The arm swing rollator:
An experimental redesign of the rollator for improved safety and ergonomics

Master Thesis

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Foreword

This report serves as the culmination of my graduation thesis for the Master's program in Integrated Product Design at TU Delft.

The project initially began with the broad idea of designing a product to support rehabilitation. During a visit to a rehabilitation centre for inspiration, my attention was unexpectedly drawn to a seemingly ordinary sight: a row of rollators lined up in the hallway. These rollators were used by patients during rehabilitation exercises and to navigate the facility. What struck me was the dated appearance of some of the designs—steel frames with metal baskets and oversized brake handles—still in regular use. This observation sparked my curiosity and inspired me to dedicate this project to rethinking rollator design and exploring potential improvements.

Embarking on this journey presented unique challenges. Without a direct client or predefined scope, I had to rely entirely on my own project definition and initiative. While the final conclusions of the project may not represent the clear-cut improvement I initially envisioned, the process taught me invaluable lessons. I am proud of the work I have accomplished and the personal and professional growth I have experienced along the way.

I would like to express my heartfelt gratitude to my supervisors, Arjen Jansen and Renate de Bruin, for their guidance and encouragement throughout this project. Their insights reminded me that no effort in design is ever wasted, as each step contributes to learning and growth.

The lessons from this project, combined with the knowledge and skills I have gained during my Bachelor's and Master's studies, have shaped me into the designer I am today. As I conclude this chapter, I feel ready to embark on my career as an industrial design engineer and look forward to discovering where this path will take me.

Puck van Boekel

November 28th, 2024

Summary

This report documents the development and evaluation of the arm swing rollator, an innovative redesign aimed at improving the safety and ergonomics of traditional rollators. Current rollators often limit natural arm movements, which are essential for stability during walking. The arm swing rollator addresses this limitation by enabling users to swing their arms naturally, mimicking a more natural gait pattern.

The project began with a review of existing rollator designs and an exploration of ergonomic and safety challenges faced by users. Literature indicates that arm swing plays a significant role in enhancing gait stability, particularly in older adults. However, minimal research exists on how rollators impact gait. The arm swing rollator was conceptualized to bridge this gap and tested experimentally for its potential benefits.

A prototype of the arm swing rollator was developed, though time constraints led to compromises in its design. Friction in the mechanism and the use of 3D-printed load-bearing components limited the prototype's performance and safety, restricting testing to young, healthy participants. To approximate the balance challenges faced by elderly users, participants wore balance distortion platforms during the tests. Stability was measured using the mediolateral Lyapunov exponent, derived from video-tracked upper body movement.

The validation tests produced unexpected results. Neither the arm swing rollator nor the traditional rollator showed significant improvements in stability compared to walking without a rollator. Possible reasons for these findings include limitations in the test setup, measurement inaccuracies, and prototype shortcomings. Despite this, participant feedback highlighted a perceived improvement in posture and support when using the arm swing rollator.

The report concludes that the arm swing rollator represents an experimental step forward in rollator design but requires further refinement and testing. Recommendations include improving the prototype's mechanism, ensuring safety for target users, and employing more accurate testing methods such as treadmill-based experiments and inertial measurement units. Future research could also explore additional rollator features to address user needs, such as enhanced braking systems, better terrain handling, and ergonomic resting solutions.

In summary, this project provides valuable insights into rollator design and testing, highlighting the potential for innovative walking aids to improve safety and quality of life for users. The findings underscore the need for continued research and development to fully realize the benefits of the arm swing rollator and similar concepts.

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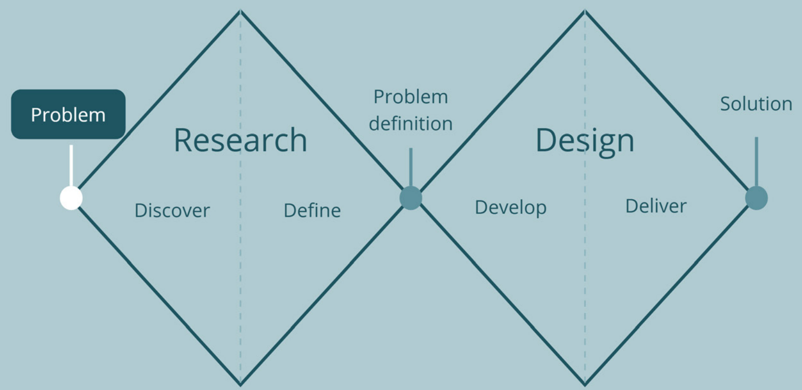
1. Introduction



In this chapter will be explained what the project assignment is, who the target group is and what the approach is to find a solution.

1.1 Project assignment

The rollator is a widely used walking aid in the Netherlands, with an estimated 750,000 in use across the country (Hoeveel rollators worden er in Nederland gebruikt?, n.d.). These devices play a crucial role in maintaining the mobility and independence of many individuals.

Despite its long-standing popularity, several questions have emerged over time: Why is the rollator designed the way it is? How does it enhance user mobility? And most importantly, can its safety and ergonomics be improved?

The aim of this project is to redesign the rollator to enhance both safety and personal ergonomics. A rollator with these improvements would not only contribute to the health and well-being of users but also increase their enjoyment of the device. Greater enjoyment could lead to increased rollator use, which, in turn, would boost physical activity and provide further health benefits.

1.2 Target group

The target group for this assignment is:

> **Individuals with mobility challenges choosing a rollator for support during walking.**

While this group primarily consists of elderly people, it also includes those rehabilitating from injuries or individuals with conditions that affect their mobility. Despite differences in age or underlying causes, these users share similar challenges: the need for a place to rest, stability while walking, and the ability to navigate uneven surfaces.

Elderly individuals, in particular, are more vulnerable to falls due to the multifactorial disturbances in their mobility. However, the redesigned rollator aims to expand beyond the “classic” view of rollator use, catering not only to elderly users but also to other groups, such as those who may want to walk faster, take larger steps, or experience fewer balance issues.

While the specific needs of non-elderly rollator users may differ, the final design will include features that accommodate a wide range of users. Though some features may not be essential for younger users, the rollator will still offer the same level of comfort and support, ensuring usability across diverse user groups.

1.3 Approach

The structure of this project follows the double diamond framework (Figure 1), which consists of four key phases. The process begins with identifying the problem, followed by the first diverging phase: the Discover phase. In this stage, the focus is on exploring and understanding all relevant issues, including the underlying causes and their ripple effects, like the expected problems with walking posture and ergonomics.

Next is the Define phase, a converging stage where the insights gathered from discovery are synthesized to pinpoint the key issues, resulting in a clear problem definition.

Following this is the second diverging stage: the Develop phase. Here, brainstorming and experimentation are used to generate a broad range of potential solutions.

Finally, in the Deliver phase, the focus shifts to converging once again, narrowing down to the most promising solution. This solution is then evaluated, ultimately leading to the optimal resolution of the identified problem.

The actions taken in each phase of this project, following the double diamond framework, are outlined as follows:

Problem
- Clearly explain and define the initial problem.

Discover
- Conduct research on the current rollator designs.
- Review relevant literature on rollators and the gait of elderly individuals.
- Perform field research by interviewing key stakeholders.

Define
- Analyse the findings from the Discover phase.
- Identify the key issues that need addressing.
- Problem definition
- Define the design goals.
- Outline requirements and wishes.

Develop
- Engage in brainstorming sessions using the “how to” method.
- Use a selection method to explore the best solutions.
- Develop and refine multiple design concepts.

Deliver
- Select the most promising concept.
- Develop the chosen concept into a detailed embodiment of the product.
- Validate the product through testing and evaluation.

Solution
- Conclude by presenting the results of this project.

At the start of each chapter, the relevant phase of the double diamond process will be highlighted, as demonstrated at the beginning of this chapter.

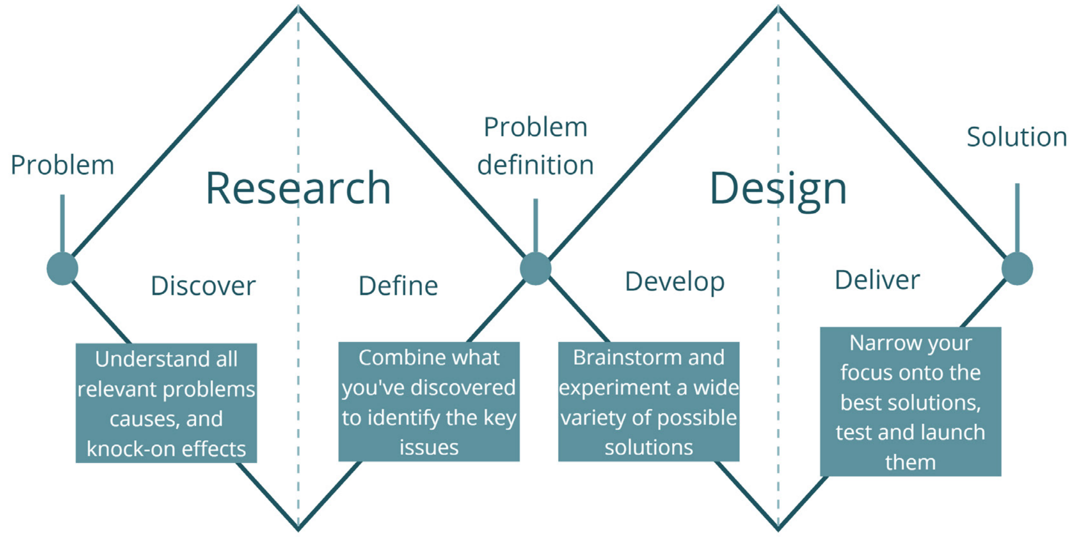
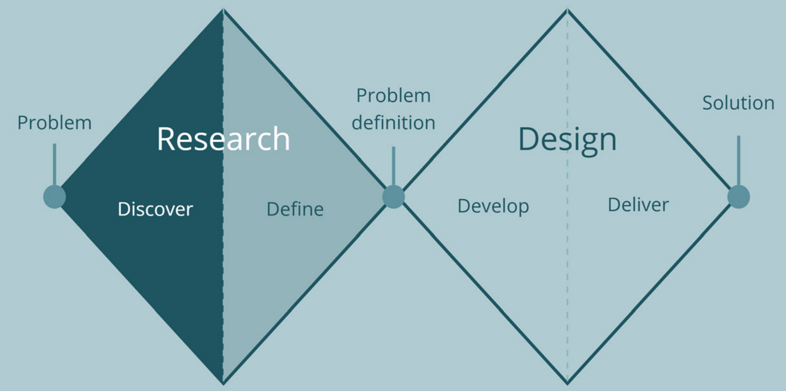


Figure 1 - Double diamond structure

2. The rollator



In this chapter will give more insight into the rollator by explaining what the origin of the first rollator is, what kind of rollators are currently sold, the expenses of buying a rollators and what stakeholders of rollators there are and their influence on rollators.

2.1 History

The rollator was invented in 1978 by Aina Wifalk (Figure 2). After contracting poliomyelitis, her ability to walk gradually declined, and she found that the four-legged walkers commonly used at the time did not meet her needs. In response, Wifalk set out to design a more effective walking aid. Her design improved stability, incorporated larger wheels for smoother movement, added brakes for better control, and introduced a seat or storage surface for convenience. She also ensured that the rollator could be used both indoors and outdoors.

Notably, Wifalk chose not to patent her design, aiming to make the rollator accessible to as many people as possible. The basic features of her original design can still be seen in the widely used “classic” rollator today (Figure 3), but it is worth exploring what has changed since then—and why certain elements have remained unchanged.

Figure 2 - The first rollator (innovation-the-swedish-way_rollator.pdf, n.d.)

Figure 3 - A “classic” rollator (rollator standaard, n.d.)

2.2 Current rollators

The evolution of rollators since Aina Wifalk’s original design has introduced several changes, though the basic concept remains recognizable. By comparing Wifalk’s first rollator to those currently available, both modifications and enduring similarities become evident.

While today’s rollators have evolved, many key features from the original design remain, such as the four wheels, basket, seat, and hand grips (Figure 4). However, some aspects have been refined: hand grips have become more ergonomically shaped, and advanced braking systems have been added. Despite these improvements, one feature that has remained relatively unchanged is the limited adjustability to accommodate different body sizes. Although the height of the hand grips can be adjusted, other components—such as the seat and frame—are typically fixed, limiting personalization for diverse users.

Contemporary rollators exhibit various small design variations. They are manufactured from different materials, ranging from aluminum to carbon fiber, resulting in differences in weight. Additionally, rollators vary in their folding capabilities—some only allow the rear wheels to fold inward, while others can be fully collapsed for compact storage. Other distinctions include the presence or absence of backrests.

Figure 4 - Modern rollator (rollator Esprit S4 kopen? | Vegro, n.d.)

Figure 5 - 3 Wheeled rollator (Rollator Delta Chroom—3 wiel rollator, n.d.)

Figure 6 - Forearm supported rollator (Mobilex—rollator—tiger outdoor—bruin—navigator air | bol, n.d.)

To enhance functionality, users can also purchase a variety of accessories tailored to their specific needs, such as grocery bags, walking stick holders, trays, umbrellas, and cup holders. These accessories offer some degree of personalization to the traditional rollator design.

Beyond the common four-wheeled rollators, alternative designs are also available. Three-wheeled rollators (Figure 5) are predominantly used indoors, while forearm-supported rollators (Figure 6) are designed for users who cannot put weight on their wrists.

In summary, while current rollators bear a strong resemblance to Wifalk’s original design, they also differ in certain aspects from both the original and from each other. These differences show efforts for innovating the rollator. This provides an opening to redesign the rollator in innovative ways that respect the traditional concept while offering improvements in safety, comfort, and adaptability.

2.3 Expenses

2.3.1 Price

The cost of a rollator varies based on several factors, including the brand, design, materials, and additional features. An analysis of the prices from four major retailers (Vergo, Medipoint, Thuiszorgwinkel XL, and Rollatorwinkel.com; see Appendix A) in November 2024 revealed that the average price for the most affordable rollator offered by each web shop was €115,75. In contrast, the most expensive model offered by each web shop averaged €727,50. This substantial price difference, approximately €600, is primarily due to the use of higher-cost materials, such as carbon fibre instead of aluminium, and the inclusion of more complex mechanisms, such as those designed to enhance portability by allowing the rollator to fold more compactly for transportation.

2.3.2 Health insurance

In the Netherlands, basic health insurance does not cover standard mobility aids such as rollators, crutches, or walkers. Individuals are responsible for purchasing or renting these devices independently. While some supplementary insurance plans may provide coverage for mobility aids, this is typically limited to specialized models. For instance, a rollator designed specifically for individuals with Parkinson’s disease may be covered if prescribed by a healthcare professional.

2.4 Stakeholders

A stakeholder diagram has been created to identify and understand the key groups that could influence the design of a rollator (Figure 7). The stakeholders are organized into three concentric circles based on their proximity to the user and their level of influence.

- **Inner Circle:** This includes care professionals in various capacities who directly assist the user in improving mobility.
- **Middle Circle:** This consists of sellers and family members who affect the user’s choices when selecting and using a rollator.
- **Outer Circle:** These stakeholders influence the rollator design or surrounding conditions (e.g., financial aspects, accessibility) without directly affecting the user.

The relationship between the user and various stakeholders can be described as follows:

- **Geriatric Doctor:** Provides medical support for age-related body issues.
- **Rehabilitation Doctor:** Assists with walking recovery after injury or surgery.
- **Physical Therapist:** Helps improve movement to reduce pain and discomfort.
- **Care Staff:** Offers day-to-day care and assistance to the user.
- **Ergonomic Therapist:** Advises on environmental adjustments to enhance user comfort and safety.
- **Resellers:** Facilitate the sale of rollators to users.
- **Family:** Influences the user’s decision-making with advice or opinions.
- **Distributors:** Manage the supply of rollators to retailers.
- **Municipalities:** Impact urban infrastructure and accessibility, which in turn affects the usability of rollators.
- **Manufacturers:** Design and produce the rollators available on the market.
- **Health Insurers:** In certain cases, provide financial coverage for rollators, depending on the user’s insurance plan.

In the design process of a rollator, it is essential to consider the input of all stakeholders. However, the opinions of stakeholders closer to the user (e.g., care staff, family, and medical professionals) carry more weight than those in the outer circles. For this research most of the stakeholders closest to the user will be asked to explain more about their knowledge of, influence on and experience with rollator use (Chapter 3). This information can be used to find good and bad aspects of current rollators.

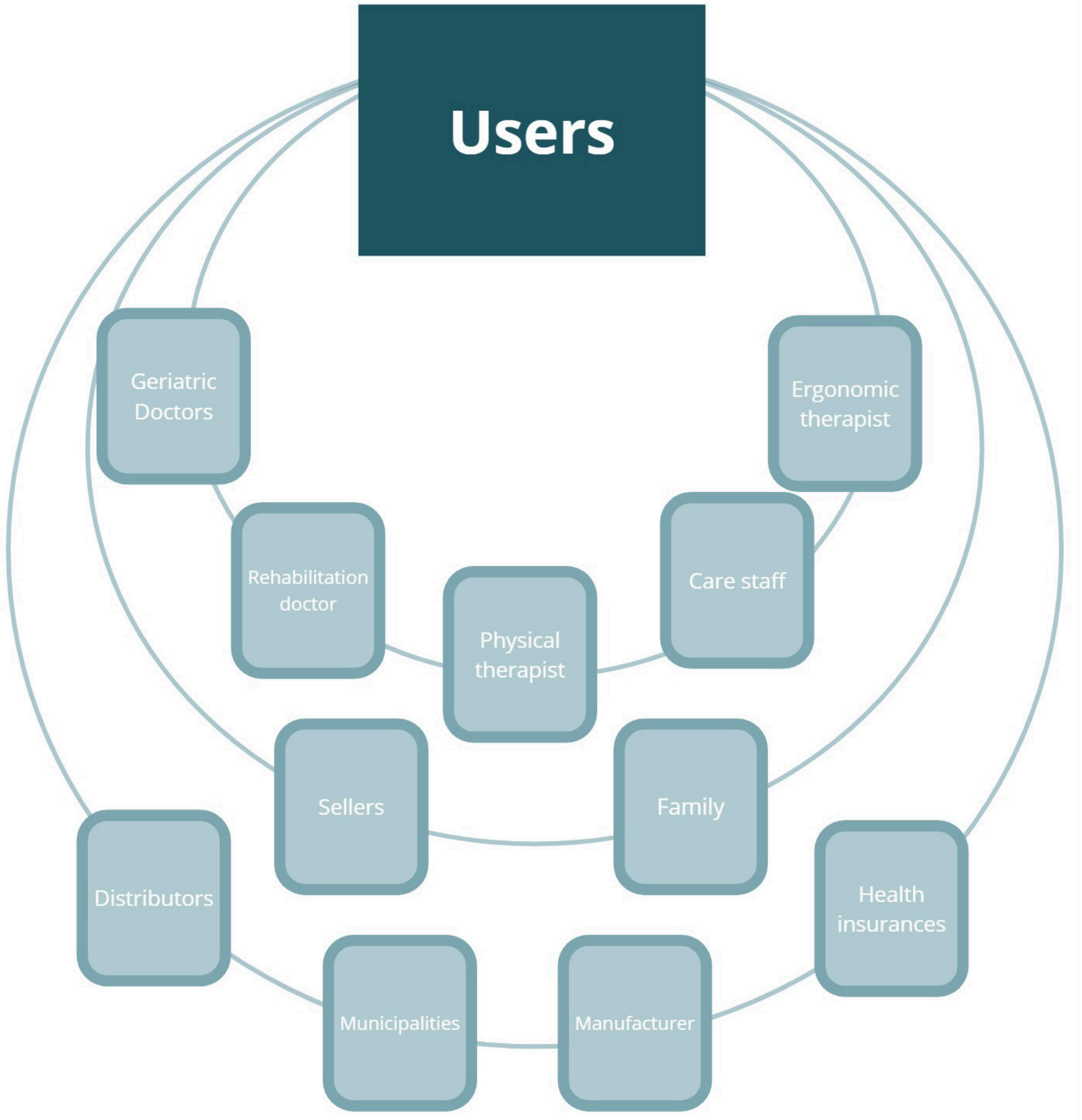


Figure 7 - Stakeholders

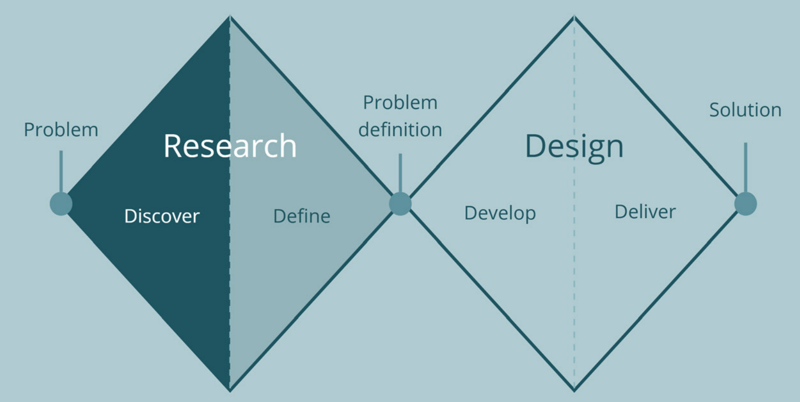
2.5 Conclusion

This chapter has highlighted several key insights:

- There is considerable scope for innovation in rollator design while maintaining the essential characteristics of a rollator.
- Users are willing to pay more for a rollator that is aesthetically pleasing and lightweight.
- Since most rollators are not covered by health insurance, affordability remains an important consideration in the design of new models.
- Input from stakeholders should be taken into account during the design process, with particular attention given to those most directly involved with the user. This will be done by interviewing them about their knowledge of, influence on and experience with rollator use.

In the next chapter, we will explore the experiences of rollator users and other stakeholders to identify the strengths and weaknesses of current rollator designs.

3. Field research



In this chapter 5 different field studies into the use of rollators will be explained. These studies are done to learn more about the good and bad aspects of current rollators, as defined in the research questions. These questions will be researched by using observations of users and interviews with users and stakeholders.

3.1 Research questions

The questions researched in this chapter are:

- How do people use rollators in their daily lives and what challenges do they face?
- Why and how do people begin using rollators, and what potential issues are associated with rollator use?
- How are rollators chosen, adjusted and used from a physical therapists perspective?
- What challenges and benefits do users encounter in their daily experiences with rollators?
- What factors influence consumers in the decision-making process when purchasing a rollator?

3.2 Observations

To understand how people use rollators in their daily lives and the challenges they face, observations were conducted in two different environments. The first setting was a shopping mall in Delft with even floors (Figure 8), and the second was the weekly market in the old city centre of Delft (Figure 9). Various aspects of rollator use were observed, including:

- Step length
- Step speed
- Stooped or upright posture
- Whether users stepped between the wheels or behind the wheels
- Angle of the arms
- Luggage carried
- Hands on the brakes during walking or not
- Left and right sway or not

Given the dynamic nature of the observation settings, it was not possible to note all aspects for every individual as some walked too fast to capture all the details. Full observation notes can be found in Appendix B.

In a time span of 4 hours, over 70 rollator users were observed and variations in their use were evident. While some users maintained an upright posture, most exhibited a slightly stooped walking stance. Some users kept their hands on the brakes while walking, whereas others did not. A notable observation was that some users took steps between the wheels as intended, while others walked behind the rollator, causing a more pronounced bend in their posture.

The use of storage also varied significantly. While some people carried only groceries in the basket, others hung additional bags from the handles or placed larger items like trays of water bottles on the seat. In one instance, two people shared a single rollator, with one person walking beside the other, leaning on the rollator with one hand.

Figure 8 – shopping mall De Hoven in Delft (winkelcentrum De Hoven, n.d.)

Figure 9 – Week market in the centre of Delft (Markt Delft, n.d.)

An unexpected observation was that many users exhibited a slight left-to-right sway while walking. This caused the front of the rollator to shift from side to side with each step. The reason for this behaviour was unclear, and even a consulted physical therapist had not previously noticed this. However, this sway could lead to imbalance and may be a factor in future design considerations for a safer rollator.

Despite the limitations of observing in just two environments in Delft, the left-right sway behaviour raises an intriguing question that could benefit from further exploration in this research.

3.3 Geriatric doctor interviews

To better understand why and how people begin using rollators, as well as the potential issues associated with rollator use, two interviews were conducted with geriatric doctors. one with a retired doctor who also worked at the Industrial Design Engineering faculty and one with a currently practicing geriatric doctor at Reinier de Graaf Gasthuis in Delft.

Key questions during the interviews included:

- What prompts elderly people to start using a rollator?
- Do you offer advice on rollator use?
- What are the common issues with current rollators?

The interviews revealed multiple reasons for rollator use and a range of causes for falls with rollators. These reasons include balance issues, leg or back pain, and endurance problems, often associated with aging, injury, surgery, or disease. Fundamentally, the need for a rollator stems from difficulties with the body's input, processing, or output mechanisms (as illustrated in Figure 10).

These factors can occur independently or in combination for individuals with mobility issues. During the rollator design process, it is crucial to consider the wide range of reasons for rollator use to ensure that the needs of all potential users are met without exclusion.

Doctors also noted that physical therapists often play a key role in choosing an appropriate rollator for the user, and doctors will often refer a patient to them for help with choosing the rollator.

A common issue with current rollator observed by the geriatric doctors was the misuse of rollators during the transition from sitting to standing. Some users pull on the rollator for support when standing up, which can cause the rollator to tip over. This issue represents a design opportunity for improving rollator stability during such transitions.

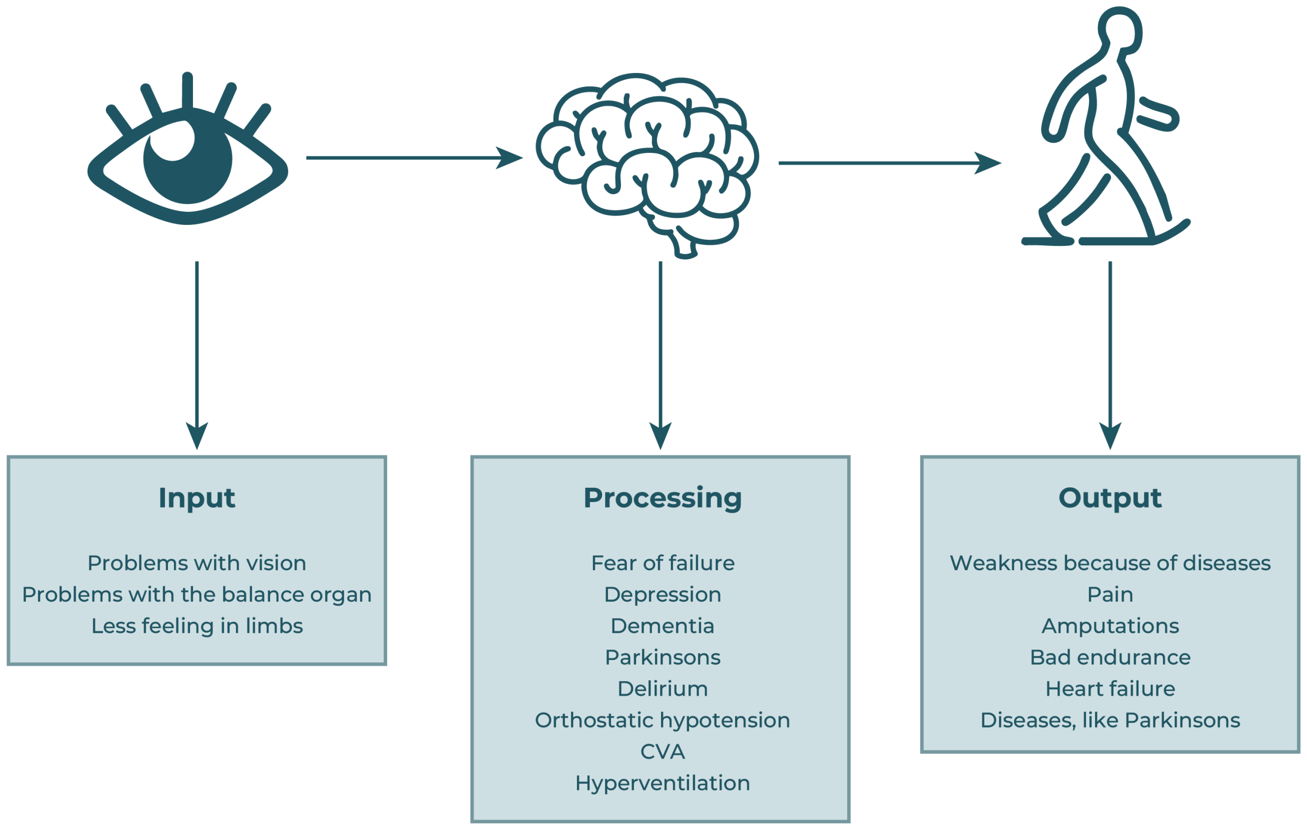


Figure 10 - Reasons for using a rollators

3.4 Physical therapist interviews

An interview with a geriatric physical therapist from Pieter van Foreest in Delft helped clarify how rollators are chosen, adjusted and used.

Key questions asked were:

- Do you help choosing a specific rollator?
- What is important when choosing a rollator?
- Do you see any problems with current rollators?

Key points included:

- The choice of a rollator depends on the user's specific needs (e.g., whether it will be used primarily indoors or outdoors, or if it needs to be lightweight for transport).
- Physical therapists assist users in adjusting handle heights to ensure an optimal walking posture.
- Gait changes when walking with a rollator, typically resulting in a more stooped posture, the absence of arm swing, and smaller steps (Figure 11) Users may also take larger steps to avoid touching the seat during walking.

The therapist highlighted several problems with current rollators. One of the most common issues is brake wear (Figure 12). Brakes often require regular checks, and in some cases, one brake fails to work, or users struggle with the force needed to engage the parking brake (Figure 13). Additionally, some users found their rollators too large and heavy.

These insights emphasize the importance of reliable brakes and proper gait when using rollators, which could be valuable starting points for design improvements.

Figure 11 – Changed posture (ouderenwegwijs.Nl., 2022, May 22)

Figure 12 – Brake wear (rollatorwinkel.com, n.d.)

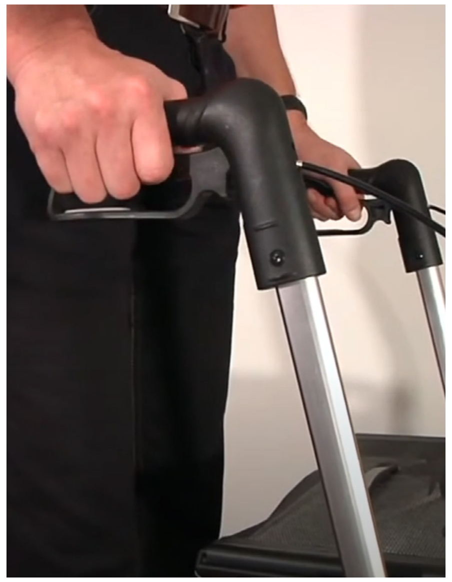


Figure 13 – High braking force (samen beter thuis, 2015, march 23)

3.5 User interviews

To gather user more information about user experiences, five interviews with rollator users were conducted (Appendix C). Overall, all users expressed high satisfaction with their rollators, emphasizing how it enabled them to maintain independence. Without it, they would need much more assistance in their daily lives.

Interestingly, users generally reported few problems with their rollators, but many highlighted issues with their surroundings. For example, they found city walkways uneven and curbs too high, both of which created difficulties during use. Some users also reported problems with the braking system, noting a decline in braking power over time and the need for more force to activate the brakes.

These findings suggest that while users are largely satisfied with their rollators, there are opportunities to improve both braking performance and the ability to navigate uneven terrain and curbs.

3.6 Interviews with sales representatives

A short interview was conducted with rollator sales representatives to gain insight into the buying process. When a customer comes to purchase a rollator, the sales staff assists by asking about their needs and recommending a suitable model. The most commonly requested features are lightweight design and compact dimensions when folded for easier transport.

After purchasing a rollator, the staff help adjust the height of the handles and explain that walking between the wheels is best for an optimal posture. The store also allows customers to return their old rollators when buying a new one.

These insights underline the importance of designing a lightweight, easily foldable rollator.

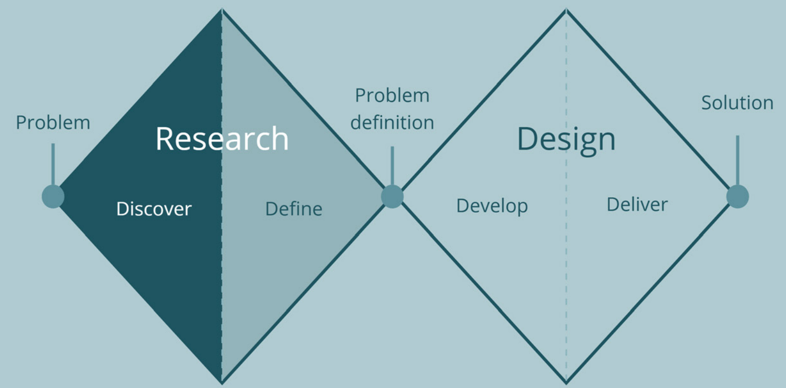
3.7 Conclusion

From this chapter, we have identified several opportunities for improving rollator design:

- Reducing the left-right sway or adding an arm swing feature could improve rollator stability.
- The diverse reasons for rollator use must be considered during the design process to ensure that the needs of all potential users are addressed.
- Addressing misuse during the transition from sitting to standing is another area for potential improvement.
- Enhancing the braking system to prevent wear and ensure ease of use could benefit users.
- Improving the rollator's ability to navigate uneven terrain and curbs is crucial for user safety and satisfaction.
- User preferences, such as a lightweight, easily foldable design, should be prioritized during the design process.

In the next chapter, we will explore the gait of elderly individuals and the reasons behind rollator use to gain a deeper understanding of the functional requirements of current rollators.

4. Background



In this chapter we dive into the background of the walking pattern of elderly, reasons for falling, reasons for the use of a rollator and the medical device regulations to further understand the function of current rollators.

4.1 Gait of elderly and falling

As people age, their gait undergoes significant changes, which can lead to an increased risk of falls. Understanding these changes is critical for optimizing rollator design. A wide range of academic papers provided insights into the gait of elderly individuals and the factors that contribute to falls. The most pertinent findings are summarized here.

The most noticeable change in gait among the elderly is a reduction in walking speed, primarily due to a shorter stride length (Kimura et al., 2007). This decrease is likely linked to a reduction in the push-off power of the centre of mass in individuals over the age of 70 (Sloot et al., 2021). Slow walking introduces several challenges: it is more sensitive to age-related declines than normal or fast walking speeds and leads to increased gait variability (Almarwani et al., 2016). Increased variability, particularly in mediolateral movements, is strongly associated with a heightened risk of falls in older adults (Osoba et al., 2019). Huijben et al. (2018) found that increasing walking speed improves gait stability, with higher step frequency, greater symmetry, and a more stable gait pattern. However, walking on slopes poses additional risks, as elderly individuals tend to adjust their gait with shorter steps and increased cadence, both of which are related to higher fall risk (Scaglioni-Solano & Aragón-Vargas, 2015).

Another significant change with age is the reduction in arm swing, which is important for maintaining stability during walking (Mirelman et al., 2015). Nakakubo et al. (2014) demonstrated that an emphasized arm swing can improve trunk stability in the mediolateral direction. Additionally, vision plays a crucial role in gait stability. Visual impairments lead to a more cautious and unstable gait, even in relatively simple conditions (Helbostad et al., 2009). Several studies highlight the benefits of enhanced lighting in improving gait: increased lighting levels can enhance walking speed, reduce step variability, and lower the risk of falls (Figueiro et al., 2011) (Ramulu et al., 2021).

Even when using a rollator, falls may still occur, often due to a combination of user and environmental factors. The most common location for falls is the user’s bedroom (Sadigh et al., 2004), and the causes are typically multifactorial (Khow & Visvanathan, 2017). In traffic, most accidents involving rollators are single-user incidents, with hip fractures being the most common injury (Carlsson & Lundälv, 2022). Fear of falling can also develop, but research indicates that physically active adults have less fear, better balance, and a stronger sense of efficacy (McAuley et al., 1997).

In conclusion, the most important risk factors for falls among the elderly include reduced walking speed, diminished arm swing, and decreased vision. These findings offer several opportunities for improving rollator design, particularly in enhancing stability and preventing falls at home or in traffic. However, there is a notable gap in research on gait patterns of elderly individuals while using rollators. Addressing this gap could provide valuable insights for future rollator innovations.

4.2 Medical device regulations

As a medical device, the rollator must meet specific regulatory requirements to ensure user safety. Research into European CE certification and ISO standards for rollators provided insight into these requirements.

All medical devices sold in Europe must have CE certification, indicating compliance with applicable regulatory standards based on the device classification. Rollators fall under Class I, which includes non-invasive, non-active devices, and thus face less stringent requirements compared to higher-class devices (EU, 2017).

In addition, rollators must meet the requirements outlined in ISO 11199-2 (ISO, 2021), which specifies both product requirements and testing methods. A detailed list of these requirements is provided in Appendix D. However, one particular ISO requirement appears insufficient: Clause 15.1 states that rollators should remain stable at sideways angles up to 3.5°. After examining walkways in Delft, it was found that some paths had angles exceeding this limit, with the steepest at 7.7°. This discrepancy raises concerns about the safety of CE-certified rollators under real-world conditions.

Since the rollator developed in this project is intended for the European market, it will need to comply with these regulations. The design will integrate these requirements into the list of necessary features and improvements.

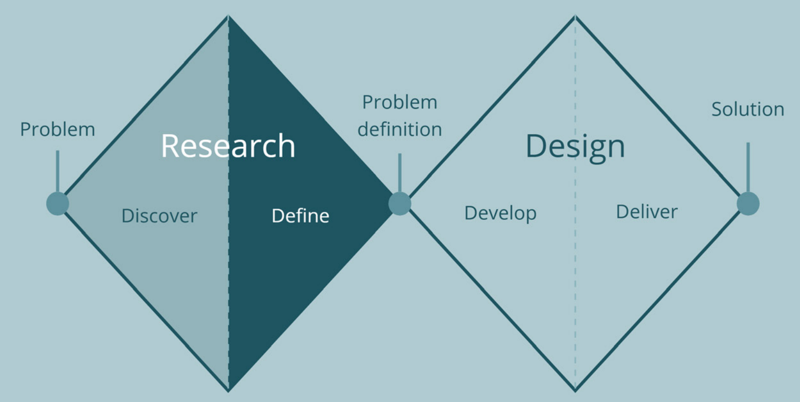
4.3 Conclusion

This chapter provided the following key insights:

- The primary risk factors for falls related to changes in the gait of elderly individuals include decreased walking speed, reduced arm swing, and diminished vision, all of which present opportunities for enhanced rollator design by finding ways to reduce the fall risk as a result of these changes in gait.
- Designing a rollator that prevents falls in the home or in traffic represents a promising area for improvement.
- New rollator designs must comply with medical device regulations, particularly CE certification and ISO standards.

In the next chapter, we will combine these findings with further analysis of rollator usage and design to uncover additional areas for improvement.

5. Problem Analysis



In this chapter the information found in the previous chapters will be combined into a function analysis, a customer journey, and a process tree, to find the most pressing problems with the current rollator.

5.1 Function analysis

The rollator serves multiple important functions beyond just supporting mobility. To provide an overview of the essential roles a new rollator design must fulfil, a function analysis was conducted, integrating findings from field research. The key functions of the rollator include:

- Support people during walking.
- Provide a place to rest.
- Store groceries and personal items.
- Reduce walking speed when necessary.
- Offer haptic feedback from the ground.
- Carry small items like cups and glasses.
- Adapt to different body sizes.
- Block movement when necessary (e.g., through braking).
- Compact in size for easier transport and storage.

This analysis reveals that a rollator serves multiple roles beyond mobility assistance, all of which must be considered in the new design to ensure it does not impede any of these critical functions.

5.2 User journey

To understand users' experiences with their rollators and identify pain points, a user journey map was created (Figure 14). This map outlines the various activities a user engages in while using a rollator and the overall emotional experience during these activities, based on insights from both desk and field research (Chapters 3 and 4).

The journey reveals that several actions with the rollator lead to unpleasant experiences. These pain points represent opportunities for improvement in the design of a new rollator. For example:

- The difficulties with encountering steps during walking could be improved by designing a new system to gain stability during moving up and down steps.
- The difficulties with walking over uneven terrains could be improved.
- The problems with the wear and tear of the brakes could be solved by designing a new braking system.
- The movements needed for resting on the seat could be reduced to prevent losing balance by designing a new resting system.
- The groceries basket can be placed in a different location or could be moved with a mechanic to reduce the steep bending over needed to place something in the basket.
- The folding of the rollator can be improved to prevent users to from having to perform actions that are difficult at an older age.
- The rollator could be lighter to make it easier to lift it into a car.

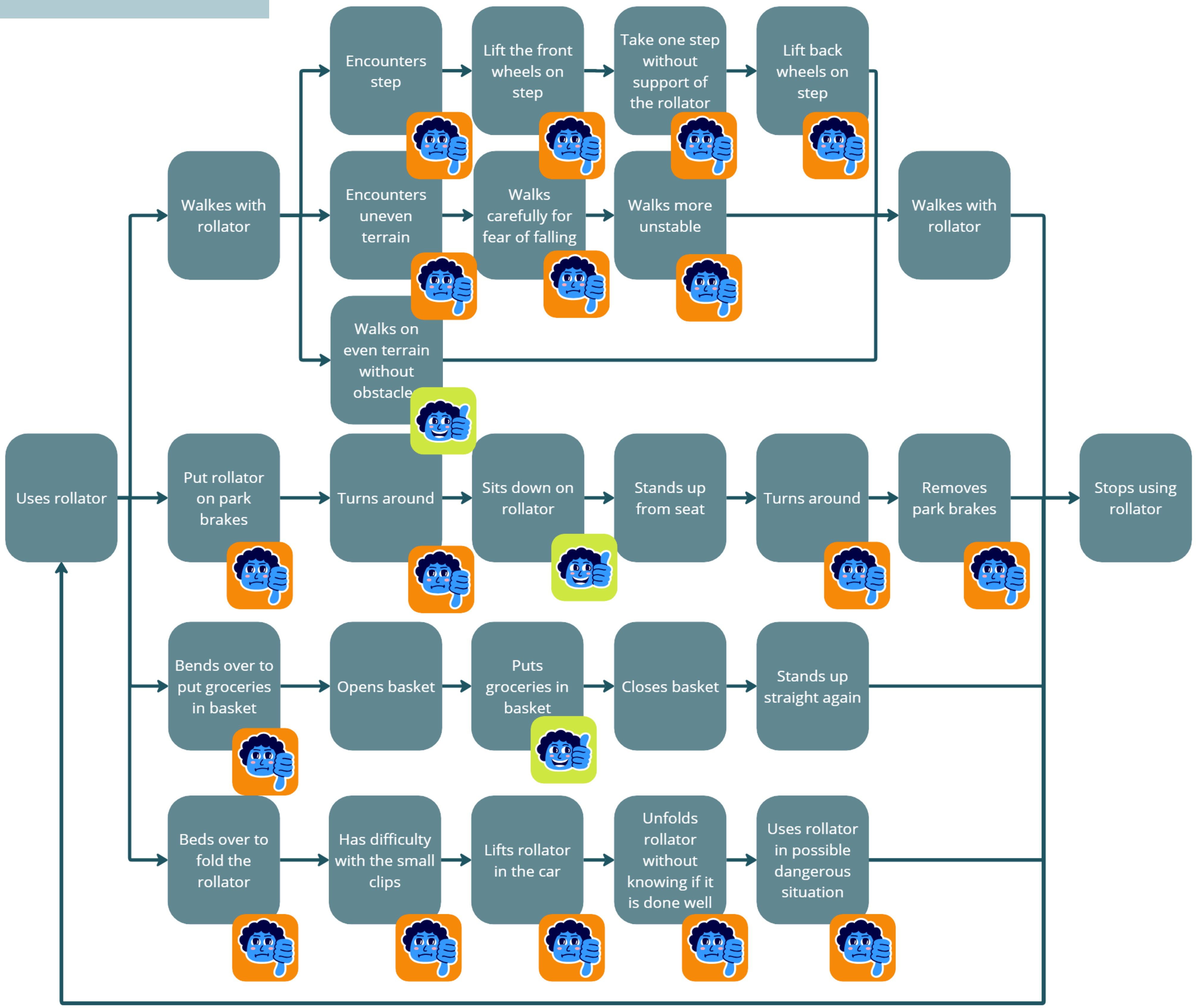


Figure 14 - User journey

5.3 Rollator analysis

To gain insights into the variety of rollators currently available for purchase and understand how they differ, various features of 30 rollator models sold through Dutch online stores were analysed (Figure 15). This analysis focused on key specifications such as price, weight, weight capacity, frame material, seat height, and additional features (Appendix E).

Figure 15 – Overview of 30 rollators

Figure 16 – Aesthetics review test

In addition to physical features, aesthetics were also considered. To assess the visual appeal of the rollators, five fellow students were asked to rank the models from least to most aesthetically pleasing. Each student was provided with printed images of the 30 rollators and asked to arrange them in an order that reflected their personal aesthetic preferences (Figure 16). Based on these rankings, each rollator was assigned an aesthetic score.

This combination of physical features and aesthetic evaluations provides an overview of the rollators currently on the market, offering insights not only into their measurable differences but also into consumer preferences regarding appearance.

To explore the relationships between various aspects of rollator design, several key specifications were analysed by plotting three different graphs: weight vs. price (Figure 17), aesthetics vs. weight (Figure 18) and aesthetics vs. price (Figure 19). In which the aesthetics score is based on the personal preferences of students.

The data reveal that lighter rollators tend to be slightly more expensive than their heavier counterparts. Additionally, lighter rollators tend to score higher in terms of aesthetics, and there is a positive correlation between aesthetics ratings and price. This suggests that rollators made with lighter materials tend to have more attention paid to their design, which, along with higher material costs, likely contributes to their increased price. This indicates that consumers are willing to pay more for both better aesthetics and lightweight materials.

An outlier in the first two graphs is the Rollz Motion, a rollator that stands out due to its ability to convert into an electric wheelchair, which increases both its weight and cost. This suggests that specialized rollators with additional functionalities may be heavier and more expensive than traditional models.

In conclusion, the analysis shows that while modern rollators still share many similarities with the original design and manufacturers are charging more for rollators that offer superior aesthetics and lower mass.

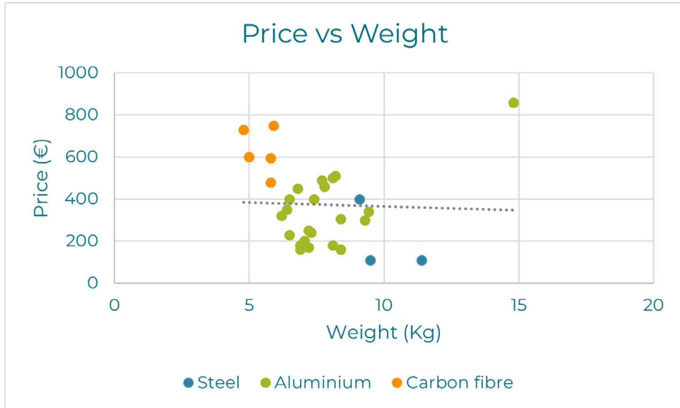


Figure 17 – Price vs weight rollator analysis

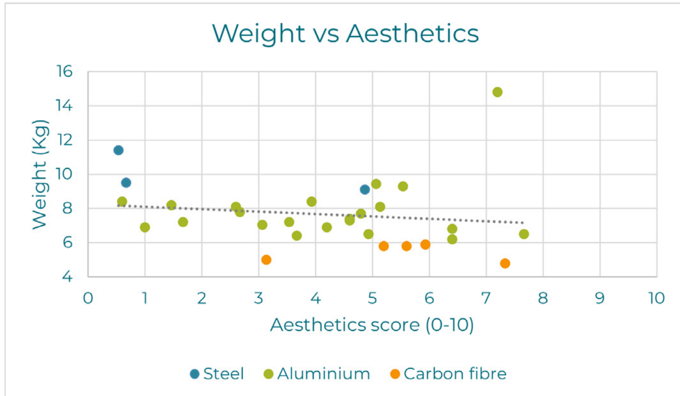


Figure 18 – Weight vs aesthetics rollator analysis

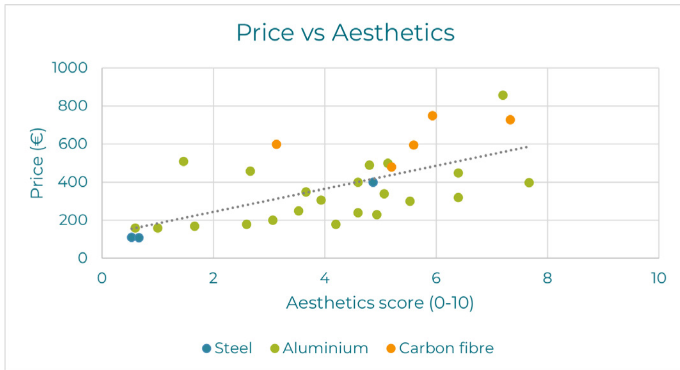


Figure 19 – Price vs aesthetics rollator analysis

5.4 Critical rollator evaluation

A critical evaluation of a rollator was conducted, combining insights from earlier findings with hands-on physical assessment. For this evaluation, the Excel Triple Motion rollator was acquired (Figure 20 & Figure 21). This assessment provided valuable insights into potential issues with current rollator designs.

5.4.1 Design inspection

Since the rollator was purchased second-hand, signs of wear and tear were apparent, providing an opportunity to assess durability. One noticeable issue was a broken hook for the basket (Figure 22), resulting in a missing basket. Additionally, the tires and brakes showed signs of wear (Figure 23 & Figure 24).

While testing the rollator outdoors, I experienced a near-fall. When encountering a curb, the rollator stopped unexpectedly, causing me to lose balance. This incident highlighted a potential safety risk, particularly for users with mobility challenges. Additionally, the design forced me to adjust my gait slightly to avoid my knees hitting the seat, indicating insufficient space for some users to walk comfortably (Figure 25).

Figure 21 – Excel Triple Motion back side (Rollator Triple Motion | driedubbel opvouwbaar, n.d.)

Figure 20 – Excel Triple Motion front side (Rollator Triple Motion | driedubbel opvouwbaar, n.d.)

Figure 22 – Broken basket hook

Figure 23 – Wear on tires

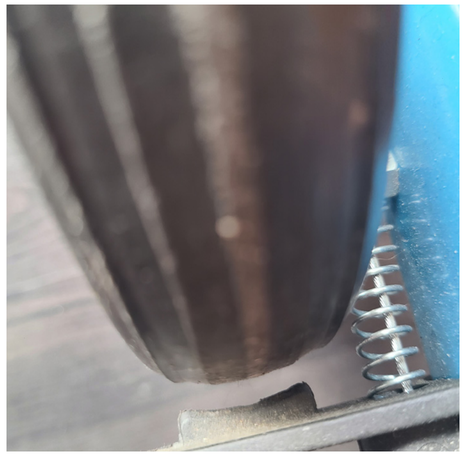


Figure 24 – Wear on brakes

Figure 25 - Knees hitting rollator during walking

5.4.2 Aging suit

To deepen the understanding of user experience, I tested the rollator while wearing an aging suit (Figure 26), which simulates limited mobility, reduced muscle strength, and impaired vision and hearing. This simulation provided valuable insights into the difficulties elderly users might face.

Key challenges observed included:

- Limited vision made it difficult to gauge where to place my feet while walking. The seat blocked visibility of the ground immediately in front, increasing reaction time when navigating obstacles.
- The lack of muscle strength and sensation in the hands made it difficult to fold the rollator, implying that users with reduced physical capacity would need assistance with this function.

Figure 26 – Rollator evaluation with aging suit

5.4.3 ISO standard

To further assess the rollator's safety and functionality, the Excel Triple Motion was evaluated against ISO 11199-2 standards, for example testing the angle at which the rollator would fall over if forces were applied to the handles (Figure 27 & Figure 28). Measurements and functionality tests were conducted, although durability tests were excluded due to time constraints. Several non-compliance issues were identified:

- The handgrip was not securely attached, causing it to rotate.
- Wheel gaps created potential foot traps, with the holes being too large to prevent feet from entering but too small to prevent feet from getting stuck.
- Handle adjustability exceeded the 25 mm increment requirement by 2 mm.
- Hand-operated controls were positioned too low, at 710 mm instead of the required 800-1200 mm above the floor.

These issues could stem from durability problems or may reflect a lack of regulation enforcement for Class I medical devices. Full test details are available in Appendix F.

Figure 27 – Example iso-standard test

Figure 28 – Forces example iso-standard test

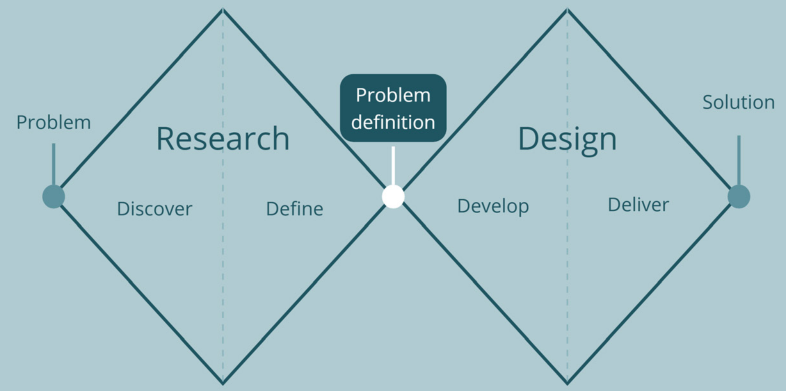
5.5 Conclusion

Key insights from this chapter include:

- All the identified functions of the rollator must be considered in the design of a new model.
  - Support people during walking.
  - Provide a place to rest.
  - Store groceries and personal items.
  - Reduce walking speed when necessary.
  - Offer haptic feedback from the ground.
  - Carry small items like cups and glasses.
  - Adapt to different body sizes.
  - Block movement when necessary (e.g., through braking).
  - Compact in size for easier transport and storage.
- Numerous unpleasant user experiences present opportunities for improvement in the rollator design.
- The difficulties with encountering steps during walking could be improved by designing a new system to gain stability during moving up and down steps.
- The difficulties with walking over uneven terrains could be improved.
  - The problems with the wear and tear of the brakes could be solved by designing a new braking system.
  - The movements needed for resting on the seat could be reduced to prevent losing balance by designing a new resting system.
  - The groceries basket can be placed in a different location or could be moved with a mechanic to reduce the steep bending over needed to place something in the basket.
  - The folding of the rollator can be improved to prevent users to from having to perform actions that are difficult at an older age.
  - The rollator could be lighter to make it easier to lift it into a car.
- Design changes should prevent users' legs from touching the rollator during walking.
- Improved visibility of the ground ahead would enhance user safety.
- Compliance with the ISO standard is essential for the new rollator design. Rules requiring special attention are:
  - The maximum force to apply and release the brakes shall not exceed: 60 N for pushing forces, and 40 N for pulling forces.
    - This is a problem in current rollators that could be solved.
  - The gap between exposed parts of a rollator that move relative to each other shall be maintained throughout the range of movement at less than the minimum value or more than the maximum value set out in ISO 11199-2:2021 clause 10.1
    - This can be difficult when designing a rollator with a new mechanism.
  - If the rollator is height adjustable, the increments shall not exceed 25 mm.
    - This is important to make the rollator a good fit for different body types
  - The diameter of any operating handles and/or knobs requiring an operating force of more than 10 N shall be between 19 mm and 43 mm.
    - Should be taken in account when redesigning the rollator to keep the rollator accessible.

In the next chapter, we will combine these findings into a clear design goal and establish a list of requirements and wishes for the new rollator design.

6. Design goal



In this chapter the goal of the project will be defined and the requirements and wishes to achieve this goal will be described.

6.1 Design goal

Following extensive research, the design goal for this project has been defined as:

> "Design a rollator for individuals with mobility challenges that enhances safety compared to current rollators."

6.2 Requirements & wishes

The design process involves two sets of criteria: requirements and wishes. The requirements are essential for the design to meet safety and regulatory standards, as well as user needs. These are non-negotiable and are influenced by ISO 11199-2 standards and previous analysis. On the other hand, the wishes represent desirable features that can elevate the design and differentiate between concepts. Both lists are ranked from most important to least important.

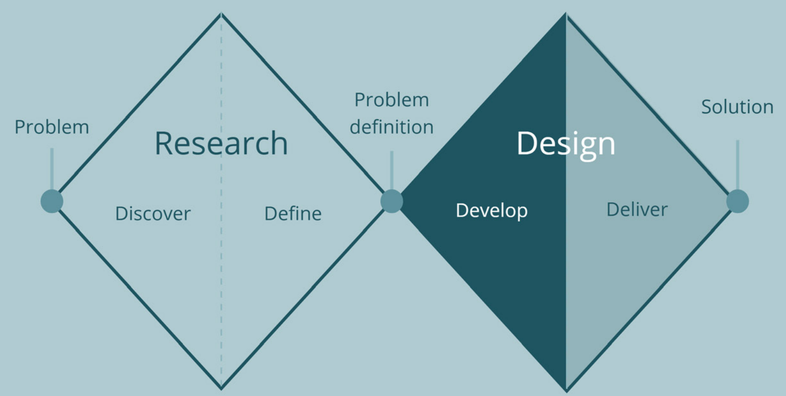
Requirements

1. **Improved Safety**
   - The rollator must improve user safety compared to current models, incorporating innovative design features.
2. **Compliance with Medical Device Regulations**
   - The rollator must meet ISO 11199-2:2021 standards (Appendix D) to be approved for sale in Europe (Chapter 4.2). With special attention to:
   - The maximum force to apply and release the brakes shall not exceed: 60 N for pushing forces, and 40 N for pulling forces.
     - This is a problem in current rollators that could be solved.
   - The gap between exposed parts of a rollator that move relative to each other shall be maintained throughout the range of movement at less than the minimum value or more than the maximum value set out in ISO 11199-2:2021 clause 10.1
     - This can be difficult when designing a rollator with a new mechanism.
   - If the rollator is height adjustable, the increments shall not exceed 25 mm.
     - This is important to make the rollator a good fit for different body types
   - The diameter of any operating handles and/or knobs requiring an operating force of more than 10 N shall be between 19 mm and 43 mm.
     - Should be taken in account when redesigning the rollator to keep the rollator accessible.
3. **Adaptability for Different Body Sizes**
   - The rollator should accommodate various body sizes to prevent stooped postures during walking (see Chapter 3.4).
4. **Return of all Current Functions**
   - The new design must retain all functions of existing rollators to maintain user satisfaction (Chapter 5.1).
5. **Durability and Wear Resistance**
   - The rollator must be designed to withstand wear, especially in key components like brakes, to ensure long-term usability (see Chapter 3.4).
6. **High supportive Seat Capacity**
   - The seat should support up to 140 kg, providing a safety margin for users weighing up to 120 kg.
7. **Lightweight Design (≤ 10 kg)**
   - The rollator should not weigh more than 10 kg to ensure ease of transport and handling.
8. **Storage Capacity**
   - The design should include sufficient storage space for users to carry essential items, such as groceries (see Chapter 3.2).

Wishes

1. **Promote Good Walking Posture**
   - The design should encourage proper walking posture to reduce back pain.
2. **Ease of Operation**
   - The rollator should be easy to use to prevent additional challenges for the user.
3. **Affordability**
   - The rollator should be priced
   - affordably to ensure broad accessibility (see Chapter 2.3).
4. **Lightweight Design**
   - The rollator should be as lightweight as possible to facilitate easy transport (see Chapter 4.4).
5. **Aesthetically Pleasing**
   - The rollator should have an appealing design, as appearance is important for user satisfaction (see Chapter 2.3).
6. **Easy Folding Mechanism**
   - The rollator should have an easy-to-use folding feature for convenience during transport and storage (see Chapter 4.5).

7. Ideation



In this chapter the ideation process is shown. First a brainstorm will be done to acquire a set of ideas. Next, using a c-box, 5 concepts will be chosen to further develop.

7.1 Brainstorm

To generate ideas for addressing the main problem, "How to improve the safety of rollator users during use," a mind map was created with this question at the centre. Potential solutions were written around it, and similar ideas were clustered together where appropriate. Combining insights from earlier stages of this research with newly developed ideas, the mind map ultimately produced 27 possible solutions to the safety issue (Figure 29).

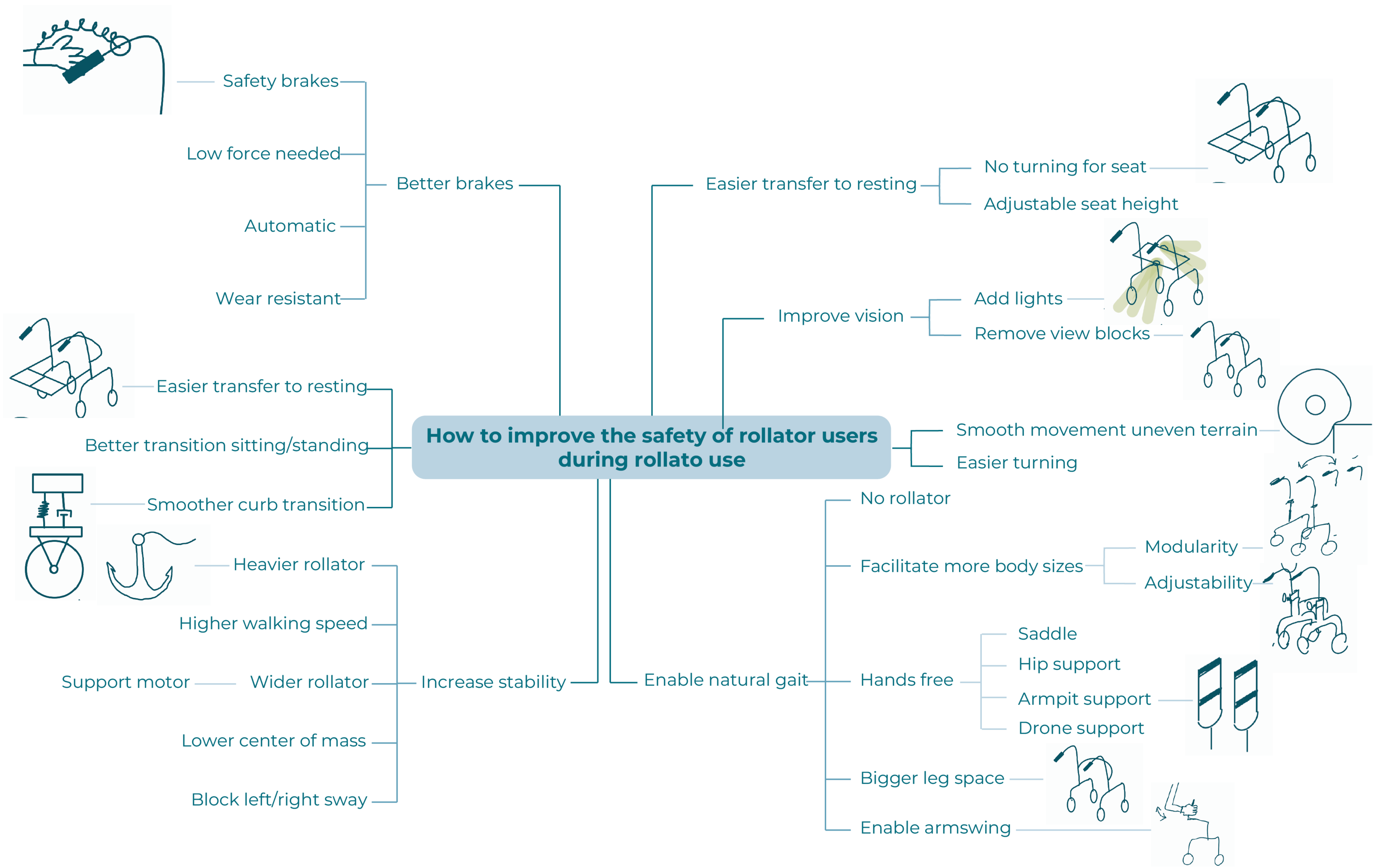


Figure 29 – Mindmap "how to improve the safety of rollator users during rollator use"

7.2 C-Box

To narrow down the 27 proposed solutions, the C-box method was employed. This method uses a matrix that maps ideas based on two key criteria: innovativeness and feasibility. An idea was considered highly innovative if it was not present in current rollator designs and if it seemed unlikely that manufacturers would adopt such a solution in the near future. In contrast, an idea was considered less innovative if it was plausible that it was already available on the market.

The feasibility scale was determined by factors such as expected mechanical feasibility and the likelihood of achieving the design within the project's timeframe. In many cases, the primary limiting factor was feasibility within the project's timeframe, leading to certain ideas being marked as very difficult to implement.

The results of the C-box analysis are shown in Figure 30. To select ideas for further development into concepts, a box was drawn around the innovative side of the matrix, excluding those deemed too difficult to implement. This process resulted in six ideas. However, two of these ideas overlapped and could be easily combined into one concept. Therefore, these six ideas were distilled into five concepts for further development.

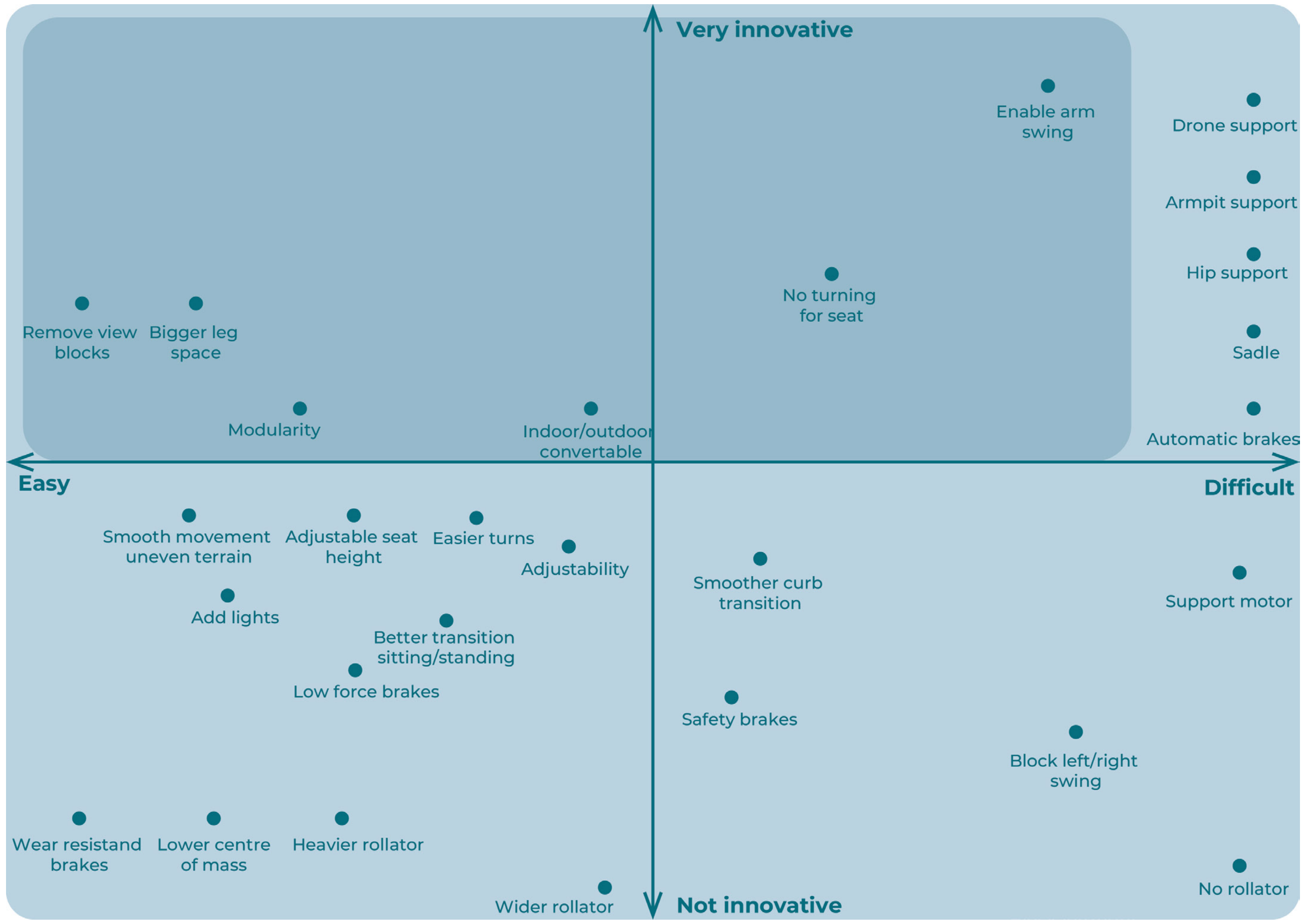


Figure 30 – C-box

7.3 Concepts

7.3.1 Concept 1

The first concept involves a redesigned rollator aimed at enhancing both leg mobility during walking and the user's visibility of the floor directly ahead (Figure 31). These improvements are achieved by repositioning the seat and basket to alternative locations on the rollator. By doing so, users can maintain a natural gait without the need to adjust their stride. Furthermore, the enhanced visibility of the floor allows users to more effectively identify potential obstacles in their path.

To address the obstruction caused by the rollator's basket, the design relocates the basket to two smaller bags positioned higher on the rollator and to its sides. This arrangement ensures an unobstructed view straight ahead, allowing for safer navigation. An additional advantage of this design is that users can more easily access these bags without needing to bend over, thereby improving overall convenience.

The seat is redesigned as a rollable fabric seat. This seat can be unrolled and secured to the opposite side of the rollator, providing a resting option during use while preserving an unobstructed view when walking. However, the usability of this seat, particularly for elderly users, must be thoroughly tested to ensure ease of use and practicality.

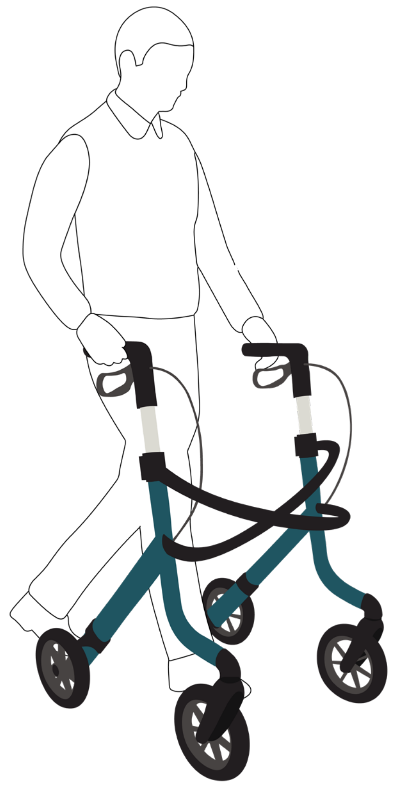


Figure 31 – Concept 1

7.3.2 Concept 2

Concept 2 presents a modular rollator designed to accommodate users by allowing components to be interchanged for different sizes (Figure 32). This modularity enables customization to suit individual body dimensions and specific needs. For manufacturers, this approach provides the flexibility to cater to a broader range of body sizes, ensuring a more precise fit for each user. A well-fitted rollator enhances posture during walking, reducing discomfort and potential physical strain associated with poor posture.

The modular design focuses on two key areas: the handles and the central frame, which includes the seat. Modular handles allow users to select the optimal height for their stature and the appropriate handle size for their hand dimensions. Similarly, the modular central frame enables users to adjust the rollator's width, ensuring that the handles are positioned at an ideal distance from the body for optimal posture. The seat height can also be tailored to the user's knee height, facilitating easier transitions between sitting and standing while minimizing the required muscular effort.

The benefits of modularity surpass those of traditional adjustability. Modularity ensures a superior fit and a more robust design. While adjustable rollators are limited by minimum and maximum size ranges and fixed increments, modular rollators can accommodate a greater diversity of body sizes. Furthermore, adjustable systems are often more prone to wear and fragility, potentially compromising the durability of the rollator over time. In contrast, the modular approach offers both adaptability and long-term reliability.

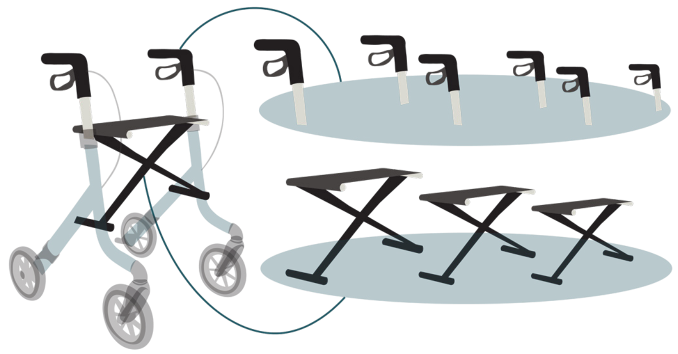


Figure 32 – Concept 2

7.3.3 Concept 3

Concept 3 introduces an innovative approach to resting while walking with a rollator (Figure 33), addressing the challenge of users needing to turn around before sitting. By eliminating this requirement, the design significantly reduces the risk of accidents that may occur during the turning process.

This improvement is achieved through a reversed rollator design. While retaining all essential functions of a traditional rollator, the reverse rollator allows users to rest on the seat without performing a 180° turn. The design incorporates rear wheels positioned farther back to provide stable support when the user is seated, while the front wheels remain in their traditional position, ensuring stability and support while walking and leaning forward.

In traditional rollators, the basket is positioned below the seat, necessitating bending over to access items. In the reverse rollator, the basket is replaced with two side-mounted bags. This modification not only eliminates the need to bend to place or retrieve items but also enhances accessibility and usability. The side bags allow users to easily reach their belongings and maintain visual oversight, contributing to both convenience and security.

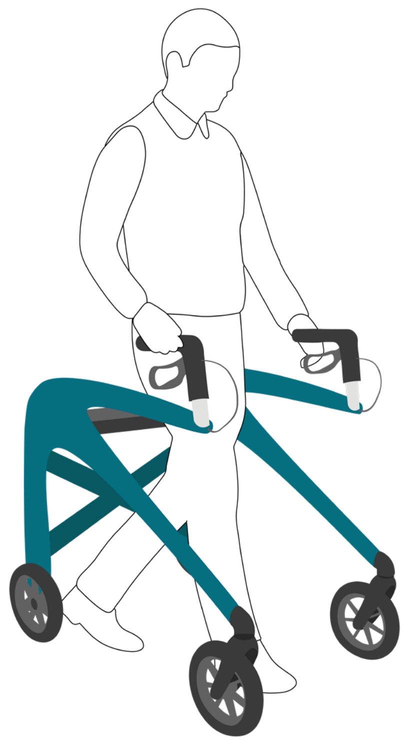


Figure 33 – Concept 3

7.3.4 Concept 4

Concept 4 introduces a convertible rollator designed for versatile use in both indoor and outdoor environments (Figure 34). When configured for indoor use, the rollator becomes more compact by removing the basket and reducing its overall width. This streamlined design enhances manoeuvrability in tight spaces, addressing the common issue of bulkiness associated with rollators. By encouraging users to continue using the rollator indoors rather than leaving it at the door and relying on furniture for support, this concept has the potential to reduce the risk of accidents within the home.

The basket is detachable via a simple mechanism that allows the support tubes to detach from the tubes of the seat. Compactness is achieved through a modified folding system, which introduces an intermediate position between fully open and completely folded. When locked in this position, the rollator remains stable and safe for indoor use. Additionally, in its compact configuration, a tray can be attached on top of the seat, enabling users to transport items such as a cup of coffee or other small objects around the house with ease.

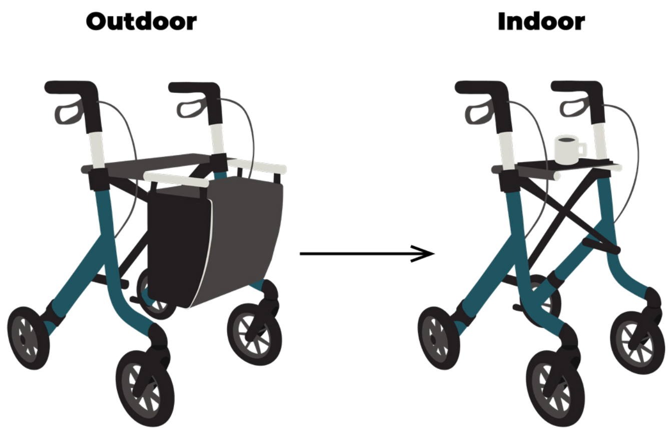


Figure 34 – Concept 4

7.3.5 Concept 5

The final concept is the arm-swing rollator (Figure 35) , a design that deviates from traditional rollators by allowing users to swing their arms naturally while walking. Research has shown that arm swing contributes to better stability during gait. By incorporating this feature, the arm-swing rollator aims to improve user safety and stability during walking.

The rollator achieves this functionality through a mechanism that guides the arms along a natural swinging path. Instead of standard handles, the design incorporates underarm supports with raised sides. These supports not only assist in steering but also maintain continuous arm movement, enabling smooth directional changes. The arm-swing mechanisms are positioned just below the shoulders, allowing users to lean comfortably on the underarm supports. To accommodate varying body sizes and ensure proper alignment, the rollator includes an adjustable-width frame.

Forward motion during walking is achieved through the natural momentum generated by arm swings, which cancel each other's opposing forces. Additionally, the slight friction within the arm-swing mechanism ensures that each forward step effectively propels the rollator forward, providing a seamless walking experience.

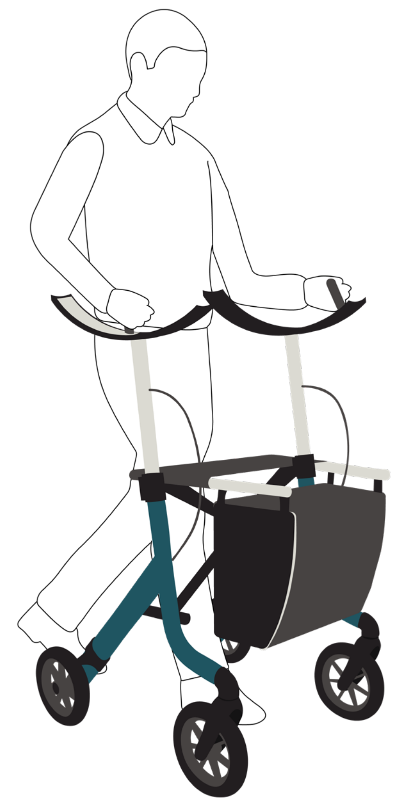
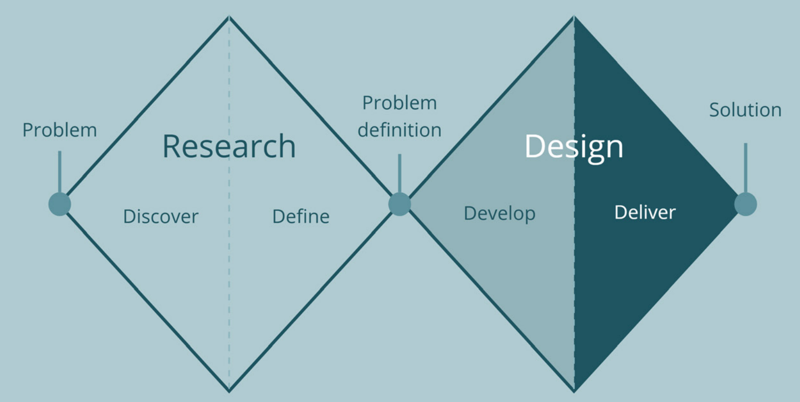


Figure 35 – Concept 5

8. Final Concept



In this chapter a final concept will be chosen and this concept will be further explained.

8.1 Concept choice

To select a concept for further development, the 5 concepts are evaluated. The innovativeness of a concept interests me most for this project. Concept 1, 2 and 4, seem less innovative than concept 3 and 5, because the mechanics behind these concepts are not new in the rollator design. However, for concept 3 and 5 new mechanics need to be designed which gives an interesting challenge. Since a lot of the problems around rollator seem to be connected to the changing gait of elderly (Chapter 4.1) The most logical option is to continue with concept 5, which focusses on making the gait of rollator users more natural. If this concept proves beneficial for the safety of rollator users, it could potentially influence manufacturers to adopt more innovative approaches in future rollator designs.

While the high level of innovation makes this concept intriguing, the lack of existing literature on the topic also makes it a risky choice. However, this project represents a unique opportunity to take such a risk, as future professional work will likely be constrained by financial and time pressures. For this reason, I have decided to pursue the development of the arm swing rollator in this project.

8.2 Final Concept

The final chosen concept is the arm swing rollator (Figure 36). This concept tackles the problems of losing balance during walking and could improve stability by allowing users to swing their arms while walking, mimicking the natural gait pattern seen in individuals not using walking aids. The specific mechanism enabling this arm movement will be detailed in Chapter 9: Embodiment.

This concept is inspired by a study conducted by Punt et al. (2015), which investigated the effects of arm swing on the local dynamic stability of human gait. The study found that excessive arm swing significantly improves dynamic stability, and the researchers concluded that individuals with a higher risk of falling should incorporate excessive arm swing. In this context, excessive arm swing refers to a normally timed arm movement with a larger amplitude (+30-50 degrees).

Since conventional rollators entirely restrict arm swing, the arm swing rollator has the potential to enhance dynamic stability for users. However, there is limited research on gait mechanics during rollator use, and no literature specifically addressing arm swing in this context. As a result, the development of this concept will be experimental and exploratory in nature.

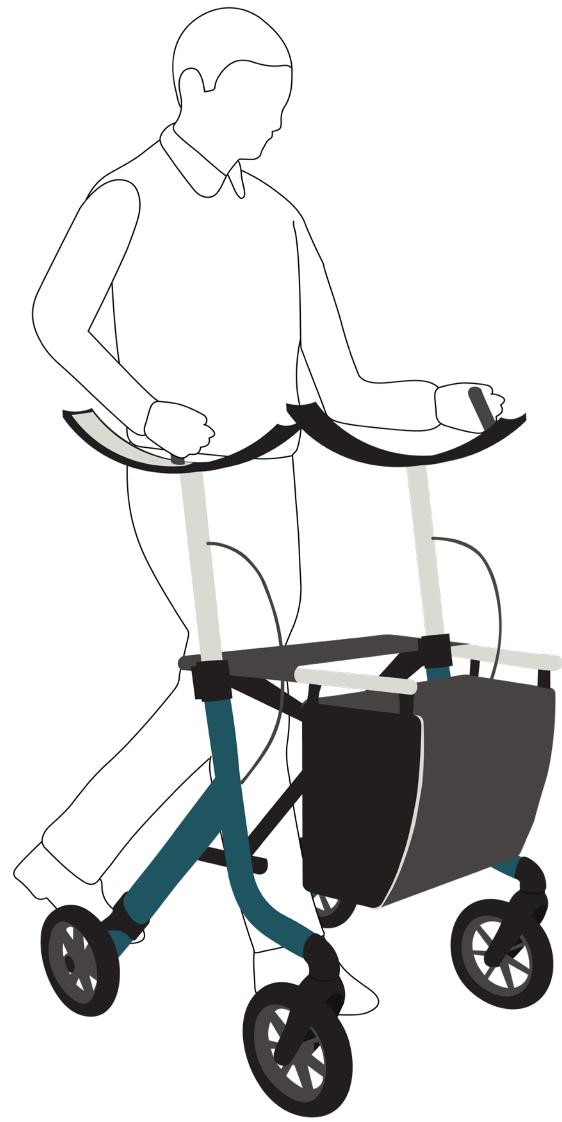
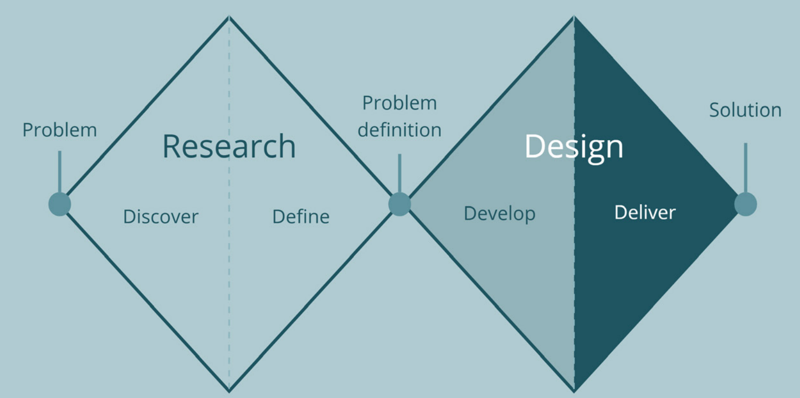


Figure 36 - Final concept

9. Embodiment



In this chapter the embodiment of the arm swing rollator will be explained, containing in depth development of the mechanism, sizing and path development, material choices and the final product.

9.1 Mechanism

The design process for the arm swing mechanism began with a "How to..." question, a design method that encourages designers to explore a wide range of solutions through sketches. The question posed was, "How to enable arm swing?" and the generated ideas are shown in Figure 37.

- **Double slider:** This mechanism uses two bars, allowing the top bar two degrees of freedom, enabling various paths required for the arm swing.
- **Elbow slider:** This design features a bowl in which the forearm support slides along a predefined path.
- **Push & pull:** A sliding handle mechanism that provides one degree of freedom, enabling a simplified version of arm swing.
- **Slider & rotational:** This mechanism combines a slider with a rotation point, offering two degrees of freedom for a simplified arm swing.
- **Four-bar mechanism:** This uses three bars, two hinges, and a fixed base to guide the top bar along a specific path.

To gain a better understanding of these mechanisms before selecting one, low-fidelity prototypes were created using cardboard and nails (Figure 38). During the evaluation, particular emphasis was placed on whether the mechanism could support body weight while still allowing freedom of movement. Due to this requirement, the double slider, slider & rotational, and push-pull mechanisms were excluded. The four-bar system was chosen to continue with, because of expected lower costs.

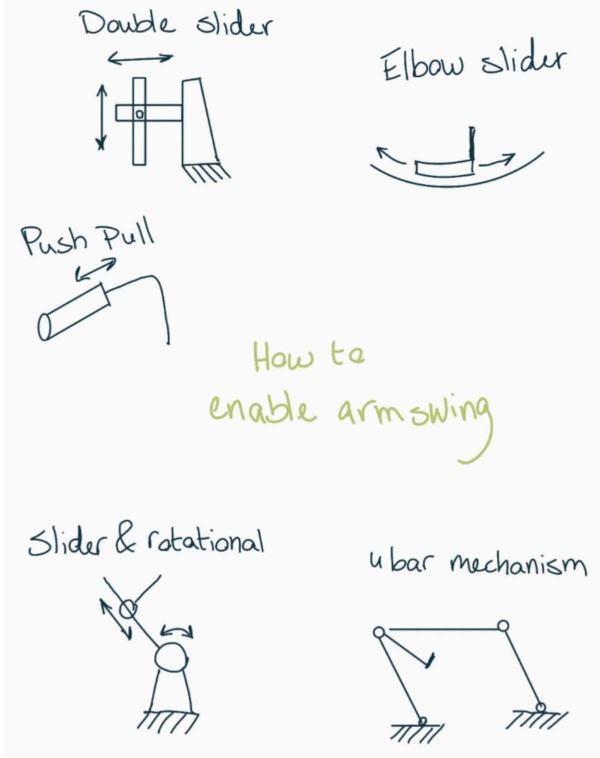


Figure 37 - How to enable arm swing

Figure 38 - Low fidelity mechanism prototypes

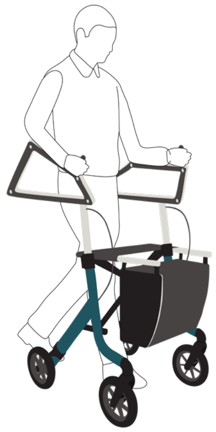


Figure 39 – Prototype 1 sketch

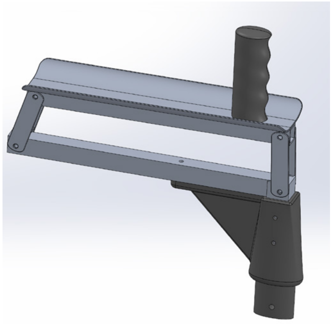


Figure 40 – Prototype 1 model

Figure 41 – Prototype 1

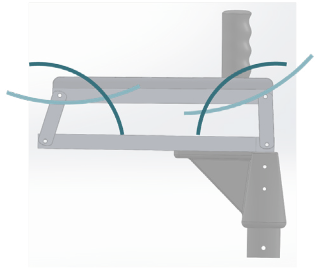


Figure 42 – Prototype 1 path

Next, a sketch and 3D model of the four-bar system incorporated into the arm swing rollator were created (Figure 39 & Figure 40). A prototype was then constructed using aluminium and 3D-printed parts (Figure 41). However, during evaluation, a major limitation was identified: the arm support path generated by the four-bar mechanism did not follow a natural arm swing path. In Figure 42, the dark line represents the path of the four-bar mechanism at both the hand and elbow, while the light line shows the ideal path. This discrepancy made it impossible to validate the rollator's effectiveness, as it interfered with natural gait, necessitating the selection of a new mechanism.

Three new mechanisms were developed during a subsequent brainstorming session and modeled in 3D to visualize their movement. The **single slider mechanism** (Figure 43) has a single slider along which the forearm support moves, following an arm swing path (Figure 46). The **crossed four-bar system** (Figure 44) is similar to the original four-bar mechanism, but the crossed bars partially invert the path (Figure 47). The **double-slider mechanism** (Figure 45) works similarly to the single slider but uses two separate sliders—one for the hand side and one for the elbow side of the forearm support, producing a path closer to a natural arm swing (Figure 48). The difference with the single slider mechanism is that the path of the hand is circular instead of linear, similar to the natural arm swing.

Due to its ability to replicate the most natural arm swing path, the double-slider mechanism was selected for further development into a functional prototype. A sketch of the prototype can be seen in Figure 49.

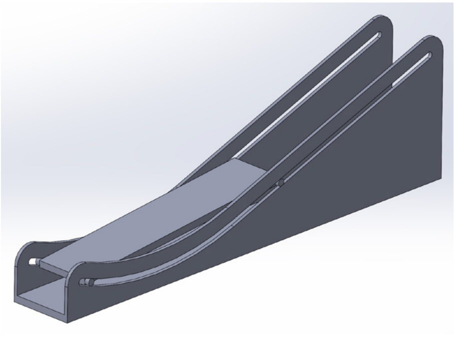


Figure 43 – Single slider mechanism

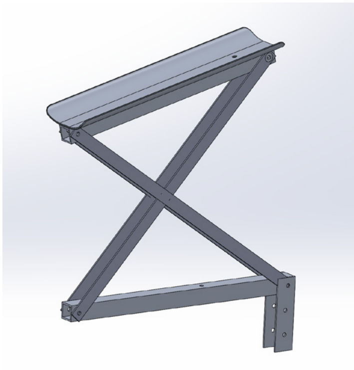


Figure 44 – Crossed 4 bar system

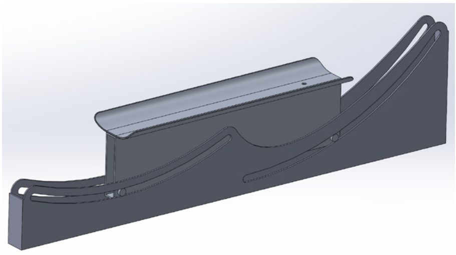


Figure 45 – Double slider mechanism

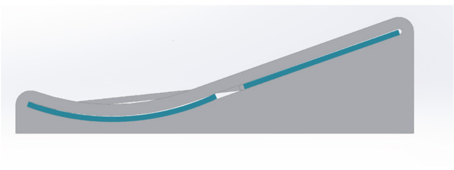


Figure 46 – Single slider mechanism path

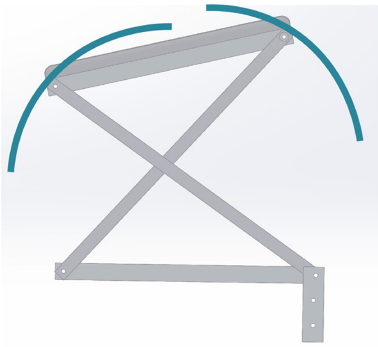


Figure 47 – Crossed 4 bar system path

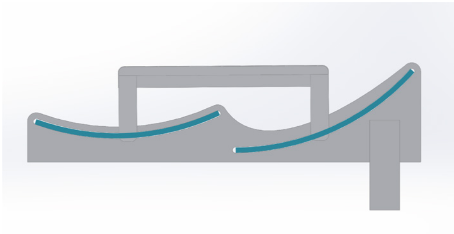


Figure 48 – Double slider mechanism path

Figure 49 – Final concept

9.2 Sizing & path

To achieve a natural arm swing, a proper fit is essential. In this mechanism, it involves designing a natural path for both the elbow and hand. The key factors for this path are the upper arm length, forearm length, and the angle of rotation. The first two measurements were obtained from the DINED database (DINED, n.d.) and are shown in Figure 50. Unfortunately this data was not available for younger age groups of the target group. The angle of rotation, or arm swing amplitude, can reach up to 40°, as determined by Punt et al. (2015). To include a safety factor, this design accommodates an arm swing of up to 45°. Since arm movement is asymmetrical due to shoulder limitations, the backward rotation is set at 20°, while the forward rotation is set at 25°.

The first challenge in designing an arm swing path for a wide range of users is the variation in arm swing radius, which depends on upper arm length. Analysing these differences to determine the elbow path endpoints (Figure 51), revealed that the distance between the P5 and P95 elbow path endpoints are only 4 and 6,5 mm, a negligible difference in this context (Figure 52). Therefore, the path design was based on the P95 upper arm length. The P95 forearm length was also used for the armrest length to prevent the elbow from extending beyond the mechanism and making contact with other components.

The second challenge was defining the hand's path during the arm swing. The hand covers the same 40° of rotation, but unlike the elbow path, where the neutral position is at the lowest point of rotation, the lowest point for the hand occurs when the arm is fully rotated backward. This creates a path from the lowest point in the rotation to 40° upward toward the front. The distance between the elbow and hand paths is measured from their neutral positions and is determined by the P95 forearm length. These two challenges result in the path shown in Figure 53.

populations	Dutch elderly 65–69, mixed		Dutch elderly 70–74, mixed		Dutch elderly 75–79, mixed		Dutch elderly 80+, mixed	
measures	P5	P95	P5	P95	P5	P95	P5	P95
Elbow-grip length (mm)	298	368	299	371	293	369	283	369
Shoulder-elbow length (mm)	306	382	308	384	296	384	297	389

Figure 50 – body measurements

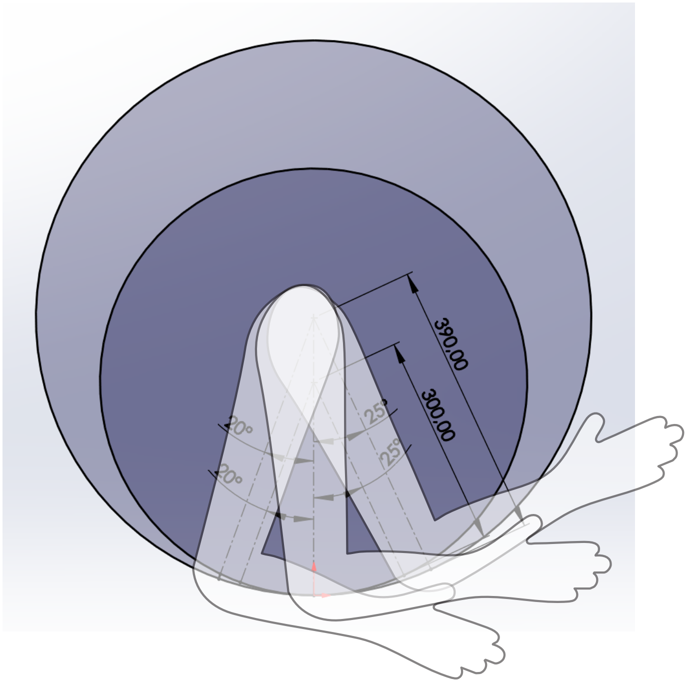


Figure 51 – P5 and P95 comparison

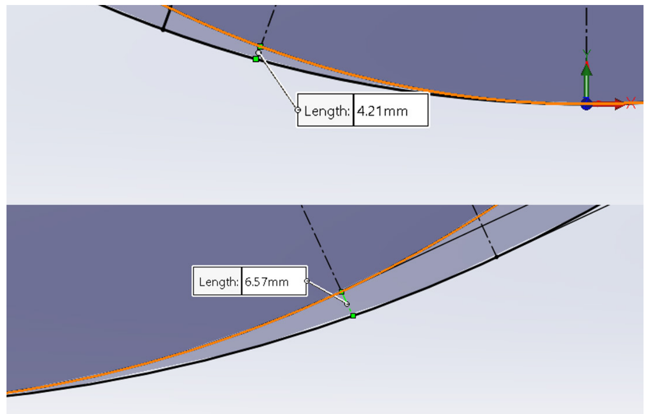


Figure 52 – P5 and P95 diference

The third challenge was making the rollator adjustable for different elbow heights and distances between elbows. Fortunately, the rollator already had an adjustable handle height system, which was repurposed to adjust the height of the arm swing mechanism (Figure 54). To accommodate varying elbow distances, a sliding mechanism was added between the two side frame pieces, and an elastic band was placed diagonally to improve the rollator's stability (Figure 55).

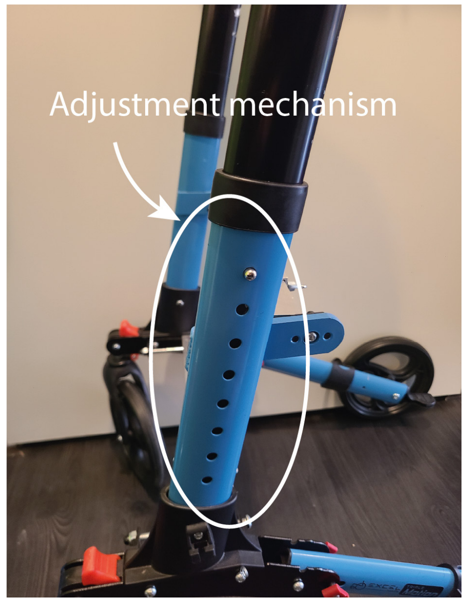


Figure 54 – Height adjustment mechanism

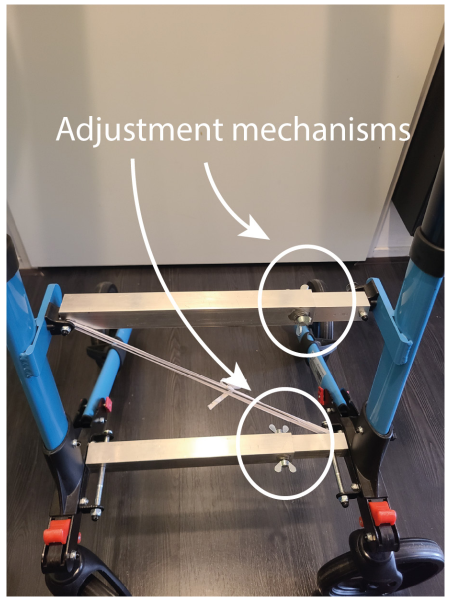


Figure 55 – Width adjustment mechanism

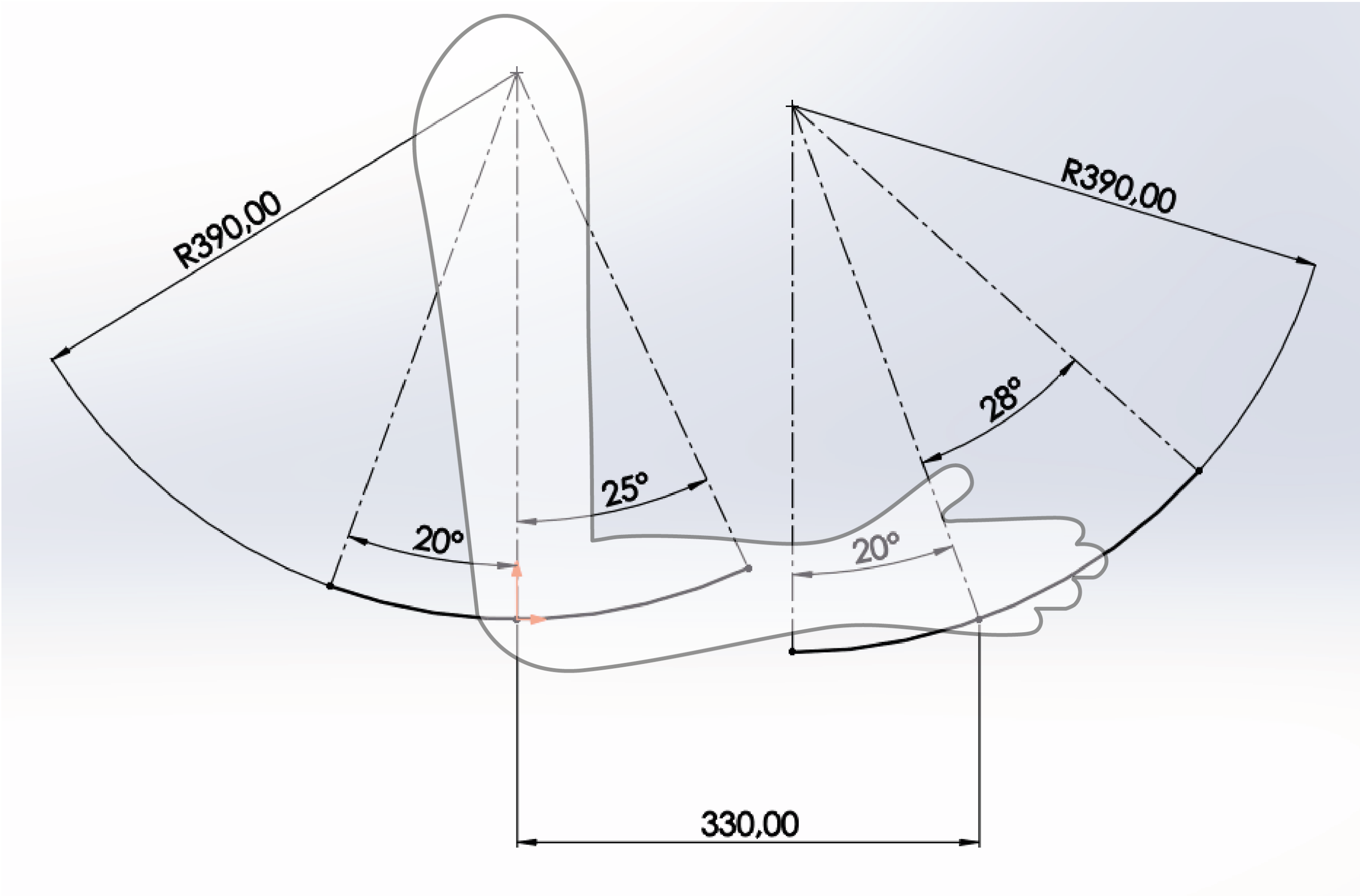


Figure 53 – Natural arm swing path

9.3 Materials

For optimal performance, the arm swing mechanism should be made from the same material as the rest of the rollator to ensure compatibility and seamless function. To determine the materials commonly used in rollators currently on the market, a sample of 30 rollators was analysed. Of these, 17% were made of steel, 73% of aluminium, and 10% of carbon fibre (Appendix A). Aluminium, being the most common rollator material, is also less heavy than steel and more cheaper and better recyclable than carbon fibre. For these reasons, aluminium was selected as the material for the arm swing rollator.

9.4 Final prototype

The mechanism, along with its dimensions, path, and materials, are integrated into an 3D model (Figure 56).

This model serves as the foundation for creating a functional prototype (Figure 57). Most components of the prototype are constructed using aluminium square tubes, U-profiles, and plates to replicate the properties of the final product, which will also be made of aluminium. To ensure a precise and secure fit, the handle and the component connecting the mechanism to the main structure of the rollator are 3D printed. Additionally, the arm support plate is cushioned with a foam layer to enhance user comfort. This prototype will be utilized for validation testing. Since this prototype has large slits which can be a finger entrapment risk, all participants will be warned about this and in the final product this will be solved.

Given the time constraints of this project, the prototype was developed within a limited timeframe. Consequently, the resulting mechanism exhibited higher friction than desired. To address this issue, efforts were made to reduce friction by sanding the metal sliders to achieve a smoother surface. Additionally, the plain bearings were lubricated with ball bearing grease to enhance their performance and minimize resistance.

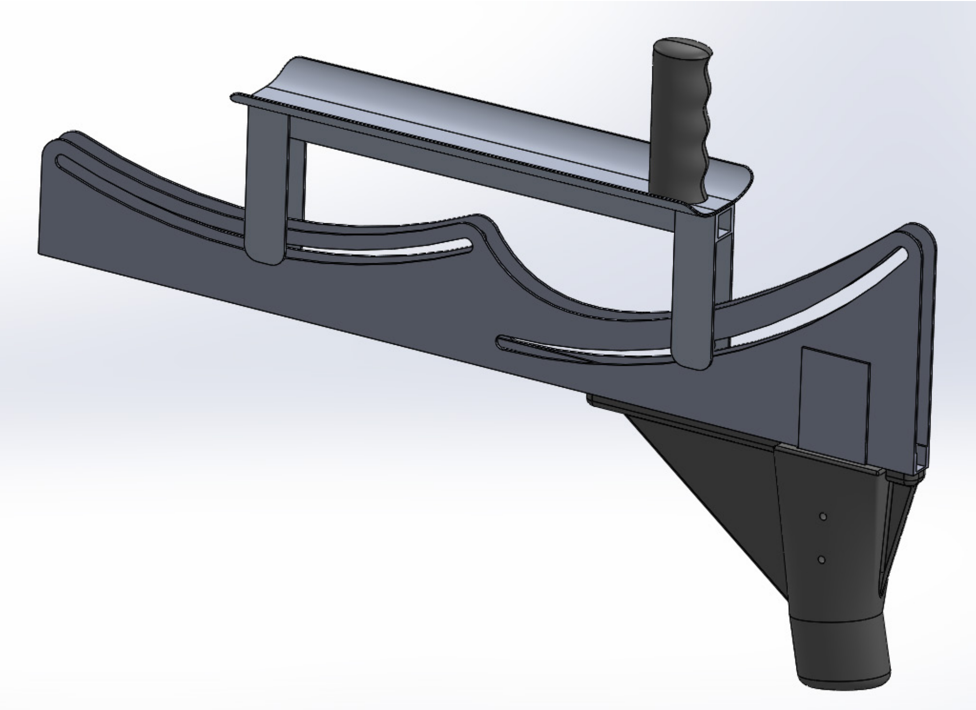


Figure 56 – Prototype 2 model

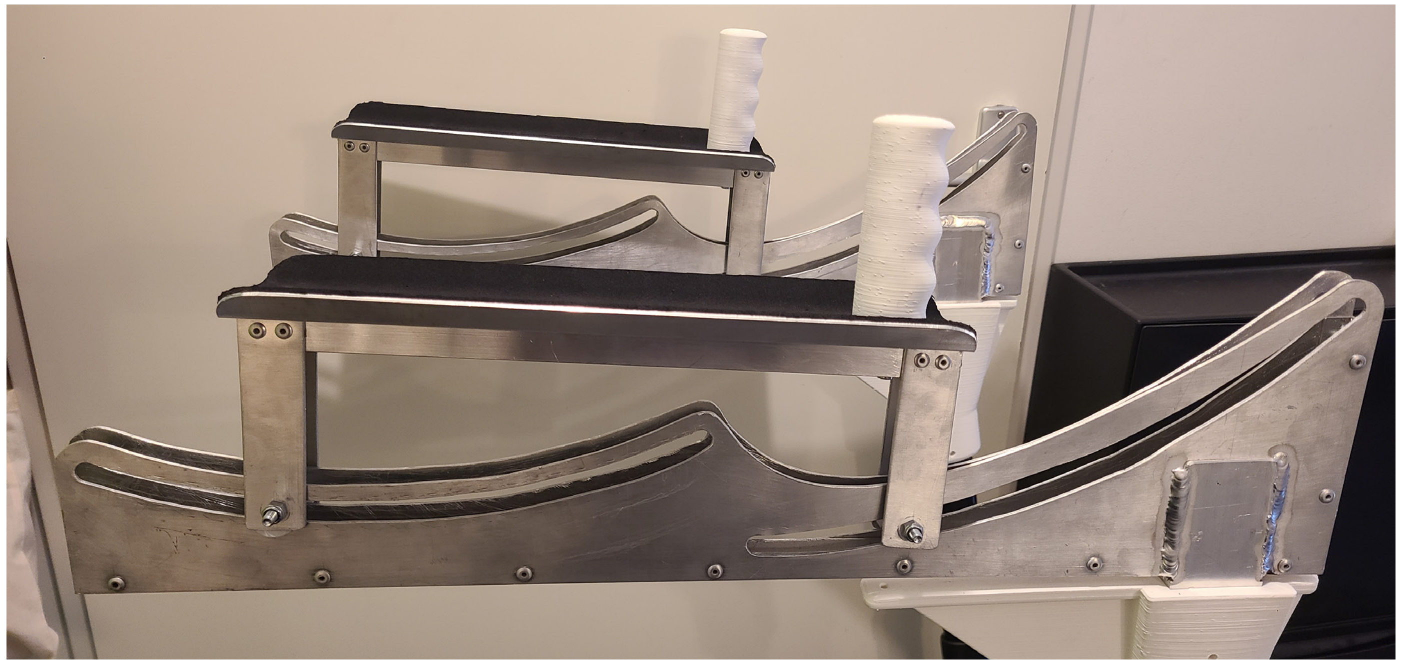
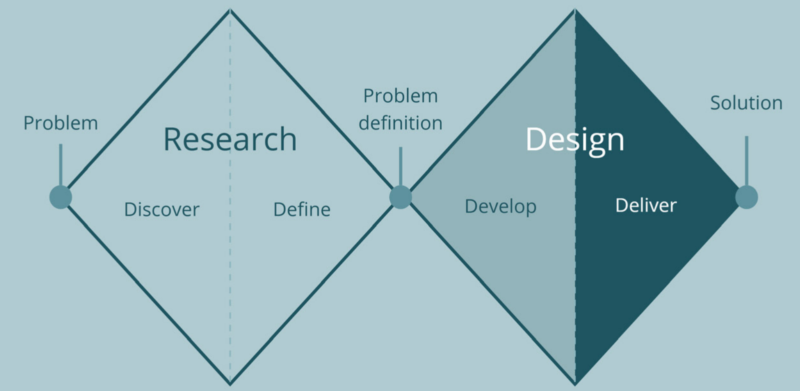


Figure 57 - Prototype

10. Validation



In this chapter the validation process of the arm swing rollator will be explained. This experiment consists of a goal, a method, results and a discussion.

10.1 Goal

The goal of this experiment is to evaluate the arm-swing rollator's ability to enhance safety by improving upper body stability during walking.

10.2 Method

10.2.1 Participants

Ten students participated in this experiment. The decision to recruit students rather than individuals from the rollator's target demographic was based on ethical considerations. The prototype rollator is not certified for safety, making it unsuitable for testing with a more fragile user group. To partially simulate the balance challenges experienced by older adults, participants wore 3D-printed balance-distortion platforms under their shoes (Figure 58). These platforms, rounded at the bottom, artificially destabilize the user's balance, approximating some challenges faced by the elderly.

Figure 58 - Balance distortion platforms

10.2.2 Measurement system

Stability was assessed using the Lyapunov exponent, which requires one-dimensional data collected over time. According to prior research (Chang et al., 2010), the mediolateral (ML) position of the upper body is particularly effective for this purpose. To track the ML position, two reflective stickers were placed on participants' shoulder blades (Figure 59). Using two trackers instead of one minimizes the impact of faulty readings, as averaging their positions provides a more reliable measurement. These trackers were filmed while the participant was walking and were kept in frame at all times. To improve the processing of the videos in the video software it was decided to zoom in the video while filming. This provided better resolution of the location of the trackers

Figure 59 - Tracker placement

10.2.3 Experiment set up

The experiment was conducted in a long hallway with a smooth, even floor. A 30-meter-long line was marked on the floor using painter's tape, with the start and end clearly delineated by perpendicular tape lines. A camera, mounted on a tripod at shoulder height, was positioned at a distance sufficient to capture the entire line in the frame. This setup is illustrated in Figure 60.

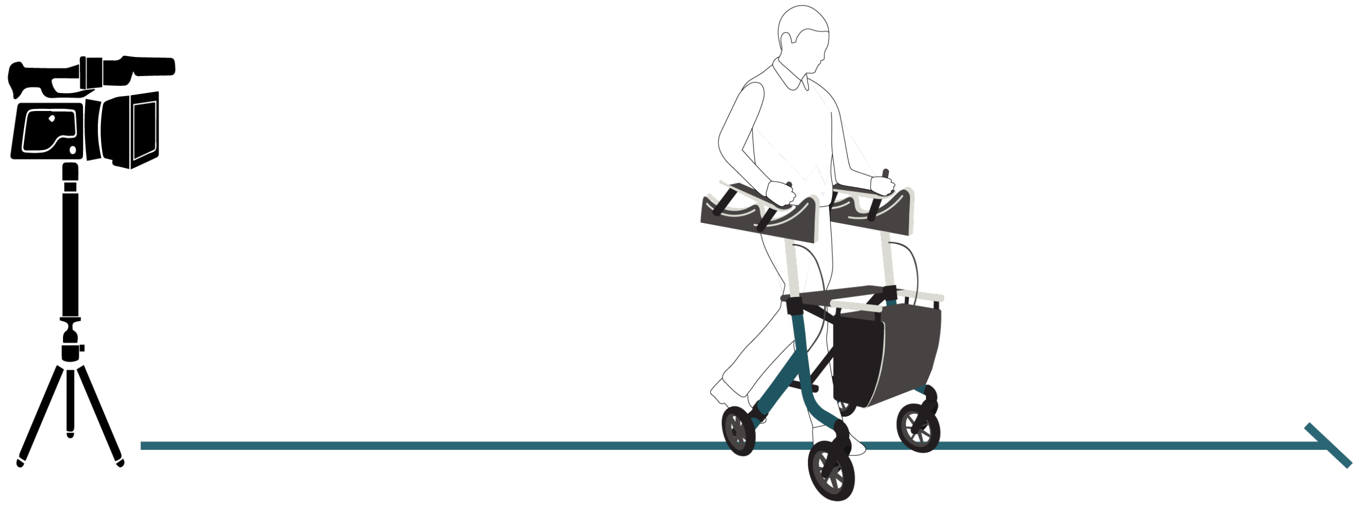


Figure 60 - Experiment set up

10.2.4 Experiment protocol

Each participant completed three walking conditions: without a walking aid, using a traditional rollator, and using the arm-swing rollator. All participants wore the balance-distortion platforms for every condition.

Before the trials, participants received a detailed explanation of the experiment and signed informed consent forms. Their height was recorded, and the arm-swing rollator was briefly demonstrated. Participants were allowed to familiarize themselves with both rollators before testing. Tracker stickers were applied to their shoulder blades, and the distance between them was measured for later analysis.

Participants completed nine walking trials, consisting of three repetitions of each condition (no aid, traditional rollator, arm-swing rollator). Every participant first did every condition one time before continuing tot the second and third set to distribute the learning curve of walking on the balance distortion platforms as much as possible over the 3 conditions. As a result, no increased stability is measured in any of the situations by learning to walk with the platforms. During each trial, they walked along the marked line while being recorded by the camera. The recording stopped when they reached the end of the line.

Following the trials, participants answered two follow-up questions:

1. How did you experience walking with both rollators?
2. Did you encounter any difficulties while using the arm-swing rollator?

Participants were then thanked for their time.

10.2.5 Data analysis

The video recordings were analysed using Tracker software (Brown et al., 2024), which identifies the position of the trackers in each frame (Figure 61). The data, consisting of time and positional information, was exported to MATLAB for further analysis.

A MATLAB code adapted from Sjoerd Bruijn (Bruijn, 2023) was used to calculate the short-term (0–0.5 strides) and long-term (4–10 strides) Lyapunov exponents for each trial (full code in appendix G). These exponents were compiled in an Excel file for statistical analysis.

- **Short-term Lyapunov exponent:** Measures the immediate stabilization response to small disturbances at the start of a step.
- **Long-term Lyapunov exponent:** Captures stability over extended walking periods, reflecting resilience to cumulative disturbances.

Higher positive Lyapunov exponents indicate reduced stability, while lower positive values suggest greater balance and resilience. Negative values represent stable movements with natural corrections to disturbances.

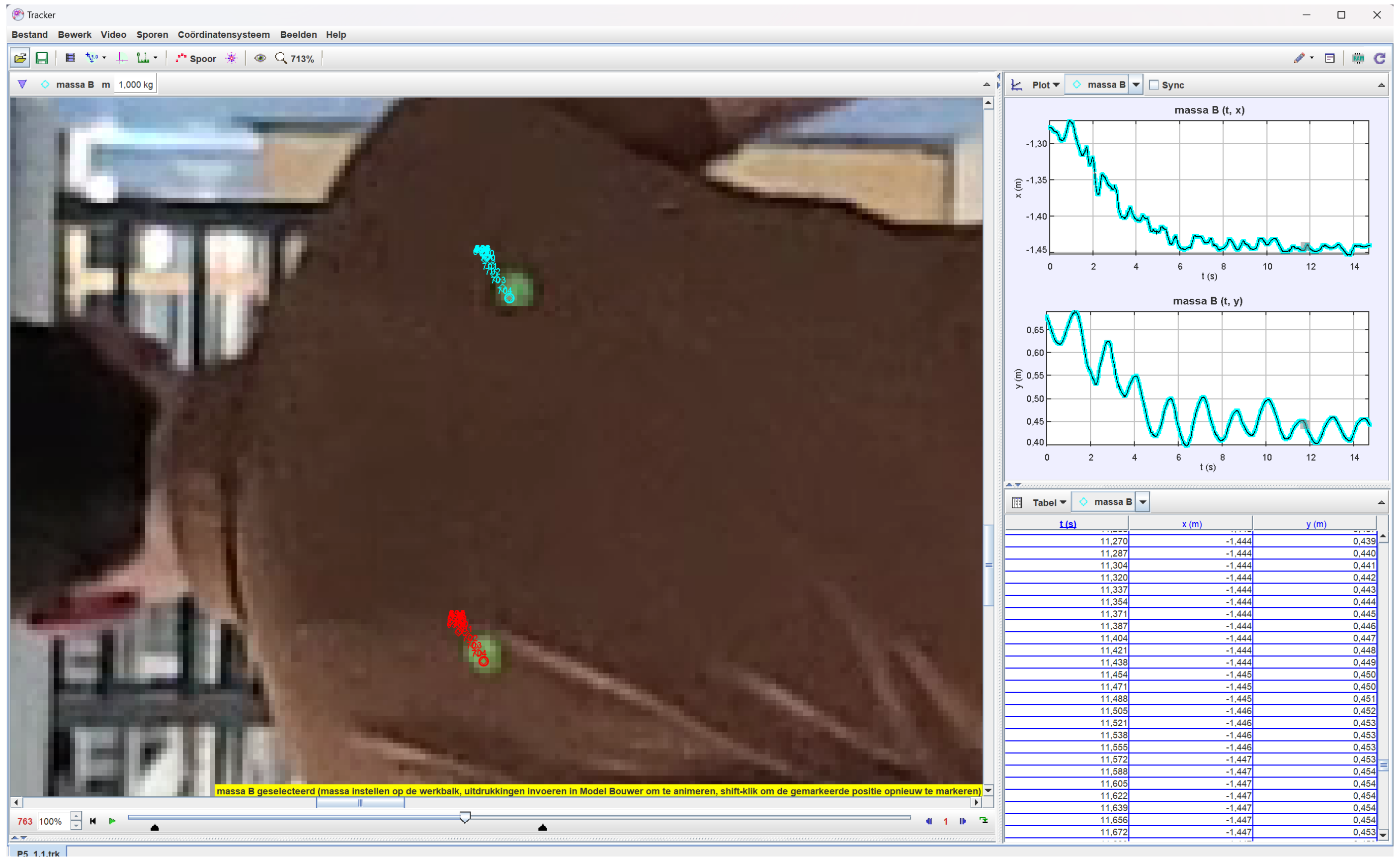


Figure 61 - Tracker analysis in tracker software

10.3 Results & discussion

The mean short term and long term stability per participant per situation can be seen in Table 1 & Table 2. The distribution of the full data set can be found in Figure 62 & Figure 63. The full results can be found in Appendix H.

	Short term		
Participant	No walking aid	Normal rollator	Arm swing rollator
P1	1,048066667	1,087133333	1,013766667
P2	1,133333333	1,094266667	1,098066667
P3	1,0417	1,024736667	1,071406667
P4	1,051636667	1,066666667	1,00864
P5	1,053693333	1,0597	1,034466667
P6	1,073233333	1,03759	1,05793
P7	1,083966667	1,043506667	1,028753333
P8	1,146666667	1,1991	1,161766667
P9	1,059883333	1,1227	1,1091
P10	1,099033333	1,099966667	1,099666667
Total	1,079121333	1,083536667	1,068356333

Table 1 - Mean short term stability per participant per situation

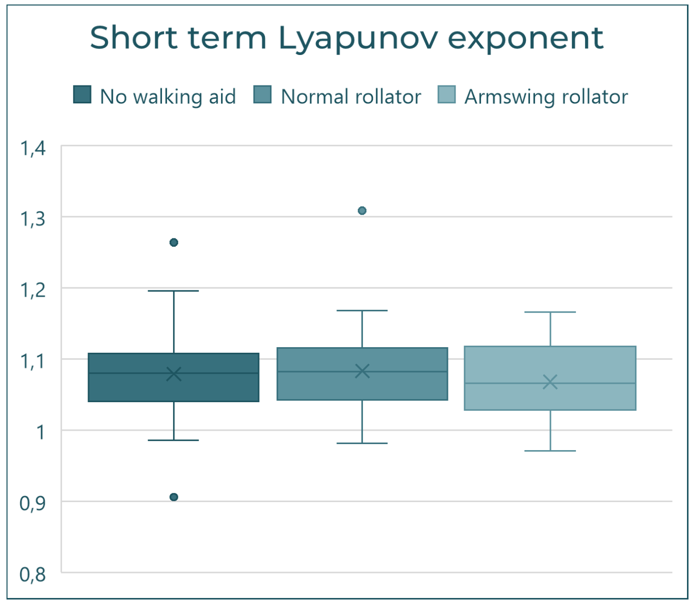


Figure 62 - Boxplot of short term lyapunov exponent

	Long term		
Participant	No walking aid	Normal rollator	Arm swing rollator
P1	-0,002119097	-0,006353067	0,0145716
P2	-0,001524033	-0,00206336	0,001478865
P3	0,003383067	0,024382333	-0,0001605
P4	-0,001026367	0,001003767	0,018827667
P5	-0,004690867	-0,003793867	0,009037467
P6	-0,006298547	0,0001853	-0,005930167
P7	0,006650067	0,000746473	0,005302233
P8	0,00310543	-0,0051313	-0,003236289
P9	6,84833E-05	-0,000444433	-0,002791818
P10	0,00161861	-0,001846233	-0,00064886
Total	-8,33254E-05	0,000668561	0,00364502

Table 2 - Mean long term stability per participant per situation

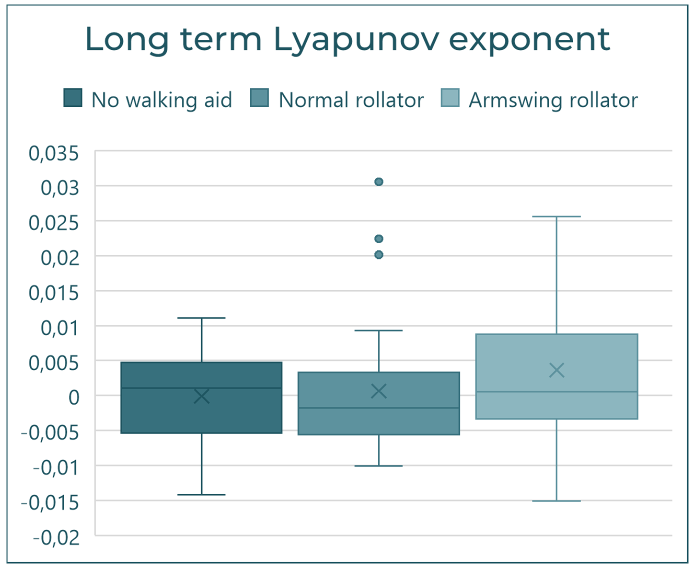


Figure 63 - Boxplot of long term lyapunov exponent

10.3.1 short and long term stability

A repeated measures ANOVA revealed no significant differences in short-term stability across the three conditions (P=0.453). However, the arm-swing rollator (P=0.371) showed a trend toward improvement compared to walking without aids, whereas the traditional rollator (P=0.761) did not. This suggests that while neither rollator significantly improves short-term stability, the arm-swing rollator may have potential for further development.

Similarly, no significant differences were found in long-term stability (P=0.273). Surprisingly, the arm-swing rollator demonstrated worse stability than walking without aids (Table 2, Figure 61). Additionally, the traditional rollator showed no significant improvement compared to walking unaided (P=0.724). However, the Lyapunov exponent values across all conditions approached zero, indicating overall stable gait patterns.

These unexpected findings could stem from limitations in the experimental setup or measurement system:

- Treadmill testing: Using a treadmill could eliminate zoom-related disturbances in video analysis.
- Closer alignment with the target group: Recruiting participants with reduced compensatory abilities could yield more representative results.
- Alternative measurement tools: Employing IMUs to track ML position directly could improve data accuracy by removing reliance on video analysis.

Alternatively, the results might indicate that rollators, including the arm-swing design, do not significantly improve stability as previously hypothesized. However, further research is required to confirm this hypothesis due to the lack of comparative studies on rollator use and gait stability.

10.3.2 Post test questions

Participants noted friction in the arm-swing mechanism, which occasionally disrupted their natural walking posture. Reducing this friction in future prototypes could enhance test validity.

Participants also reported feeling better supported and experiencing improved posture with the arm-swing rollator, likely due to the high underarm supports. Future studies could investigate the impact of rollators on user posture.

10.3.1 short and long term stability

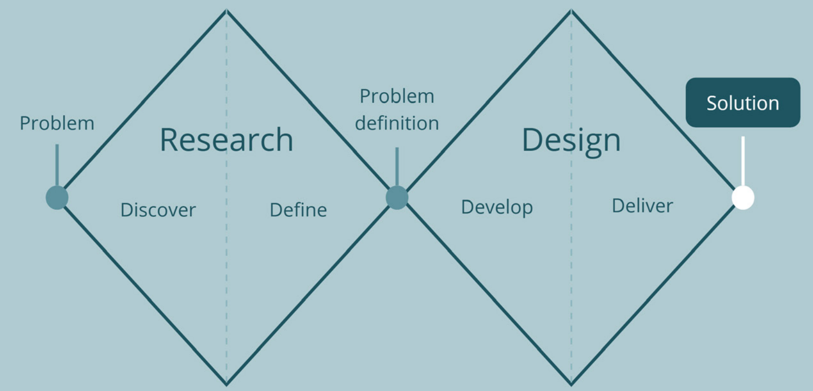
Most participants found the traditional rollator handles too low for proper posture, even at the highest setting. The average participant height was 182.7 cm (Appendix I), exceeding the 95th percentile height for Dutch individuals over 60 years old (181.3 cm; DINED, n.d.). This discrepancy might be due to age-related changes in posture, which could reduce effective height.

10.4 Conclusion

The validation test revealed no significant improvements in stability with the arm-swing rollator compared to the traditional rollator. However, the arm-swing rollator (P=0.371) showed a closer trend toward improved short term stability than the traditional rollator (P=0.761) compared to no walking aid, warranting further investigation.

Future studies should address limitations in the current setup, such as testing with treadmills, recruiting participants closer to the target group, employing IMUs for ML tracking, and improving the arm-swing mechanism. Comparative testing with forearm rollators could also provide insights into the relative benefits of arm-swing functionality versus enhanced support.

11. Conclusion & Recommendations



In this chapter the project will be concluded and recommendations for future research will be given.

11.1 Conclusion

The aim of this project was to redesign the rollator to enhance both safety and personal ergonomics. The resulting concept, the arm swing rollator, introduced an innovative feature: the ability for users to swing their arms naturally while walking. Arm swing has been shown in literature to improve gait stability in the elderly, making this feature a potentially significant advancement. However, limited research exists on how rollators impact gait stability, leaving the experimental design and validation process of this project as uncharted territory.

Validation testing did not yield conclusive evidence that the arm swing rollator significantly improves stability compared to traditional rollators or no walking aid. Surprisingly, the traditional rollator also did not demonstrate a notable improvement in stability over unaided walking. These unexpected results highlight potential issues with the test setup or raise questions about the assumed stability benefits of traditional rollators. The testing challenges included friction in the prototype's mechanism, limitations of the participant sample, and the accuracy of the measurement setup. Further investigation is essential to refine the design and better understand its effects on gait stability.

Despite these challenges, this project provided valuable insights into the complexities of designing walking aids and testing the stability of their users. It also laid a foundation for future research, offering directions for improving both the design and evaluation of rollators.

11.2 Recommendations

11.2.1 Rollator recommendations

Future development and research on rollators should address the wide range of challenges faced by users. While this project focused on enabling natural arm swing, other aspects of rollator design merit attention, including:

- **Improved braking systems:** Enhancing user control in diverse environments.
- **Performance on uneven terrain:** Ensuring stability and ease of use outdoors.
- **Visibility of feet and path:** Preventing trips and improving user confidence.
- **Ergonomic resting solutions:** Creating more accessible and comfortable seating.
- **Compact and modular designs:** Adapting rollators for different environments, such as indoor versus outdoor use.

By addressing these aspects, future designs could further enhance safety, usability, and overall user experience.

11.2.2 Prototype recommendations

To enable more reliable testing and encourage user adoption, future prototypes of the arm swing rollator should prioritize:

- **Reduction of friction in the arm-swing mechanism:** This will provide a smoother user experience and more accurate testing of the arm swing functionality.
- **Safety improvements:** Eliminating 3D-printed load-bearing parts and addressing risks like finger entrapment will ensure a safer and more robust prototype suitable for testing with the target group.
- **Professional-grade materials and assembly:** Building prototypes with high-quality components will enhance durability and performance.

11.2.3 Test recommendations

To address the limitations encountered in this study, future experiments should implement the following improvements:

- **Utilizing treadmills for controlled testing:** This eliminates inconsistencies caused by varying speeds or distances in hallway setups and minimizes camera zoom issues during data collection.
- **Recruiting participants closer to the target group:** Elderly individuals with limited balance compensation capabilities will provide more relevant insights into the design's effectiveness.
- **Employing IMUs (Inertial Measurement Units):** These sensors can more accurately track mediolateral movement without the need for extensive video analysis, reducing potential sources of error.
- **Exploring comparative testing:** Including forearm rollators and other walking aids in the tests can help isolate the effects of arm-swing mechanisms versus other supportive features.
- **More extensive user feedback:** Combining quantitative measurements with qualitative input from participants, especially from the target demographic, will provide a holistic understanding of the rollator's performance.

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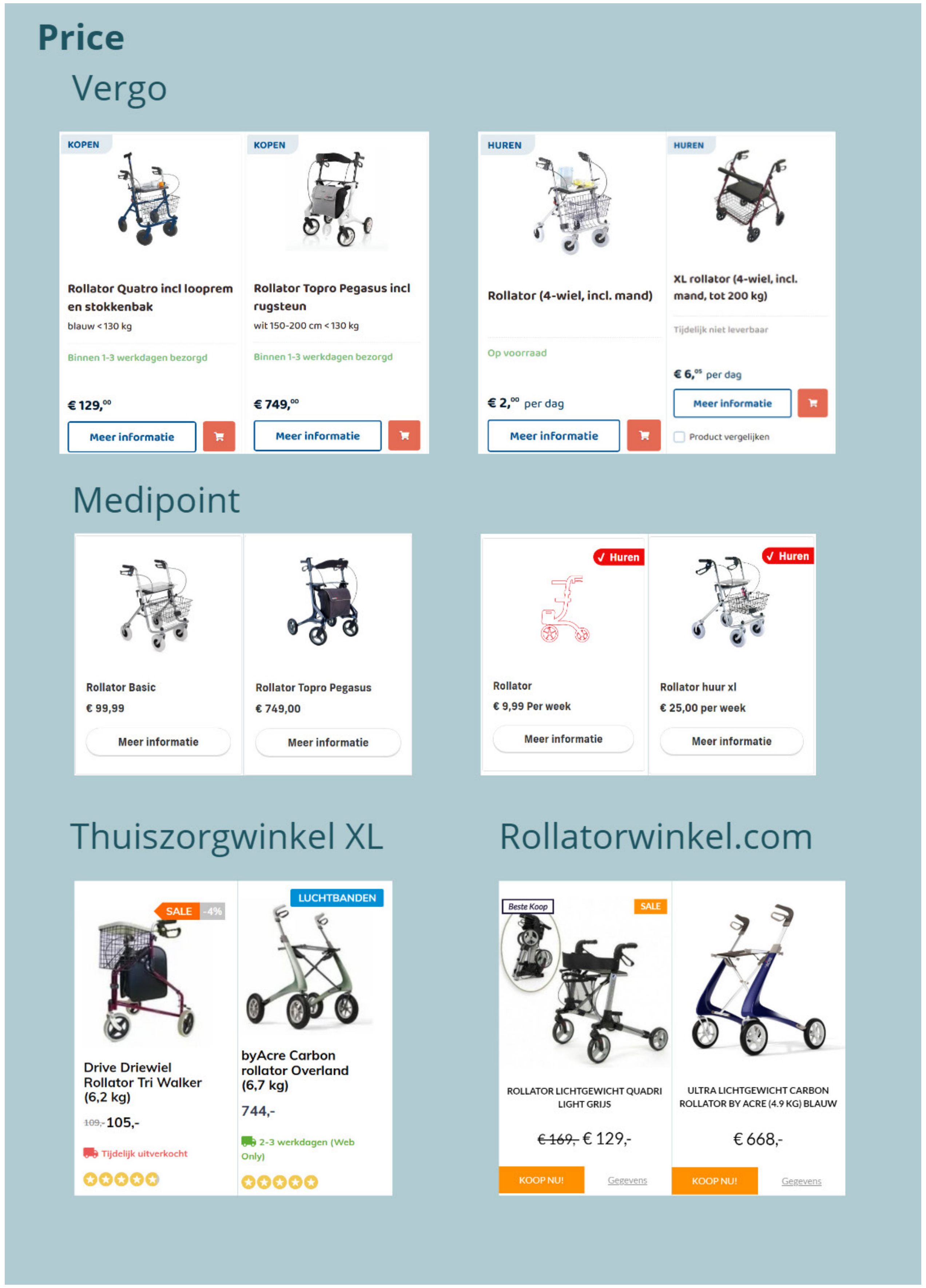
Appendices

Appendix A – Rollator prices

In this appendix you can find the least and most expensive rollator sold by 4 big rollator web shops in the Netherlands and their prices at 20-11-2024.



Appendix B – Observations

The results of the observations can be found in this appendix.

2 hour observation De Hoven:

- 1st hour: 20 rollators
- 2nd hour: 30 rollators
- Mostly sitting in one place. Last 15 minutes walking around.
- Rollator 1-51

1 hour observation Week market:

- Walking around
- Rollator 52-73

General observations:

- Saw 2 people walking with a walking stick
- New requirement: standing still, braking and leaning on the rollator in the same time
- New requirement: braking while walking
- New requirement: braking while standing up form seat
- It is possible some people are observed twice
- Could be interesting to do the same observation in the city centre, because there are more obstacles during walking there prices at 20-11-2024.

Rollator 1

- Standing still while braking with the handbrakes
- Upright walking
- Big steps
- Female

Rollator 2

- Bend over walking
- Big pack of bottled water on the seat
- High shoulders

Rollator 3

- Big steps
- Arms in a 135 degrees angle
- Bag and a basket

Rollator 4

- Unknown if it is a rollator or a grocery bag on wheels
- Smaller wheels

Rollator 5

- Small steps
- Low speed
- Hands constantly on the brakes

Rollator 6

- Small steps
- High speed
- Hand not on the brakes

Rollator 7

- Small steps
- High speed
- Upright walking
- Hand not on the brakes
- Small sway from left to right

Rollator 8

- Medium steps
- Medium speed
- Upright walking
- Hand not on the brakes

Rollator 9

- Low speed
- Medium steps
- Walks in between the wheels
- Elbows far outward while walking
- Could the hand rests be too high?

Rollator 10

- Bend over walking
- Low speed

Rollator 11

- Upright walking
- medium speed

Rollator 12

- upright walking
- walking in between the wheels
- hands not on the brakes
- small sway

- medium speed

Rollator 13
- upright walking
- hands not on the brakes
- walking in between the wheels

Rollator 14
- lightly bend over walking
- walking just behind the wheels
- hands not on the brakes
- small steps

Rollator 15
- lightly bend over walking
- Arms in a 110 degrees angle
- walking just behind the wheels
- hands not on the brakes

Rollator 16
- Arms in a 90 degrees angle
- walking just behind the wheels
- upright walking
- High shoulders
- small sway

Rollator 17
- lightly bend over walking
- walking in between the wheels
- hands not on the brakes

Rollator 18
- Small steps
- walking in between the wheels
- Arms in a 110 degrees angle
- hands not on the brakes

Rollator 19
- lightly bend over walking
- Hands on the brakes

Rollator 20
- Bend over walking
- 2 bags and a basket
- Arms in a 135 degrees angle

Rollator 21
- walking in between the wheels
- High speed

Rollator 22
- walking just behind the wheels
- High speed
- Arms in a 135 degrees angle

Rollator 23
- Bend over walking
- Hands on the brakes
- Small steps
- walking just behind the wheels
- new rollator + backrest
- groceries crate on the seat

Rollator 24
- Upright walking
- High shoulders
- Partner also leans with one hand on the rollator

Rollator 25
- Uses shopping cart as rollator
- Bend over walking
- Small steps
- Walking stick is in the cart

Rollator 26
- Very high shoulders
- Arms in a 135 degrees angle

Rollator 27
- Small steps
- High shoulders
- Arms in a 165 degrees angle
- New rollator
- Walking just behind the wheels

Rollator 28
- Very bend over walking
- No sway
- A lot of items being carried on the seat

Rollator 29
- Bend over walking
- Looks at the ground in front of the rollator
- Small steps
- Walks on flip flops
- Small sway
- Old rollator

Rollator 30
- Hand are on the brakes
- Small sway
- Small steps

Rollator 31
- Small sway
- Shaking hands
- Hands not on the brakes
- New rollator

Rollator 32
- Bag on the seat
- New rollator
- Rollator walking together
- Hands not on the brakes
- Small sway

Rollator 33
- New rollator
- Rollator walking together
- Hands on the brakes
- Small sway

Rollator 34
- Lightly bend over walking
- Small sway
- High shoulders
- Old rollator

Rollator 35
- Low speed
- Small sway

Rollator 36
- Sway from left to right
- High shoulders
- Hands not on the brakes

Rollator 37
- Low speed
- Hands not on the brakes
- No sway
- Basket is very low and thus needs to bend very far to get something

Rollator 38
- No sway
- Hands on the brakes
- Basket is very full

Rollator 39
- Almost no sway
- Bend over walking

Rollator 40
- High speed
- Almost upright walking
- Walking in between the wheels
- Hands not on the brakes

Rollator 41
- Hands not on the brakes
- Walks just behind the wheels

Rollator 42
- Hands on the brakes
- Walks just behind the wheels

Rollator 43
- Bend over walking
- Walks just behind the wheels
- New rollator

Rollator 44
- Hands not on the brakes
- Walks in between the wheels
- Upright walking
- Holds bag strap in the same hand as hand grip

Rollator 45
- Upright walking
- Hand grips look very high
- New rollator

Rollator 46
- Medium speed
- Hands on the brakes
- New rollator

Rollator 47
- Old rollator
- Medium speed
- Hands not on the brakes

Rollator 48
- Hands on the brakes
- Lightly bend over walking
- Walks behind the wheels
- Small steps

Rollator 49
- Big robust rollator
- Grocery bag hanging from one hand grip

Rollator 50
- Upright walking
- High speed
- Hands not on the brakes
- Walk in between the wheels

Rollator 51
- Slow
- Skinny rollator
- Long man
- Walks in between the wheels

Rollator 52
- Basket filled with groceries
- Walks behind the wheels
- Small steps

Rollator 53
- Walks behind the wheels
- Hands not on the brakes
- Bag wrapped around handles

Rollator 54
- Small steps
- Walks behind the wheels
- Bend over walking
- Hands not on the brakes
- Lots of ground vibrations

Rollator 55

- Lightly bend over walking
- Walks fast

Rollator 56

- Hand turned inward
- Light sway
- Walk in between the wheels
- One wheel lifting up from the ground

Rollator 57

- Bend over walking
- Small rollator
- Walks fast

Rollator 58

- Walks fast
- Upright walking
- Hands not on the brakes

Rollator 59

- Lightly bend over walking
- High shoulders
- Fast steps
- Hands not on the brakes

Rollator 60

- Walks just behind the wheels
- Lightly bend over walking
- Hands not on the brakes
- High speed steps

Rollator 61

- Big wheels
- Bend over walking
- Handles at the lowest setting
- Releases rollator without applying the hand brakes
- Better posture without rollator
- Bending deeply for basket

Rollator 62

- Keeps hold of rollator while standing still and talking
- Hands on the brakes

Rollator 63

- High speed
- No sway

Rollator 64

- Releases rollator without applying the hand brakes
- Bending deeply for basket
- Walks behind the wheels
- No sway

Rollator 65

- Sitting, rollator in front of feet
- Hand brakes applied
- Bag is hanging on handles

Rollator 66

- High speed
- Sideways sway
- Hands not on the brakes

Rollator 67

- Standing still with one foot on the wheel
- No braking
- Lightly bend over
- Arms in a 110° angle

Rollator 68

- Umbrella in walking stick holder
- Walks behind the wheels
- Walks bend over

Rollator 69

- Bend over walking
- Small steps
- Hands on the brakes
- Walkes behind the wheels
- Arms in a 135° angle
- Lots of vibrations
- Small sway

Rollator 70

- Small sway
- Small steps
- Lots of vibrations

Rollator 71

- Rollz motion
- Holding on behind the handles
- Walks just behind the wheels
- Standing still with one hand on handle

Rollator 72

- Rollz motion as wheelchair

Rollator 73

- Lots of vibrations
- No sway
- Hands not on the brakes
- Upright walking

Appendix C – User interviews

The full interviews will be transcribed below in Dutch to keep their authenticity. The names are changed into pseudonyms to maintain anonymity.

Interview 1

Pseudoniem - Gerda

Interviewer

Hoe lang gebruikt u al de rollator?

Gerda

10 jaar, denk ik.

Interviewer

Goed dat ik u dan spreek. Mag ik vragen waarom u de rollator gebruikt?

Gerda

Omdat ik slecht kan lopen. Ik heb neuropathie In de benen en speciaal in de voeten. En dan ben ik dan ook nog in het hoofd. Het correspondeert niet, de voeten en het hoofd. Dat dus Ik ben ook een beetje duizelig.

Interviewer

Oh ja en dan helpt de rollator met stabiliteit?

Gerda

Ja, dus met de rollator durf ik wel naar de Plus, maar niet alleen.

Interviewer

Ja precies. Fijn dat de rollator daarbij kan helpen. En, Ik denk dat u dan ook wel met 10 jaar ervaring wel een specifieke rollator hebt uitgekozen die heel fijn bij u past.

Gerda

Ik heb een hele fijne, vind ik. Ik heb hem toevallig niet hier, want Ik heb ook een scootmobiel en ik woon hier aan de overkant. Tenminste twee straatjes dat we dus ik kom niet met het busje. Ik woon hier aan de overkant. Ik woon hier ook niet. En dan kom ik met de scootmobiel. Die staat hier voor. En ik pak hier een rollator.

Interviewer

Oh, hier staan er. Maar uw eigen rollator. Die heeft die uitgekozen Omdat hij heel fijn is?

Gerda

Dat is. Ik vind dat een hele fijne. Ten eerste vind ik hem al fijn omdat ik hem heel makkelijk kan inklappen, heel makkelijk. En er zit dus een zitting, zeg maar niet zo groot, maar een zitting. En daar zit een touwtje en Dat is heel vreemd hoor. Dus jammer dat ik hem niet hier heb. Ik trek aan het touwtje en hoppa. En dat klapt samen. Oh, ideaal.

Interviewer

Want dat doet u vaak het inklappen?

Gerda

Ja. Nou ik gebruik hem ook in huis. Want ik sinds kort ben ik alleenstaand. Mijn man is overleden 3 en 4 weken geleden. En ik gebruiken hem dus ook in huis, keuken. En dan doe ik hem natuurlijk heel vaak eventjes een beetje kleiner maken.

Interviewer

Als er een krap stukje in huis is bijvoorbeeld?

Gerda

Ja, en dan vind ik dat touwtje nou, hup, ik trek aan het touwtje en hup, het klapt zo in en dat vind ik een ideale. Jammer dat ik het adres enzo daarvan niet weet. Volgens mij komt hij uit Nijmegen.

Interviewer

Zal eens naar kijken, want Ik denk niet dat er heel veel zijn die op zo'n manier werken.

Gerda

Nee, zeker niet, want mijn man had ook een. Die is nu weg, maar dat moest omhoog. En ja, dat moest anders. Er zat een band geloof ik, en dan moest je zo doen (trekt hand omhoog). Nou ja, goed. Hij is weg. Je bent natuurlijk aan het opruimen als mijn man overleden is en alles opgeruimd. Nou niet alles. Maar ik vond mijn eigen rollator het fijnste.

Interviewer

En zijn er dan ook nog dingen die u minder fijn vindt aan uw eigen rollator of bijvoorbeeld aan die die u hier gebruikt?

Gerda

Nee. De een is mooier dan de andere. Het uitvoering daarvan is mooie. Ik zie ook de rollators van de mensen die hier zijn en de meeste hebben een rollator en die zijn mooier als die van mij. Die is eenvoudig en met dat touwtje, hup, heel gemakkelijk is ie. Maar van hun zijn mooier. Die van mij niet. Ik heb gewoon een eenvoudige.

Interviewer

En u zei al dat u het onhandig vindt aan de rollator, of nou ja, aan de stoep eigenlijk dat het niet te doen is?

Gerda

Vreselijk vind ik dat. Er zit iets aan de voet bij een van de wielen en dan moet je even zo doen (tilt voet op en duwt hem omlaag) en dan gaat hij een beetje omhoog. Gaat de rollator omhoog en dan nou ja, dan ga je wel. Dat zijn zulke stukjes vaak hè '(gebaart ongeveer 10 cm). Waar je tegenaan botst. Dat weet ik nog dat mijn man ook, verleden jaar heb ik het dan over hoor, dat hij tegen zo'n randje was gebotst. En als je dan boodschappen hebt gedaan. En je gaat dan met die rollator en je hebt dat niet in de gaten. Nou, toen lag mijn man op de grond, want die heeft dat niet in de gaten. Ja, hij was 10 jaar ouder als ik hoor. Hij is 96. En die is dan sinds kort overleden, maar ja, daar ging hij dan tegenaan met boodschappen. En hij had niet die randjes waar die dan op moest letten. Nou, dat had ie niet in de gaten. Dus je moet overal opletten en juist met het oud worden. Ja, dat gaat nu weer zo goed natuurlijk in dat hoofd en dan moet je moet overal opletten. Wat je doet en hoe je rijdt. Want ja, het blijft toch een beetje een handicap van jezelf die dat wordt overgenomen door die rollator.

Interviewer

Ja precies ja. Vervelend dat het die stoeprandje er dan zo zijn. En er zijn ook geen stukjes In de buurt waar het stoeprand verlaagd is of is dat dan nog steeds een te hoge hobbel?

Gerda

Zelf hebben wij dat al 10 jaar geleden aan de gemeente gevraagd, want ik woon dus in de ***straat. En daar heb je altijd als je naar binnen gaat, zo'n drempel. Dat hebben we toen al gevraagd of onze kinderen hebben gevraagd aan de gemeente of ze dat gelijk willen maken. Dus het is nu bij mij, ik ben de enige geloof ik, gelijk. Dus je kan met je rollator zo naar binnen. Ideaal. Dat is ideaal, hè, dat je makkelijk naar binnen kan en niet dat je met boodschappen dat dat je dat weer moet op tillen.

Interviewer

Ja want onhandig eigenlijk dat je met de voet zo'n zetje moet geven.

Gerda

Toch ja, bij het wiel zit iets en dan doe je zo (tilt voet op en duwt hem omlaag) en dan gaat hij iets omhoog. Ja en je moet ook goed kunnen remmen. Want overal waar je stilstaat, moet je hem op de rem zetten, want hij rijdt er natuurlijk zo van door.

Interviewer

Uw rollator heeft van die knijpremmen. Wat vindt u daarvan? Zijn die fijn, werkt dat goed?

Gerda

Ja nou, ik heb hem natuurlijk 10 jaar dus de ene kant wordt iets minder, maar ja. Er is misschien wat aan te doen. Dat weet ik niet, maar ik heb er niet zoveel last van. Dat gaat heel goed. Een kant doet het ietsje minder, maar hij doet het nog wel.

Interviewer

En zijn er nog bepaalde situaties die u ontwijkt, omdat u weet dat dat niet goed gaat met de rollator.

Gerda

Wat ik ontwijk?

Interviewer

Bijvoorbeeld, zeg ik loop eigenlijk niet meer die route ergens heen, want daar zitten alleen maar vervelende stoep randjes.

Gerda

Nou ja. Ik denk niet dat ik laat maar zeggen 3, 4, 5 km kan lopen. Als ik een blokje rondloop, want het is natuurlijk geadviseerd dat je elke dag een blokje rond moet lopen. Gewoon voor het geheel hè. Niet alleen voor die rollator. Voor de beweging. En, dat doe ik dan. 1,5 km, dat gaat waar ik loop, dat stukje. Dat gaat goed. Op de stoep loop ik dan hè? Daar liggen ook wel eens stenen zo zo zo (gebaart schots en scheef), maar dan weet ik toch wel precies waar dat is. Ik zou niet naar de stad gaan. Ik ga dan naar de Plus. Nou, dat gaat goed. Ga ik ook wel eens met mijn scootmobiel. Ook makkelijk, te makkelijk. Maar voor de rest doet hij het wel goed, vind ik, mijn rollator. En ook in huis. Ja, de kinderen zeggen, ja, je moet er meer gebruiken. Want Ik heb natuurlijk ook thuis zo'n rollator met zo'n plateau. zo'n dienblad. heb ik ook, dus dat gebruik ik dan weer meestal in huis. En in de keuken en daar zet ik dan mijn kopjes op of mijn boterham, wat dan ook. En dat rijdt ook makkelijk. Daar zit alleen geen rem op, daar zit wel een rem op. Ik moet niet liegen. Er zit een rem op en die doet het heel goed. Die kan niet inklappen.

Interviewer

Dus u vind dat vervelend in de smallere stukjes. Maar is hij niet iets smaller dan de normale rollator?

Gerda

Nou. Misschien wel, daar heb ik niet naar gekeken. Die heb ik pas. 1,5 jaar geloof ik, nog niet zo lang.

Interviewer

Maar die wisselt U een beetje af?

Gerda

Ja, die wissel ik af in huis. In huis, want ik ga daar niet mee naar buiten natuurlijk. Nee. Die gebruik ik in huis veel. Ja ook een hele fijne vind ik.

Interviewer

Nog een vraag. Gaat de rollator wel eens mee In de auto? Als uw kinderen bijvoorbeeld langskomen en u mee op stap gaat.

Gerda

Ja.

Interviewer

En, zij zetten hem voor u in de auto?

Gerda

Ja, ze trekken even aan het touwtje en dan is hij ingeklapt. Want ik ben toevallig met een van mijn kinderen ben ik 4 dagen mee geweest naar Ommen. Ook ingeklapt In de auto, nou dat gaat goed.

Interviewer

Dus u zegt eigenlijk wel dat inklappen, Dat is niet te missen uit een rollator?

Gerda

Nee, nou ik denk dat die niet eens te koop zijn. Ja, Misschien hier iets, dat weet ik niet.

Interviewer

Dat waren alle vragen. Bedankt voor uw tijd.

Interview 2

Pseudoniem - Marie

Interviewer

Ik doe dus onderzoek naar het gebruik van de rollator. Hoe lang gebruikt u al een rollator?

Marie

Een jaar of 3, denk ik ja, Omdat ik niet zo stevig mee om mijn. Voet te stijven. Interviewer

Interviewer

Mag ik vragen Waarom?

Marie

Omdat ik niet zo stevig meer op mijn voet sta.

Interviewer

Nou fijn dat de rollator daarbij kan helpen.

Marie

Ja, het is een uitvinding apart.

Interviewer

Ja. Inderdaad en hij bestaat al ontzettend lang eigenlijk, maar er is weinig veranderd over de tijd aan de rollator. Ook al zie ik dat u wel een hele mooie nieuwe heeft.

Marie

Oh hij is wel een jaar of 3 oud. Maar hij staat wel binnen.

Interviewer

Waarom heeft u specifiek voor deze rollator gekozen? Ik bedoel, Als je In de winkel komt. Staan er heel veel opties.

Marie

Nee door praten en zeggen wat het beste gaat. Zodoende ben ik bij deze terecht gekomen, want ik had geen ervaring natuurlijk.

Interviewer

En, wat vindt u fijn aan deze rollator?

Marie

Dat ik boodschappen ermee kan doen. En Ik kan erop zitten eventueel.

Interviewer

Dat gebruikt u veel?

Marie

Ik kan niet meer zon eind lopen, dus ja.

Interviewer

Zijn er ook dingen die u minder fijn vindt aan de rollator.

Marie

Nou, de wegen zijn ook niet zo lekker. Ze lopen af en toe schuin, dat ligt niet aan de rollator natuurlijk.

Interviewer

Dan is de stoep schuin, en dan heeft u het idee dat hij omvalt?

Marie

Nou, je loopt niet lekker. Dus we zoeken altijd dat dat je een beetje midden op de stoep of zo loopt.

Interviewer

Heeft u ook problemen met stoeprandje is of gaat dat eigenlijk wel goed?

Marie

Dat moet eigenlijk dat dingetje gebruiken, maar dat vergeet ik. Dus dan til ik hem.

Interviewer

Ja. Die tilt er nog gewoon op? En dan alle wielen tegelijkertijd of eerst voor dan achter.

Marie

Ik geloof dat ik dat niet eens weet.

Interviewer

Dat is ook begrijpelijk. Ik heb daar helemaal oog voor gekregen door mijn onderzoek.

Marie

Wat wilt u eraan gaan veranderen?

Interviewer

Ja, ik zou willen kijken of we hem veiliger of fijner kunnen maken. Maar we moeten eerst ontdekken wat er niet goed aan is.

Marie

Ja. Maar ik kan hem ook inklappen. Dat als ik hem thuis kom, dan zet ik hem in de berging.

Interviewer

En dan klapt u hem in en dan staat hij mooi aan de kant?

Marie

Ja.

Interviewer

En klapt u me ook wel eens in, omdat hij dan meegenomen wordt In de auto?

Marie

Ja, als ik met mijn kinderen meega of met het busje. Dan kan die ingeklapt worden.

Interviewer

Ja en dan doen zij hem voor u inklappen?

Marie

Ja en ook weer uitklappen.

Interviewer

Zijn er nog bepaalde situaties die u ontwijkt met de rollator?

Waarvan u zegt dat doe ik eigenlijk niet, want dat is niet fijn met de rollator?

Marie

Met een harde wind heb ik wel eens dat mijn karretje gewoon omhoog ging. Door die wind. De wind trekt daar bij dat hotel.

Interviewer

Oh, dan is de rollator eigenlijk te licht?

Marie

Dan is die te licht, ja. Dan zit er niks in natuurlijk. Dat is maar één keer gebeurd hoor. De tweede keer ben ik binnen gebleven. Nou binnen gebleven of een andere weg. Bij dat hotel trekt het altijd.

Interviewer

Ervaart u wel eens ongemak tijdens het gebruik van de rollator?

Marie

Nee. Zou ik zeggen.

Interviewer

Dat waren alle vragen. Bedankt voor uw tijd.

Interview 3

Pseudoniem - Piet

Interviewer

Mag ik vragen hoe lang u al met een rollator loopt?

Piet

Ik loop er al een jaar of 6 mee.

Interviewer

U heeft een mooie rollator. Is er een reden dat u specifiek deze heeft gekozen?

Piet

Nou, mijn vrouw heeft hem gekocht. Ik wou daar nooit aan, want ik vond het altijd maar eh ja. Je weet nooit wat de buren zeggen. Mijn vrouw heeft hem gekocht en het is gewoon een gouden ding. Dus hij kan zeg maar in een keer in elkaar klappen hè? En hij heeft ook een tassie.

Interviewer

Want neemt u hem veel in die vorm mee? In de auto?

Piet

Ik mag geen auto meer rijden, maar normaal gesproken in de auto of met een busje gaat hij altijd mee.

Interviewer

Dat is al een goed punt van de rollator. Kunt u nog twee andere goeie dingen aan deze rollator noemen?

Piet

Nou, in principe is die veder licht Misschien bestaan ze nog wel lichter, maar dat weet ik niet. Natuurlijk, is dat ding al 5 of 6 jaar oud. En ja, Hij is heel handig. Je kan hier een blad op zetten. Een blad zit erbij, dus als je ergens in een restaurant bent. Dan ja dan blad neem je natuurlijk nooit mee, maar normaal doe je dat blad erop en dan kan je daar je bord opzetten. En je kan zeg maar 500- 600 m lopen en als je moe bent, ga je erop zitten. Zo simpel, je hebt een bandje in je rug. Je kan echt uren erop zitten.

Interviewer

En zijn er ook dingen die u minder fijn vindt aan deze rollator.

Piet

Mee lopen natuurlijk, ik had liever normaal gelopen. Maar voor de rest, ik zal nooit meer een kopen met plastic wielen. Het glijd. Het glijd alle kanten uit, er zit wel wat op natuurlijk. Maar ja, dat is in principe niks. Als je de op de straat loopt dat ze trillen voelt. Dat is kei en keihard, het is ook plastic. Het liefst zou ik dan zo'n zelfde rollator hebben maar dan met rubber bandjes. Ook grip met het remmen. Kijk, hij gaat er nog steeds vandoor.

Interviewer

Ervaart u nog ander ongemak tijdens het gebruik van de rollator?

Piet

Nee, voor de rest is het eigenlijk gewoon een fantastisch ding. Je hebt ze tegenwoordig met GPS en weet ik het allemaal wat. Je hebt tegenwoordig zulke mooie dingen.

Interviewer

Zijn er nog bepaalde situaties die ontwijkt met het gebruik van een rollator?

Piet

Ja, ik heb ook nog een scootmobiel hè. Ik zet hem bij mij onderin de garage dat ding en ga met de scootmobiel weg. Dus buiten gebruik ik hem eigenlijk niet zoveel. Ik heb het geluk dat ik tegenover een park woon. Als ik naar buiten loop, loop ik gelijk het park in. Er is een grind pad en dan daar loop ik dan wel een stuk door het bos heen. En even onderweg gaan zitten op mijn gemakje maar echt op de straat heel weinig.

Interviewer

Dan kiest u toch voor de scootmobiel?

Piet

Ja.

Interviewer

Omdat dan de afstand verder is of omdat u het niet fijn vindt?

Piet

Je hebt natuurlijk allemaal ongelijke tegels enzo, dat is heel vervelend. Als je hier naar buiten loopt, loopt het gelijk schuin. Als je dan een bocht moet maken, dan is dat heel vervelend, want dan heb je elke keer het idee van oeh. Maar ja, op straat heb je dat natuurlijk ook. En ook die harde wielen hè? Dat tik tik tik dat voel je echt. En dan zeg ik, het is een prachtig mooi ding, Alleen maar rubber wieltjes moeten even.

Interviewer

En klapt u hem thuis ook regelmatig in? Dat u hem inklapt en aan de kant zet of gebruikt u hem in huis ook?

Piet

Ja, Ik heb thuis maar korte stukjes, en die kan ik gewoon lopen. Maar zeg maar als ik opsta en ik moet naar het toilet toe of zo, dan neem ik hem even mee, want dan staat die achter me en dan klapt hij vanzelf uit. Dan loop ik naar het toilet toe en ben ik daar, dan klap ik hem weer even in. Ik neem niet eens mee dat toilet in dat doe ik niet.

Interviewer

Dat waren alle vragen al. U heeft me een duidelijk beeld gegeven van uw gebruik. Heeft u nog vragen aan mij?

Piet

Ik moet eerlijk zeggen. Ik denk alleen qua gewicht enzo er wat te verbeteren is aan dat ding. Voor de rest is er denk ik weinig aan te verbeteren?

Interviewer

Nou, dat zou ook een uitkomst kunnen zijn van mijn onderzoek.

Piet

Ja. Ik neem aan dat iedereen die je hier spreekt zeer tevreden is over de rollator. En je hebt allemaal dingen die je erbij kan kopen. Je kan er een ding opzetten waar je stok dan in klemt. En dingen voor je telefoon. En het tasje is ook erg handig, maar je moet er geen zware dingen in stoppen.

Interviewer

Dat waren alle vragen. Bedankt voor uw tijd.

Interview 4

Pseudoniem - Anja

Interviewer

Hoe lang gebruikt u al de rollator?

Anja

Even kijken hoor, 17 jaar.

Interviewer

En mag ik vragen waarom u de rollator gebruikt?

Anja

Niet nou, Ik heb 17 jaar geleden een nieuwe linker knie gekregen. Ja, toen met lopen, dan mag je met krukken. Nou, dat vond ik zo eng. Dus toen heb ik meteen een rollator genomen en dat ging prima.

Interviewer

En Waarom heeft die specifiek voor deze rollator gekozen?

Anja

Nou ik had eerst een andere, maar die was zwaar en die konden ze dan met de regio moeilijk ja in de auto tillen, maar toen hebben we die gekocht. Maar die is ook al oud, dus nu moet ik weer een andere hebben. Ik heb nou die stok daarnaast, maar misschien dat je ook op een andere manier zo kan doen. Dat weet ik ook allemaal niet. Maar ja, ben eigenlijk steeds te moe om naar Vegro te gaan.

Interviewer

Wat vindt u fijn aan deze rollator?

Anja

Ja, Hij is licht en gaat allemaal lekker, hè? Niet moeilijk.

Interviewer

Mooi. Zijn er nog dingen die u minder fijn vindt aan uw rollator?

Anja

Ja die wieltjes hè? Die zijn zwaarder. Tegenwoordig heb je ook andere wielen. Dat loopt Misschien beter. Dat weet ik ook niet, hoor. En ik woon dus in de binnenstad en daar al die stenen, die liggen allemaal schots en scheef. Dat is wel moeilijk lopen hoor, dan moet heel erg uitkijken.

Interviewer

Al die stenen. En vaak ervaart u nog ander ongemak tijdens het lopen.

Anja

Nou ja, ik met mijn ogen dus? Dat is een ongemak in het altijd opletten en naar de grond kijken. Kan ik lopen, is er geen steen schreven, wat dan ook dat.

Interviewer

En, is het dan nog een nadeel dat er een stoeltje en een mandje hangt op de plek waar je wil gaan lopen? Dat u niet kan zien waar u loopt?

Anja

Ik vind het geen nadeel, maar misschien anderen wel, dat weet ik niet.

Interviewer

Zijn er nog bepaalde situaties die u ontwijkt omdat het niet fijn is?

Anja

Ja als het heel druk is, dan ga ik eigenlijk, niet naar buiten of ik loop een beetje aan de zijkant. Ja, dat doe ik dus niet.

Interviewer

Omdat mensen dan u niet aan zien komen?

Anja

Ja of ze gaan niet eens op zij. Mensen zijn heel anders tegenwoordig, hè?

Interviewer

U zei dat de rollator ook wel eens in het busje wordt meegenomen of in de auto. Wordt de rollator dan voor u ingeklapt?

Anja

Ja, met de regio ga je ook vaak met een personenauto en dan wordt ie ingeklapt, gaat hij achterin. Maar als hij een groot busje gaat, dan gaat ie gewoon zo.

Interviewer

Ik ben al door mijn vragen heen. Heeft iemand dingen die u kwijt wil of vraag aan mij ook?

Anja

Ja eigenlijk. Niet. Zou het niet weten eigenlijk?

Interviewer

Bedankt dan voor uw tijd en uw antwoorden.

Interview 5

Pseudoniem: Jan

Interviewer

Hoe lang gebruikt u de rollator al?

Jan

Nou een jaar zeker wel.

Interviewer

Ja en dan specifiek deze speciale.

Jan

Ja wat wel een nadeel is. Maar ik vind het een voordeel. Hij is wel zwaar, maar ook wel breed. Ik woon in een flat. Daar heb ik gevraagd om strippen bij de deurpost te doen, want je rijdt behoorlijk veel tegenaan. De drempels zijn er om uitgehaald, maar bij het deurposten. Want ik weet niet hoeveel centimeter breed ze zijn, maar je gaat nog makkelijk tegen de deurpost aan. En het huis wordt dan overal beschadigd. Dat is wel een nadeel. Een kleinere rollator die je in elkaar klapt, dat gaat wel makkelijker in naar huis. Thuis gebruik ik hem niet zo gek veel, want ik wil niet dat alles lelijk wordt. Maar verder ben ik er wel tevreden over, maar ik vind enkel een nadeel als u hem In de auto moet tillen. Ik weet niet hoeveel kilo die precies weegt. Maar ik vind hem wel vrij zwaar. Als je hem In de auto tilt ook. Je kan hem opklappen. Maar als de bus komt, dan moet hij ook opgeklapt worden, maar je zit te zoeken om hem ergens beet te pakken. Dat gaat een beetje moeilijk.

Interviewer

Ja nu is het zoeken waar je hem vast kan houden?

Jan

Ja. als er nou gewoon een beugeltje van metaal was waarmee je hem makkelijk op kan tillen en in de auto kan zetten. Dat vind ik wel een nadeel. En die andere rollators? Ja, die zijn een stuk lichter en dan pak je hem beet en dan gaat het. Natuurlijk klapte hij hem in en met deze gaat het een beetje moeilijk.

Interviewer

En u heeft een hele mooie rollator, maar zijn er nog situaties die ontwijkt omdat u dit toch niet fijn vindt?

Jan

Ik ontwijk het niet, maar ik zit wel iedere keer een beetje te pielen om hem in de auto te krijgen, in een personenwagen. Dan moet je hem op tillen, en ik kan nog wel aardige wat tillen, maar dat is niet voor mijn vrouw. En als er nou één of andere beugel aan zit of ik weet niet wat. Je moet ook uitkijken voor die draden, dat je die niet kapot trekt. Daar hadden ze wel iets mee mogen doen?

Jan

Ja en een bosje erop, ja, Ik weet niet. Het zou wel mogelijk wijzen, Maar ik weet niet of dat interessant is.

Interviewer

Ik denk dat ik alle vragen al gesteld heb, wilt u nog iets kwijt over de rollator of heeft uw vraag aan mij over mijn onderzoek?

Jan

Een één of ander systeem om hem makkelijker beet te pakken, nou zit je dikwijls te knoeien. Ja, waar pak je hem beet je om in de auto te tillen of wat dan ook?

Interviewer

Dat waren alle vragen. Bedankt voor uw tijd.

Appendix D – ISO 11199-2 requirements

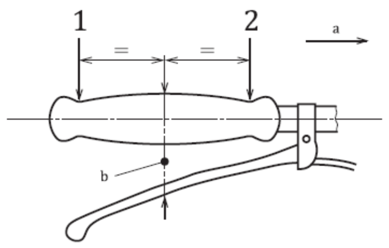
In this appendix you can find most of the regulations of the ISO 11199-2 standard.

Regulatory requirements

1. It shall not be possible to reassemble the rollator in a manner that presents a hazard after dismantling for transport or storage.
    a. According to ISO 11199-2:2021 clause 6.2
2. The fasteners that are loosened or removed to allow dismantling shall not be single use fasteners.
    a. According to ISO 11199-2:2021 clause 6.2
3. All load-bearing fasteners shall be either self-locking or fitted with a locking device to prevent inadvertent detachment.
    a. According to ISO 11199-2:2021 clause 6.3
4. The maximum user mass shall be specified. For load carrying accessories, the load capacity of the accessories shall be specified.
    a. According to ISO 11199-2:2021 clause 6.4
5. the front wheel diameter shall be greater or equal to 180 mm.
    a. According to ISO 11199-2:2021 clause 6.5
6. the wheel width shall be greater or equal to 22 mm.
    a. According to ISO 11199-2:2021 clause 6.5
7. the rollator shall be equipped with running brakes operating on two wheels.
    a. According to ISO 11199-2:2021 clause 6.5
8. The user shall be able to manipulate the brakes when walking.
    a. According to ISO 11199-2:2021 clause 6.5 and 6.6.1
9. a rollator shall be equipped with parking brakes operating on two wheels that can be integrated with the running brakes.
    a. According to ISO 11199-2:2021 clause 6.5 and 6.6.1
10. Maximum grip distance for operating running brakes shall be not greater than 75 mm (see Appendix A)
    a. According to ISO 11199-2:2021 clause 6.6.1
    b. NOTE: For rollators with pressure brakes, there is no grip distance.
11. If the effectiveness of the brake will be reduced by wear, it shall have means for the compensation of wear.
    a. According to ISO 11199-2:2021 clause 6.6.1
12. Brake performance shall not be adversely affected by folding, unfolding, or adjusting actions.
    a. According to ISO 11199-2:2021 clause 6.6.1
13. If readjustment of the brakes is necessary following an adjustment action of the rollator, tools shall not be required (e.g. height adjustment).
    a. According to ISO 11199-2:2021 clause 6.6.1
14. Shall not move more than 10 mm in 1 min if the running brake or the parking brake is activated.
    a. According to ISO 11199-2:2021 clause 6.6.2
15. The maximum force to apply and release the brakes shall not exceed: 60 N for pushing forces, and 40 N for pulling forces.
    a. According to ISO 11199-2:2021 clause 6.6.2
16. No part of the brakes shall crack or break and the effectiveness of the brake shall meet the requirements in 6.6.2.1 after the durability test.
    a. According to ISO 11199-2:2021 clause 6.6.3
17. The handgrip width shall be no less than 20 mm and not more than 50 mm. This shall be checked by measurement.

a. According to ISO 11199-2:2021 clause 6.7
b. NOTE: This requirement is not applicable to anatomic handgrips.

18. The handgrip shall be securely fixed to the handle of the rollator.
    a. According to ISO 11199-2:2021 clause 6.7
19. The materials used in a rollator should not mark, or scratch.
    a. According to ISO 11199-2:2021 clause 7.1
20. The rollator materials should not cause discoloration of skin or clothing when the rollator is in normal use.
    a. According to ISO 11199-2:2021 clause 7.1
21. Manufacturers should, wherever possible, use materials that can be recycled for further use. It shall be stated in the instructions for use which parts can be recycled.
    a. According to ISO 11199-2:2021 clause 7.1
22. Risk of flammability that can affect user safety shall be assessed by the manufacturer in the risk analysis. Parts identified by risk of flammability shall be tested according to ISO 8191-2. Residual risks should be reported in the instruction.
    a. According to ISO 11199-2:2021 clause 7.2.1
23. If the manufacturer claims that the upholstered parts are resistant to ignition by cigarette, progressive smouldering ignition and flaming ignition shall not occur when the materials used for the upholstered parts of an assistive product are tested in accordance with ISO 8191-2.
    a. According to ISO 11199-2:2021 clause 7.2.2
24. Materials that come into contact with the human body shall be assessed for biocompatibility using the guidance in ISO 10993-1.
    a. According to ISO 11199-2:2021 clause 7.3
25. The rollator and its auxiliary parts should be designed to be accessible for cleaning to prevent cross infection.
    a. According to ISO 11199-2:2021 clause 7.4.1
26. If liquid can come unintentionally into any cavities or enclosure, it shall be able to drain through drain holes again.
    a. According to ISO 11199-2:2021 clause 8
27. the gap between exposed parts of a rollator that move relative to each other shall be maintained throughout the range of movement at less than the minimum value or more than the maximum value set out in Table 1 (Appendix A).
    a. According to ISO 11199-2:2021 clause 10.1
28. Parts subject to mechanical wear likely to result in a safety hazard shall be accessible for inspection, unless it is intended to be replaced by a service interval specified by the manufacturer.
    a. According to ISO 11199-2:2021 clause 10.2
29. Holes in and clearances between stationary parts that are accessible to the user and/or assistant during the intended use of a rollator shall be as specified in Table 2 (appendix A).
    a. According to ISO 11199-2:2021 clause 11.1
30. On holes with the shape of a keyhole or V-shaped openings the lower limit shall not apply. When inspecting the rollator for traps for body parts, any flexibility/elasticity of adjacent parts shall be considered.
    a. According to ISO 11199-2:2021 clause 11.2
31. If a rollator incorporates folding and/or adjusting mechanisms, it shall conform to Clauses 10 and 11.
    a. According to ISO 11199-2:2021 clause 12.1
32. If the rollator is height adjustable, the increments shall not exceed 25 mm.
    a. According to ISO 11199-2:2021 clause 12.1
33. Adjustments shall be securely fixed when in use.
    a. According to ISO 11199-2:2021 clause 12.1
34. The maximum allowable elongation shall be clearly marked.
    a. According to ISO 11199-2:2021 clause 12.1
35. the rollator shall incorporate means to protect the user from trapping and/or squeezing hazards when the rollator is folded or the gap between exposed parts of a rollator that move relative to each other shall be maintained throughout the range of movement at less than the minimum value or more than the maximum value set out in Table 1 (Appendix A)
    a. According to ISO 11199-2:2021 clause 12.2
36. Locking mechanisms shall be required to maintain the rollator in the folder or in the working configuration if the absence of the locking device presents a hazard to the user. Locking mechanisms shall lock securely and shall be protected from unintended release.
    a. According to ISO 11199-2:2021 clause 12.3
37. If not required for the intended function for a rollator, all accessible edges, corners and surfaces shall be smooth and be free from burrs and protruding parts and sharp edges shall be rounded or chamfered.
    a. According to ISO 11199-2:2021 clause 14
38. If not required for the intended function, the rollator shall not have protruding parts. Where possible, necessary protruding parts shall have protection to prevent injury and/or damage.
    a. According to ISO 11199-2:2021 clause 14
39. In forward direction, the angle of the plane at the point of rollator tilting shall be no less than 15,0° from the horizontal.
    a. According to ISO 11199-2:2021 clause 15.1
40. In backward direction, the angle of the plane at the point of rollator tilting shall be no less than 7° from the horizontal.
    a. According to ISO 11199-2:2021 clause 15.1
41. To the sideways direction the angle of the plane at the point of rollator tilting shall be no less than 3,5° from the horizontal.
    a. According to ISO 11199-2:2021 clause 15.1
42. the distance between any handle (part intended to be grabbed) requiring an operating force of more than 10 N and any construction part of the assistive product shall not be less than 35 mm.
    a. According to ISO 11199-2:2021 clause 18
43. the distance between any upper surface of a pedal (in its operating position) and any other part of the assistive product shall have a vertical toe clearance of not less than 75 mm.
    a. According to ISO 11199-2:2021 clause 18
44. the diameter of any operating handles and/or knobs requiring an operating force of more than 10 N shall be between 19 mm and 43 mm.
    a. According to ISO 11199-2:2021 clause 18
45. for assistive products operated from a standing position, pedals (tipping aid) shall be placed not more than 300 mm above the surface of the floor.
    a. According to ISO 11199-2:2021 clause 18
46. for assistive products operated from a standing position, hand operated controls shall be placed at a height of 800 mm to 1200 mm above the surface of the floor.
    a. According to ISO 11199-2:2021 clause 18
47. for a rollator operated from a sitting position, controls intended to be operated by the occupant while seated shall be within the occupant’s reach space.
    a. According to ISO 11199-2:2021 clause 18
48. the operating forces or torques required for those parts of the rollator that are designed to be operated by fingers, hands/arms or feet shall not exceed the values in Table 3 (Appendix A).
    a. According to ISO 11199-2:2021 clause 18



Key

1 rear handgrip reference point

2 front handgrip reference point

a Front.

b Brake grip distance.

Figure 3 — Brake grip distance

Table 1 — Safe distances between moving parts

To avoid	Safe distances for adults	Safe distances for children[a]
Finger traps	Less than 8 mm or more than 25 mm	Less than 4 mm or more than 25 mm
Foot traps	Less than 35 mm or more than 120 mm	Less than 25 mm or more than 120 mm
Head traps	Less than 120 mm or more than 300 mm	Less than 60 mm or more than 300 mm
Genitalia traps	Less than 8 mm or more than 75 mm	Less than 8 mm or more than 75 mm
[a] Also includes adults with a height of less than 146 cm, or a mass of less than 40 kg, or a BMI of less than 17.		

Table 2 — Safe distances between stationary parts

To avoid	Safe distances for adults	Safe distances for children[a]
Finger traps	Less than 8 mm or more than 25 mm	Less than 5 mm or more than 12 mm
Foot traps	Less than 35 mm or more than 100 mm	Less than 25 mm or more than 45 mm
Head traps	Less than 120 mm or more than 250 mm	Less than 60 mm or more than 250 mm
Genitalia traps	Less than 8 mm or more than 75 mm	Less than 8 mm or more than 75 mm
[a] Also includes adults with a height of less than 146 cm, or a mass of less than 40 kg, or a BMI of less than 17.		

Table 3 — Operating forces

Operation	Force/torque
operation by using a finger	5 N
operation by using a hand/arm (pushing)	60 N
operation by using a hand/arm (pulling)	40 N
operation by using a foot	300 N
operation by turning	1,9 Nm
rotation of seat surface	60 N

Appendix E – Rollator comparison

In this appendix you can find all the data of the analysed rollators.

Rollator analysis

	Brand	Type	Shop	Price	Weight	Weight limit	Material frame	Seat height	Aesthetics score	# of extra features	Extra feature 1	Extra feature 2	Extra feature 3	Extra feature 4	Extra feature 5
1	Topro	Troja 5G	Vegro	459	7,8	150	Aluminium	63,5	2,666666667	2	Backrest	Basket			
2	Topro	Odyssé	Vegro	509,15	8,2	150	Aluminium	62	1,466666667	2	Basket	Double folding system			
3	Rollz	Motion performance	Vegro	857,65	14,8	125	Aluminium	55	7,2	4	Backrest	Also wheelchair	Threshold aid	Drum brakes	
4	Thuasne	Quatro	Vegro	109,65	11,4	130	Steel	60,5	0,533333333	3	Basket	Servingtray	Walking stick holder		
5	Saljol	Carbon	Vegro	594,15	5,8	150	Carbon fibre	62,5	5,6	4	Soft wheels	(adjustable) Drag brake	Basket	Walking stick holder	
6	Mobilex	Esprit S4	Vegro	305,15	8,4	130	Aluminium		3,933333333	3	Backrest	Basket	Walking stick holder		
7	Mobilex	Panda comfort	Vegro	339,15	9,44	150	Aluminium		5,066666667	4	Backrest	Basket	Threshold aid	Walking stick holder	
8	Excel	Carbon F1	Medipoint	749	5,9	100	Carbon fibre	62	5,933333333	3	Backrest	Basket	Walking stick holder		
9	Rollz	Flex 2	Medipoint	489	7,7	125	Aluminium	62	4,8	2	Backrest	Basket			
10	Travixx	Traveller	Medipoint	499	8,1	130	Aluminium	59	5,133333333	3	Backrest	Basket	Walking stick holder		
11	Gemino	30	Medipoint	399	7,4	150	Aluminium	62	4,6	1	Basket				
12	Travixx	Classic	Medipoint	349	6,4	130	Aluminium	54	3,666666667	4	Backrest	Soft wheels	Basket	Walking stick holder	
13	Thuasne	Light	Medipoint	159	8,4	125	Aluminium	56,5	0,6	3	Backrest	Basket	Threshold aid		
14	MultiMotion	Double	ThuiszorgwinkelXL	179	6,9	113	Aluminium		4,2	5	Backrest	Basket	Walking stick holder	Soft wheels	Servingtray
15	TrustCare	Let's Go Out	ThuiszorgwinkelXL	319	6,2	130	Aluminium		6,4	3	Shock absorbing suspension system	Mudguards	Basket		
16	byAcre	Ultralight	ThuiszorgwinkelXL	729	4,8	130	Carbon fibre		7,333333333	2	Soft wheels	Basket			
17	Uplivin	Trive	ThuiszorgwinkelXL	398	6,5	125	Aluminium		7,666666667	4	Backrest	Basket	Unique folding system	Walking stick holder	
18	Able2	Saturn	ThuiszorgwinkelXL	239	7,3	136	Aluminium		4,6	4	Backrest	Basket	Walking stick holder	Cup holder	
19	MultiMotion	Tripod	ThuiszorgwinkelXL	159	6,9	113	Aluminium		1	2	3 wheels	Basket			
20	Rehasense	Server CF	ThuiszorgwinkelXL	599	5	150	Carbon fibre		3,133333333	3	Basket	Soft wheels	Walking stick holder		
21	Kaigo	Travel delux	Rollatorwinkel.com	249	7,2	136	Aluminium	53	3,533333333	4	Backrest	Basket	Walking stick holder	Threshold aid	
22	Quadri	Light	Rollatorwinkel.com	169	7,2	130	Aluminium	53	1,666666667	5	Backrest	Extra small foldable	Basket	Walking stick holder	Threshold aid
23	Trustcare	Lets fly	Rollatorwinkel.com	449	6,8	130	Aluminium	60	6,4	4	Backrest	Big front wheels	Brake cables in the frame	Basket	
24	Dietz	Taima XC Outdoor	Rollatorwinkel.com	399	9,1	150	Steel	60	4,866666667	2	Air tires	Basket			
25	Vitility	Zigzag	Rollatorwinkel.com	299	9,3	120	Aluminium	54	5,533333333	3	Backrest	Brake cables in the frame	Double folding system		
26	Vermeiren	Quava	Rollator.shop	199,95	7,05	136	Aluminium	54	3,066666667	4	Backrest	Double folding system	Basket	Walking stick holder	
27	Easy	Easy (286B)	Rollator.shop	108,95	9,5	130	Steel	57	0,666666667	2	Basket	Servingtray			
28	Excel	Triple motion	Rollator.shop	179	8,1	100	Aluminium	54	2,6	4	Backrest	Triple folding system	Basket	Threshold aid	
29	Bischoff & Bischoff	Alevo Country	Rollator.shop	479	5,8	130	Carbon fibre		5,2	3	Backrest	Basket	Soft wheels		
30	Excel	EZ Lite	Rollator.shop	229	6,5	100	Aluminium	54	4,933333333	3	Backrest	Basket	Threshold aid		

Appendix F – ISO standard test

In this appendix the ISO standard test performed on the Excel Triple Motion can be found

Goal

Test a currently on the market rollator on the demands of the ISO standard to check if a current popular rollators complies with these rules and get familiar with the ways of testing a product on these regulations.

Method

The rollator will be tested on the requirements described in ISO 11199-2:2021. Some requirements covering durability, materials and information supplied by the manufacturer will be excluded from this test, because of a lack of time and means.

Materials

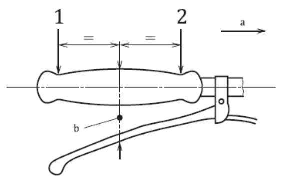
All materials needed for this test are:

- Ruler
- Caliper (schuifmaat)
- Tilting plane
  - Wooden board
  - Hinge
  - Bolt and nut
- Level

Requirements

Following is a list of all the requirements that will be tested:

1. Rollators that can be dismantled
   a. If it is intended that a rollator can be dismantled for storage or transportation, it shall not be possible to reassemble it in a manner that presents a hazard.
   b. The fasteners that are loosened or removed to allow dismantling shall not be single use fasteners.
2. All load-bearing fasteners shall be either self-locking or fitted with a locking device to prevent inadvertent detachment.
3. The maximum user mass shall be specified by the manufacturer. For load carrying accessories, the load capacity of the accessories shall be specified by the manufacturer.
4. Structure requirements
   a. the front wheel diameter shall be greater or equal to 180 mm;
   b. the wheel width shall be greater or equal to 22 mm;
   c. the rollator shall be equipped with brakes operating on two wheels. The user shall be able to manipulate the brakes when walking;
   d. a rollator shall be equipped with parking brakes operating on two wheels.
5. Brakes
   a. Maximum grip distance for operating running brakes shall be not greater than 75 mm, measured (see Figure 3, Key 1). NOTE For rollators with pressure brakes, there is no grip distance.
   b. If the effectiveness of the brake will be reduced by wear, it shall have means for the compensation of wear.
   c. Brake performance shall not be adversely affected by folding, unfolding or adjusting actions.
   d. If readjustment of the brakes is necessary following an adjustment action of the rollator, tools shall not be required (e.g. height adjustment).



Key
1 rear handgrip reference point
2 front handgrip reference point
a Front.
b Brake grip distance.

Figure 3 — Brake grip distance

6. Brake effectiveness (This requirement applies to both, parking brakes and running brakes.) TEST METHOD IN ISO.
   a. The rollator shall not move more than 10 mm in 1 min if the running brake or the parking brake is activated.
   b. The maximum force to apply and release the brakes shall not exceed 60 N for pushing forces, and 40 N for pulling forces.
7. Handgrip
   a. The handgrip width shall be no less than 20 mm and not more than 50 mm. This shall be checked by measurement. NOTE This requirement is not applicable to anatomic handgrips.
   b. The handgrip shall be securely fixed to the handle of the rollator.
8. If liquid can come unintentionally into any cavities or enclosure, it shall be able to drain through drain holes again.
9. Safety of moving parts
   a. any moving parts that constitute a safety hazard shall be provided with guards that can only be removed by the use of a tool, or
   b. the gap between exposed parts of a rollator that move relative to each other shall be maintained throughout the range of movement at less than the minimum value or more than the maximum value set out in Table 1.

Table 1 — Safe distances between moving parts

To avoid	Safe distances for adults	Safe distances for children[a]
Finger traps	Less than 8 mm or more than 25 mm	Less than 4 mm or more than 25 mm
Foot traps	Less than 35 mm or more than 120 mm	Less than 25 mm or more than 120 mm
Head traps	Less than 120 mm or more than 300 mm	Less than 60 mm or more than 300 mm
Genitalia traps	Less than 8 mm or more than 75 mm	Less than 8 mm or more than 75 mm
[a] Also includes adults with a height of less than 146 cm, or a mass of less than 40 kg, or a BMI of less than 17.		

10. Prevention of traps for parts of the human body
    a. If the intended purpose of a rollator cannot be met without a hazard caused by the size of holes and the clearance between stationary parts, a warning and instructions on how to operate the rollator safely shall be provided in the instructions for use.
    b. Holes in and clearances between stationary parts that are accessible to the user and/or assistant during the intended use of a rollator shall be as specified in Table 2.

Table 2 — Safe distances between stationary parts

To avoid	Safe distances for adults	Safe distances for children[a]
Finger traps	Less than 8 mm or more than 25 mm	Less than 5 mm or more than 12 mm
Foot traps	Less than 35 mm or more than 100 mm	Less than 25 mm or more than 45 mm
Head traps	Less than 120 mm or more than 250 mm	Less than 60 mm or more than 250 mm
Genitalia traps	Less than 8 mm or more than 75 mm	Less than 8 mm or more than 75 mm
[a] Also includes adults with a height of less than 146 cm, or a mass of less than 40 kg, or a BMI of less than 17.		

11. Folding, adjusting and locking mechanisms
    a. Folding and adjusting mechanisms may cause a hazard if parts of the body can enter a gap between parts and be trapped when the gap is closed.
    b. If a rollator incorporates folding and/or adjusting mechanisms, it shall conform to Clauses 10 and 11.
    c. If the rollator is height adjustable, the increments shall not exceed 25 mm.
    d. Adjustments shall be securely fixed when in use.
    e. The maximum allowable elongation shall be clearly marked.

f. After the durability test (see 17.2), the adjustment/folding mechanisms shall operate as intended by the manufacturer.

g. the rollator shall incorporate means to protect the user from trapping and/or squeezing hazards; or

h. the gap between exposed parts of a rollator that move relative to each other shall be maintained throughout the range of movement at less than the minimum value or more than the maximum value set out in Table 1; or

i. if the intended purpose of a rollator cannot be met without a hazard such as squeezing, a warning and instructions on how to operate the rollator safely shall be provided in the instructions for use.

j. Locking mechanisms shall be required to maintain the rollator in the folded or in the working configuration if the absence of the locking device presents a hazard to the user. Locking mechanisms shall lock securely and shall be protected from unintended release.

12. Carrying handles TEST METHOD IN ISO

a. If a rollator or a part of a rollator has a mass of 10 kg or more and the intended purpose is for it to be portable or to be handled according to manufacturer's instructions, it shall either have one or more handles suitably placed that enable the rollator or part to be carried by two or more persons, or be provided with suitable handling devices (e.g. handles, lifting eyes), or the instructions for use shall indicate the points where the rollator or its part can be lifted safely and describe how they should be handled during lifting, assembly and/or carrying. If practical, the rollator or component parts shall be labelled to indicate where it can be lifted safely and/or how it can be handled during assembly and/or carrying.

b. If a rollator incorporates carrying handles or grips, they shall not become detached from the rollator and there shall not be any permanent distortion, cracking or other evidence of failure when tested as specified in 13.3.

13. Static stability TEST METHOD IN ISO

a. In forward direction, the angle of the plane at the point of rollator tilting shall be no less than 15,0° from the horizontal.

b. In backward direction, the angle of the plane at the point of rollator tilting shall be no less than 7° from the horizontal.

c. To the sideways direction the angle of the plane at the point of rollator tilting shall be no less than 3,5° from the horizontal.

14. Ergonomic principles

a. the distance between any handle (part intended to be grabbed) requiring an operating force of more than 10 N and any construction part of the assistive product shall not be less than 35 mm;

b. the distance between any upper surface of a pedal (in its operating position) and any other part of the assistive product shall have a vertical toe clearance of not less than 75 mm;

c. the diameter of any operating handles and/or knobs requiring an operating force of more than 10 N shall be between 19 mm and 43 mm;

d. for assistive products operated from a standing position, pedals (tipping aid) shall be placed not more than 300 mm above the surface of the floor;

e. for assistive products operated from a standing position, hand operated controls shall be placed at a height of 800 mm to 1200 mm above the surface of the floor;

f. for a rollator operated from a sitting position, controls intended to be operated by the occupant while seated shall be within the occupant's reach space;

g. the operating forces or torques required for those parts of the rollator that are designed to be operated by fingers, hands/arms or feet shall not exceed the values in Table 3.

Table 3 — Operating forces

Operation	Force/torque
operation by using a finger	5 N
operation by using a hand/arm (pushing)	60 N
operation by using a hand/arm (pulling)	40 N
operation by using a foot	300 N
operation by turning	1,9 Nm
rotation of seat surface	60 N

Results

Requirement	Required value	Requirement met
1a	-	Y
1b	-	Y
2	-	Y
3	-	Y
4a	> 180 mm	195 mm
4b	> 22 mm	29 mm
4c	-	Y
4d	-	Y
5a	< 75 mm	73 mm
5b	-	Y
5c	-	Y
5d	-	n/a
6a	10 mm	0 mm
6b	60N and 40 N	
7a	Between 20 – 50 mm	32 – 46 mm
7b	-	**N**
8	-	Y
9a	-	n/a
9b	-	Y
10a	-	Y
10b	-	**Hole of 81 mm in wheel**
11a	-	Y
11b	-	Y
11c	< 25 mm	**27 mm**
11d	-	Y
11e	-	Y
11f	-	Y
11g	-	Y
11h	-	Y
11i	-	Y
11j	-	Y
12a	-	n/a
12b	-	n/a
13a	< 15°	22,5° (25N)
13b	< 7°	35,6° (25N)
13c	< 3,5°	25,6° (25N)
14a	35 mm	n/a
14b	75 mm	n/a
14c	19 – 43 mm	n/a
14d	< 300 mm	80 mm
14e	800 – 1200 mm	**710 – 960 mm**
14f	-	n/a
14g	-	

Appendix G – Lyapunov exponent code

In this appendix the full MATLAB code used to calculate the Lyapunov exponent (stability) can be found.

Credits

Code is based on code of:

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(https://zenodo.org/badge/85585950.svg) (https://zenodo.org/badge/latestdoi/85585950)

Local dynamic stability

Clear

```
clear;
load 'testdata';
```

Variables

```
ws          = 20;    % window size to track the divergence (gait cycles or seconds)
fs          = 40;   % sample frequency of the resampled data (we resample to 100 samples (on average) per stride)
period      = 1;    % the period of the resulting resampled signal is 1 (i.e. 1 stride every 100 samples on average)
n_dim       = 5;    % dimensionality of state space
delay       = 10;   % delay of state space (after time normalization)
showplot    = 1;    % show a figure of the resulting divergence curve
sdistance   = 0.16;   % distance between the markers on the shoulders

```

Import data

ML position & Heel strike moment

```
% Set up the Import Options and import the data for
opts = delimitedTextImportOptions("NumVariables", 3);
opts2 = delimitedTextImportOptions("NumVariables", 1);

% Specify range and delimiter
opts.DataLines = [2, Inf];
opts.Delimiter = "\t";
opts2.DataLines = [1, Inf];
opts2.Delimiter = ",";

% Specify column names and types
opts.VariableNames = ["Tijdms", "Markeerder2", "Markeerder1"];
opts.VariableTypes = ["double", "double", "double"];
opts2.VariableNames = "VarName2";
opts2.VariableTypes = "double";


% Specify file level properties
opts.ExtraColumnsRule = "ignore";
opts.EmptyLineRule = "read";
opts2.ExtraColumnsRule = "ignore";
opts2.EmptyLineRule = "read";


% Specify variable properties
opts = setvaropts(opts, ["Tijdms", "Markeerder2", "Markeerder1"], "DecimalSeparator", ",");
opts = setvaropts(opts, ["Tijdms", "Markeerder2", "Markeerder1"], "ThousandsSeparator", ".");

% Import the data
MLpos = readtable("C:\Users\pvboe\OneDrive\Documents\1. Studie\1. TUDelft\Jaar 6\Graduation\5. Validation\4. Results\2. ML Positions\Participant 10\P10_1.2.txt", opts);
HS = readtable("C:\Users\pvboe\OneDrive\Documents\1. Studie\1. TUDelft\Jaar 6\Graduation\5. Validation\4. Results\3. Heel strike moments\Participant 10\P10_1.2.txt", opts2);

% Convert to output type
MLpos = table2array(MLpos);
HS = table2array(HS);


% Clear temporary variables
clear opts
clear opts2
```

Transform data to mean scaled ML position

```
MLpos(:,4) = MLpos(:,3) - MLpos(:,2); % distance between the markers
MLpos(:,5) = (sdistance ./ MLpos(:,4)) .* MLpos(:,2); % new distance of marker 2 scaled for the the distance to the camera
MLpos(:,6) = (sdistance ./ MLpos(:,4)) .* MLpos(:,3); % new distance of marker 1 scaled for the the distance to the camera
MLpos(:,7) = mean(MLpos(:,5:6), 2) % mean location of the 2 markers
MLpos(:, 2:6) = []
clf;
plot(MLpos(:,1), MLpos(:,2), '-');  % plot the ML position
xlabel('Time');
ylabel('Position');
title('Mean ML Position');
MLpos(:, 1) = []
```

Centre of mass velocity

```
CoM_vel  = gradient(MLpos,1/fs_opto);
```

Create time normalised state space

```
state = makestatelocal(CoM_vel,HS,n_dim,delay);

```

Calculate local divergence exponent

```
clf;
[divergence,lds] = lds_calc(state,ws,fs,period, showplot)
```

```
%           ws: window size over which divergence should be calculated(in seconds/cycles)
%           fs: sample frequency
%           period: dominant period in the signal(in seconds/cycles),
%           plotje: 1= show a graph, other= don't show graph
% Output:   divergence: the divergence curve
%           lds: the 2 estimates of the local divergence exponents ( long term and short term)
%           note that if ws is not larger then 4*period, long term is not calculated,
%           as this is normally calculated 4*period to ws.
% Note:     The slope calculated is from 0-0.5 strides, and from 4-10
%           strides.

%% setting up some variables
ws          = round(ws*fs); % as ws is input in cycles, and better to have it in samples
[m,n]       = size(state);
state       = [state;NaN*ones(ws,n)]; % we extend the state space with NaN, so that we don't run into problems later
divergence  = NaN*ones(m,ws); % set up the output divergence matrix
difference  = NaN*ones(m+ws,n); % set up some difference matrix that we will use

%% find and track nearest neighbours
for i_t = 1:m % loop over time samples
    for i_d = 1:n % loop over dimensions
        difference(:,i_d) = (state(:,i_d)-state(i_t,i_d)).^2;
    end
    start_index         = round(max([1,i_t-round(0.5*period*fs)])); %find point half a period befor current point
    stop_index          = round(min([m,i_t+round(0.5*period*fs)])); %find point half a period past current point
    difference(start_index:stop_index,:) = NaN;% discard data within one period from sample i_t putting it to nan
    [~,index]           = min(sum(difference,2));% find nearest neighbour
    divergence(i_t,:)   = sqrt(sum((state(i_t:i_t+ws-1,:)-state(index:index+ws-1,:)).^2,2)');% track divergence, and store
end
divergence=mean (log(divergence),'omitnan'); % calculate average for output

%% calculate least squares fit
L1 = 0.5*period*fs;
Ps = polyfit(1/fs:1/fs:L1/fs,divergence(:,1:L1),1);
if ws>4*period*fs
    L2 = 4*period*fs;
    Pl = polyfit(L2/fs:1/fs:ws/fs,divergence(:,L2:ws),1);
else
    Pl(:,1)=NaN;
end
lds=[Ps(:,1) Pl(:,1)];

%% plot if indicated
if nargout==0 ||plotje==1
    figure;
    Ys = polyval(Ps,1/fs:1/fs:L1/fs);
    Yl = polyval(Pl,L2/fs:1/fs:ws/fs);
    plot((1:ws)/fs,divergence); hold on
    plot(1/fs:1/fs:L1/fs,Ys,'m');hold on
    plot(L2/fs:1/fs:ws/fs,Yl,'r'); hold on
    legend({'Divergence Curve  ';['Lambda S: ',num2str(Ps(1))];['Lambda L: ',num2str(Pl(1)) ]});
    title('Divergence curve');
    xlabel('Time (sec)');
    ylabel('Ln(divergence)');
```

```
function [state]=makestatelocal(signal,hc,n_dim,delay)

% build a state space for the calculation of local dynamic stability. a
% standard delay of 10 samples is chosen, and the signal is resampled so
% that on average each stride is 100 samples in length ( see England &
% granata)
% Input:    signal: the signal you want to make a state space for.
%           hc: vector with moments (in samples) in which heelstrikes happen.
%           ideally, has the same number of elements for each subject/
%           condition, as the number of strides has been shown to influence
%           lds calculations.
%           n_dim: number of dimensions that the state space should consits of.
%           delay: (optional!) delay in samples. When no input is given,
%           this is set to 10.
% Output    state: n_dim dimensional state space, where all the states have
%           been normalized such that there length is (length(hc)-1)*100 samples
%           (i.e. 100 samples per stride on average.
%% check for inputs
if nargin <= 3
    delay = 10;
end
n_strides   = length(hc); % how much heelstrikes do we have
n_samples   = (n_strides-1)*100;% amount of samples we will normalize to

%% set up outputs
state = NaN*ones(n_samples-delay*(n_dim-1),n_dim);

%% time normalization
signal_new  = signal(hc(1):hc(end));% take out only the time period we need
t_new       = 1:length(signal_new); % fix time axis for time normalization
t_interp    = (1:n_samples)/n_samples*t_new(end); % new time axis, contains (n_steps-1)*100 data points
signal_interp = interp1(t_new,signal_new,t_interp,'spline'); % interpolate

%% create state space
for i_dim = 1:n_dim
    state(:,i_dim) = signal_interp(((i_dim-1)*delay)+1:end-(n_dim-i_dim)*delay);
end

```

Appendix H – Lyapunov exponent per test

In this appendix the Lyapunov exponents of every single test and the mean per situation can be found. In Table 3 the short term Lyapunov exponent can be seen. In Table 4 the long term Lyapunov exponent can be seen.

	Short		
	No walking aid	Normal rollator	Armswing rollator
P1_1	1,0023	1,0375	1,034
P1_2	1,0744	1,1072	1,03
P1_3	1,0675	1,1167	0,9773
P2_1	1,0739	1,1233	1,1149
P2_2	1,13	1,09	1,0614
P2_3	1,1961	1,0695	1,1179
P3_1	0,9868	0,98621	0,98102
P3_2	1,0318	1,014	1,1296
P3_3	1,1065	1,074	1,1036
P4_1	0,99651	1,0443	0,97919
P4_2	1,0914	1,0531	0,97133
P4_3	1,067	1,1026	1,0754
P5_1	0,98618	1,0183	1,037
P5_2	1,0436	1,0864	1,0238
P5_3	1,1313	1,0744	1,0426
P6_1	1,0744	0,98157	0,99669
P6_2	1,0594	1,0594	1,0838
P6_3	1,0859	1,0718	1,0933
P7_1	1,0322	1,0338	0,99736
P7_2	1,1315	0,98762	1,0356
P7_3	1,0882	1,1091	1,0533
P8_1	1,0648	1,1202	1,1568
P8_2	1,1113	1,3088	1,1658
P8_3	1,2639	1,1683	1,1627
P9_1	1,0876	1,1315	1,1192
P9_2	1,1859	1,1023	1,1512
P9_3	0,90615	1,1343	1,0569
P10_1	1,1041	1,1155	1,0706
P10_2	1,0966	1,0786	1,1199
P10_3	1,0964	1,1058	1,1085
Mean	**1,079121333**	**1,083536667**	**1,068356333**

Table 3 - Short term lyapunov exponent per test

	Long		
	No walking aid	Normal rollator	Armswing rollator
P1_1	0,000079708	-0,007494	-0,0072912
P1_2	-0,0076062	-0,0097566	0,025385
P1_3	0,0012	-0,0018086	0,025621
P2_1	0,003155	-0,0017057	0,000066194
P2_2	-0,0050631	-0,00098068	0,0027088
P2_3	-0,002664	-0,0035037	0,0016616
P3_1	0,00986	0,02242	0,0077061
P3_2	0,0080551	0,020151	-0,011198
P3_3	-0,0077659	0,030576	0,0030104
P4_1	0,0014169	0,0056337	0,021278
P4_2	0,0039433	-0,0058708	0,018503
P4_3	-0,0084393	0,0032484	0,016702
P5_1	0,0055468	-0,0073211	0,011572
P5_2	-0,011537	-0,0001848	0,023123
P5_3	-0,0080824	-0,0038757	-0,0075826
P6_1	-0,0037876	-0,002507	0,001385
P6_2	-0,00090504	-0,0062444	-0,0040625
P6_3	-0,014203	0,0093073	-0,015113
P7_1	0,0048219	-0,00048098	0,0078361
P7_2	0,011102	0,0011624	0,0076996
P7_3	0,0040263	0,001558	0,000371
P8_1	0,00095449	-0,0031362	-0,0019462
P8_2	0,0047395	-0,0041166	-0,0078502
P8_3	0,0036223	-0,0081411	0,000087533
P9_1	-0,0064188	0,005467	-0,00090379
P9_2	0,00065015	-0,010091	-0,0074883
P9_3	0,0059741	0,0032907	0,000016636
P10_1	0,0016544	-0,0033845	0,00054821
P10_2	0,00644933	-0,0055379	-0,0031044
P10_3	-0,0032479	0,0033837	0,00060961
Mean	**-8,33254E-05**	**0,000668561**	**0,00364502**

Table 4 - Long term lyapunov exponent per test

Appendix I – Participant Length table

In this appendix the length of each participant can be found (Table 5).

Participant	Length
Participant 1	189
Participant 2	177
Participant 3	178
Participant 4	177
Participant 5	184
Participant 6	187
Participant 7	182
Participant 8	184
Participant 9	176
Participant 10	193
Mean	**182,7**

Table 5 - Participant length

Appendix J – Project brief

In this appendix the project brief as defined at the start of the project can be seen.

Personal Project Brief – IDE Master Graduation Project

Problem Definition

What problem do you want to solve in the context described in the introduction, and within the available time frame of 100 working days? (= Master Graduation Project of 30 EC). What opportunities do you see to create added value for the described stakeholders? Substantiate your choice.
(max 200 words)

Current designs of the rollator have one thing in common, it is not possible to adapt them to personal needs. It is unknown how an improved design might benefit the users. However, ergonomics and safety are logical focus points for this project.

The adjustability in current rollators is very limited since the users can be very different and a bad fitting rollator can cause a bad posture and back problems. Moreover, current rollators have poor sideways stability which can cause a user to fall over when the ground is not fully flat. Also, the seat and the basket of the rollator obstruct the view of the floor right in font of the feet of the user. Since elderly tend to fall because they don't lift their feet enough, it could be safer that they are able to see possible hazards in their way.

Not only will the use of the Rollator be better for the physical health of users, but they will also enjoy using the rollator even more.

Assignment

This is the most important part of the project brief because it will give a clear direction of what you are heading for.
Formulate an assignment to yourself regarding what you expect to deliver as result at the end of your project. (1 sentence)
As you graduate as an industrial design engineer, your assignment will start with a verb (Design/Investigate/Validate/Create), and you may use the green text format:

Re-design the rollator so that the user perceives increased safety, comfort and ergonomics.

Then explain your project approach to carrying out your graduation project and what research and design methods you plan to use to generate your design solution (max 150 words)

Start by doing desk research on the current design of rollators and interview the target group to research their problems and needs. Next these insights will be used to make a SWOT analysis and set a design goal and a list of wishes and requirements. By making multiple concepts and evaluating them on the requirements and wishes a final concept will be chosen. Then the final concept will turned into a product by an embodiment phase. The result in model will allow for final validation by means of user testing.

Project planning and key moments

To make visible how you plan to spend your time, you must make a planning for the full project. You are advised to use a Gantt chart format to show the different phases of your project, deliverables you have in mind, meetings and in-between deadlines. Keep in mind that all activities should fit within the given run time of 100 working days. Your planning should include a ***kick-off meeting****,* ***mid-term evaluation meeting****,* ***green light meeting*** *and* ***graduation ceremony****. Please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any (for instance because of holidays or parallel course activities).*

Make sure to attach the full plan to this project brief.
The four key moment dates must be filled in below

Kick off meeting	17 mei 2024
Mid-term evaluation	1 juli 2024
Green light meeting	31 okt 2024
Graduation ceremony	5 dec 2024

In exceptional cases (part of) the Graduation Project may need to be scheduled part-time. Indicate here if such applies to your project

Part of project scheduled part-time	
For how many project weeks	
Number of project days per week	

Comments:

Motivation and personal ambitions

Explain why you wish to start this project, what competencies you want to prove or develop (e.g. competencies acquired in your MSc programme, electives, extra-curricular activities or other).

Optionally, describe whether you have some personal learning ambitions which you explicitly want to address in this project, on top of the learning objectives of the Graduation Project itself. You might think of e.g. acquiring in depth knowledge on a specific subject, broadening your competencies or experimenting with a specific tool or methodology. Personal learning ambitions are limited to a maximum number of five.
(200 words max)

With my graduation project I want to show I can design a (medical) product from start to finish, while keeping in mind the needs and preferences of the users.