishwasher on floor height, because of repeated deep bends and holding the deep bends for a period of time. This was improved by a large extent in the raised dishwasher, where no pain or discomfort in the back was expressed. Layout & space was also an important topic where the participants stressed the importance of a good overview, organized baskets, space for pots and pans and an understandable layout. In the user tests it was also observed what the results were when the layout or functions were unclear: When the users were trying to make everything fit in the baskets they were forced to stay in uncomfortable positions for longer periods of time, especially when loading the lower basket. When forced into these uncomfortable positions frustration also arose. This frustration also led to some compensatory behavior, such as sitting down on the floor to get a better view and reach of the lower basket. Furthermore, there were other user behaviors that became prominent in the user tests. For example, many participants missed the cutlery basket, or just didn't find it. This resulted

in awkward positions when trying to find the cutlery basket. The participants also didn't pull out the baskets fully. This was a behavior that was repeated among every participant. This resulted in the participants themselves limiting their reachability and forcing themselves into awkward positions, especially when loading and unloading the lower basket. It was also evident that all participants wanted the loading and unloading of the dishwasher to go fast. Therefore, all participants took several things at the same time. For example, several plates were grabbed at the same time in the process of unloading the dishwasher, resulting in non-ergonomic grips and wrist positions that could have been avoided if the participants took one plate at a time, or if the plates had better grip possibilities. Additionally, themes such as an upright position, the dishwasher door and flexibility were also mentioned during these tests.

9.5 Merged KJ

To analyze all gathered data from the user studies a merged KJ-analysis was created (see Figure 41).

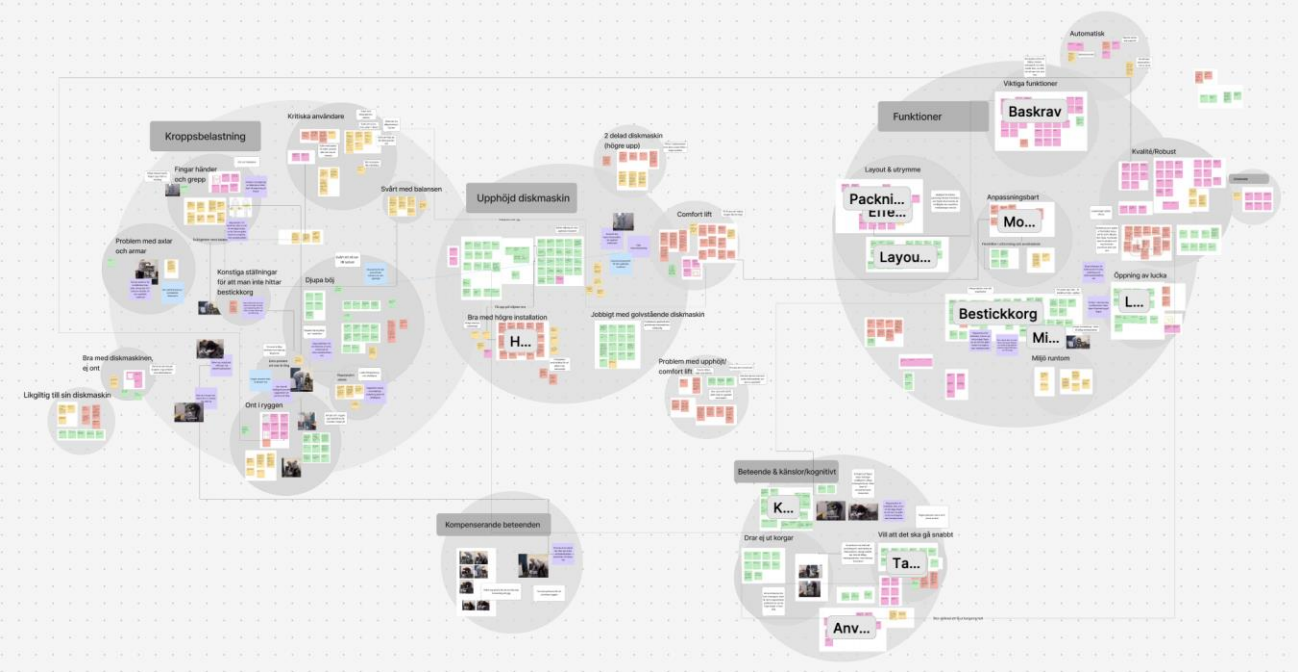

Figure 41: Merged KJ

This KJ-analysis includes what was said during the interviews, what was said during the user tests, the observations and the user responses from the letters. Larger circles represent larger themes which include smaller circles that represent smaller themes and there are also smaller titles that do not create an independent theme, but a category within a larger theme. In this KJ-analysis pictures from the user tests and notes from PEPA and REBA are also included.

The larger themes with the larger number of opinions and sub-themes were Body load, Raised dishwasher, Compensatory behavior, Behavior & feelings / Cognitive and Functions. See Appendix 5: KJ-analysis themes for a complete account for all the themes and sub-themes.

In the merged KJ it became evident what the users expect, want and need in regard to both general wishes such as quality, but mainly regarding ergonomics. Through the merged KJ repeated opinions and observations throughout the user studies could be viewed in a larger context. From all opinions and observations, the most common points were back-related, such as pain in the back, lumbago, deep bends and praise regarding a raised dishwasher or higher installation. This appeared across all studies conducted. Other themes related to the body that became larger themes in the merged KJ were fingers, hands & grip and critical users. In the merged KJ there were also repeated opinions and observations regarding cognitive and emotional aspects, such as wanting to feel effective or not pulling out the baskets fully, risking worse ergonomic working positions. Layout & space and quality & robustness were also largely important aspects across all studies, where layout & space goes hand in hand with wanting to feel effective and aligning with other cognitive aspects such as understanding functions or the interior of the dishwasher. Quality and robustness point to the user wanting to have the same dishwasher for a long time and they want it to look and feel like it is of high quality, which also is a criterion for them to be able to trust the functionalities of the dishwasher.

Since the merged KJ-analysis was rather big and had low readability, it was decided to ensure the understanding of the themes through a mapping of them and their connections to each other (see Figure 42). There were three different kinds of connections in this mapping; Solution, a dashed line; leads to, a line with one arrow; and affects each other, a line with two arrows one on each side.

From the number of connections and number of opinions in each theme, the first base-themes emerged, later translating to the user needs.

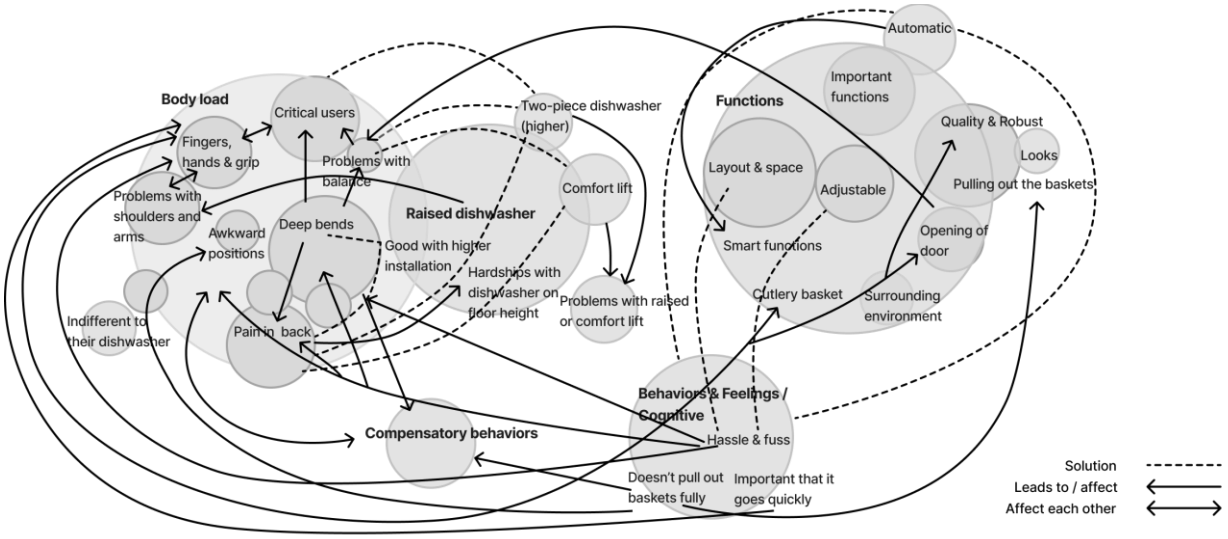

Figure 42: Merged KJ Connections

The base themes that came from the connections mapping of the merged KJ-analysis were:

- Critical users
- Fingers, hands & grip
- Awkward positions
- Deep bends
- Pain in back
- Compensatory behaviors
- Good with higher installation
- Hardships with dishwasher on floor height
- Hussle & fuss
- Doesn't pull out baskets fully
- Important that it goes quickly
- Layout & space
- Adjustable
- Quality & Robust

To ensure that no smaller theme or category of importance were overlooked, each small theme and category were compiled into sub-themes and later came to be combined and translated into sub-needs. The sub-needs specified and defined the needs.

9.6 List of user needs

The list of user needs emerged from the merged KJ-analysis as mentioned above (see Appendix 6: Complete list of user needs). The list of user needs was created by rephrasing the base-themes and sub-themes from the merged KJ-analysis into user needs and sub-needs. This was done to structure the problem picture and get a basis for future decision making. The needs were divided into four sections: Product needs (connected to the dishwasher functions), Ergonomic needs (physical and cognitive), Emotional needs (such as trust and minimizing frustration) and Other needs (not connected to any other section).

9.7 Summary of results of Define phase

To summarize, this phase resulted in the identification of ergonomic pain points in both the task sequence and in specific working positions. The task of loading and unloading the lower basket were the most straining steps in the sequence and precision, trunk bend, extension of arms, and bending of legs were some of the problems identified. In the merged KJ-analysis themes such as deep bends, critical users, hussle & fuss and fingers, hands & grip were of importance. Lastly, these themes were translated into a list of user needs, compiling all user needs found in this phase.

10 Results of Ideate, Prototype and Evaluate phases

In this section the results from three phases are presented: Ideate, Prototype and Evaluate. Since these phases are iterative and overlap, the results of them are presented together. This is to ensure a presentation of the results that mirrors the true order in which it was done.

10.1 Concepts

In Figure 43 several ideas from the idea generation sessions are presented, where the concepts suggest various ways of designing a dishwasher that meet the user's needs. The ideas are widely spread from small changes of the dishwasher to whole new concepts of how it should function. In the figure below some of the concepts can be viewed, they were grouped based on similar performance or function.

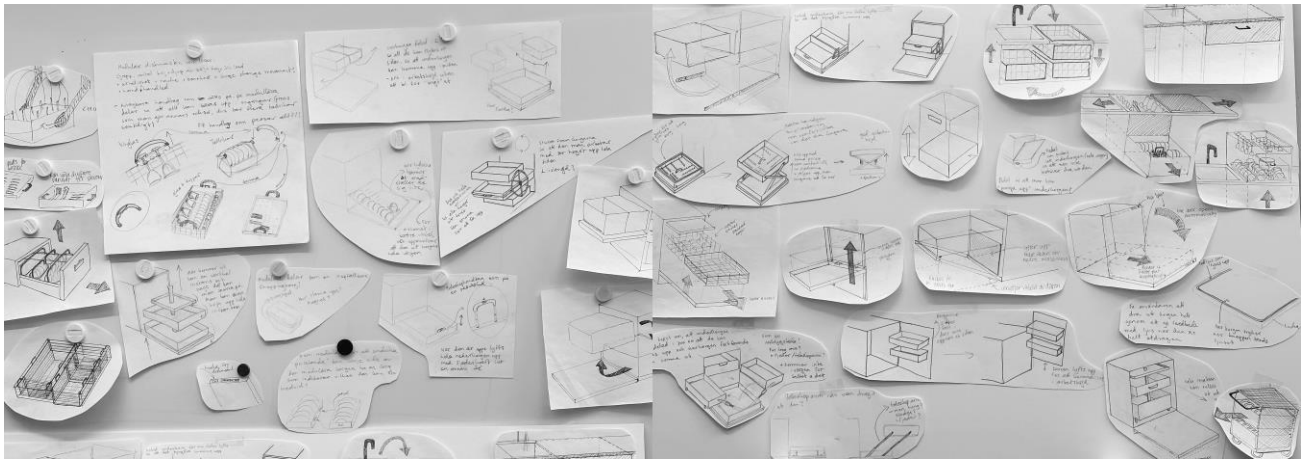

Figure 43: Sketches

Rotation of the baskets

To have a more ergonomic working height when loading and unloading both the upper and lower basket, these concepts solve the problem by rotating the baskets, so that the user always interacts with the basket at the top level.

Elevated lower basket

Several concepts solved the deep bend, visibility and reachability problem by integrating some kind of lift or movement that vertically moved the lower basket up. Either only the basket, or the entirety of the dishwasher door. These concepts also allowed for the user to adjust the dishwasher to their liking in accordance with the user study findings.

Non-standardized dishwashers

Some of the concepts solved the ergonomic problems by new ideas of the dishwasher concept, either by a wide drawer or by raising the whole inside of the dishwasher though the kitchen countertop. Also, ideas of sink dishwashers solved the ergonomic issues of deep bend, visibility and reachability.

Modular baskets

Modularity of the baskets was found in several concepts as well, solving the issue of the repetitive deep bend problem, but that still would require some deep bends. The idea of these concepts was to minimize the repetitive workload by placing the basket on the countertop to sort the dishware from a more optimal work height, to increase the feeling of being effective by being able to store modular baskets directly in storage and provide optimized grip.

Several concepts from the concept groups were further refined, with for example materials, using AI (see Figure 44). This resulted in a better understanding of how a final product might look like. By using this AI tool, more knowledge of the possibilities and limitations of each concept was realized, thanks to the higher fidelity.

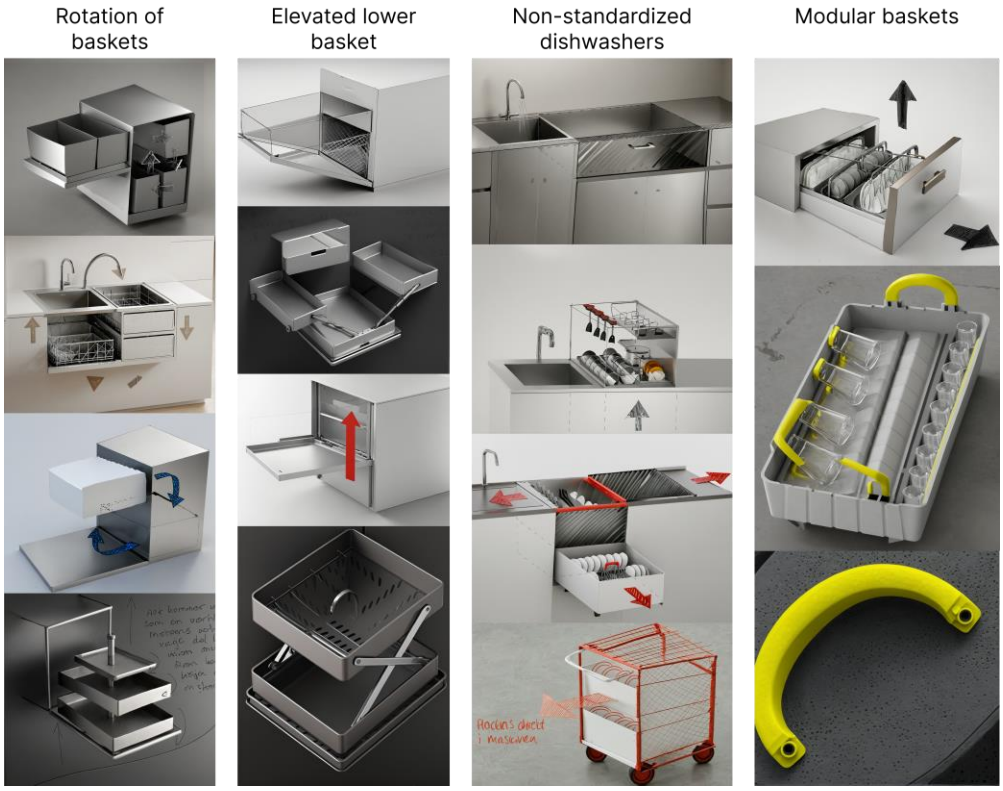

Figure 44: Sketches refined with AI

From the iterative ideation, prototype and evaluate phases, elimination processes were carried out through a concept selection process, discussing and eliminating concepts based on feasibility and mechanical properties.

10.2 Selected concepts moving forward

Seven concepts that potentially could improve the ergonomic issues of dishwasher use and meet several of the user needs were identified and are presented in Figure 45.

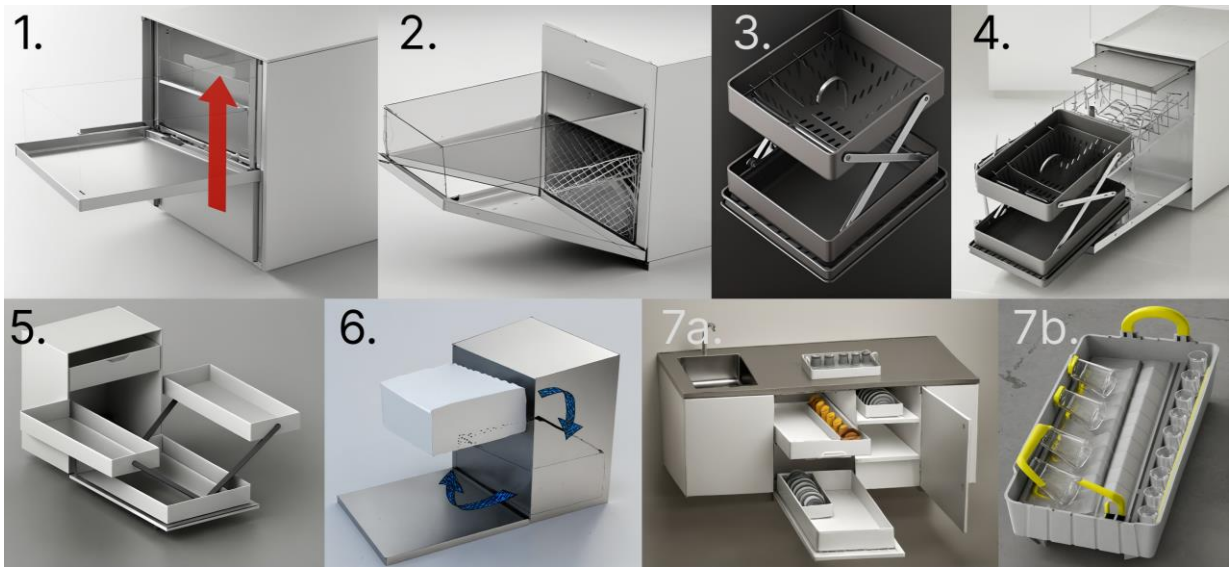

Figure 45: Refined concepts

1. **Door lift**

The door lift lifts the dishwasher door and thereby the lower basket by an electric function, to achieve a more ergonomically suited working height.

2. **Angled door**

This concept is a further developed idea from the door lift. The concept lifts the lower basket when the user closes the dishwasher door. It takes advantage of the angle and positioning of the outer edge of the dishwasher door. The lower basket is fastened on this edge and while closing the door,

the weight is compensated on the back edge of the lower basket through an extruding wall and the basket is lifted.

3. **Scissors lift**

The scissors lift is constructed as a “basket in basket”, where the inner basket acts as the lower dishwasher basket. The whole system is first pulled out from the dishwasher, and then the lower part stays in place on the dishwasher door whilst the inner basket raises by a scissors lift function to an ergonomic work height.

4. **Scissors lift + reach top basket**

This concept is based on the same concept as the scissors lift but ensures that the top basket can be pulled out when the lower basket is elevated. The scissors lift is pulled out and extended from the dishwasher door and then raised to a more ergonomic work height, providing the possibility to work on the upper basket simultaneously.

5. **Toolbox**

The toolbox concept is based on that the lower basket is divided into two parts. These two parts work as individual baskets and can be raised to a more ergonomic working height and extend outside the dishwasher door using metal arms, like a traditional toolbox.

6. **Rotation**

The concept rotation is based on the idea of the user only handling dishes from the upper basket, requiring the lower and upper basket to swap place. This is done by rotation from lower to upper level.

7. **Modular baskets**

The modular baskets are a combination of concepts, where the baskets are constructed to be lifted out from the upper and lower dishwasher baskets. The moveable baskets can then be placed on the countertop to be loaded and unloaded on a more ergonomic work height. The baskets can also be placed and stored directly in cupboards or shelves without having to place the plates one by one.

10.3 Mockups

Some of the above-mentioned concepts were further investigated with the help of mockups. This was mainly done to investigate size, movement and force on concepts that lacked this information (see Figure 46). Examples shown in the figure are the door lift concept (to the left) and the rotation concept (in the middle and to the right).

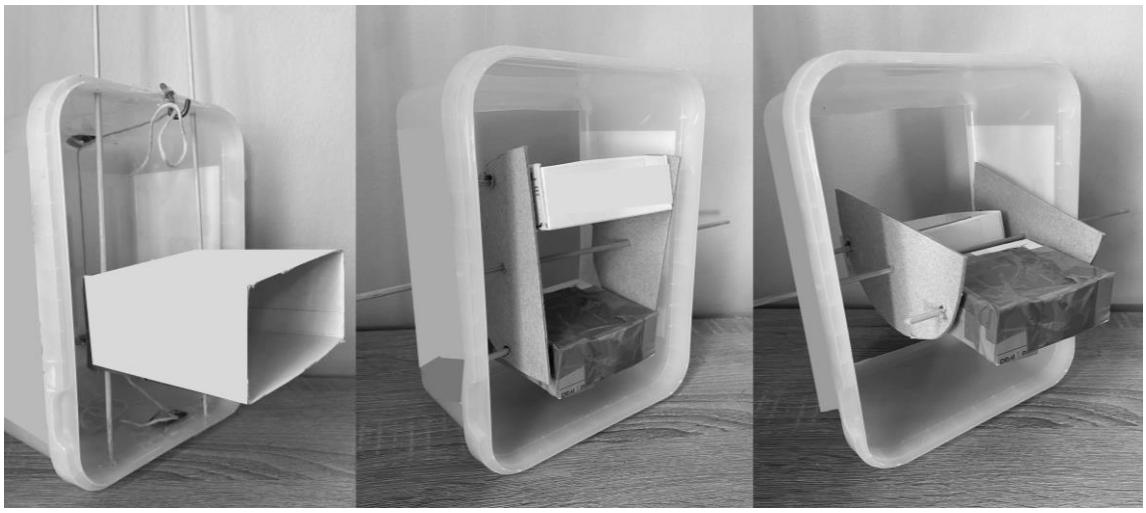

Figure 46: Mockups

From the mockups it became evident that the rotation concept would need a lot of space in the dishwasher to work. Meaning that the dishwasher either would need to be larger in size, or the baskets had to be smaller in size for the concept to work.

10.4 Decision making

To eliminate the worse performing concepts, a Pugh matrix was used. In Table 1, the results from the matrix are shown. The reasons and comments to explain some individual columns in the table are found in Appendix 9: Pugh matrix. From the table, the scissor lift combined with reaching the top basket scored highest, followed by the modular baskets. The door lift and the scissor lift without reaching the top basket scored equally, but a few question marks created difficulties in fairly evaluating these concepts, therefore the decision was made to further refine these concepts to understand which concept is better suited for the aim of this project.

Table 1: Pugh matrix

Requirements	Door lift	Angled door	Scissor lift	Scissor lift + reach top basket	Toolbox	Rotation	Modular baskets
Be robust	? / (-)	(-)	(+)	(+)	(?)	(+)	(+) /?
Provide adequate space	0	0	? / (-)	? / (-)	(-)	(-)	0
Provide automated functions	(+)	(+)	(+)	(+)	(+)	(+)	(+)
Be adjustable	(+)	(+)	(+)	(+)	(+)	(+)	0
Running quiet	0	0	0	0	0	0	0
Clean dishes	0	0	0	0	0	0	0
Be compatible with standard measurements	0	0	0	0	0	0	0
Emotional requirements							
Not to feel overwhelmed	(?)	(?)	(?)	(?)	(?)	(?)	(?)
Trust the functionality	0	-	0	0	-	-	0
Feel effective	(+)	(+)	(+)	(+)	-	-	(+)
Recognize the technology	(+)	-	(+)	(+)	(+)	(+)	(+)
Understand the purpose of functions	(+)	-	(+)	(+)	(+)	-	(+)
Minimize frustration	(+)	(+)	(+)	(+)	-	-	(+) /?
Other user requirements							
Be fast to load and unload	(+)	(+)	(+)	(+)	-	0	(+)
Physical ergonomics							
Minimize strain on back	(+)	(+)	(+)	(+)	(+)	(+)	(+)
Provide a good work height	(+)	(+)	(+)	(+)	(+)	(+)	(+)
Minimize high precision work	0	0	0	0	0	0	(+)
Provide adequate grip	0	0	0	0	0	0	(+)
Adapted for critical users	(+)	(+)	(+)	(+)	(+)	(+)	(+)
Minimize awkward positions	(+)	(+)	(+)	(+)	(+)	(+)	(+)
Minimize repetitive workload	0	0	0	0	-	0	(+)
Cognitive ergonomics							
Reduce cognitive load	0	0	0	(+)	-	0	?
Reduce risk of user error	0	-	0	0	0	0	0
Provide good visibility	(+)	(+)	(+)	(+)	(+)	(+)	(+)
Easy to organize	0	0	0	(+)	-	0	(+)
Total score	12	5	12	15	1	4	14

10.5 Functional prototypes

In Figure 47 the first 3D-printed prototypes of the concepts that were decided to further develop are presented. The aim of these prototypes was to explore the functions, test movement and to address the question marks in the Pugh matrix.

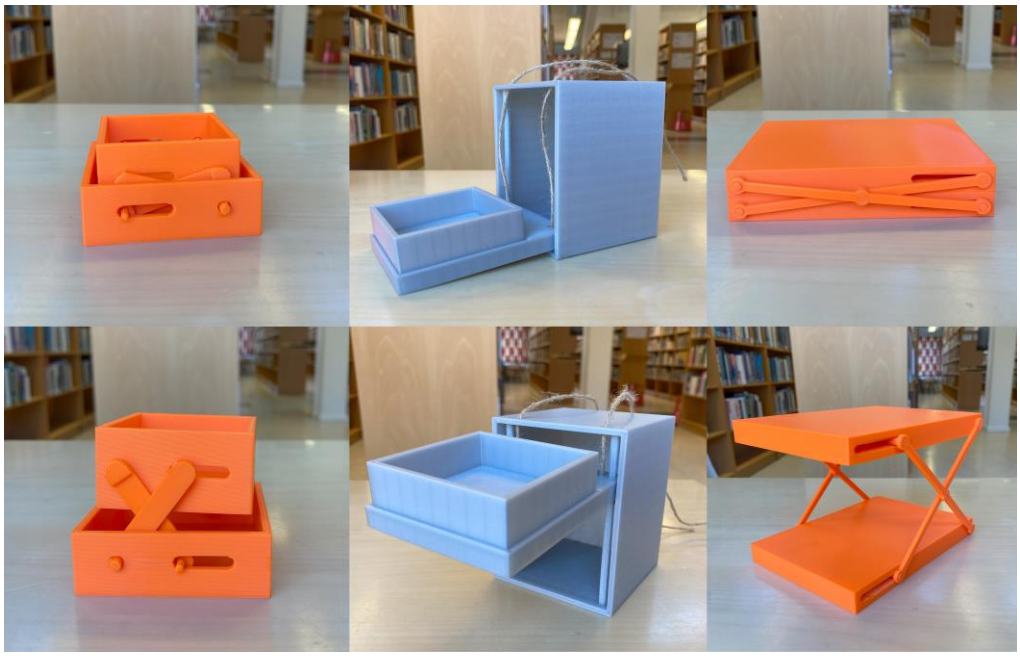

Figure 47: 3D-printed functional prototypes

The results from the prototype of the door lift showed that the lifting mechanism could potentially result in issues related to too much strain on the attachments of the lift mechanism (see the middle pictures of Figure 47). The reason for this is that the anchor points of the mechanism are not equally distributed on the door and only on two points in the corners of the door. Moreover, the rods used for the lift mechanism in this concept would in the current construction block the movement of the baskets. Therefore, the lifting mechanism would have to be placed outside of the dishwasher, or somewhere in between the inner and outer dishwasher walls. Furthermore, the opening mechanism of the dishwasher door today is built with springs that allow the dishwasher door to open and close smoothly. The placement of the spring would either have to be moved or be reconstructed to work. With all these issues to be solved, the scissor lift resulted in a better option to the solution.

Regarding the scissor lift, some concerns arose as well. If the scissor lift would be pulled out together with the lower basket, and then elevated once pulled out, this would result in the scissor lift mechanism being inside the dishwasher when running. Since electric components would have to be sealed so that no water would enter, the lower part of the scissor lift would have to be partly sealed. But if the lower part of the scissor lift is sealed, the dishwasher would not function as it does today, as the baskets are made by thin strings, the food particles can easily be flushed down the filter. But if the scissor lift blocks the filter, the food particles would be spread out on top of the scissor lift.

10.6 Merged Concept Development

To solve the problems regarding having to protect the components of the scissors lift mechanism, but at the same time not blocking the filter, a combination of the scissor lift and the door lift was created. This concept is a scissors lift, integrated in the door. Thus, the lower part of the scissor lift is a part of the door, and the upper part will be lifted from the door once activated (see Figure 48).

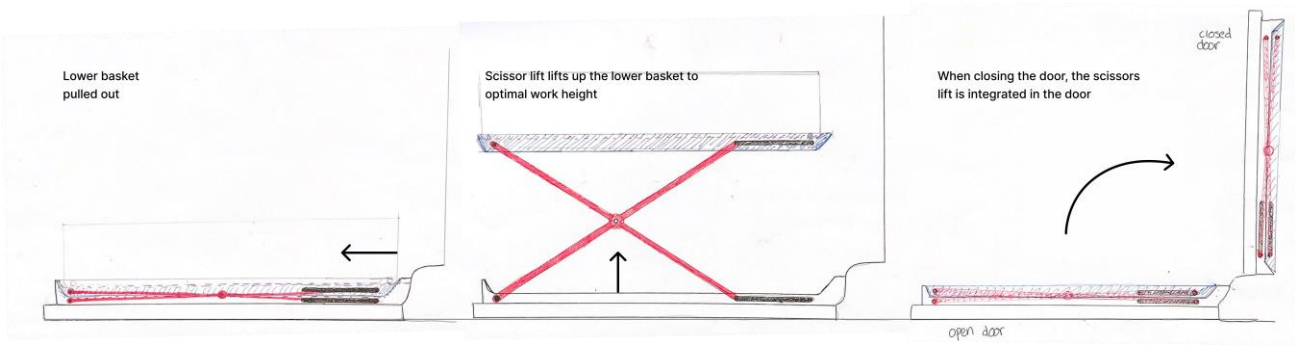

Figure 48: Scissors lift integrated into the door

The results from the Pugh matrix showed that the scissors lift concept combined with reaching both the upper and lower basket simultaneously received the most points. Therefore, the aim was to ensure that this merged concept would enable this. Since the construction of the scissors lift is placed within the door, the space that this mechanism occupies would affect the depth of the baskets when the door is closed to fit into the machine. If the scissors lift had been placed under the lower basket inside the machine, like the previous scissors lift concept, the basket would have to decrease in all directions since it needs to fit in the outer basket.

Since the aim is to enable the user to use the upper and lower basket simultaneously in this concept, the need to decrease the depth of the baskets to accommodate for the scissors lift mechanism, is an advantage of this concept. If both baskets decrease the depth slightly, both baskets could be pulled out and fit next to each other at the height of the upper basket. The baskets would also fit within the frame of the dishwasher door, sufficiently collecting food waste and water falling from dirty dishes. The downside is less place settings.

If this construction is possible, the concept would improve the ergonomic working positions when using a dishwasher. It could also improve the cognitive ergonomics through providing visibility of both baskets and their content at the same time and improve reachability, but as mentioned, to the price of less place settings.

10.7 Final decision making

The concept chosen to further develop as the final concept is the scissors lift integrated in the door, from here on out referred to as the “contemporary concept”. This concept reduces ergonomic pain-points described in previous chapters and provides the possibility to have the upper and lower basket pulled out simultaneously. To visualize this, it was decided to build this concept in a full-size prototype.

Moreover, the modular baskets will also be further developed, both separately, and combined with the above stated concept as a “future concept” to not be implemented within the nearest years. The future concept is a holistic concept redefining how the dishwasher functions in relation to kitchen storage.

10.8 Summary of results of Ideate, Prototype and Evaluate phases

The iterative process of ideation, prototyping and evaluation led to the development and refinement of several concepts that aimed to address the ergonomic challenges of dishwasher use. Through mockups, 3D-printed prototypes and decision making with a Pugh matrix, the concepts were further refined and eliminated one by one. In the final stage of the phase, a merged solution emerged that combined promising alternatives, resulting in the contemporary concept: A scissors lift mechanism integrated into the dishwasher door. Moreover, the concept of modular baskets also received high points in the Pugh matrix, resulting in the decision to further develop this concept as a holistic future concept.

11 Results of final concept

The final concept resulted in a scissors-lift integrated into the dishwasher door and modular baskets, as described in the previous chapter. This chapter will present these final concepts.

11.1 Contemporary concept

This dishwasher allows the user to raise the lower basket of the dishwasher and work at an ergonomic height when loading and unloading the dishwasher (see Figure 49). The concept focuses on minimizing bending by adjusting the lower basket to a more favorable working height and thereby improving both visibility and overview.

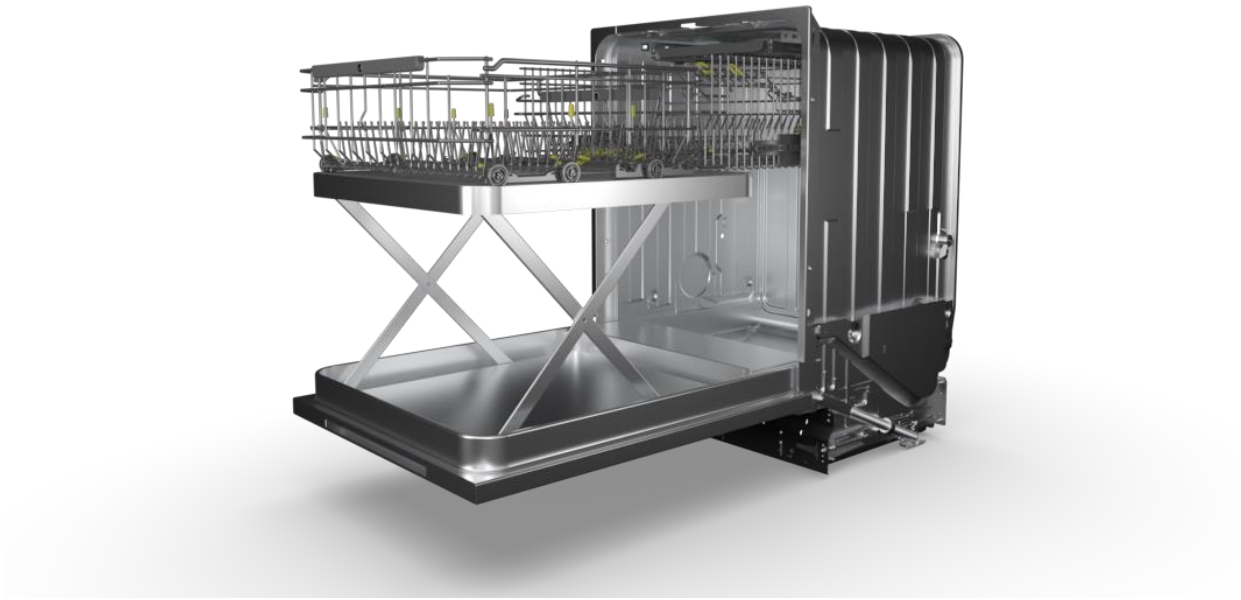

Figure 49: The Contemporary concept

This concept features a built-in lifting function, that changes how the users interact with the lower basket of the dishwasher. The lifting function is inspired by the mechanics of a scissors lift, where the function is integrated into the dishwasher door. In Figure 50 the main components in the contemporary concept are displayed.

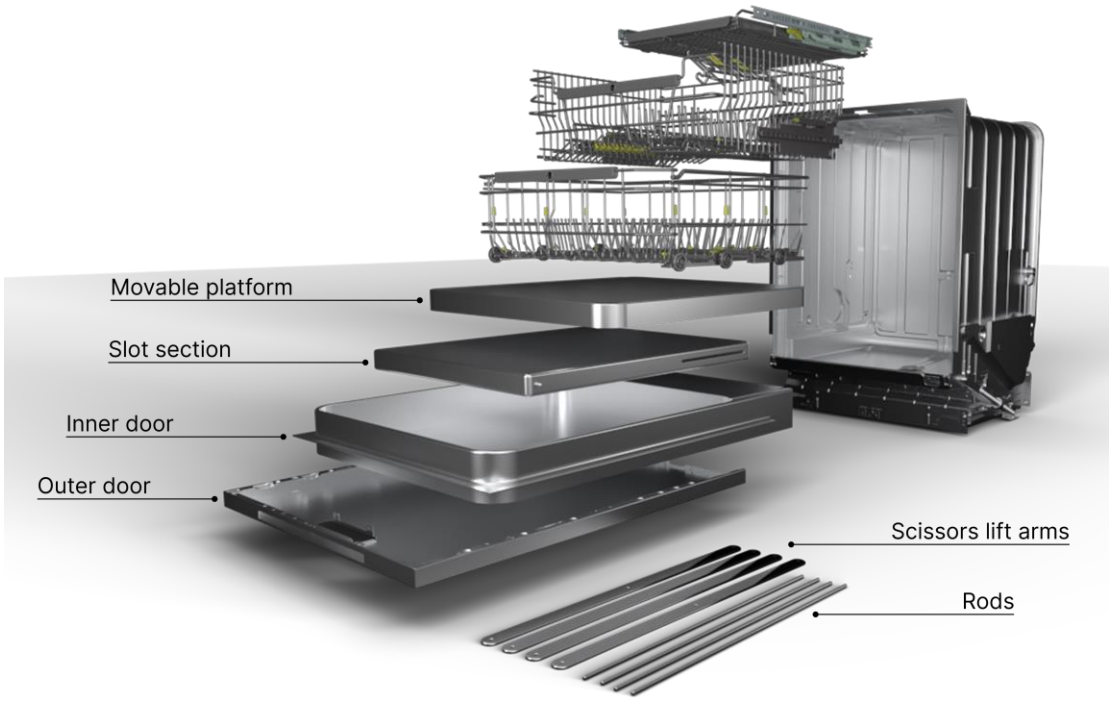

Figure 50: Exploded view

The primary modifications to the existing ASKO dishwasher are found in the door. The door is divided into two parts, one fixed to the outer structure of the dishwasher door, and another movable section connected through four arms. Both the upper and lower sections of the door contain slots that guide the rod mechanism. As the basket and movable section of the door are lifted, the rods slide toward the front of the door, making the lift rise. When the rods slide inward toward the inside of the machine, the lift is lowered. This mechanism will be electric, with for example an electric actuator. The electrifications and mechanics of the concept remain a subject for future work.

The moveable part of the door includes wheel tracks, which ensure that the basket can be pulled out smoothly and straight without derailing. At the end of the tracks, there is a stop that ensures that the basket is fully extended once lifted (see Figure 51).

Figure 51: Wheel tracks

To construct this concept, the depth of the baskets had to be reduced. The basket in this design is approximately 60 mm shorter in depth, since the lift mechanism occupies space once the dishwasher door is closed. The reduced depth also allows the upper and lower basket to fit side by side when raised. This enables users to work with both baskets simultaneously at the same ergonomic working height (see Figure 52).

Figure 52: Upper and lower basket

The user activates the dishwasher door's lifting function by pressing a button, which raises the lower basket to the same height as the upper one, eliminating the need for bending. In Figure 53 the sequence of the scissors lift is shown.

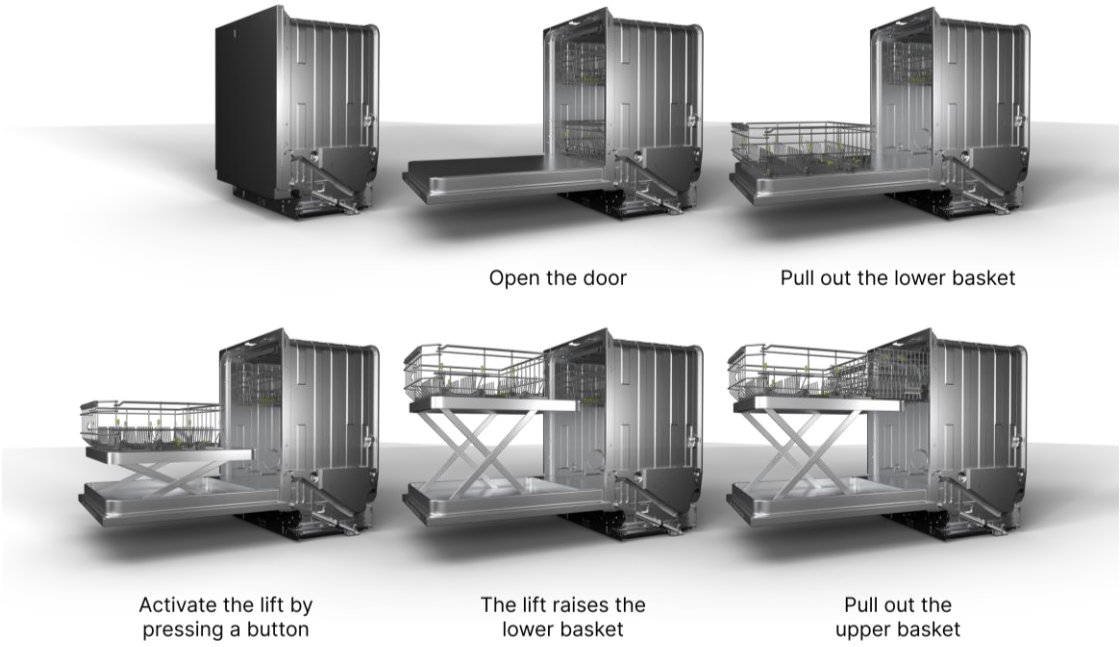

Figure 53: Lifting sequence

11.2 Prototype of Contemporary concept

This section presents and visualizes the contemporary concept and the user interaction with the help of a prototype, developed as a static representation. Figure 54 shows the final prototype in a contextual scenario.

Figure 54: Final prototype

This prototype is focused on visualizing the concept and the user interaction, meaning that the function of the scissors lift is not applied in this prototype. However, real materials (mostly metals) commonly used in a dishwasher as well as authentic dishwasher baskets are used to convey a higher fidelity concept.

As seen in Figure 55 the user obtains a good visibility of the dishwasher baskets and can reach both the upper and lower basket simultaneously since they are positioned next to each other.

Figure 55: Both baskets at the same height

In Figure 56 detailed pictures of the prototype are shown, visualizing the lower basket positioned all the way out on the inner dishwasher door. To the right, the attachment of the scissor lift arms is shown.

Figure 56: Scissors lift prototype

11.3 Ergonomic assessment of contemporary concept

As mentioned, the most straining steps as seen from the PEPA in the user test (see chapter 9.1) were step 4 and 10, loading and unloading the lower basket, which were the focus points of the development process. Therefore, these are the steps focused on in the ergonomic assessment of the contemporary concept. To assess the possible improvements in these steps a new REBA is made.

A REBA of the deepest bends and most awkward positions of loading and unloading the dishwasher of the new concept was done and showed an improvement of the ergonomic situation (see Figure 57).

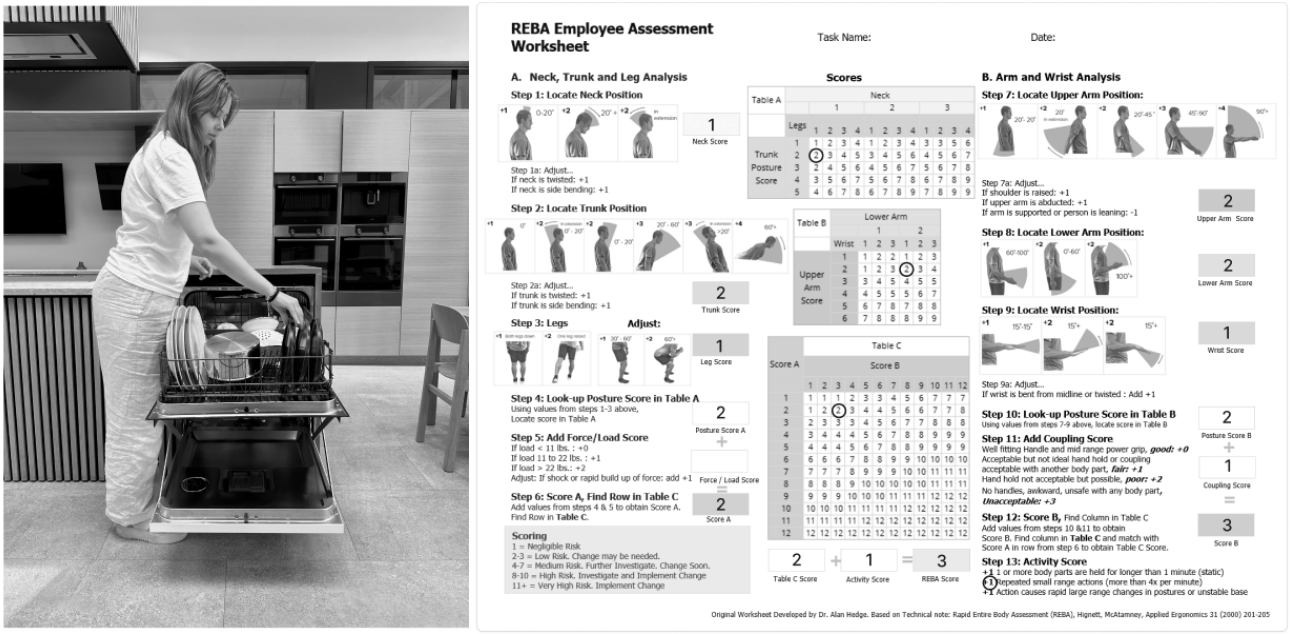

Figure 57: REBA of final concept

As seen from the REBA above, the new concept received a score of 3, suggesting a low-risk position. The main reason for these low points is the straight neck position, small trunk bend, steady posture on the legs and low extension of the arms and wrists. In this case, the person is also reaching for the plate furthest away from them, meaning that this concept would score even lower when grabbing plates closer to the body.

When looking at the position for unloading the lower basket on the dishwasher on floor height and the position for the same task in the contemporary concept, obvious differences can be observed (see Figure 58). The bend of the back is largely improved because the concept provides adjustability via changing the height of the lower basket. When having the lower basket be raised, a more favorable working height is achieved resulting in a more upright position. The raising of the lower basket also improves both visibility (coming closer to the line of sight while standing), overview and reachability (also resulting in avoiding twisting and extension of the neck and arms), all being frequently mentioned or observed user needs. This concept also reduces cognitive load by presenting the baskets at the same height, side by side, providing the possibility to view and work with both baskets at the same time.

Figure 58: Comparison of position unloading lower basket

These prominent differences in working position are also prominent in the numbers in the REBA (see Figure 59).

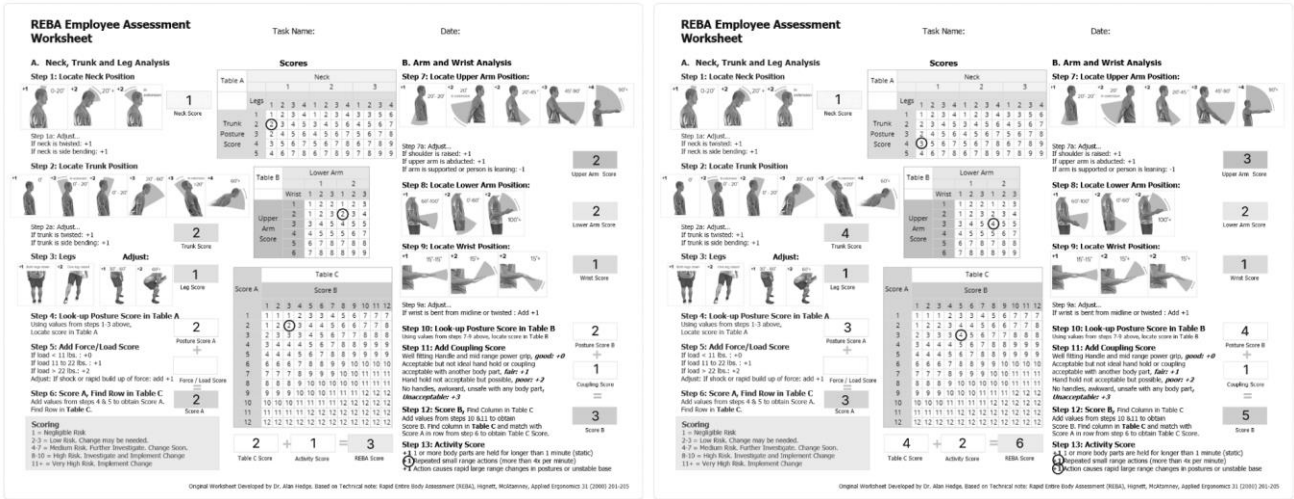

Figure 59: Comparison of REBA

As seen in Figure 59 there is a difference in the REBA results for the contemporary concept and the regular dishwasher on floor height during the same task (unloading the lower basket). The contemporary concept received 3 points, suggesting a low-risk position, while the regular dishwasher on floor height received 6 points suggesting a medium-risk position. The main reason

for these differences stems from the higher positioning of the lower basket. This eliminates the deep bend, provides good visibility and reachability eliminating twist of the neck, provides a stable position on two legs when not needing to bend or lean over, provides the possibility to have the upper arms closer to the body minimizing extensions and lastly, minimizing large change movements since unloading in an upright position also results in a closer distance to a countertop or work surface.

The results from the PEPA from the user tests suggested that raising the entirety of the dishwasher could come with new issues for shorter users, where raised shoulders when trying to reach contribute to straining positions when unloading the top cutlery basket (see chapter 9.1). This suggests that only raising the lower basket, which was the most troublesome basket on the dishwasher on floor height overall, does not risk this problem.

11.4 Future concept

The second concept is a holistic approach that redefines how the dishwasher functions in relation to kitchen storage. This concept blurs the line between storage and the dishwasher's baskets by introducing modular baskets inside the dishwasher. These baskets can easily be removed and placed at a comfortable working height (see Figure 60).

Figure 60: Modular baskets[1]

The baskets can also be placed straight into kitchen drawers and cupboards, shifting the process from unloading each individual dish, sorting, and storing it, to simply lifting out a few modular

baskets and placing them directly onto shelves and in cabinets. The modular baskets therefore act as an extension of the dishwasher (see Figure 61). The modular basket concept focuses on the main pain points established from the user studies and ergonomic assessment such as deep bends, but mainly regarding repetition of bend. It also focuses on improving grip and the effectiveness of using the dishwasher, as seen as an important aspect expressed by the users.

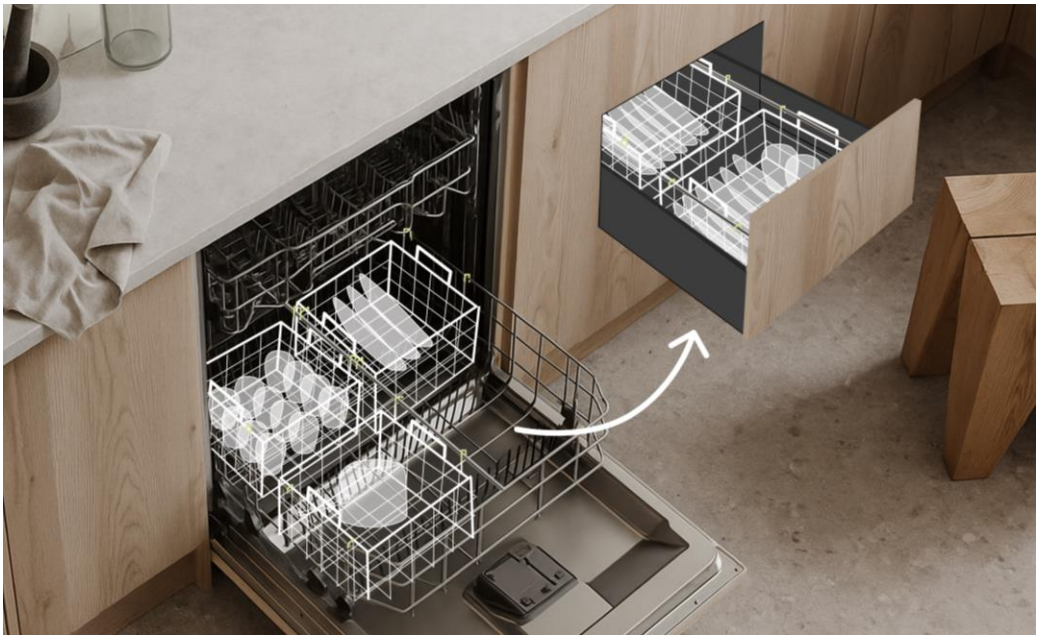

Figure 61: Store in cupboards[1]

In Figure 62, a suggestion of how the modular baskets could look are visualized. The modular baskets are designed so that the user can place the baskets correctly in the dishwasher, by hooks that hang on the rods of the original baskets.

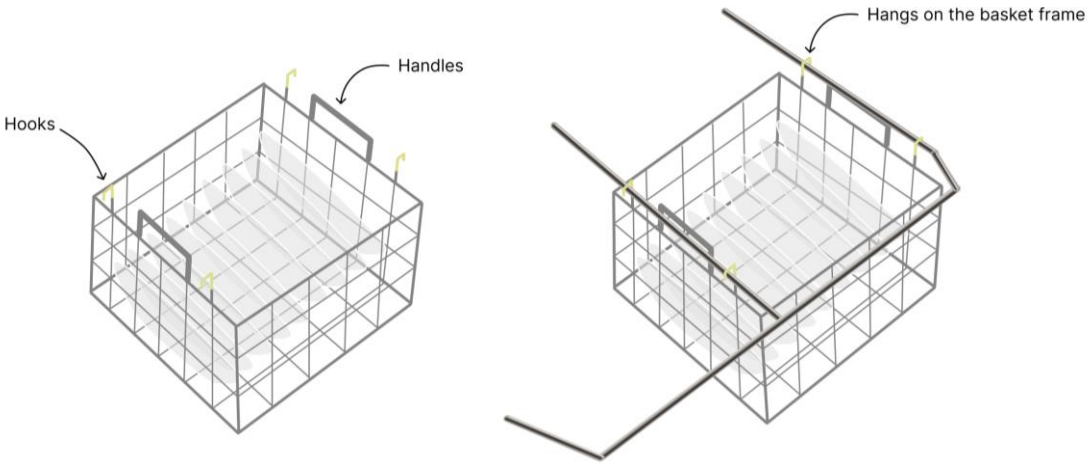

Figure 62: Modular baskets

In addition to simplifying the unloading sequence in terms of time, this concept also offers several ergonomic advantages when using the dishwasher. Firstly, since the user only needs to lift a few modular baskets instead of handling each plate or glass individually, fewer bends and twists are required to perform the same task. Moreover, the modular baskets feature handles on each side, providing a more ergonomic grip compared to the pinch grip typically used when holding a small fork or the edge of a thin plate. The weight of the modular baskets was tested in the prototypes made (see section 7.3.5), ensuring that the modular baskets would not be too heavy to lift. Finally, placing the modular baskets on the countertop offers better visibility, which reduces cognitive load.

This concept also provides the possibility to be combined with the contemporary concept, resulting in an optimized dishwashing experience, with both elimination of deep bends, improved ergonomic grip as well as effective dishwasher use.

11.5 PEPA estimation

Since the modular concept has not been physically developed nor tested, Figure 63 shows an estimation of a PEPA when using the modular concept combined with the contemporary concept. This estimation is based on the PEPA for the dishwasher on floor height for test person 1 (the tallest participant) (see Appendix 8: PEPA). The changes that the modular concept combined with the contemporary concept in theory would make are improving the ergonomic precision in the steps relating to unloading dishware. Moreover, minimizing strain on the back as well as endurance for step 4 and 10. Lastly, improving the neck position in step 12 due to the modular baskets. The cells in the figure that are outlined are those estimated to be improved.

Physical Ergonomics Product Assessment	Steg 1: Öppna dörren	Steg 2: Dra ut underkorg	Steg 3: Dra ut överkorg	Steg 4: Ställ ner disk underkrog	Steg 5: Ställ ner disk överkrog	Steg 6: Placera bestick	Steg 7: Lägg in diskmedel	Steg 8: Stäng dörr	Steg 9: Dra ut full underkorg	Steg 10:Plocka ur disk ur underkorg	Steg 11: Dra ut full överkorg	Steg 12: Plocka ur disk ur överkorg	Steg 13: Plocka ur bestick
(1) Hantering (Hålla, Förflytta, Impuls, Fånga)	förflytta	förflytta	förflytta	förflytta	förflytta	förflytta	förflytta	förflytta, impuls	förflytta	förflytta	förflytta	förflytta	förflytta
(2) Styrka	l	l	l	l	l	l	l	l	l	l	l	l	l
(3) Precision	l	l	l	m	m	h	m	l	l	l	l	l	l
(4) Uthållighet	l	l	l	l	l	l	l	l	l	l	l	l	l
(5) Grepp	l	l	l	l	l	l	l	l	l	l	l	l	l
(6a) Nacke	l	l	l	l	l	l	l	l	l	l	l	l	l
(6b) Axlar/ Skuldror	l	l	l	l	l	l	l	l	l	l	l	l	l
(6c) Arm/ armbåge	l	l	l	l	l	l	l	l	l	l	l	l	l
(6d) Hand/ handled	l	l	l	l	l	l	l	l	l	l	l	l	l
(6e) Fingrar	m	l	l	l	l	l	l	l	l	l	l	l	l
(6f) Rygg	m	m	l	l	l	l	m	l	l	l	l	l	l
(6g) Ben/ knä	l	l	l	l	l	l	l	l	l	l	l	l	l
(6h) Fot/fotled	l	l	l	l	l	l	l	l	l	l	l	l	l
(7) Yttre omständigheter				Kladdig disk	Kladdig disk	Kladdig disk			Blött och varmt	Blött och varmt	Blött och varmt	Blött och varmt	Blött och varmt

Figure 63: Estimation on PEPA when combining concepts

Discussion

12 Discussion

This chapter will discuss the results in relation to theory, process and methods. The aims and objectives from the introduction chapter will be addressed and discussed. Thereafter the validation of results will be discussed, and finally sustainability and ethics of the project will be addressed.

12.1 Aim and objectives

The first objective of the thesis was to *Analyze the current ergonomic challenges of an ASKO dishwasher in everyday tasks.* This objective was met through a comprehensive investigation including several user study methods. By triangulating the results from interviews, user test (with both REBA and PEPA as ergonomic assessment tools), as well as users own reflective thoughts of dishwasher use from the method Letters, a robust understanding of the current ergonomic challenges was obtained. The insights regarding this objective resulted in a merged KJ of all insights, that was translated into a comprehensive list of user needs.

The second objective was to *Develop a redesigned dishwasher concept with enhanced ergonomic features.* The ideation phase was informed by the list of user needs from the empathize phase and pain points from the ergonomic assessments, resulting in two final concepts with a clear focus on improving these issues. Special attention was paid to back pain regarding loading and unloading the dishwasher, which successfully fulfilled the goal of enhancing ergonomic usability. Both concepts stemmed from a user-centered approach improving posture and reducing strain while meeting several of the users' emotional and functional requirements. Thus, the objective was met through the final concepts and their development processes.

The last objective was to *Evaluate the final concept based on ergonomic performance.* While a final user test of the final concepts was not conducted due to time constraints, the contemporary concept was partly assessed through self-evaluation using the same approach of assessing REBA as the first user test. A new evaluation in terms of PEPA was not performed for the final concepts, however, an estimation was made based on the previous PEPA on a raised dishwasher. Possible changes the PEPA would result in when combining the contemporary and future concept was also discussed. Furthermore, the concepts have continually been compared against the list of user needs, which is the result of a comprehensive ergonomic investigation. With these assessments, a review of the concepts from several perspectives ensured a rigid evaluation based on both ergonomic theory and real-world user test. However, the modular concept remained unevaluated through any type of user testing and was decided to keep as a future concept, which is more deeply described in chapter 13.

The aim of enhancing the physical ergonomics of ASKO dishwashers is addressed through a process allowing both user-centered as well as ergonomic principles to lead to the final outcome. By identifying critical pain-points and translating these into requirements, the project successfully resulted in a concept with clear ergonomic improvements. The continuous discussions with both a

researcher in production ergonomics and socially sustainable workplace design, a researcher in Human-Technology Design and industrial input from ASKO as well as an external engineer, reinforce the validation, thus achieving the thesis aim to a successful degree.

12.2 Contemporary concept

The contemporary concept primarily targets the issue of the deep bend during loading and unloading of the lower basket, as this was identified as the biggest ergonomic problem in the empathize phase.

The back related issues that are a result of these deep bends were suspected already before the research was initiated and was confirmed by the literature. Bohgard states that lumbago is a common result of unexpected load of the back in an unexpected direction (Bohgard, et al., 2009). This could be due to small displacements in the vertebrae that are due to insufficient preparation in stabilizing back muscles. Frequent heavy lifting is a risk factor in back problems and twisted and bent postures can increase these risks. It's also stated that regardless of the work being "light", prolonged twisting and bending of the back often lead to back problems, due to the load, but also due to the actual weight of the body itself, which is a factor that could easily be disregarded.

Like the literature suggests, it was suspected that for example, lumbago would be a large topic during the empathize phase. These suspicions also came to be true as participants in all studies mentioned this issue in some way.

Furthermore, it was also suspected that raising the dishwasher from the floor could provide a better ergonomic situation, which the literature also suggested. Baden-Powell explains how the modern kitchen is based on some key dimension for ergonomic efficiency for reducing strain and improving comfort (Baden-Powell, 2005). These key dimensions are, for example, measures of reach and space between counters, where standard heights for countertops are about 900mm, adapted for the average user. Appliances such as microwaves and ovens are also more commonly being installed at higher levels, around 1200 mm, suggesting that minimizing back pain and providing better overview is of importance.

The early interviews with, for example, the dishwasher experts also suggested that a high installation would be beneficial, aligning with the literature. Therefore, the idea of raising the entirety of the dishwasher to a better working height was then applied to the user tests, where one of the dishwashers used was raised about 35cm of the floor. It was anticipated that this installation would be most beneficial across all ergonomic aspects. Surprisingly, that was not the case for the shorter participants where positional issues and static load of the shoulders were observed when using the top basket.

When returning to the literature, Bohgard states that when it comes to standing work it's highly dependent on the height above the floor at which the work is carried out (Bohgard, et al., 2009). This means that if the working height is too low, the body must be bent forward, and that increases

load on the back as well as neck muscles, but on the other hand, if the work height is too high the arms are kept in a high position resulting in a heavier static load, which is also unfavorable from an ergonomic standpoint.

Thus, the idea of only raising the lower basket was implemented, to avoid creating new ergonomic problems and to keep the concept accessible, usable and comfortable for a larger group of the population.

Additionally, it was not anticipated that the deep bend seen in the user test would be the root cause to such a large number of other problems. It was seen that a deep bend to reach the lower basket also causes extensions of the arms, bending of the legs and twisting or bending of the neck. In the Letters study and in the interviews, it was also mentioned that balance was a potential problem caused by the deep bend. Meaning that the suspicion of a deep bend not being favorable based on the literature, turned into an actual problem, spanning across many different bodily functions.

Another surprising factor was the cognitive and behavioral aspects of using a dishwasher. It was anticipated that some cognitive factors would arise, but not to the extent that it did. It was observed that users experienced frustration, for example due to not understanding how to pack the dishwasher or not being able to see some functions, such as the cutlery basket. These issues could be connected to the mental capabilities of perception and mental models. These problems resulted in compensatory positions that worsen the ergonomic situation, such as twisting and bending down at the same time. It was also observed that users had some behaviors that worsened the ergonomic situation as well, such as not pulling out the baskets fully, reducing reachability and visibility even more.

According to Berlin & Adams, a well-designed work system, focused on improving cognitive ergonomics, can decrease the impact of fatigue by minimizing the ability to execute a task incorrectly (Berlin & Adams, 2017). When designing to support mental capabilities there are a few principles aimed at supporting the capabilities of attention, perception and mental models. Two of these principles are *minimize time and effort for finding information* and *proximity*, meaning that making it easy for the user to understand functions of the dishwasher fast and the user being close to the information was seen as largely important topics and also affected the physical ergonomics.

With the above information in mind, it was seen as beneficial to provide both baskets at the same height, while providing the possibility to be close to the information, increasing the probability of finding the information fast, to avoid executing a task incorrectly.

12.3 Future concept

The future concept was an unanticipated concept that came about from the findings of the connection between cognitive and physical ergonomics. This concept aims to address the deep bend but also provides the possibility to shorten the task sequence of using the dishwasher.

As found in the literature, it's beneficial to minimize time and effort to find information. This was also found as a need in the empathize phase where users expressed the need for feeling efficient. This was also especially evident during the user tests where the users grabbed several plates at a time while loading and unloading the dishwasher. This suggested that it might be beneficial to reduce the time of the task itself or even eliminate or combine some steps.

In the empathize phase it was also found that grip was an important aspect for the users, where broken handles and several slippery, thin plates could be troublesome to handle. Berlin & Adams explain that hands and wrists are critical parts of the human body for one to be able to execute various tasks (Berlin & Adams, 2017). The hand, wrist and arm together form a structure that is especially complex and sensitive to injury in physical work. It's also explained that the hand is used as an important tool for gripping, with different functional positions depending on the amount of power and/or precision needed for a specific activity. The complex structures of the hand are not to be overloaded with unnecessary twisting and bending, instead, the hand should be as close to its resting position as possible. The resting position of the hand is when the wrist is straight, muscles are relaxed, and fingers are slightly curled. A few typical work-related issues that could risk injury to the hand are repetitive tasks, high forces and incorrect grips.

The grip aspect was also something that was suspected to be an issue in the early stages of this project, however, it was not anticipated to be connected to the feeling of being effective, which is a cognitive and emotional aspect. The future concept of modular baskets, with built-in handles, that can be stored in cabinets directly from the dishwasher was therefore a surprising concept, trying to solve a bigger problem, spanning physical- and cognitive ergonomics but also emotional needs.

12.4 Process

The process of this project has been both iterative and user-centered, which were the aspects on which the project model was chosen. The iterative nature has however blurred the lines between the phases in the project model to a much larger extent than intended. Some phases, such as the evaluate phase, have been present almost throughout all phases, making the methods used in these phases hard to place. For example, it has been hard to place ergonomic assessments, as they are both a part of the define phase, defining ergonomic pain-points, the evaluate phase, evaluating ergonomic position in concepts, and the empathize phase as the ergonomic assessments are a result of the user tests.

This iterative process has also been beneficial. It has provided the possibility to explore every possible problem and solution in different phases of the project. For example, iterative information retrieval between the empathize and ideate phases have multiplied the number of possible solutions, meeting the aim of the ideate phase sufficiently. Also, the prototype phase has proved to be positively affected by this process. Rapid prototyping, to learn more about concept functions and to be able to evaluate them fairly, created the opportunity to realize new possibilities. In this case,

viewing the rapid prototypes enabled a merged concept development, which would probably not have happened without this process.

Furthermore, this project has been largely user-centered which have affected the results. The user has not only been the center of the project in ergonomic aspects, but they have also provided their emotional needs to this study. Emotional needs were not a part of the initial scope, however, as the user have become known, it has become evident that the emotional needs do affect physical ergonomics. While the acknowledgement of the emotional needs did take time from the actual scope of ergonomics, it also created a more meaningful and holistic solution. For example, the need to feel effective is an emotional need that emerged from the more qualitative studies such as Letters. This need showed to affect the user in terms of taking short cuts, ignoring functions and worsening their ergonomic situation for the purpose of being fast, meaning that ergonomic solutions must be effortless and intuitive for the user, otherwise they won't use it. This emotional need was also one of the building stones for the future concept, where the idea to shorten the unloading sequence was born, to address the emotional need of wanting to feel effective.

Finally, the needs obtained from the empathize phase were hard to weigh and prioritize. The reason for this is the subjective nature of user opinions and experiences. Prioritization of the needs were suggested to ASKO, but it was decided rather not to limit the development process with company opinions, both because it narrows the solution space and because it is hard to prioritize when the values are soft or unmeasurable. Because the needs were not prioritized, the evaluation of the concepts against the needs were based on intuition and with all needs on the same level. Meaning that the need of the dishwasher cleaning the dishes had the same prioritization as minimizing back pain, which could be questionable.

12.5 Validity of methods

This section will discuss the validation of some of the methods used in the project, addressing both limitations and advantages.

12.5.1 Letters

The method *Letters* was used to gain deeper insight into users' experiences of dishwashers in their home environment. By combining parts of both diary studies and cultural probes, the method encourages deep reflection of long-term use of dishwashers. This method provided rich understanding and thoughtful responses, showing that the method was successful in prompting them to consider their experiences from different perspectives. A limitation of this method is that it requires a high level of motivation among the participants. In this case, it was attempted to achieve high motivation by careful participant selection, and clear instructions of the method.

However, there was a wide spread of engagement in the answers form the letters, even though precautions were made to avoid this. Some participants truly immersed themselves in the theme of the letters, while others responded without much empathy. In addition, the letters were mostly open-ended, allowing the participants to write about what they personally wished for in a dream dishwasher, as well as what they love or hate about their current one. This led to some responses being very specific to their individual experiences and dreams.

Regardless of variations in participant engagement and expressions in the letters, the validity of this method is supported by the richness and depth of the themes identified through the KJ analysis, as well as their alignment with findings from the other studies. Overall, letters provided valuable insights and captured both physical and emotional user needs associated with long-term dishwasher use, hence a meaningful complement to the other user studies in this project.

Creating a new method could be a risk as it has not been tested or proved to be useful in similar processes. Nevertheless, this method is a combination of two established methods; *Cultural probe* and *Diary studies*. Moreover, to ensure a successful combination of these methods a pilot study was performed securing a valuable outcome. Furthermore, a researcher in the area helped to form and evaluate the outlines of the method, further ensuring validation for this method.

Lastly, the participant selection was thoroughly thought out, ensuring a spread in ages, experiences and included both men and women. However, the method did not reach the same saturation that the user tests did, mainly because of the open-ended nature of the method. Thus, it would be beneficial to have included more participants within the study, if the timeframe would have allowed it.

12.5.2 PEPA

The method PEPA was used to analyze ergonomic pain points in a specific task sequence in dishwasher use. As a relatively unknown and rarely cited method in broader ergonomic research, PEPA lacks extensive validation, that is found in more established assessment tools like REBA. However, there is a gap of ergonomic assessment tools directly linked to a specific product, and since this method has been used in education contexts at Chalmers, and was developed by lecturers at Chalmers, this supports the inclusion of the method in this project.

The strength of PEPA lies in the ability to identify pain points and problematic areas within the activity steps when using a product. And moreover, what type of problematic areas in the body it refers to. To validate the PEPA results, the method was used parallel with the more established method REBA.

One challenge the method PEPA faces is that it involves subjective judgements from the evaluators, regarding ergonomic knowledge and consistency in interpretation of what the “critical users” may experience. A more accurate way might be to let the critical users themselves interpret and fill in

the chart of the PEPA. Despite this limitation, the results from the PEPA contributed to meaningful insights to the define phase of this project.

12.5.3 REBA

REBA method is a well-established ergonomic assessment tool, generally associated with high validity. However, challenges can arise during the REBA analysis, as individual analysts may interpret posture scoring differently. To minimize this issue, each step of the REBA evaluation was discussed among the analysts and the assessments were conducted and interpreted consistently throughout all REBAS.

Another challenge concerns the comparison of different REBAs. Since the still images used for comparison were selected based on the most critical posture observed, for example during the deepest bend, other body parts sometimes influenced the results. This sometimes resulted in higher REBA scores. Which was not always connected to the back posture, but for example due to grip or raised shoulders. This challenge and explanations of the REBA results are more deeply explained in section 9.2. This challenge stems from the variations of how users interact with the dishwasher, and the fact that the REBA is based on the full-body posture captured in the image.

12.5.4 User test

The user test was central to understanding how the users interact with dishwashers and to identify ergonomic problems. The combination of video observations from two angles, audio recordings, that the participants were asked to think out loud, as well as the survey provided rich data to be analyzed. The study also included two dishwashers at different heights, enabling comparative analysis that ended up being crucial for the continuous work of the project.

One limitation of the set-up was the fact that the dishwashers were not identical. The one on floor height was an ASKO, and the one raised was a Gorenje. This may affect the results slightly if the participants, for example, preferred one layout better than another. However, the first objective states "*Analyze the current ergonomic challenges of an ASKO dishwasher in everyday tasks"* which was the most important aspect of the user tests. The raised dishwasher was an addition, as the potential of a raised installation had been found in previous stages of the project.

Another limitation was the small sample size. However, saturation of the results was achieved, meaning that the final participants contributed little new information, instead, repeating points that had already been mentioned or observed earlier. Additionally, the selection of participants was diverse in terms of gender and height, which ensured wide spread of insights, which was crucial for the investigation.

12.6 Sustainability and ethics

This project aims to enhance the ergonomics of an ASKO dishwasher. This aim thereby improves daily life for dishwasher users. By addressing the usability and ergonomic issues, this project benefits a wide range of individuals in their daily life. This project invites actual users to give their input into dishwasher use, creating a space for meaningful and user-centered product development. Furthermore, this project also invited experts in the area of ergonomics to ensure a fair and accurate representation of ergonomic issues. This way, critical users were also represented more thoroughly, such as the elderly or people with disabilities, even though they were not frequently participating in the user studies. The vision was to provide a more inclusive product that reduces physical strain and discomfort when being used and therefore aims for a better quality of life.

To outline the ethical aspects of the project, a user-centered approach was used to ensure the involvement of the end users of the product. These individuals were chosen carefully to minimize bias that could result from a too narrow user group. The user tests and interviews were conducted with respect to the participants privacy, ensuring that the data collection was implemented with ethical standards with informed consent. GDPR forms were also created and signed by users in the user tests to ensure transparency in use of their data, including pictures and videos.

The project itself does not focus on improving ecological parameters. However, since ASKO products are made from durable materials, are energy efficient and have a long lifespan, the products of this project are a part of that vision, aiming for the same level of sustainability. While ecological considerations were not the main focus, this project strived to avoid creating a worse ecological scenario. In addition, efforts were made to reduce material waste when prototyping. For example, through using a dishwasher at the end of its life as a base and using scrap material for building several parts.

13 Future Work

Although this thesis successfully resulted in an ergonomically improved dishwasher, several areas are open for further exploration and refinement. This section will give suggestions on future work.

13.1 Refine the concepts

The feasibility of the concepts is still at a theoretical design stage. Further refinement of both the contemporary and the future concepts are needed. Regarding the contemporary concept, more technical feasibility and mechanical integration is of importance, especially regarding the scissors lift mechanism integrated into the dishwasher door. Moreover, since the concept at this stage has not taken the components in the dishwasher door into consideration, changes are needed to fit all these components and make them function properly.

One problem that arose regarding the contemporary concept was that when using the lift function, there is a risk of the lower basket clashing into the upper basket, if the upper basket is fully pulled out when the lower basket is raised to the final height. This problem is due to the baskets being longer than the length of the dishwasher door, once both are pulled out fully. The maximum of using both baskets at the same time without clashing is reached when the upper basket is approximately a decimeter inside the dishwasher. To solve this problem, a few changes could be made. Either, both baskets could be decreased in depth size, which would solve the problem, but, resulting in less place settings. Or the function of raising the dishwasher door could be locked until the user pushes the upper basket in to the correct place. A third alternative would be to hinder the upper basket to be pulled out further than the max.

Regarding the future concept, the modular baskets need to be continually developed and prototyped in full size. Moreover, engineering analysis of strength, durability, and manufacturability of both concepts are needed, to meet standards set for dishwashers.

13.2 User testing of final concepts

A key limitation of the project was that there was no final user testing of the final concepts. Therefore, this is a subject for future work. It would be interesting to complete a comprehensive user test in realistic scenarios. This would enable validation of the ergonomic improvements identified through REBA and PEPA in a real-world context, as well as receive users' input of the concepts.

When doing these tests, it would be interesting for future studies to include a broader range of participants like children, people with physical impairments, and users with limited grip strength.

13.3 Test concepts as combined

Once both concepts are refined, it would also be of interest to carry out a user test with both concepts combined to observe what the ergonomic situation would result in. Moreover, it would be interesting to do a user test of cognitive ergonomics, to compare to the ASKO dishwasher today, since both concepts have been addressing cognitive ergonomics in various aspects.

13.4 Kitchen storage systems

Moreover, regarding the modular concepts, it would be interesting to see how kitchen storage as cabinets and drawers could be designed so that the modular baskets seamlessly can be integrated into these. Maybe a collaboration between kitchen architects, ASKO and furniture manufacturers would provide insights into how this could be realized as a holistic kitchen system.

Conclusion

14 Conclusions

As has been presented in the results of this thesis work, deep bends are the root of several ergonomic issues when using a dishwasher. This is suggested in the literature and proved through ergonomic assessments. There are several ways of solving this, two of them being lifting the lower basket, and providing modularity in the dishwasher interior.

It is also evident in this thesis work that ergonomic issues can be interconnected, where cognitive and physical ergonomics both affect each other and can solve issues related to one another.

The user tests show that raising the entirety of the dishwasher can create new ergonomic issues, for example raised shoulders for shorter users, meaning that raising only the lower basket is better suited for over-all ergonomic improvements.

The thesis shows that users want to feel effective, which often leads to frustration or short-cuts that result in worse working positions, such as not pulling out the basket fully. Thus, it is of value to consider making the sequence of using the dishwasher shorter or simpler. This, to ensure that the most ergonomic option is the most accessible and intuitive for the user.

The dishwasher is a very common and standardized appliance, which is the reason for them looking very similar and being placed on floor height. However, this study shows that critical users, for example a person with scoliosis, have difficulty using the machine, sitting down on their knees to avoid discomfort in the back. This further emphasizes the need to design ergonomically adapted products for the home, to ensure that they are accessible and comfortable for all users.

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Appendix

Appendix 1: Interview guides

Interview ergonomic experts

Inledande frågor

1. Vad är din erfarenhet med ergonomi kopplat till produktutveckling?
2. Vad tycker du om ergonomin i hemmet generellt?
    a. ge gärna bra och dåliga exempel
    b. Hur viktigt är det att tänka på ergonomin i hemmet?
3. Vad tycker du om ergonomin i köket i ett hem generellt?
    a. ge gärna bra och dåliga exempel
4. Har du en diskmaskin hemma?
    a. Vad tycker du om den?
        i. Skulle du säga att den är ergonomisk?
        ii. Isåfall vad?

Ergonomi

1. Vilka är de viktigaste ergonomiska aspekterna som man ska tänka på när man designar hushållsapparater för hemmabruk?
    a. Vilka är de viktigaste ergonomiska aspekterna man ska tänka på när man designar en diskmaskin?

Nu kommer mer frågor specifikt om diskmaskinen så vi kan kolla på dessa bilder för lite visuell hjälp.
Visa bilder

2. Vilka är de vanligaste fysiska ansträngningarna användare utsätts för när de använder en diskmaskin?
    a. Hur skulle det kunna förbättras?
3. Vilka är några vanliga ergonomiska misstag som görs i design av diskmaskiner?
4. Finns det några specifika ergonomiska standarder eller guidelines som diskmaskiner bör följa?
5. Påverkar arbetshöjden ergonomin mycket i en diskmaskin?
    a. Både lastning och avlastning från korgar men även öppning av dörr
6. Vilka typer av personer tror du kan ha svårt med att använda en diskmaskin?
    a. Vilka är de specifika ergonomiska problemen som de då stöter på vid användningen av en diskmaskin?
    b. Äldre?
    c. Hur skulle det kunna förbättras?
7. Vilka lärdomar kan dras från andra produkter för att förbättra ergonomin i en diskmaskin?
8. Tror du att de nuvarande diskmaskinerna på marknaden är fulländade när det kommer till ergonomin, eller finns det rum till förbättring?
    a. När vi har läst på om ergonomiska utvärderingar är många metoder baserade på repetitivt arbete eller tunga lyft under en 8-timmars arbetsdag. En diskmaskin används kanske 10-20 minuter per dag.
    b. Är det motiverat att lägga fokus på ergonomiska förbättringar i en diskmaskin?

Avslut

1. Vilka ergonomiska innovationer skulle du kunna tänka dig i framtidens diskmaskiner?
2. Beskriv din drömdiskmaskin!

Extra frågor

Berätta om vår studie för att utvärdera ergonomin

1. User study frågor
    a. Vilka uppgifter tycker du att vi ska be användaren göra i vårt test för att utvärdera de största ergonomiska problemområdena?

Interview dishwasher experts

Inledande frågor

1. Hur länge har du jobbat med diskmaskiner (eller home appliances / vitvaror) ?
2. Vad är det för funktioner som du ser att kunderna värderar mest i sina diskmaskiner?
3. Vilka diskmaskiner säljer bäst och varför?
4. Vilka är de vanligaste klagomålen eller missnöjena som användare uttrycker när det kommer till diskmaskiner?
5. Hur ser önskemålen kring diskmaskiner för olika marknader, regioner eller åldrar ut?

Ergonomi

1. Har du sett några ergonomiska lösningar på produkter i hemmet generellt?
    a. och vad tycker du själv om de i sådana fall?
2. Har du sett några ergonomiska lösningar på diskmaskiner (exempelvis comfort lift)?
    a. Vad tycker du själv om dem i så fall?
3. Vilken är den minst ergonomiska diskmaskinen du har sett?
    a. Varför var den minst ergonomisk?
4. Vilka är de vanligaste fysiska problemen som kan uppstå i användandet av diskmaskiner idag anser du?
5. Finns det några vanliga misstag som användare gör när de använder sina diskmaskiner som du tror kan förbättras?
    a. Hur tror du att det kan förbättras?
6. Vad tycker du är de viktigaste sakerna att tänka på om man ska designa en mer ergonomisk diskmaskin?
7. Hur viktigt tror du det är med modulära och/eller anpassningsbara diskmaskiner? (Exempelvis höj- och sänkbara korgar, uttagbara delar att ställa på bänken etc.)
8. Hur mycket tror du att höjden av diskmaskinen påverkar komforten och användarvänligheten?
9. Vad tror du är det bästa sättet att designa en diskmaskin för att minimera nedböjning, utsträckning eller andra svårare positioner?

Framtida trender

1. Vilka trender ser du i kommande diskmaskiner på marknaden?
2. Hur tror du att diskmaskiner kan bli mer ergonomiska och användarvänliga i framtiden?
3. Hur skulle du beskriva din drömdiskmaskin? Om du inte hade några begränsningar!

Appendix 2: Letters

Overview

The “Letters” method is a user research tool designed to gather deep reflective insights from participants in their home environment. Inspired by a combination of diary studies and cultural probes, the method replaces traditional diaries with handwritten letters. Participants receive letters with various themes, which encourage them to reflect on everyday interactions. See the method section 5.1.4 for more details about Diary studies and cultural probes.

Purpose

The goal of the method is to gain qualitative insights into long-term use of everyday items, in this case dishwashers. These insights should cover both emotional and functional experiences from various perspectives.

Procedure and format

In the beginning of the test period, the user receives five letters in envelopes, stating which envelope to begin with. Each letter contains probes relating to the theme of the letter. Each day of the week, the user opens a letter and reads the probe. The user can then reflect over the day and fill the letter in later during the day, giving time to the participant to reflect on the theme and questions.

Before opening the first letter, a note of instructions of the method were given to the participant to explain the study, how to use the letters and encourage the participants to be open minded to the unusual type of format of the method. It also asked the participants to open the letter in the morning, reflect during the day, and write it later during the day.

The letters are delivered in a physical, analogue format. The reason was to engage the participants and let them take their time to write down their reflections, as when writing a letter. The font of the letters was mimicking handwriting, to evoke a personal feeling.

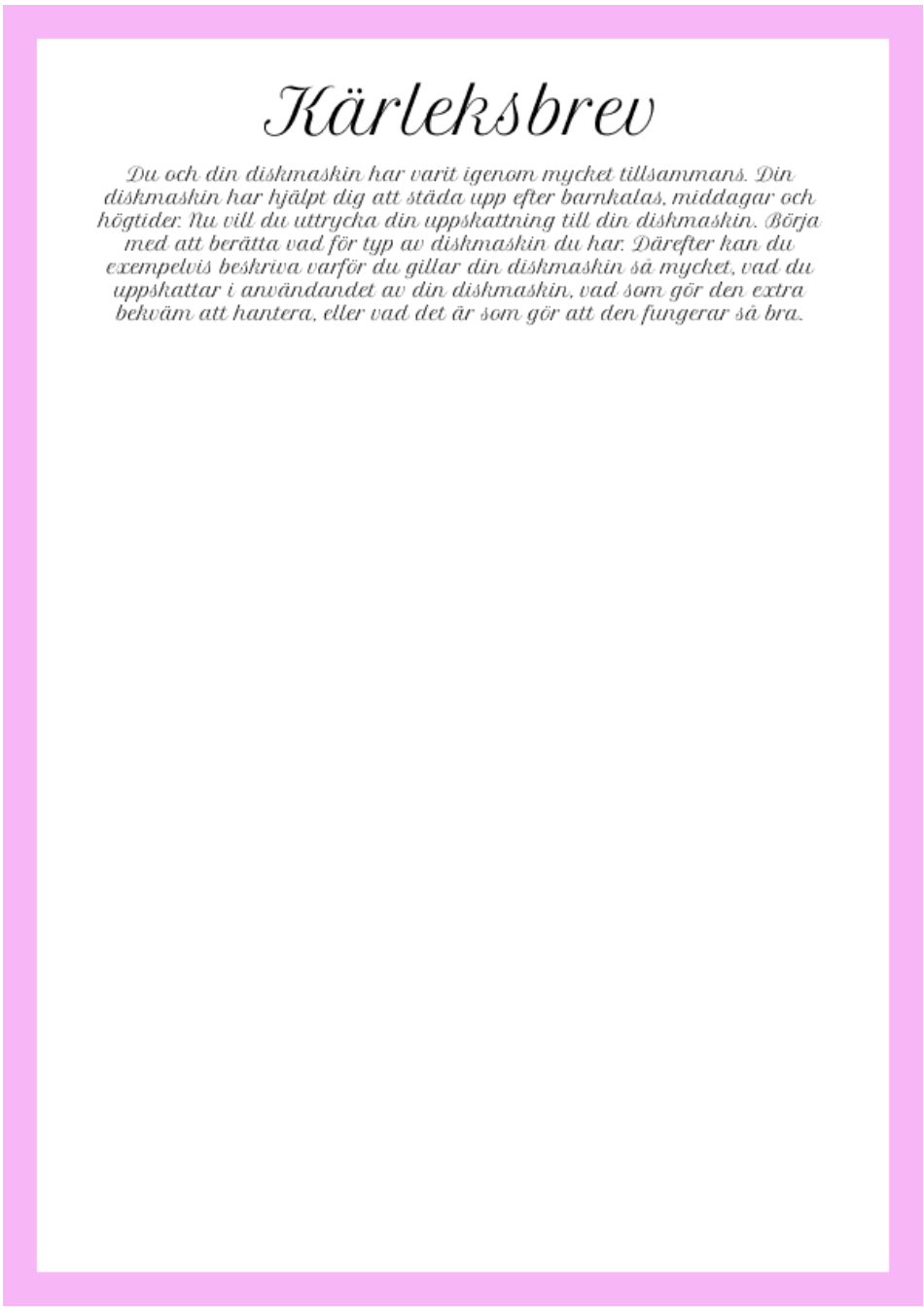
Participant selection

Participants were selected based on several criteria. From 30+ year olds, include both men and women, and people thar are willing to engage with an unconventional and reflective method. Participants needed to be curious and open, since this method is in a special, unconventional format.

The five letters

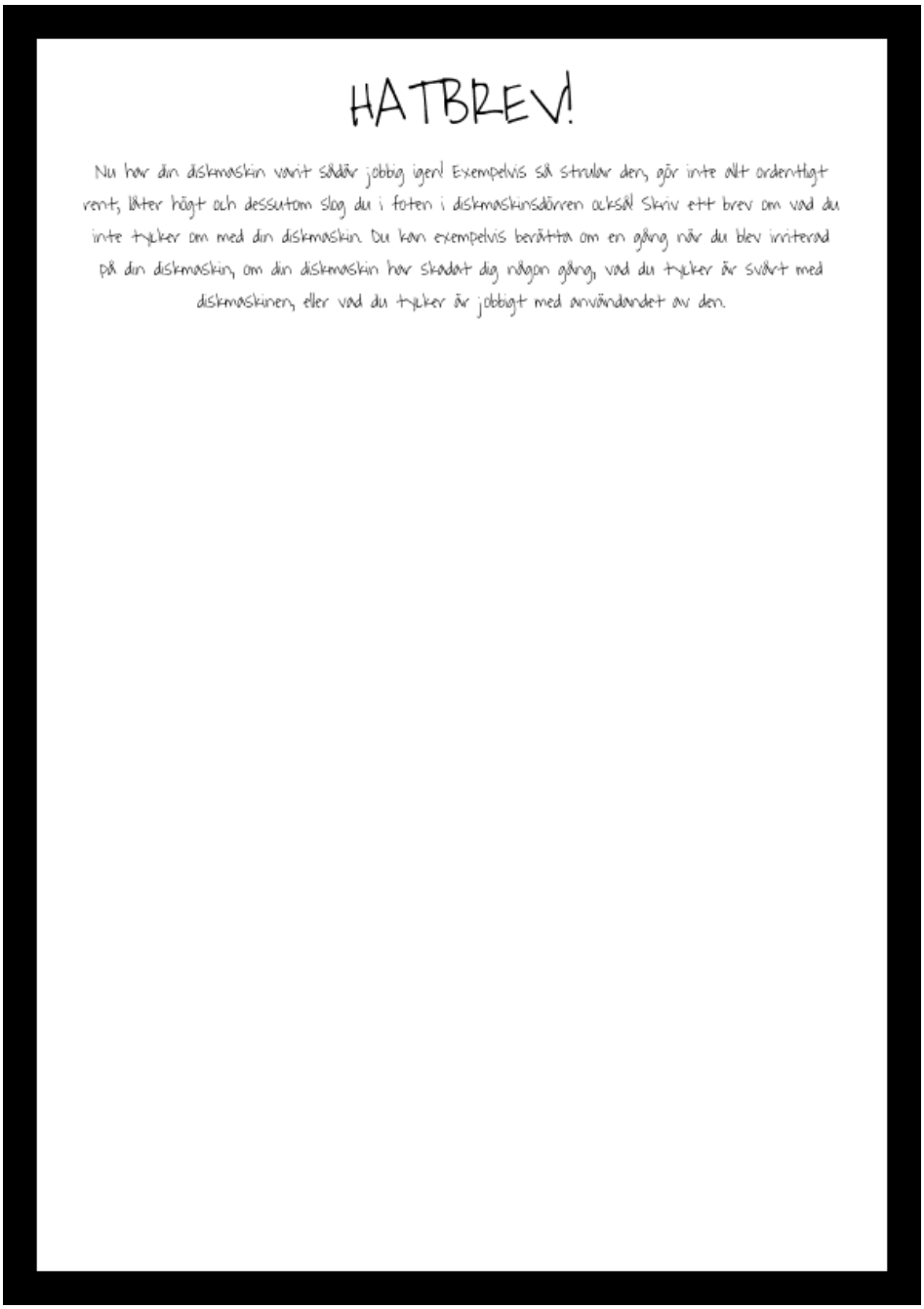
1. *Love letter*

The first letter asks participants to write a love letter. This is to get an understanding of what is good with their current experiences and what they value the most about their dishwasher.



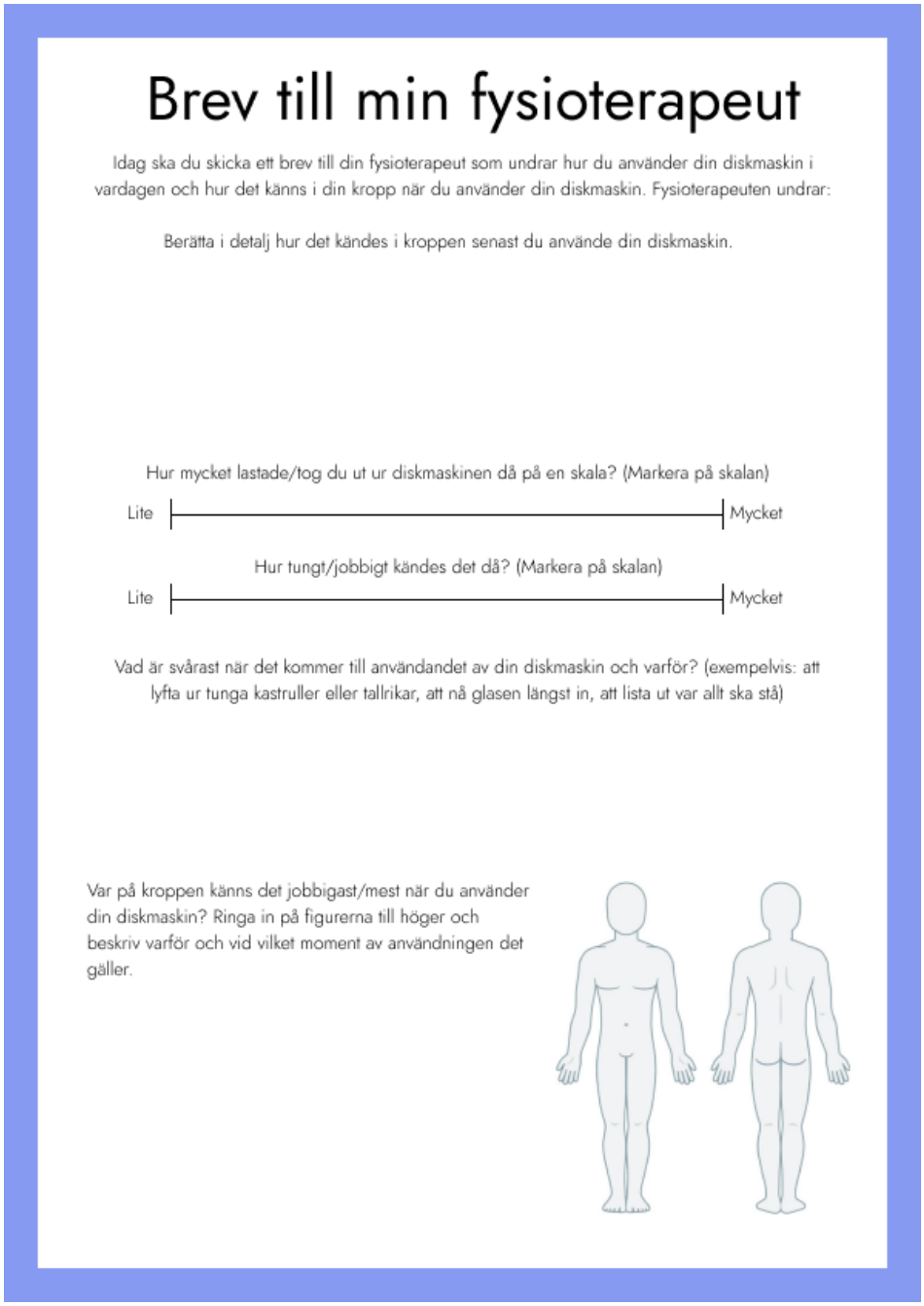
2. Hate Letter

The second letter prompted the participants to express frustrations and what they dislike about their dishwasher. The goals was to identify pain-points, negative experiences and unmet needs.



3. *Letter to your physiotherapist*

In the third letter the participants were asked to talk about experiences connected to their body. For example, where they experience the most strain while using their dishwasher. This letter provides insights into potential ergonomic challenges.



Brev till min fysioterapeut

Idag ska du skicka ett brev till din fysioterapeut som undrar hur du använder din diskmaskin i vardagen och hur det känns i din kropp när du använder din diskmaskin. Fysioterapeuten undrar:

Berätta i detalj hur det kändes i kroppen senast du använde din diskmaskin.

Hur mycket lastade/tog du ut ur diskmaskinen då på en skala? (Markera på skalan)

Lite — Mycket

Hur tungt/jobbigt kändes det då? (Markera på skalan)

Lite — Mycket

Vad är svårast när det kommer till användandet av din diskmaskin och varför? (exempelvis: att lyfta ur tunga kastruller eller tallrikar, att nå glasen längst in, att lista ut var allt ska stå)

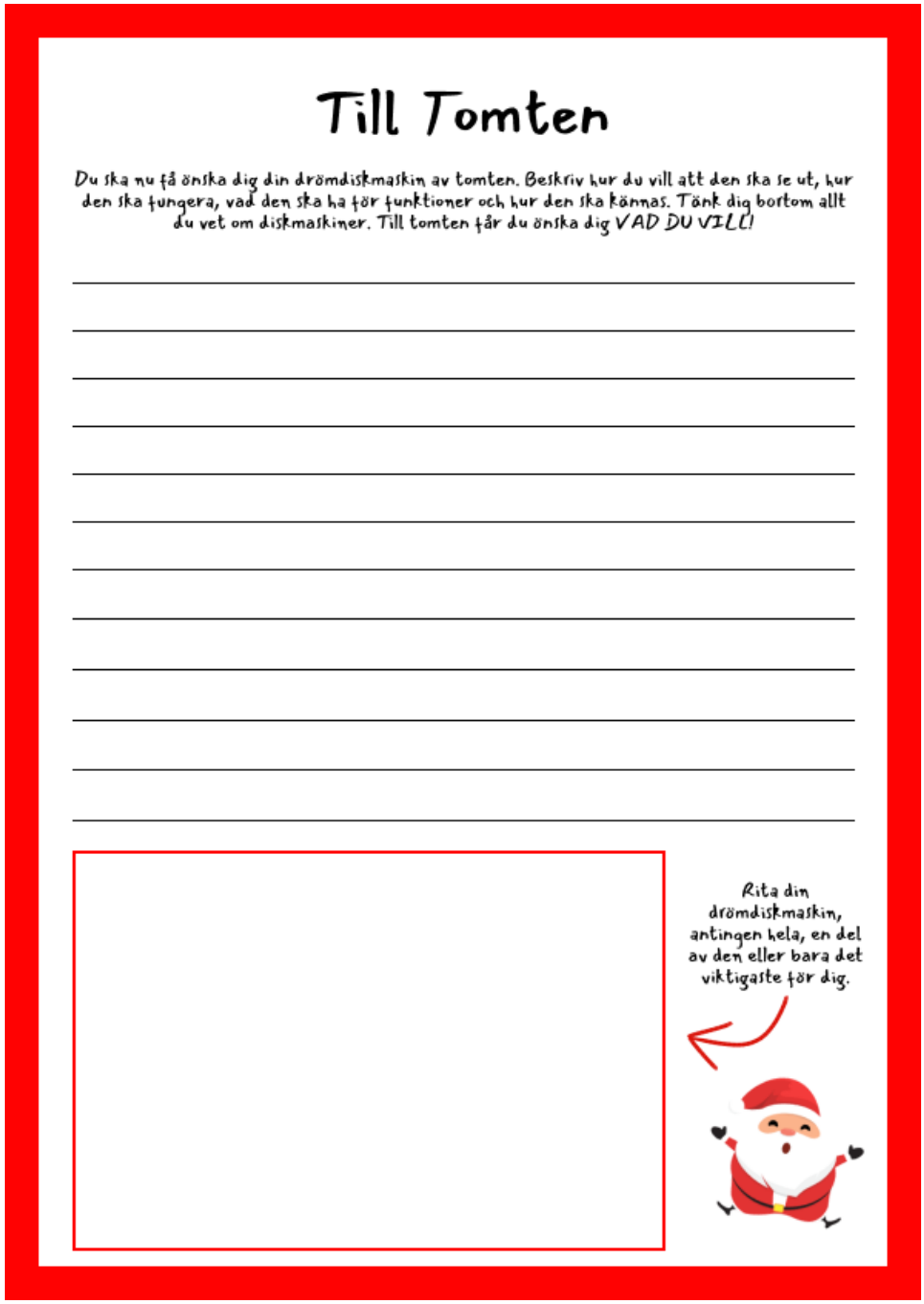
Var på kroppen känns det jobbigast/mest när du använder din diskmaskin? Ringa in på figurerna till höger och beskriv varför och vid vilket moment av användningen det gäller.

4. Excerpt from my diary

The fourth letter asked the participants got to fill in a timeline explaining about times in their life where it was especially difficult to use their dishwasher, when the dishwasher potentially broke down, when they saw someone else having a difficult time when using the dishwasher. This letter was included to gain knowledge not only of the participants' experiences in their current state of mind, but also in other aspects of their life. This letter also opened to include reflections of participants observations of others, relating to dishwasher use.

5. *Letter to Santa*

The last letter asked the participants to describe their dream dishwasher, with no limitations. They were also able to add to their description with drawings. This letter aimed to give the participants an opportunity to think outside of the box and reflect on their imaginative dream scenario when it comes to dishwashers. This is to get an understanding of the dream scenario and receive requirements or wishes from the users.



Appendix 3: Competitor analysis

Below, one can view the competitor analysis that was conducted based on ergonomic performance. The table includes descriptions of found products and comments regarding level of interest.

Dishwashers							
	ASKO	Fisher & Paykel's	800 ComfortLift,Electrolux	AEG	Concept (no company): Vertical Dishwasher	Concept: The Circular dishwasher	Concept: Sink dishwasher
Picture							
Link		https://www.architecturaldigest.com/sponsored/story/the-most-ergonomic-and-stylish-dishwasher-is-actually-a-dishdrawer	https://www.electroluxhome.se/vitvaror/diskmaskin/integrerad-diskmaskin/eec67305l-1/	https://www.aeg.se/taste/inspiration/mastery-range/mastery-products/comfortlift/?utm_source=chatgpt.com	https://dornob.com/vertical-dishwasher-design-an-ergonomic-update-for-a-kitchen-classic/	https://www.behance.net/gallery/215884649/Reci-The-circular-dishwasher?tracking_source=search_projects|dishwasher+product+design&l=5	https://liveaco.com/fotile-sink-dishwasher/
Search words		Google: Ergonomic dishwasher	Google: Ergonomisk diskmaskin	Google: comfort lift dishwasher	Google: ergonomic dishwasher	Behance: dishwasher product design	Google pic: Dishwasher use ergonomics
Description		Dishwasher as a "drawer". The reason to this deisgn is for sustainable purpose, to be able to wash a smaller section of the dishwasher.	Ergonomic dishwasher, basket lift of lower basket.	Ergonomic dishwasher, basket lift of lower basket.	Vertical dishwasher concept with rotational basket. Have not reached the market.	Project work Milano University. Circular dishwasher. Including some ergonomic parts, with a simple lifting mechanism in the dishwasher	Intresting concept with the dishwasher from the countertop
Comments		Could also be very interesting in ergonomic aspects	Very interesting. Should look into patent.	Sister company to elektrolux, probably the same comfort lift.	Very interesting concept, both in ergonmic terms but also as for compact living.	Interesting ergnomic parts and liftting mechanism	Loading and unloading from above

Appendix 4: Questionnaire answers

Answers for dishwasher on floor height

Öppna och stänga diskmaskins luckan	Lasta **in** disk i **övre** korgen	Lasta **in** disk i **undre** korgen	Lasta **ur** disk ur **övre** korgen	Lasta **ur** disk ur **undre** korgen	Fyll på diskta blett	I vilken/vilka delar av kroppen kände du mest belastning i? Varför?
1	1	2	1	2	1	nedre delen av ryggen
2	1	2	1	2	1	Ryggen. Kombinerat lyft och vridning under en förlängd tid.
1	3	2	3	2	1	ländrygg
2	1	3	1	4	1	Det kändes som den stod långt ner och att jag fick böja mig mycket. Ont i ländryggen
3	2	6	2	6	6	ryggen, blev snabbt statisk belastad, otrevlig arbetsställning
4	2	5	2	4	3	Kanske lite i ryggen, eftersom man fick stå böjd hela tiden.

Answers for raised dishwasher + final question

Öppna och stänga diskmaskin sluckan	Lasta **in** disk i **övre** korgen	Lasta **in** disk i **undre** korgen	Lasta **ur** disk ur **övre** korgen	Lasta **ur** disk ur **undre** korgen	Fyll på disktabl ett	I vilken/vilka delar av kroppen kände du mest belastning i? Varför?	Vilken av diskmaskinerna tycker du var mest fysiskt krävande?
1	1	2	1	2	1	lasta i undre korgen	Diskmaskin på golvet
1	1	1	1	1	1	Ryggen. Vridning (ej kombinerat med lyft)	Diskmaskin på golvet
2	1	2	1	2	1	ländrygg	Diskmaskin på golvet
2	1	1	1	1	1	Inte alls	Diskmaskin på golvet
2	2	1	1	1	1	axlar. Lite för hög	Diskmaskin på golvet
1	1	1	1	1	1	Inget	Diskmaskin på golvet

Appendix 5: KJ-analysis themes

KJ analysis themes interviews ergonomic experts

- Working height
    - Heavy lifts
- Grip and hand strength
- Back and bends
- Critical users
- Space
- Balance
- Dream dishwasher
    - Other wishes
- Two dishwashers next to each other
- Robust
- Repetetive work
- The average user
- Neutral opinion on dishwashers
- Adjustability
- Work surface
- Contrast
- Shoulders
- Other

KJ analysis themes interviews dishwasher experts

- High installation
    - Eventual problems
- Comfort Lift
    - Good properties
    - Bad properties
    - Further development
- Pulling out the lower basket
    - Lower basket derails
- Modular baskets and inserts
    - Flexibility
- Smart functions
- User behaviors
- Parted dishwasher / Fisher and Paykel's
- Other needs and opinions

- Opening mechanism
- The elderly
- No opinion on dishwashers
- Where it hurts
- Standard measurements for dishwashers
- Ergonomic handles
- Twists and flexations

KJ analysis themes Letters

- User friendliness
    - Amount of programs
    - Display
    - Choose to wash dishes later (timer)
- Quality
    - Baskets derailing
    - Broken
    - Robust
    - Stand firm
    - Frustration because of bad quality
- Body
    - Pain in lower back
    - Fingers/hands
    - Bodily hinders
- Base requirements
    - Clean the dishes
    - Silent
    - Quick
    - Dry the dishes
    - Energy efficient
    - Material
- Packing
    - Effective packing
    - Accommodate a lot
    - Automated packing
    - Regular cutlary basket (good)
- Raised/adjustable height
    - Upper basket feels easier
- Maintanence of machine

- Open door problematic for children
- Looks
- Dishing fine porcelain
- Hand dishing

KJ analysis themes user tests

- Layout and space
    - Good layout
    - Bad layout
- Taking several things at once
    - Takes several plates at once
    - Takes cutlery at once
- Hassle and fuss
    - Trying to make everything fit
    - Frustration because of hassle
    - Hassle with wine glasses
    - Leads to bends and endurance
- Cutlery basket
    - Bad, hard or complicated
    - Regular cutlery basket
    - Likes sorted
    - Doesn't see the cutlery basket
- Deep bends
    - Deep bends for dishwasher on floor
    - Deep bends for middle basket
    - Deep bends lower basket
    - Lowest point of the machine
- Dishwasher on floor (bad)
    - Bad for back
        - Pain in back
    - Compensatory behavior
- Raised dishwasher (good)
- Doesn't pull out baskets fully
- Upright position for raised diswasher
    - Upper basket
    - Lower basket
    - Genereally
- Upright position

    - Cutlery basket
- Movements of baskets
    - Ratly
- Flexible
- Door
    - Hardships
    - Easy
- Dishwasher use
    - Nautral/used to the dishwasher
    - Likes to use the dishwasher
    - Does not like to use the dishwasher
    - Maintanence
- Installation for raised dishwsher
- Compensatory position
    - Sitting down on knees
- Third basket
    - Missing the third basket

KJ analysis themes for Merged KJ

- Body load
    - Critical users
        - The elderly
        - People having a hard time when using dishwashers
        - Bodily hinders
        - The avarage person
    - Issues with balance
        - Balance
    - Fingers, hands & grip
        - Grip and hand strenght
        - Fingers/hands
    - Shoulders and arms
        - shoulders
    - Pain in back
        - Lumbago
        - Bad for the back
        - Back and bends
        - Extra issues for tall people
    - Deep bends
        - Generall deep bends

        - Deep bends for the middle basket
        - Deep bends for the lower basket
        - Furthest down on the machine
        - Repetative work
    - No pain using the dishwasher
- Raised dishwasher
        - Upright position for raised dishwasher
            - Upper basket
            - Lower basket
            - Generally
        - Upright position
            - Cutlary basket
        - Raised dishwasher good
        - Higher installation
        - Issues with dishwasher on floor height
    - Divided dishwasher
        - Parted dishwasher / fisher & Paykel's
        - 2 dishwashers
    - Comfort-Lift
        - Comfort-lift further development
        - Comfort-Lift (good)
        - Adjustable height
    - Issues with raised dishwasher/Comfort-Lift
        - Comfort-lift (bad)
        - Standard measurments for dishwashers
        - Problems with raised
        - Installation for raised
- Compensatory behavior
        - Compensatory position for the back
        - Sits down on knees
- Behavior & feelings / Cognitive
        - Hassle and fuss
            - Trying to make everything fit
            - Fuss because of wine glasses
            - Frustration because of fuss
            - Leads to bends and endurance
            - Feels stupid
        - Ease of use
            - Number of programs
            - Choose to wash dishes later (timer)

                - Display
                - Contrast
                - Dishwasher use
        - Doesn’t pull out baskets
            - Doesn’t pull out baskets fully
        - Wants it to go quickly
            - Takes several things at once (e.g. plates, cutlery)
            - Washing dishes by hand (tedious)
- Functions
    - Layout & space
        - Packing
            - Regular cutlary basket
            - Effective packing
            - Fit a lot
            - Pack automatically
        - Layout
            - Good layout
            - Bad layout
    - Important functionality
        - Dish clean
        - Dish fast
        - Running quiet
        - Material
        - Energy effective
        - Dry dishes
    - Adjustable
        - Modularity
        - Flexibility
        - adjustibility
    - Quality/Robust
        - Basket does not stay in place
        - Stand firm
        - Quality/Broken
            - Frustration because of bad quality
            -
        - Robust
        - Pulling out the lower basket
            - Lower basket derailing
        - Movement of baskets
            - Scrambling

- Looks
- Surrounding environment
  - Space (in kitchen)
  - Work surface
- Automatic
- Opening of the door
  - Door
    - Hardships
    - Easy
  - Opening mechanism
  - Open door cause problems for children
- Smart functions
- Maintanance
- Dish fine porcelain

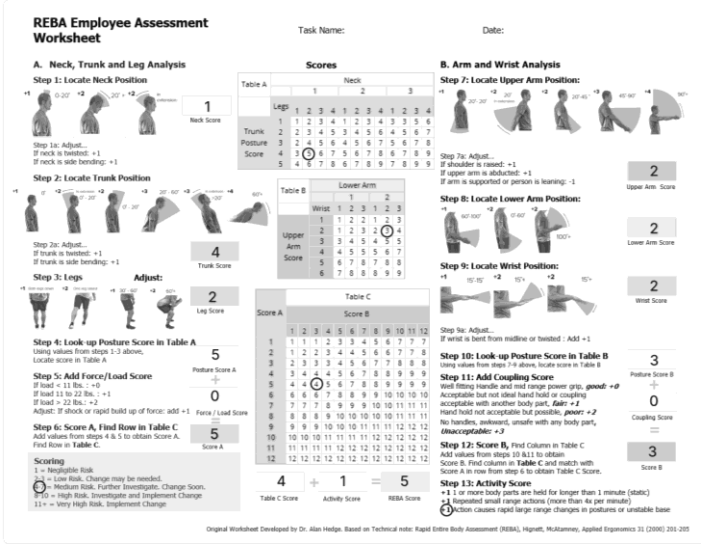
Appendix 6: Complete list of user needs

Requirement	Comment
Product requirements	
1. Be robust	Frequently mentioned
1.1 Baskets should stay in place	Frequently mentioned
1.2 Baskets should run smoothly	Frequently mentioned
1.2.1 The lower basket should be able to be rolled out all the way without derailing.	Frequently mentioned
1.3 Baskets should not be rickety	
1.4 Buttons should not wear out easily	
1.5 Handle should not break easily	
1.6 Dishware should stand firmly	
1.7 Robust material (stainless steel)	
2. Provide adequate space	Frequently mentioned + relevant
2.1 Accommodate a lot of dishes	
2.2 Provide a good overview	Frequently mentioned + relevant
2.3 Not too many baskets and compartments	Frequently mentioned
2.4 Provide optimized packing surface	
2.5 Easily organized	Frequently mentioned
2.6 Cutlary basket: Accomondate a lot of cutlary	
2.7 Provide enough depth for bigger spoons/spatula	
3. Provide automated functions	
3.1 Loading and unloading dishwasher should be automatic	Frequently mentioned
3.2 Self-dosing dishwasher	
3.3 Automatic door opening after washing	Frequently mentioned
3.4 Self-cleaning dishwasher (clean strainer)	
3.5 The machine automatically loads dishes in the most optimal way	
4. Be adjustable	Frequently mentioned + relevant
4.1 Provide flexibility	Frequently mentioned + relevant
4.2 Provide possibility to demolish and rearrange layout	Frequently mentioned
4.3 Provide replaceable inserts	
4.4 Provide modular baskets and shelves	Frequently mentioned
4.5 Provide liftable bottom basket	Frequently mentioned
4.6 Provide adjustable height of baskets	Frequently mentioned + relevant
5. Running quiet	
6. Clean dishes	
6.1 Wash dishes completely clean (even when packed)	
6.2 Wash dishes quickly	
7. Be sustainable	
7.1 Made of recycklable materials	
7.2 Be energy efficent	
7.3 Minimize water use	
7.4 Be durable (long life-time)	
8. Be compatible with standard measurments	

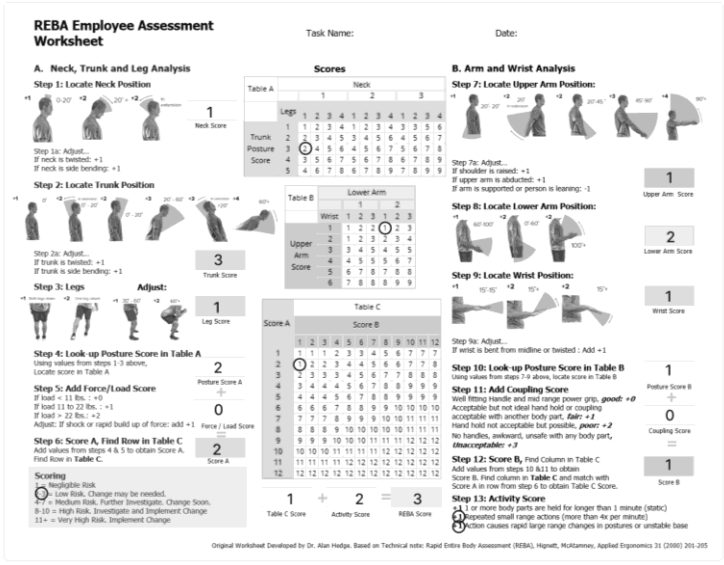
Ergnomic requirements	
Physical ergonomics	
9. Minimize strain on back	Frequently mentioned + relevant
9.1 Minimize pain in back	Frequently mentioned
9.2 Reduce depth of bends	Frequently mentioned + relevant
9.3 Reduce amount of bends	Frequently mentioned + relevant
9.4 Minimize heavy lifts	Frequently mentioned
10. Provide a good work height	Frequently mentioned + relevant
10.1 Minimize bodily extentions	Frequently mentioned
10.2 Upright position when loading and unloading	Frequently mentioned + relevant
10.3 Provide good reachability	Frequently mentioned + relevant
10.4 Provide possibility for good bodily balance	Frequently mentioned
10.5 Provide good work height for sholders	Frequently mentioned
11. Minimize high precision work	Frequently mentioned
11.1 Reduce fiddling	Frequently mentioned
12. Provide adequate grip	Frequently mentioned + relevant
12.1 Require low hand strength	Frequently mentioned
12.2 Minimize pain in hands and fingers	Frequently mentioned
13. Adapted for critical users	Frequently mentioned + relevant
13.1 Adapted for tall people	Frequently mentioned
13.2 Adapted for short people	Frequently mentioned
13.3 Adapted for the elderly	Frequently mentioned
14. Minimize awkward positions	Frequently mentioned
15. Minimize repetitive workload	Frequently mentioned
Cognitive ergonomics	
16. Reduce cognitive load	Frequently mentioned + relevant
16.1 Not too many programs	
16.2 Not too many functions	
17. Reduce risk of user error	
17.1 Provide understandable layout	Frequently mentioned
17.2 Provide understandable functions	Frequently mentioned
18. Provide good visibility	Frequently mentioned + relevant
18.1 Be able to find cutlary basket	Frequently mentioned
18.2 Clear program menu and display	
18.3 Provide good contrast	
18.4 Provide good readability (display)	
19. Easy to organize	Frequently mentioned
19.1 Easy to organize cutlary	Frequently mentioned
Emotional requirements	
20. Not to feel overwhelmed	
21. Trust the functionality	
21.1 Drag baskets out the full amount	Frequently mentioned
22. Feel effective	Frequently mentioned + relevant
23. Recognize the functions	
24. Recognize the technology	
25. Understand the purpose of functions	Frequently mentioned
26. Minimize frustration	
Other user requirements	
27. Handle dishes with care	
27.1 Provide possibility to wash fine china with gold trim	
27.2 Provide care for dishes with damping, (no chipped edges)	
28. Be fast to load and unload	Frequently mentioned
28.1 Effective unload of cutlery	
29. Two-pieced dishwasher. Both on optimal height	Frequently mentioned
30. Be able to delay wash start	
31. Dishwasher should be good looking	
32. Provide smooth open and close mechanism for door	Frequently mentioned
33. Door should not obstruct when opened	Frequently mentioned

Appendix 7: REBA

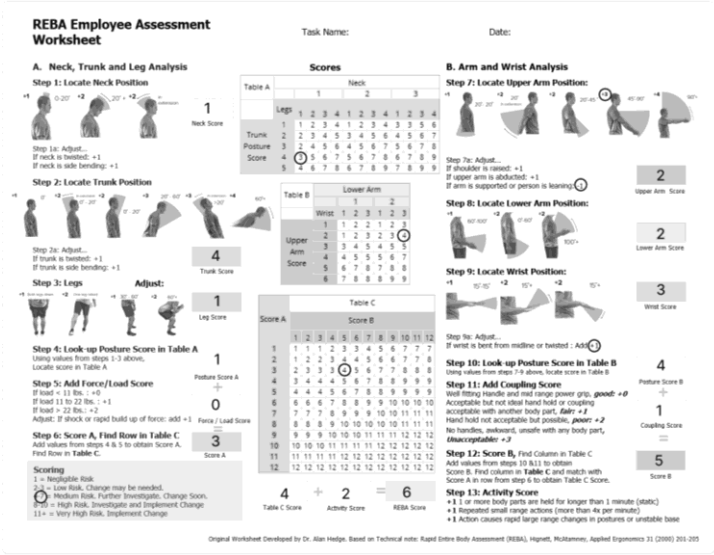
Reba 1: During the task of opening the dishwasher door and about to pull out the lower basket. Done on a dishwasher on floor height.



Reba 2: During the task of unloading the lower basket of the dishwasher. Done on a raised dishwasher.



Reba 3: During the task of unloading the lower basket of a dishwasher. Done on a dishwasher on floor height.



REBA Employee Assessment Worksheet

Task Name: Date:

A. Neck, Trunk and Leg Analysis

Step 1: Locate Neck Position — Neck Score: 1

Step 2: Locate Trunk Position — Trunk Score: 4

Step 3: Legs — Adjust: — Leg Score: 1

Step 4: Look-up Posture Score in Table A — Posture Score A: 1

Step 5: Add Force/Load Score — Force / Load Score: 0

Step 6: Score A, Find Row in Table C — Score A: 3

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

Scores — Table A: Neck / Legs / Trunk Posture Score; Table B: Lower Arm / Wrist / Upper Arm Score; Table C: Score A / Score B

4 (Table C Score) + 2 (Activity Score) = 6 (REBA Score)

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 — Posture Score B: 4

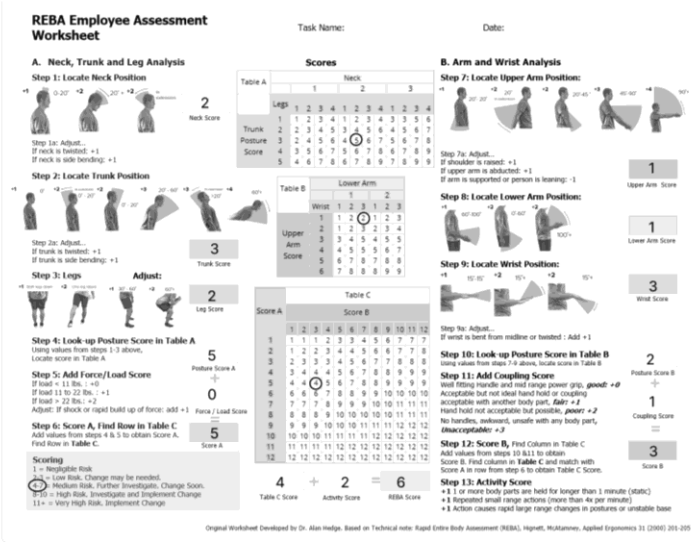
Step 11: Add Coupling Score — Coupling Score: 1

Step 12: Score B, Find Column in Table C — Score B: 5

Step 13: Activity Score
+1 1 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

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

Reba 4: During the task of unloading the lower basket of a dishwasher. Done on a raised dishwasher.



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: 3

Step 3: Legs — Adjust: — Leg Score: 2

Step 4: Look-up Posture Score in Table A — Posture Score A: 5

Step 5: Add Force/Load Score — Force / Load Score: 0

Step 6: Score A, Find Row in Table C — Score A: 5

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

Scores — Table A: Neck / Legs / Trunk Posture Score; Table B: Lower Arm / Wrist / Upper Arm Score; Table C: Score A / Score B

4 (Table C Score) + 2 (Activity Score) = 6 (REBA Score)

B. Arm and Wrist Analysis

Step 7: Locate Upper Arm Position — Upper Arm Score: 1

Step 8: Locate Lower Arm Position — Lower Arm Score: 1

Step 9: Locate Wrist Position — Wrist Score: 3

Step 10: Look-up Posture Score in Table B — Posture Score B: 2

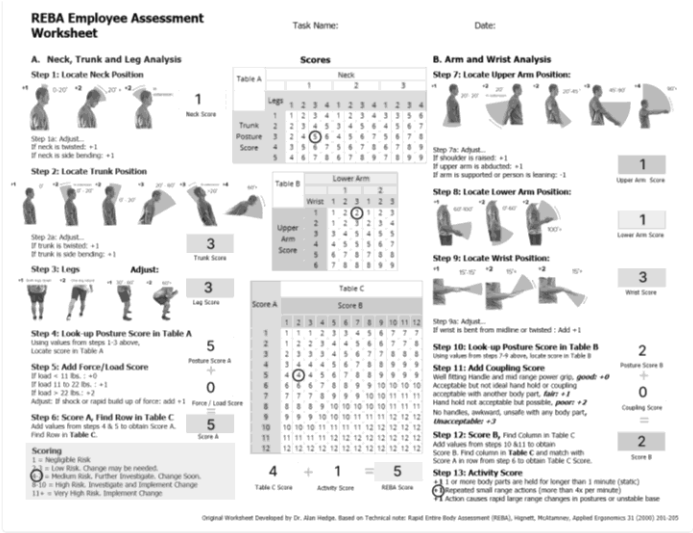
Step 11: Add Coupling Score — Coupling Score: 1

Step 12: Score B, Find Column in Table C — Score B: 3

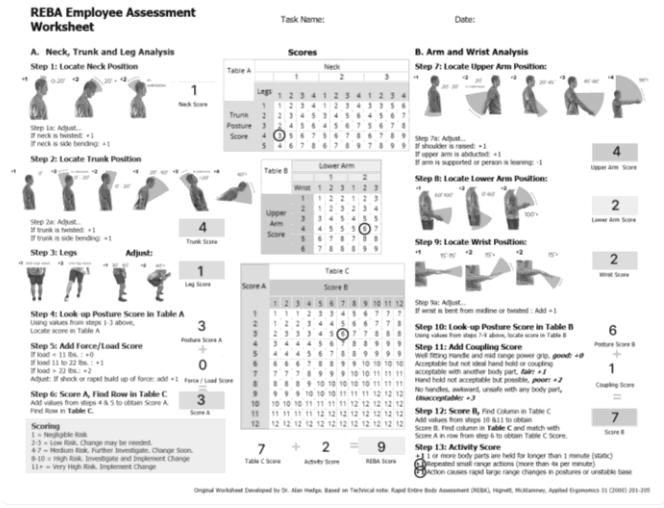
Step 13: Activity Score
+1 1 or more body parts are held for longer than 1 minute (static)
+1 Repeated small range actions (more than 4x per minute)
+1 Action causes rapid large range changes in postures or unstable base

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

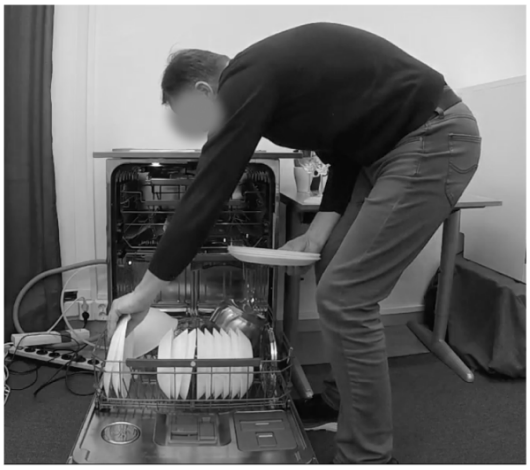
Reba 5: During the task of loading the lower basket of the dishwasher. Done on a dishwasher on floor height.

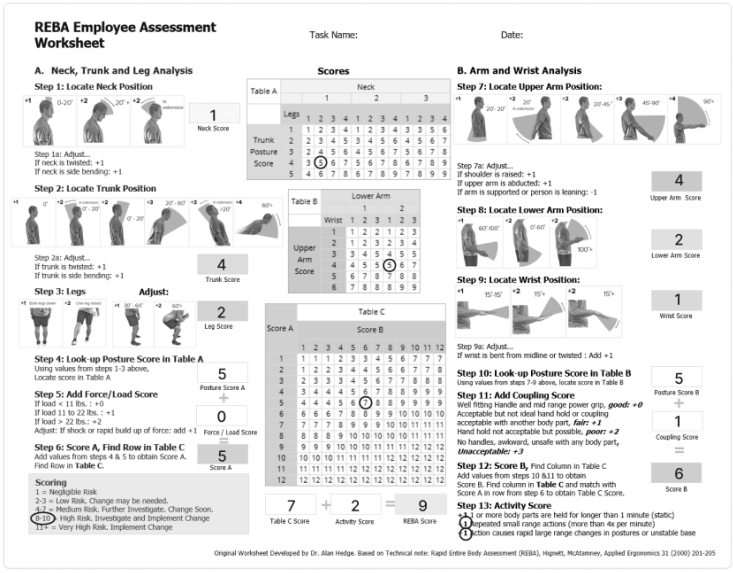


Reba 6: During the task of loading the lower basket of the dishwasher. Done on a dishwasher on floor height.



Reba 7: During the task of unloading the lower basket of the dishwasher. Done on a dishwasher on floor height.





REBA Employee Assessment Worksheet

Task Name: Date:

A. Neck, Trunk and Leg Analysis

Step 1: Locate Neck Position — Neck Score: 1

Step 1a: Adjust... If neck is twisted: +1 If neck is side bending: +1

Step 2: Locate Trunk Position — Trunk Score: 4

Step 2a: Adjust... If trunk is twisted: +1 If trunk is side bending: +1

Step 3: Legs — Adjust: — Leg Score: 2

Step 4: Look-up Posture Score in Table A — Posture Score A: 5

Using values from steps 1-3 above, Locate score in Table A

Step 5: Add Force/Load Score — Force / Load Score: 0

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

Step 6: Score A, Find Row in Table C — Score A: 5

Add values from steps 4 & 5 to obtain Score A. Find Row in Table C.

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

Scores

Table A

Trunk Posture Score \ Legs	Neck 1	Neck 2	Neck 3
1	1 2 3 4	1 2 3 4	3 3 5 6
2	2 3 4 5	3 4 5 6	4 5 6 7
3	2 4 5 6	4 5 6 7	5 6 7 8
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

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

Table C

Score A \ Score B	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
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	11	11	11	11
9	9	9	9	10	10	10	11	11	11	12	12	12
10	10	10	10	11	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: 7 + Activity Score: 2 = REBA Score: 9

B. Arm and Wrist Analysis

Step 7: Locate Upper Arm Position

Step 7a: Adjust... If shoulder is raised: +1 If upper arm is abducted: +1 If arm is supported or person is leaning: -1 — Upper Arm Score: 4

Step 8: Locate Lower Arm Position — Lower Arm Score: 2

Step 9: Locate Wrist Position — Wrist Score: 1

Step 9a: Adjust... If wrist is bent from midline or twisted : Add +1

Step 10: Look-up Posture Score in Table B — Posture Score B: 5

Using values from steps 7-9 above, locate score in Table B

Step 11: Add Coupling Score — Coupling Score: 1

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***

Step 12: Score B, Find Column in Table C — Score B: 6

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.

Step 13: Activity Score

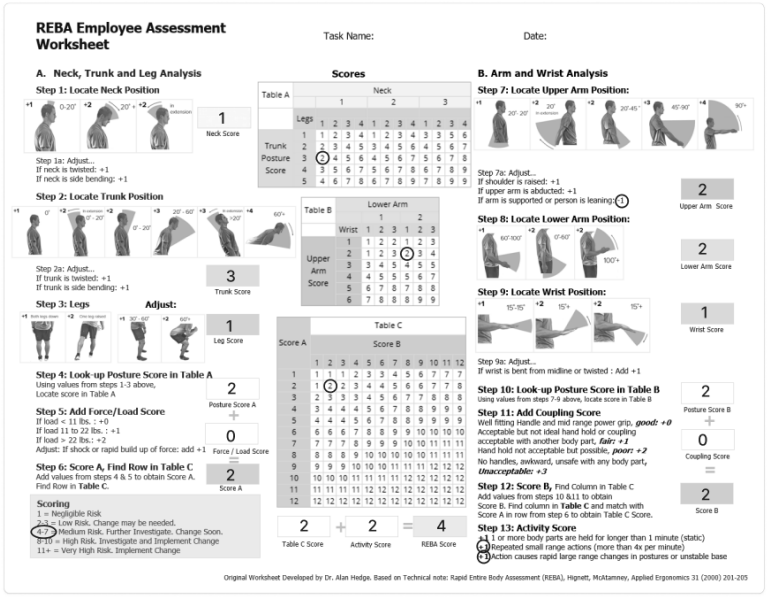
+1 1 or more body parts are held for longer than 1 minute (static)

+1 Repeated small range actions (more than 4x per minute)

+1 Action causes rapid large range changes in postures or unstable base

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

Reba 8: During the task of unloading the lower basket of the dishwasher. Done on a raised dishwasher.



REBA Employee Assessment Worksheet

Task Name: Date:

A. Neck, Trunk and Leg Analysis

Step 1: Locate Neck Position — Neck Score: 1

Step 1a: Adjust... If neck is twisted: +1 If neck is side bending: +1

Step 2: Locate Trunk Position — Trunk Score: 3

Step 2a: Adjust... If trunk is twisted: +1 If trunk is side bending: +1

Step 3: Legs — Adjust: — Leg Score: 1

Step 4: Look-up Posture Score in Table A — Posture Score A: 2

Using values from steps 1-3 above, Locate score in Table A

Step 5: Add Force/Load Score — Force / Load Score: 0

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

Step 6: Score A, Find Row in Table C — Score A: 2

Add values from steps 4 & 5 to obtain Score A. Find Row in Table C.

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

Scores

Table A

Trunk Posture Score \ Legs	Neck 1	Neck 2	Neck 3
1	1 2 3 4	1 2 3 4	3 3 5 6
2	2 3 4 5	3 4 5 6	4 5 6 7
3	2 4 5 6	4 5 6 7	5 6 7 8
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

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

Table C

Score A \ Score B	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
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	11	11	11	11
9	9	9	9	10	10	10	11	11	11	12	12	12
10	10	10	10	11	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: 2 + Activity Score: 2 = REBA Score: 4

B. Arm and Wrist Analysis

Step 7: Locate Upper Arm Position

Step 7a: Adjust... If shoulder is raised: +1 If upper arm is abducted: +1 If arm is supported or person is leaning: 1 — Upper Arm Score: 2

Step 8: Locate Lower Arm Position — Lower Arm Score: 2

Step 9: Locate Wrist Position — Wrist Score: 1

Step 9a: Adjust... If wrist is bent from midline or twisted : Add +1

Step 10: Look-up Posture Score in Table B — Posture Score B: 2

Using values from steps 7-9 above, locate score in Table B

Step 11: Add Coupling Score — Coupling Score: 0

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***

Step 12: Score B, Find Column in Table C — Score B: 2

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.

Step 13: Activity Score

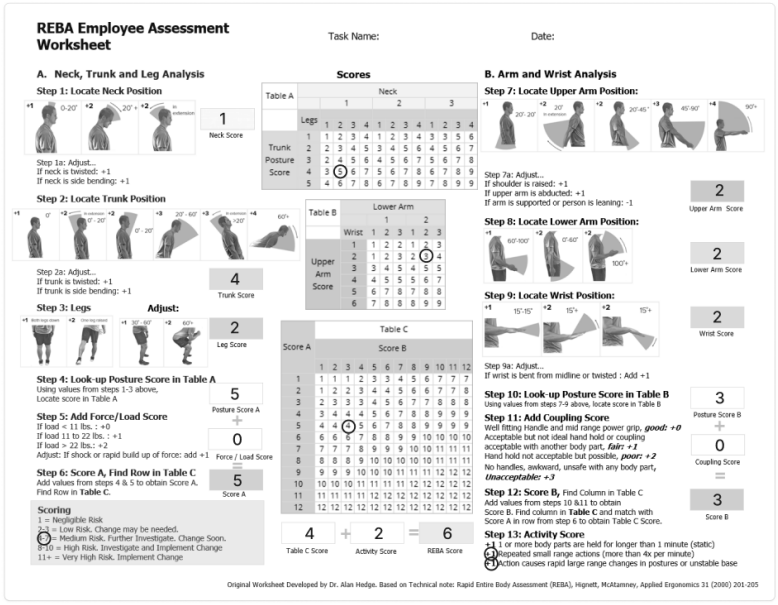
+1 1 or more body parts are held for longer than 1 minute (static)

+1 Repeated small range actions (more than 4x per minute)

+1 Action causes rapid large range changes in postures or unstable base

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

Reba 9: During the task of loading the lower basket of the dishwasher. Done on a dishwasher on floor height.



REBA Employee Assessment Worksheet

Task Name: Date:

A. Neck, Trunk and Leg Analysis

Step 1: Locate Neck Position — Neck Score: 1

Step 1a: Adjust... If neck is twisted: +1 If neck is side bending: +1

Step 2: Locate Trunk Position — Trunk Score: 4

Step 2a: Adjust... If trunk is twisted: +1 If trunk is side bending: +1

Step 3: Legs — Adjust: — Leg Score: 2

Step 4: Look-up Posture Score in Table A — Using values from steps 1-3 above, Locate score in Table A — Posture Score A: 5

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: 0

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: 5

Scoring: 1 = Negligible Risk; 2-3 = Low Risk. Change may be needed.; 4-5 = Medium Risk. Further Investigate. Change Soon.; 6-10 = High Risk. Investigate and Implement Change; 11+ = Very High Risk. Implement Change

Scores

Table A

Trunk Posture Score	Neck 1 · Legs 1	Neck 1 · Legs 2	Neck 1 · Legs 3	Neck 1 · Legs 4	Neck 2 · Legs 1	Neck 2 · Legs 2	Neck 2 · Legs 3	Neck 2 · Legs 4	Neck 3 · Legs 1	Neck 3 · Legs 2	Neck 3 · Legs 3	Neck 3 · Legs 4
1	1	2	3	4	1	2	3	4	3	3	5	6
2	2	3	4	5	3	4	5	6	4	5	6	7
3	2	4	5	6	4	5	6	7	5	6	7	8
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

Upper Arm Score	Wrist 1 · Lower Arm 1	Wrist 1 · Lower Arm 2	Wrist 2 · Lower Arm 1	Wrist 2 · Lower Arm 2	Wrist 3 · Lower Arm 1	Wrist 3 · Lower Arm 2
1	1	1	2	1	2	3
2	1	2	3	2	(3)	4
3	3	3	4	5	4	5
4	4	4	5	5	5	6
5	6	7	8	7	8	8
6	7	8	8	8	9	9

Table C

Score A \ Score B	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
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	11	11	12	12	12	12
10	10	10	10	11	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: 4 + Activity Score: 2 = REBA Score: 6

B. Arm and Wrist Analysis

Step 7: Locate Upper Arm Position — Step 7a: Adjust... If shoulder is raised: +1 If upper arm is abducted: +1 If arm is supported or person is leaning: -1 — Upper Arm Score: 2

Step 8: Locate Lower Arm Position — Lower Arm Score: 2

Step 9: Locate Wrist Position — Step 9a: Adjust... If wrist is bent from midline or twisted : Add +1 — Wrist Score: 2

Step 10: Look-up Posture Score in Table B — Using values from steps 7-9 above, locate score in Table B — Posture Score B: 3

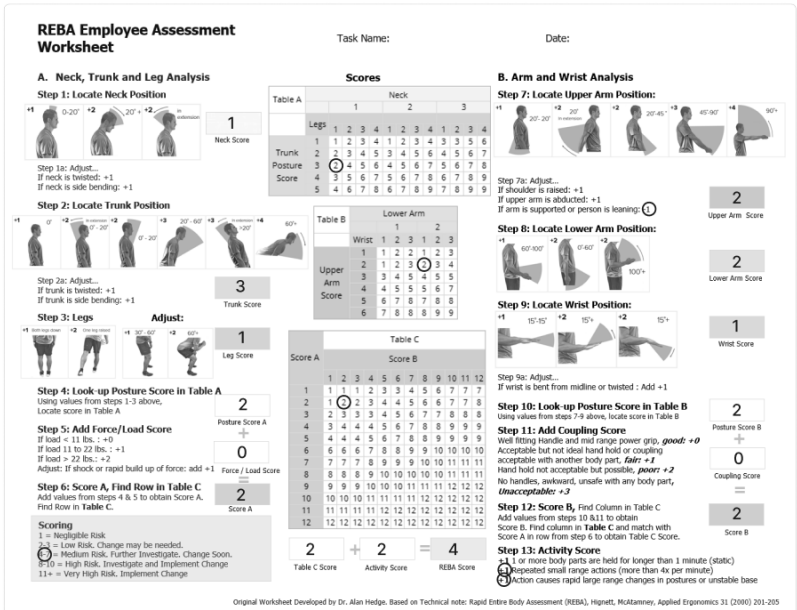
Step 11: Add Coupling Score — Well fitting Handle and mid range power grip, *good: +0* Acceptable but not ideal hand hold or coupling acceptable with another body part, *fair: +1* Hand hold not acceptable but possible, *poor: +2* No handles, awkward, unsafe with any body part, *Unacceptable: +3* — Coupling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

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: 3

Step 13: Activity Score — +1 1 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

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

Reba 10: During the task of unloading the lower basket of the dishwasher. Done on a raised dishwasher.



REBA Employee Assessment Worksheet

Task Name: Date:

A. Neck, Trunk and Leg Analysis

Step 1: Locate Neck Position — Neck Score: 1

Step 1a: Adjust... If neck is twisted: +1 If neck is side bending: +1

Step 2: Locate Trunk Position — Trunk Score: 3

Step 2a: Adjust... If trunk is twisted: +1 If trunk is side bending: +1

Step 3: Legs — Adjust: — Leg Score: 1

Step 4: Look-up Posture Score in Table A — Using values from steps 1-3 above, Locate score in Table A — Posture Score A: 2

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: 0

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: 2

Scoring: 1 = Negligible Risk; 2-3 = Low Risk. Change may be needed.; 4-5 = Medium Risk. Further Investigate. Change Soon.; 6-10 = High Risk. Investigate and Implement Change; 11+ = Very High Risk. Implement Change

Scores

Table A

Trunk Posture Score	Neck 1 · Legs 1	Neck 1 · Legs 2	Neck 1 · Legs 3	Neck 1 · Legs 4	Neck 2 · Legs 1	Neck 2 · Legs 2	Neck 2 · Legs 3	Neck 2 · Legs 4	Neck 3 · Legs 1	Neck 3 · Legs 2	Neck 3 · Legs 3	Neck 3 · Legs 4
1	1	2	3	4	1	2	3	4	3	3	5	6
2	2	3	4	5	3	4	5	6	4	5	6	7
3	(3)	4	5	6	4	5	6	7	5	6	7	8
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

Upper Arm Score	Wrist 1 · Lower Arm 1	Wrist 1 · Lower Arm 2	Wrist 2 · Lower Arm 1	Wrist 2 · Lower Arm 2	Wrist 3 · Lower Arm 1	Wrist 3 · Lower Arm 2
1	1	1	2	1	2	3
2	1	(2)	3	2	3	4
3	3	3	4	5	4	5
4	4	4	5	5	5	6
5	6	7	8	7	8	8
6	7	8	8	8	9	9

Table C

Score A \ Score B	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	(2)	2	3	4	4	5	6	6	7	7	8
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	11	11	12	12	12	12
10	10	10	10	11	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: 2 + Activity Score: 2 = REBA Score: 4

B. Arm and Wrist Analysis

Step 7: Locate Upper Arm Position — Step 7a: Adjust... If shoulder is raised: +1 If upper arm is abducted: +1 If arm is supported or person is leaning: (1) — Upper Arm Score: 2

Step 8: Locate Lower Arm Position — Lower Arm Score: 2

Step 9: Locate Wrist Position — Step 9a: Adjust... If wrist is bent from midline or twisted : Add +1 — Wrist Score: 1

Step 10: Look-up Posture Score in Table B — Using values from steps 7-9 above, locate score in Table B — Posture Score B: 2

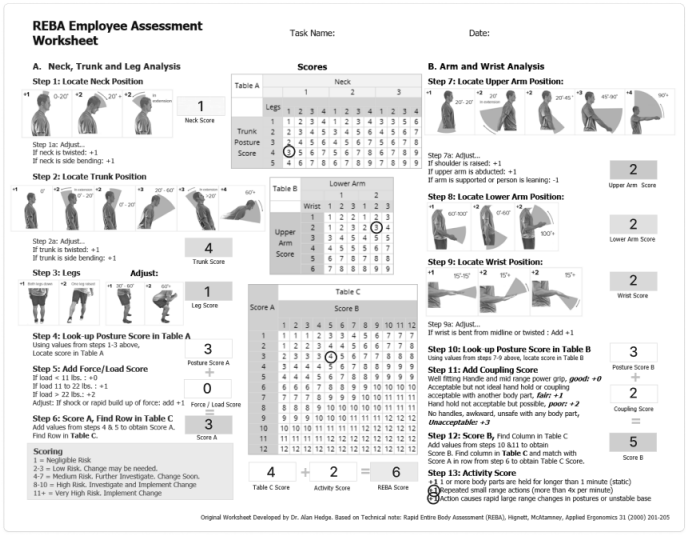
Step 11: Add Coupling Score — Well fitting Handle and mid range power grip, *good: +0* Acceptable but not ideal hand hold or coupling acceptable with another body part, *fair: +1* Hand hold not acceptable but possible, *poor: +2* No handles, awkward, unsafe with any body part, *Unacceptable: +3* — Coupling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

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: 2

Step 13: Activity Score — +1 1 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

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

Reba 11: During the task of unloading the lower basket of the dishwasher. Done on a dishwasher on floor height.



REBA Employee Assessment Worksheet

Task Name: Date:

A. Neck, Trunk and Leg Analysis

Step 1: Locate Neck Position — Neck Score: 1

Step 1a: Adjust... If neck is twisted: +1 If neck is side bending: +1

Step 2: Locate Trunk Position — Trunk Score: 4

Step 2a: Adjust... If trunk is twisted: +1 If trunk is side bending: +1

Step 3: Legs Adjust: — Leg Score: 1

Step 4: Look-up Posture Score in Table A — Posture Score A: 3

Using values from steps 1-3 above, Locate score in Table A

Step 5: Add Force/Load Score — Force / Load Score: 0

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

Step 6: Score A, Find Row in Table C — Score A: 3

Add values from steps 4 & 5 to obtain Score A. Find Row in **Table C**.

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

Scores

Table A

Legs \ Neck	1	2	3
Trunk Posture Score 1	1	2	3
Trunk Posture Score 2	2	3	4
Trunk Posture Score 3	3	4	5
Trunk Posture Score 4	4	5	6
Trunk Posture Score 5	5	6	7

Table B

Upper Arm \ Lower Arm / Wrist	1 / 1	1 / 2	2 / 1	2 / 2
1	1	2	2	3
2	2	3	3	4
3	3	4	4	5
4	4	5	5	6
5	5	6	6	7
6	7	8	8	9

Table C

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

4 (Table C Score) + 2 (Activity Score) = 6 (REBA Score)

B. Arm and Wrist Analysis

Step 7: Locate Upper Arm Position — Upper Arm Score: 2

Step 7a: Adjust... If shoulder is raised: +1 If upper arm is abducted: +1 If arm is supported or person is leaning: -1

Step 8: Locate Lower Arm Position — Lower Arm Score: 2

Step 9: Locate Wrist Position — Wrist Score: 2

Step 9a: Adjust... If wrist is bent from midline or twisted : Add +1

Step 10: Look-up Posture Score in Table B — Posture Score B: 3

Using values from steps 7-9 above, locate score in Table B

Step 11: Add Coupling Score — Coupling Score: 2

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***

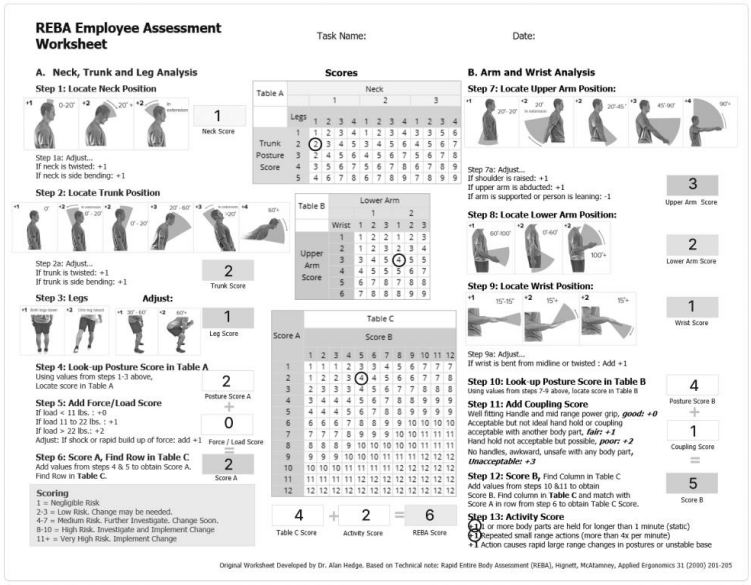
Step 12: Score B_1 Find Column in Table C — Score B: 5

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.

Step 13: Activity Score
+1 1 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

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

Reba 12: During the task of loading the lower basket of a dishwasher. Done on a raised dishwasher.



REBA Employee Assessment Worksheet

Task Name: Date:

A. Neck, Trunk and Leg Analysis

Step 1: Locate Neck Position — Neck Score: 1

Step 1a: Adjust... If neck is twisted: +1 If neck is side bending: +1

Step 2: Locate Trunk Position — Trunk Score: 2

Step 2a: Adjust... If trunk is twisted: +1 If trunk is side bending: +1

Step 3: Legs Adjust: — Leg Score: 1

Step 4: Look-up Posture Score in Table A — Posture Score A: 2

Using values from steps 1-3 above, Locate score in Table A

Step 5: Add Force/Load Score — Force / Load Score: 0

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

Step 6: Score A, Find Row in Table C — Score A: 2

Add values from steps 4 & 5 to obtain Score A. Find Row in **Table C**.

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

Scores

Table A

Legs \ Neck	1	2	3
Trunk Posture Score 1	1	2	3
Trunk Posture Score 2	2	3	4
Trunk Posture Score 3	3	4	5
Trunk Posture Score 4	4	5	6
Trunk Posture Score 5	5	6	7

Table B

Upper Arm \ Lower Arm / Wrist	1 / 1	1 / 2	2 / 1	2 / 2
1	1	2	2	3
2	2	3	3	4
3	3	4	4	5
4	4	5	5	6
5	5	6	6	7
6	7	8	8	9

Table C

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

4 (Table C Score) + 2 (Activity Score) = 6 (REBA Score)

B. Arm and Wrist Analysis

Step 7: Locate Upper Arm Position — Upper Arm Score: 3

Step 7a: Adjust... If shoulder is raised: +1 If upper arm is abducted: +1 If arm is supported or person is leaning: -1

Step 8: Locate Lower Arm Position — Lower Arm Score: 2

Step 9: Locate Wrist Position — Wrist Score: 1

Step 9a: Adjust... If wrist is bent from midline or twisted : Add +1

Step 10: Look-up Posture Score in Table B — Posture Score B: 4

Using values from steps 7-9 above, locate score in Table B

Step 11: Add Coupling Score — Coupling Score: 1

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***

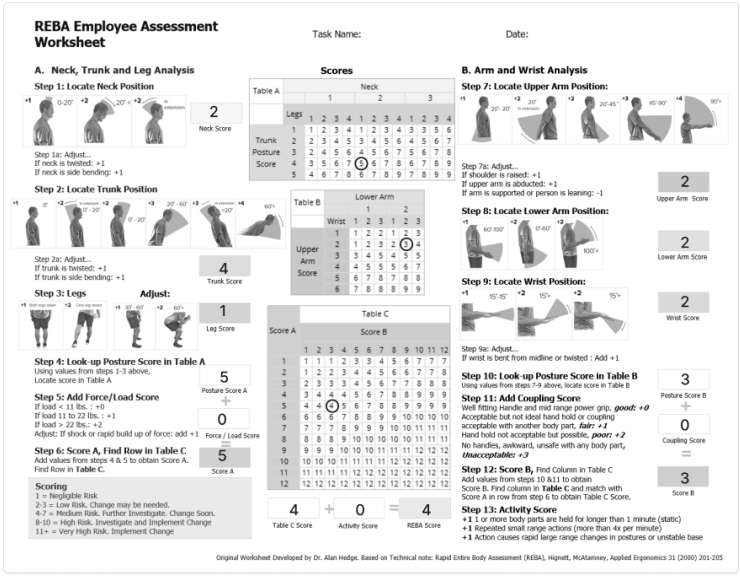
Step 12: Score B_1 Find Column in Table C — Score B: 5

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.

Step 13: Activity Score
+1 1 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

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

Reba 13: During the task of loading detergent. Done on a dishwasher on floor height.



REBA Employee Assessment Worksheet

Task Name: Date:

A. Neck, Trunk and Leg Analysis

Step 1: Locate Neck Position — Neck Score: 2

Step 1a: Adjust...
If neck is twisted: +1
If neck is side bending: +1

Step 2: Locate Trunk Position — Trunk Score: 4

Step 2a: Adjust...
If trunk is twisted: +1
If trunk is side bending: +1

Step 3: Legs — Adjust: — Leg Score: 1

Step 4: Look-up Posture Score in Table A
Using values from steps 1-3 above, Locate score in Table A — Posture Score A: 5

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: 0

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: 5

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

Scores

Table A

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

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

Table C

Score A \ Score B	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
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	11	11	11	11
9	9	9	9	10	10	11	11	11	11	12	12	12
10	10	10	10	11	11	11	12	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: 4 + Activity Score: 0 = REBA Score: 4

B. Arm and Wrist Analysis

Step 7: Locate Upper Arm Position — Upper Arm Score: 2

Step 7a: Adjust...
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Step 8: Locate Lower Arm Position — Lower Arm Score: 2

Step 9: Locate Wrist Position — Wrist Score: 2

Step 9a: Adjust...
If wrist is bent from midline or twisted : Add +1

Step 10: Look-up Posture Score in Table B — Posture Score B: 3
Using values from steps 7-9 above, locate score in Table B

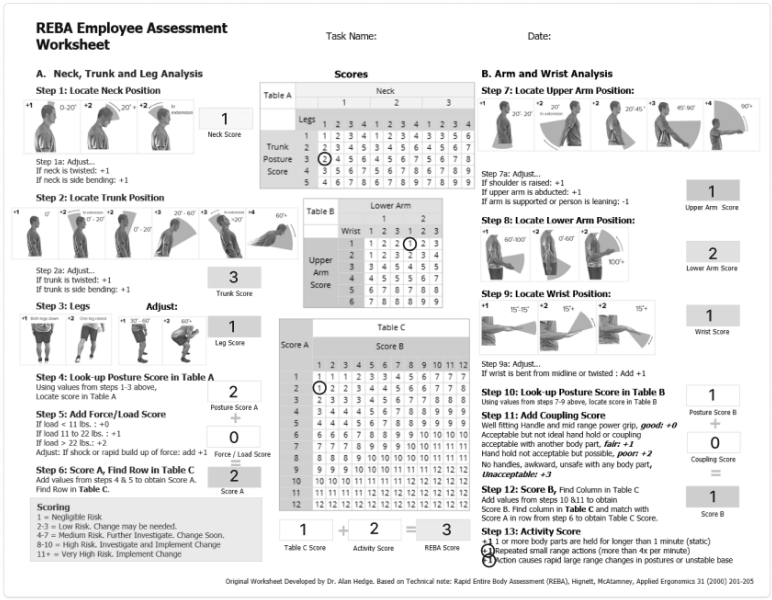
Step 11: Add Coupling Score — Coupling Score: 0
Well fitting Handle and mid range power grip, ***good: +0***
Acceptable but not ideal hand hold or coupling acceptable with another body part, ***fair: +1***
Hand hold not acceptable but possible, ***poor: +2***
No handles, awkward, unsafe with any body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

Step 12: Score B, Find Column in Table C — Score B: 3
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.

Step 13: Activity Score
+1 1 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

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

Reba 14: During the task of unloading the lower basket of the dishwasher. Done on a raised dishwasher.



REBA Employee Assessment Worksheet

Task Name: Date:

A. Neck, Trunk and Leg Analysis

Step 1: Locate Neck Position — Neck Score: 1

Step 1a: Adjust...
If neck is twisted: +1
If neck is side bending: +1

Step 2: Locate Trunk Position — Trunk Score: 3

Step 2a: Adjust...
If trunk is twisted: +1
If trunk is side bending: +1

Step 3: Legs — Adjust: — Leg Score: 1

Step 4: Look-up Posture Score in Table A
Using values from steps 1-3 above, Locate score in Table A — Posture Score A: 2

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: 0

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: 2

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

Scores

Table A

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

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

Table C

Score A \ Score B	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
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	11	11	11	11
9	9	9	9	10	10	10	11	11	11	12	12	12
10	10	10	10	11	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: 1 + Activity Score: 2 = REBA Score: 3

B. Arm and Wrist Analysis

Step 7: Locate Upper Arm Position — Upper Arm Score: 1

Step 7a: Adjust...
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Step 8: Locate Lower Arm Position — Lower Arm Score: 2

Step 9: Locate Wrist Position — Wrist Score: 1

Step 9a: Adjust...
If wrist is bent from midline or twisted : Add +1

Step 10: Look-up Posture Score in Table B — Posture Score B: 1
Using values from steps 7-9 above, locate score in Table B

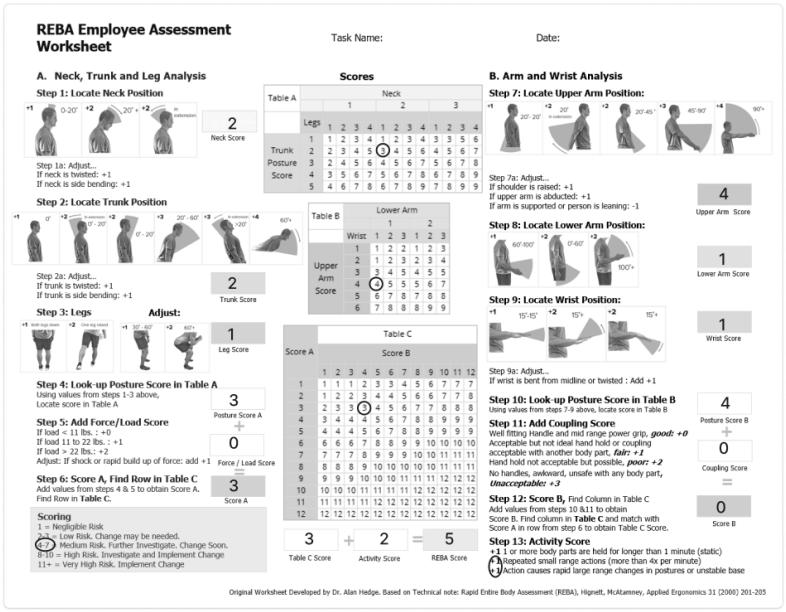
Step 11: Add Coupling Score — Coupling Score: 0
Well fitting Handle and mid range power grip, ***good: +0***
Acceptable but not ideal hand hold or coupling acceptable with another body part, ***fair: +1***
Hand hold not acceptable but possible, ***poor: +2***
No handles, awkward, unsafe with any body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

Step 12: Score B, Find Column in Table C — Score B: 1
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.

Step 13: Activity Score
+1 1 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

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

Reba 15: During the task of loading the upper basket of the dishwasher. Done on a raised dishwasher.



REBA Employee Assessment Worksheet

Task Name:

Date:

A. Neck, Trunk and Leg Analysis

Step 1: Locate Neck Position

Step 1a: Adjust...
If neck is twisted: +1
If neck is side bending: +1

2 Neck Score

Step 2: Locate Trunk Position

Step 2a: Adjust...
If trunk is twisted: +1
If trunk is side bending: +1

2 Trunk Score

Step 3: Legs

Adjust:

1 Leg Score

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

3 Posture Score A

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

0 Force / Load Score

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

3 Score A

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

Scores

Table A

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

Table B

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

Table C

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

3 Table C Score + 2 Activity Score = 5 REBA Score

B. Arm and Wrist Analysis

Step 7: Locate Upper Arm Position:

Step 7a: Adjust...
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

4 Upper Arm Score

Step 8: Locate Lower Arm Position:

1 Lower Arm Score

Step 9: Locate Wrist Position:

1 Wrist Score

Step 9a: Adjust...
If wrist is bent from midline or twisted : Add +1

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

4 Posture Score B

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***

0 Coupling Score

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.

0 Score B

Step 13: Activity Score
+1 1 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

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

Appendix 8: PEPA

TP1 floor height

Physical Ergonomics Product Assessment (PEPA)	Steg 1: Öppna dörren	Steg 2: Dra ut underkorg	Steg 3: Dra ut överkorg	Steg 4: Ställ ner disk under korg	Steg 5: Ställ ner disk över korg	Steg 6: Placera bestick	Steg 7: Lägg in diskmedel	Steg 8: Stäng dörr	Steg 9: Dra ut full underkorg	Steg 10: Plocka ur disk ur underkorg	Steg 11: Dra ut full överkorg	Steg 12: Plocka ur överkorg	Steg 13: Plocka ur bestick
(1) Hantering (Hålla, Förflytta, Impuls, Fånga)	impuls	förflytta	förflytta	förflytta	förflytta	förflytta	förflytta	impuls	förflytta	förflytta	förflytta	förflytta	förflytta
(2) Styrka	l	l	l	l	l	l	l	l	l	l	l	l	l
(3) Precision	l	l	l	m	m	h	m	l	l	m	l	m	m
(4) Uthållighet	l	l	l	m	l	l	l	l	l	m	l	l	l
(5) Grepp	l	l	l	l	l	l	l	l	l	l	l	l	l
(6a) Nacke	l	l	l	l	l	l	l	l	l	l	l	m	l
(6b) Axlar/Skuldror	l	l	l	l	l	l	l	l	l	l	l	l	l
(6c) Arm/armbåge	l	l	l	l	l	l	l	l	l	l	l	l	l
(6d) Hand/ handled	l	l	l	l	l	l	l	l	l	l	l	l	l
(6e) Fingrar	m	l	l	l	l	l	l	l	l	l	l	l	l
(6f) Rygg	m	m	l	m	l	l	m	l	l	m	l	l	l
(6g) Ben/ knä	l	l	l	l	l	l	l	l	l	l	l	l	l
(6h) Fot/fotled	l	l	l	l	l	l	l	l	l	l	l	l	l
(7) Yttre omständigheter				Kladdig disk	Kladdig disk	Kladdig disk			Blött och varmt	Blött och varmt	Blött och varmt	Blött och varmt	Blött och varmt

Tp1 Raised dishwasher

Physical Ergonomics Product Assessment (PEPA)	Steg 1: Öppna dörren	Steg 2: Dra ut underkorg	Steg 3: Dra ut överkorg	Steg 4: Ställ ner disk underkorg	Steg 5: Ställ ner disk över korg	Steg 6: Placera bestick	Steg 7: Lägg in diskmedel	Steg 8: Stäng dörr	Steg 9: Dra ut full underkorg	Steg 10:Plocka ur disk ur underkorg	Steg 11: Dra ut full överkorg	Steg 12: Plocka ur disk ur överkorg	Steg 13: Plocka ur bestick
(1) Hantering (Hålla, Förflytta, Impuls, Fånga)	förflytta	förflytta	förflytta	förflytta	förflytta	förflytta	förflytta	förflytta, impuls	förflytta	förflytta	förflytta	förflytta	förflytta
(2) Styrka	l	l	l	l	l	l	l	l	l	l	l	l	l
(3) Precision	l	l	l	m	m	h	m	l	l	m	l	m	m
(4) Uthållighet	l	l	l	l	l	l	l	l	l	l	l	l	l
(5) Grepp	h	l	l	l	l	l	l	l	l	l	l	l	l
(6a) Nacke	l	l	l	l	l	l	l	l	l	l	l	l	l
(6b) Axlar/Skuldror	l	l	l	l	l	l	l	l	l	l	l	l	l
(6c) Arm/armbåge	l	l	l	l	l	l	l	l	l	l	l	l	l
(6d) Hand/ handled	l	l	l	l	l	l	l	l	l	l	l	l	l
(6e) Fingrar	m	l	l	l	l	l	l	l	l	l	l	l	l
(6f) Rygg	l	l	l	l	l	l	l	l	l	l	l	l	l
(6g) Ben/ knä	l	l	l	l	l	l	l	l	l	l	l	l	l
(6h) Fot/fotled	l	l	l	l	l	l	l	l	l	l	l	l	l
(7) Yttre omständigheter				Kladdig disk	Kladdig disk	Kladdig disk			Blött och varmt	Blött och varmt	Blött och varmt	Blött och varmt	Blött och varmt

TP3 Floor height

Physical Ergonomics Product Assessment (PEPA)	Steg 1: Öppna dörren	Steg 2: Dra ut underkorg	Steg 3: Dra ut överkorg	Steg 4: Ställ ner disk under korg	Steg 5: Ställ ner disk över korg	Steg 6: Placera bestick	Steg 7: Lägg in diskmedel	Steg 8: Stäng dörr	Steg 9: Dra ut full underkorg	Steg 10: Plocka ur disk ur underkorg	Steg 11: Dra ut full överkorg	Steg 12: Plocka ur överkorg	Steg 13: Plocka ur bestick
(1) Hantering (Hålla, Förflytta, Impuls, Fånga)	impuls	förflytta	förflytta	förflytta	förflytta	förflytta	förflytta	impuls	förflytta	förflytta	förflytta	förflytta	förflytta
(2) Styrka	l	l	l	l	l	l	l	l	l	l	l	l	l
(3) Precision	l	l	l	m	m	h	m	l	l	m	l	m	m
(4) Uthållighet	l	l	l	m	m	l	l	l	l	m	l	l	l
(5) Grepp	l	l	l	l	l	l	l	l	l	l	l	l	l
(6a) Nacke	l	l	l	l	l	l	l	l	l	l	l	l	l
(6b) Axlar/Skuldror	l	l	l	l	l	l	l	l	l	l	l	l	l
(6c) Arm/armbåge	l	l	l	l	l	l	l	l	l	l	l	l	l
(6d) Hand/ handled	l	l	l	l	l	l	l	l	l	l	l	l	l
(6e) Fingrar	l	l	l	l	l	l	l	l	l	l	l	l	l
(6f) Rygg	l	m	l	m	m	l	l	l	l	m	l	l	m
(6g) Ben/ knä	l	m	l	m	l	l	m	m	l	m	l	l	l
(6h) Fot/fotled	l	l	l	l	l	l	l	l	l	l	l	l	l
(7) Yttre omständigheter				Kladdig disk	Kladdig disk	Kladdig disk			Blött och varmt	Blött och varmt	Blött och varmt	Blött och varmt	Blött och varmt

Tp3 Raised dishwasher

Physical Ergonomics Product Assessment (PEPA)	Steg 1: Öppna dörren	Steg 2: Dra ut underkorg	Steg 3: Dra ut överkorg	Steg 4: Ställ ner disk underkorg	Steg 5: Ställ ner disk över korg	Steg 6: Placera bestick	Steg 7: Lägg in diskmedel	Steg 8: Stäng dörr	Steg 9: Dra ut full underkorg	Steg 10:Plocka ur disk ur underkorg	Steg 11: Dra ut full överkorg	Steg 12: Plocka ur disk ur överkorg	Steg 13: Plocka ur bestick
(1) Hantering (Hålla, Förflytta, Impuls, Fånga)	förflytta	förflytta	förflytta	förflytta	förflytta	förflytta	förfltrra	förfölyyta	förflytta	förflytta	förflytta	förflytta	förflytta
(2) Styrka	l	l	l	l	l	l	l	l	l	l	l	l	l
(3) Precision	l	l	l	m	m	h	m	l	l	m	l	m	m
(4) Uthållighet	l	l	l	l	m	l	l	l	l	l	l	l	l
(5) Grepp	h	l	l	l	l	l	l	l	l	l	l	l	l
(6a) Nacke	l	l	l	l	l	l	l	l	l	l	l	l	l
(6b) Axlar/Skuldror	l	l	l	l	l	l	l	l	l	l	l	l	l
(6c) Arm/armbåge	l	l	l	l	l	l	l	l	l	l	l	l	l
(6d) Hand/ handled	l	l	l	l	l	l	l	l	l	l	l	l	l
(6e) Fingrar	m	l	l	l	l	l	l	l	l	l	l	l	l
(6f) Rygg	l	l	l	l	l	l	l	l	l	l	l	l	l
(6g) Ben/ knä	l	l	l	l	l	l	l	l	l	l	l	l	l
(6h) Fot/fotled	l	l	l	l	l	l	l	l	l	l	l	l	l
(7) Yttre omständigheter				Kladdig disk	Kladdig disk	Kladdig disk			Blött och varmt	Blött och varmt	Blött och varmt	Blött och varmt	Blött och varmt

Tp5 Floor height

Physical Ergonomics Product Assessment (PEPA)	Steg 1: Öppna dörren	Steg 2: Dra ut underkorg	Steg 3: Dra ut överkorg	Steg 4: Ställ ner disk under korg	Steg 5: Ställ ner disk över korg	Steg 6: Placera bestick	Steg 7: Lägg in diskmedel	Steg 8: Stäng dörr	Steg 9: Dra ut full underkorg	Steg 10: Plocka ur disk ur underkorg	Steg 11: Dra ut full överkorg	Steg 12: Plocka ur överkorg	Steg 13: Plocka ur bestick
(1) Hantering (Hålla, Förflytta, Impuls, Fånga)	impuls	förflytta	förflytta	förflytta	förflytta	förflytta	förflytta	impuls	förflytta	förflytta	förflytta	förflytta	förflytta
(2) Styrka	l	l	l	l	l	l	l	l	l	l	l	l	l
(3) Precision	l	l	l	m	m	h	m	l	l	m	l	m	m
(4) Uthållighet	l	l	l	m	l	l	l	l	l	m	l	l	l
(5) Grepp	l	l	l	l	l	l	l	l	l	l	l	l	l
(6a) Nacke	l	l	l	l	l	l	l	l	l	l	l	l	l
(6b) Axlar/Skuldror	l	l	l	l	l	l	l	l	l	l	l	l	l
(6c) Arm/armbåge	l	l	l	l	l	l	l	l	l	l	l	l	l
(6d) Hand/ handled	l	l	l	l	l	l	l	l	l	l	l	m	l
(6e) Fingrar	m	l	l	l	l	l	l	l	l	l	l	l	l
(6f) Rygg	m	m	l	m	l	l	m	m	m	m	l	l	l
(6g) Ben/ knä	l	l	l	l	l	l	l	l	l	l	l	l	l
(6h) Fot/fotled	l	l	l	l	l	l	l	l	l	l	l	l	l
(7) Yttre omständigheter				Kladdig disk	Kladdig disk	Kladdig disk			Blött och varmt	Blött och varmt	Blött och varmt	Blött och varmt	Blött och varmt

Tp5 Raised dishwahser

Physical Ergonomics Product Assessment (PEPA)	Steg 1: Öppna dörren	Steg 2: Dra ut underkorg	Steg 3: Dra ut överkorg	Steg 5: Ställ ner disk underkorg	Steg 4: Ställ ner disk över korg	Steg 6: Placera bestick	Steg 7: Lägg in diskmedel	Steg 8: Stäng dörr	Steg 9: Dra ut full underkorg	Steg 10:Plocka ur disk ur underkorg	Steg 11: Dra ut full överkorg	Steg 12: Plocka ur disk ur överkorg	Steg 13: Plocka ur bestick
(1) Hantering (Hålla, Förflytta, Impuls, Fånga)	förflytta	förflytta	förflytta	förflytta	förflytta	förflytta	förflytta	förflytta, impuls	förflytta	förflytta	förflytta	förflytta	förflytta
(2) Styrka	l	l	l	l	l	l	l	l	l	l	l	l	l
(3) Precision	l	l	l	m	m	h	m	l	l	m	l	m	m
(4) Uthållighet	l	l	l	l	l	m	l	l	l	l	l	l	l
(5) Grepp	l	l	l	l	l	l	l	l	l	l	l	l	l
(6a) Nacke	l	l	l	l	m	l	l	l	l	l	l	l	l
(6b) Axlar/Skuldror	l	l	l	l	l	m	l	l	l	l	l	l	l
(6c) Arm/armbåge	l	l	l	l	l	l	l	l	l	l	l	l	l
(6d) Hand/ handled	l	l	l	l	l	l	l	l	l	l	l	l	l
(6e) Fingrar	l	l	l	l	l	l	l	l	l	l	l	l	l
(6f) Rygg	l	l	l	l	l	l	l	l	l	l	l	l	l
(6g) Ben/ knä	l	l	l	l	l	l	l	l	l	l	l	l	l
(6h) Fot/fotled	l	l	l	l	l	l	l	l	l	l	l	l	l
(7) Yttre omständigheter				Kladdig disk	Kladdig disk	Kladdig disk			Blött och varmt	Blött och varmt	Blött och varmt	Blött och varmt	Blött och varmt

Appendix 9: Pugh matrix

Below, a complete account of the Pugh matrix is shown, including "+" if performing better than the current ASKO dishwasher, "-" if performing worse and "0" if no change is made. Comments are also included.

Requirements	Door lift	Angled door	Scissor lift	Scissor lift + reach top basket	Toolbox	Rotation	Modular baskets
Be robust	? / (-) hävstångseffekt/ stor belastning där den ska lyftas	(-) Endast stöd kant i kant. Kommer ej se robust ut för användaren	(+)	(+)	(?) parallellarmar	(+)	(+) /? kan upplevas mer robust om det är starkare än piggar
Provide adequate space	0	0	? / (-) hur stor plats tar funktionen av saxliften?	? / (-) hur stor plats tar funktionen av saxliften?	(-) hur stor plats tar funktionen av uppfällningen, samt den är delad på 2.	(-) korgarna blir mindre	0
Provide automated functions	(+) om den är automatiskt	(+)	(+)	(+)	(+)	(+)	(+)
Be adjustable	(+)	(+)	(+)	(+)	(+)	(+)	0
Running quiet	0	0	0	0	0	0	0
Clean dishes	0	0	0	0	0	0	0
Be compatible with standard measurements	0	0	0	0	0	0	0
Emotional requirements							
Not to feel overwhelmed	(?)	(?)	(?)	(?)	(?)	(?)	(?) kanske + för att man jobbar med en låda i taget, kanske - pga planera
Trust the functionality	0	-	0	0	- känns rangligt	- (vi har testat konstruktion - blir svajigt)	0
Feel effective	(+)	(+)	(+)	(+)	- kanske ej når allt och måste gå runt	- (måste alltid rotera för att nå disk)	(+) förvaringen och urplockningen gör det effektivt, men ej om man ej förstår
Recognize the technology	(+)	-	(+)	(+)	(+)	(+)	(+)
Understand the purpose of functions	(+)	-	(+)	(+)	(+)	-	(+)
Minimize frustration	(+)	(+)	(+)	(+)	- om det börjar droppa på golvet, och att den är uppdelad på 2, samt att man måste gå runt för att nå korgarna kan vara frustrerande	- på grund av att man måste rotera fram korgarna hela tiden	(+) /? hoppet är ja, men om det är krångligt att få plats / ändra form på korgarna kanske det känns jobbigt

Other user requirements							
Be fast to load and unload	(+)	(+)	(+)	(+)	- pga att man behöver gå runt för att nå	0	(+)
Physical ergonomics							
Minimize strain on back	(+)	(+)	(+)	(+)	(+) om du ej ska sträcka dig	(+)	(+) inte lika mycket bättre som de andra men ändå bättre
Provide a good work height	(+)	(+)	(+)	(+)	(+)	(+)	(+) när man väl tar ut korgen, ja
Minimize high precision work	0	0	0	0	0	0	(+) om man lägger in korgen direkt i skåpen, är den delen av pepan utan precision
Provide adequate grip	0	0	0	0	0	0	(+) bättre grepp än tallrikarna
Adapted for critical users	(+)	(+)	(+)	(+)	(+)	(+)	(+) framförallt med precision
Minimize awkward positions	(+)	(+)	(+)	(+)	(+)	(+)	(+) framförallt med kombination med ett korglyft. men också att man kommer upp på bra höjd och jobbar där uppe
Minimize repetitive workload	0 minimerar workloaden, men inte repetitioner	0 minimerar workloaden, men inte repetitioner	0 minimerar workloaden, men inte repetitioner	0 minimerar workloaden, men inte repetitioner	- kan leda till fler rörelser när man behöver gå runt diskmaskinen	0 minimerar workloaden, men inte repetitioner	(+) färre gånger ta upp korgar, men även att ej ta ut en och en till skåpet.
Cognitive ergonomics							
Reduce cognitive load	0	0	0	(+) lite bättre pga man har båda korgarna bredvid varandra och inte behöver tänka vilken av dem man ska börja plocka ur	- om det ej får plats med disken på ett bra sätt och att man måste gå runt och kolla	0	? kanske svårare med laddning om man ska planera vilka korgar som passar. men enklare vid urplock
Reduce risk of user error	0 om enkelt med knapp eller annat	- för att användaren kan koppla in korgen fel	0	0	0	0	0
Provide good visibility	(+)	(+)	(+)	(+)	(+)	(+)	(+) pga man kommer upp
Easy to organize	0	0	0	(+)	- (pga att den är uppdelad, och mindre sektioner)	0	(+) kan hända att man måste byta ut korgar.
Total score	12	5	12	15	1	4	14

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