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A Participatory Risk-Matrix Framework for User-Centered Validation of a Manual Standing Wheelchair

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Abstract

This study presents a participatory, risk-based validation framework for a manually actuated standing wheelchair. The standing function offers both physical and psychosocial benefits, including greater independence, improved social interaction, and better access to vertical space. However, adoption of such devices remains limited, especially in low-resource settings, due to concerns about usability, comfort, and safety. Rather than emphasizing technical novelty, the contribution of this study lies in applying a user-centered risk-matrix approach to systematically translate stakeholder concerns into design priorities. Through engagement with eight stakeholders, including direct users and institutional representatives, the study collected qualitative feedback on user experience. This feedback was organized into eight thematic risk categories. Among them, stability during transitions and the level of physical effort required were identified as the most pressing concerns. Each risk type was then evaluated using a qualitative 5×5 matrix to assess its likelihood and potential impact. This structured process enabled the design team to prioritize and implement targeted improvements, effectively reducing the likelihood of tipping-related risks. However, physical accessibility, particularly for users with limited upper-body strength, remained a high, unmitigated risk due to inherent limitations of manual operation. The study highlights the importance of integrating structured risk analysis with real user input to inform assistive technology development that is not only functional, but also contextually responsive.

Keywords: standing wheelchair, assistive technology, risk matrix, participatory validation, user-centered design

1. Introduction

Wheelchairs remain one of the most essential assistive technologies for individuals with mobility impairments. They serve not only as mobility aids but also as instruments that affect users' autonomy, physical health, psychological well-being, and social participation. However, reliance on conventional seated wheelchairs has been associated with various long-term physiological and lifestyle limitations. These include musculoskeletal pain, reduced cardiorespiratory fitness, risk of pressure injuries, and social exclusion due to postural constraints. [1–3]

Several review papers have provided valuable syntheses of wheelchair-related challenges. [1] conducted a systematic review and meta-analysis on musculoskeletal pain due to wheelchair use, revealing consistent patterns of shoulder and back pain across diverse user populations. [4] extended the analysis to the socio-emotional domain, identifying key experiential dimensions that are often overlooked in design considerations. Moreover, [5] reviewed the built environment challenges faced by manual wheelchair users, calling attention to infrastructural and architectural inadequacies that hinder mobility. Other reviews by [6–8] highlighted the broader implications of limited physical activity among wheelchair users, especially in conditions such as multiple sclerosis and spinal cord injury.

Meanwhile, [9] performed a scoping review focused on manual wheelchair training approaches for new users, emphasizing the need for structured onboarding that considers skill progression and user confidence. Similarly, [10] reviewed assessment techniques for community mobility, showing a lack of standardized metrics in evaluating real-world participation. These insights are crucial, as the effectiveness of any wheelchair, manual or powered, is contingent on both design quality and user adaptation. [11, 12] have also examined adaptive sports and user satisfaction, underscoring the multidimensional impact of wheelchair experience on daily life.

[13, 14] offered biomechanical evaluations of manual wheelchair steering and type, respectively, linking hardware design to physical exertion and movement efficiency. [15] provided a longitudinal perspective, demonstrating that shoulder pain alters propulsion biomechanics over time. In addition, [16] explored perceptions toward power-assist devices, while [17] studied how cognitive sta-

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tus affects wheelchair skills. These studies collectively illustrate that wheelchair performance and user experience are affected by a complex interplay of physical, cognitive, emotional, and environmental factors.

Beyond seated mobility, growing attention has been given to standing wheelchairs, which allow users to assume a vertical posture. The ability to stand provides physiological benefits such as better circulation, pressure relief, and bone loading, as well as psychological and social advantages like enhanced interaction and self-esteem [18, 19]. [20, 21] documented the design journey of standing wheelchair systems, focusing on both feasibility and affordability. [22] explored virtual reality frameworks to simulate control algorithms for robotic standing wheelchairs, while [23] developed a low-cost model with improved transition stability. The work of [24] emphasized the value of understanding user experience in evaluating such devices.

More recent contributions have advanced the technical complexity of these systems. [25] introduced a modular wheelchair design with dynamic posture transformation. [26] tested an open-source manual standing wheelchair in low-resource environments, highlighting usability and adaptability to local contexts. [27] integrated voice and gesture control to enhance accessibility in standing models. Meanwhile, [28, 29] extended prior work by assessing long-term community integration of a manual standing wheelchair. These studies highlight a shift toward inclusive innovation, where affordable, user-friendly designs align with biomechanical and social needs.

Despite the innovation in mechanical design and control systems, few studies have combined user feedback with structured design evaluation frameworks. Some work has begun to explore stakeholder involvement. [18] collected qualitative input from pediatric users and caregivers regarding powered standing devices. Similarly, [16] gathered user perceptions of power-assist systems, while [30] examined sociodemographic factors affecting perceptions of physical activity barriers. These efforts align with user-centered design (UCD) principles, which argue that assistive technologies must be developed with direct user involvement to ensure real-world applicability and acceptance.

However, existing literature reveals a significant methodological gap. Although many studies incorporate user insights, there is a lack of structured, risk-informed approaches to prioritize design responses. Most notably, no prior work has explicitly applied a risk matrix or a risk-based prioritization framework to the evaluation of standing wheelchairs. While 21, 23 acknowledge stability and usability issues, they stop short of translating qualitative feedback into structured risk categories. Likewise, while [24] conducted user experience studies, they did not incorporate risk scoring to determine which issues warranted immediate design intervention.

This study seeks to address that gap by introducing a participatory, risk-matrix based framework as its primary contribution. It combines a user-centered design methodology with a qualitative 5×5 risk matrix to systematically assess and prioritize usability concerns in a manually actuated standing wheelchair. Drawing on feedback from eight stakeholders, including users, clinicians, and institutional actors, the study identifies eight key risk types. These are then ranked by severity and likelihood to guide design refinement. This integrative approach enables a deeper alignment between engineering solutions and real-world user needs, particularly in resource-constrained environments where powered solutions are impractical.

By positioning itself at the intersection of participatory design and structured risk assessment, the current research contributes a replicable model for assistive technology validation. It moves beyond mechanical performance tests, instead offering a methodology that systematically links user concerns to design priorities. In doing so, it responds to the growing demand for assistive technologies that are not only functional but also inclusive, safe, and emotionally acceptable.

2. Material & methods

2.1. Study Design and Participants

This study adopts a user-centered methodology to validate and assess the risks associated with a manually actuated standing wheelchair designed to enhance physical engagement and vertical mobility in individuals with lower-limb disabilities. The research involved a multidisciplinary team of mechanical engineers and design researchers who collaboratively developed the standing wheelchair prototype. The device was designed to transition users from a seated to a standing position using a mechanical lift system, without the use of electricity, to promote simplicity and affordability. Key design features include a foldable mainframe for portability, manual actuation levers, thigh supports for body alignment during standing, and integrated safety harnesses to secure users throughout the transition. The overall structure of the prototype is illustrated in Figure 1, which shows the components of the wheelchair.

Participant recruitment for the user trials followed a purposive sampling strategy to capture diverse perspectives rather than to achieve statistical representativeness. A total of eight individuals with varied backgrounds were selected. Among them were both direct users with physical disabilities and indirect stakeholders such as caregivers, community organizers, and professionals working in the disability sector. While the sample size was small, it provided sufficient heterogeneity to identify key usability concerns and inform iterative design refinement.

Their demographic information and contextual roles are detailed in Table 1, which presents eight early users involved in the evaluation process. The group includes a balance of male and female participants, aged between 26 and 57 years, with a variety of professional and experiential backgrounds related to disability and assistive technology use.

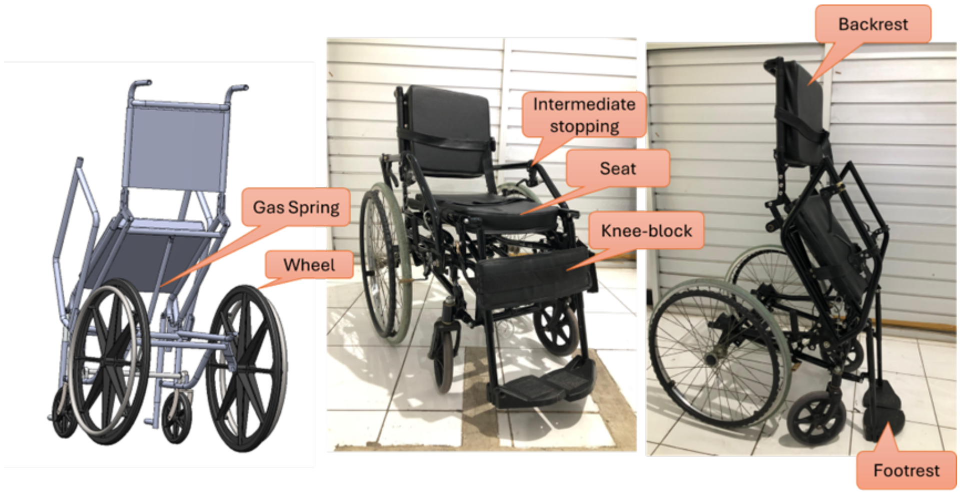

Figure 1. Components of manual standing wheelchair prototype in seated and standing configurations

Table 1. User and Stakeholder Characteristics with Corresponding Feedback

User ID	Stakeholder Role	Gender	Age	Primary Concern
U01	Physiotherapist at Ministry of Social Affairs	Female	47	Great for users with strong arms; supports upper-body strength.
U02	Wheelchair user & community leader	Male	45	Fear of falling due to large body size.
U03	Wheelchair user, mobility with walker	Female	30	Concern about leg strength; likened to sport wheelchair.
U04	Wheelchair user (young female)	Female	26	Scary design; weak legs and arms; fear of falling.
U05	YPAC administrator	Male	50	Appreciated product; will help find user testers.
U06	Social Services official	Male	52	Compared to electric wheelchair features.
U07	Community leader & user	Male	53	Worried about elderly use; checked door/classroom accessibility.
U08	Disability rights lecturer	Female	57	Needs sizing per user; design may not suit weak legs and arms.

2.2. Usability Testing and Qualitative Risk Assessment

The usability testing was conducted in controlled environments including rehabilitation centers, community halls, and university spaces adapted for accessibility. Prior to testing, each participant received an introduction to the standing wheelchair's features, followed by a hands-on demonstration by the research team. Participants were then invited to use the wheelchair in both its primary seated mode and its standing mode. Researchers observed and guided the process to ensure safety. Special attention was paid to the participants' initial reactions, comfort during operation, and expressed confidence or hesitation in transitioning to a standing position.

Data collection relied entirely on qualitative methods. The usability data was gathered through a mix of observation and structured interviews. Each session was documented through direct field notes and photographs (with consent), focusing on indicators such as body posture, facial expression, ease of gripping or pushing the actuation mechanism, and signs of physical strain. Participants were later asked to describe their experience, expectations, and any difficulties they encountered. These narratives helped uncover both overt usability challenges and more subtle psychological or ergonomic issues.

To interpret the qualitative data systematically, the research team used a risk identification and mapping framework, translating user responses into thematic risk categories such as manual dependency, stability, effort of use, perception, sizing, and institutional compatibility. For each participant, at least two prominent risks were derived, resulting in a total of sixteen distinct risk points which were further analyzed.

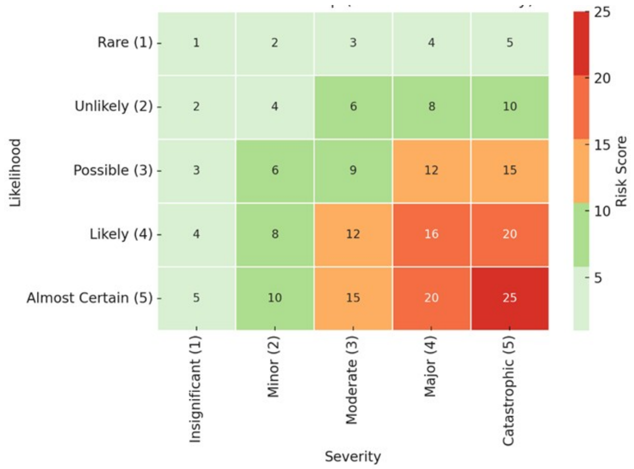

Figure 2. Risk Matrix Heatmap (Likelihood vs Severity)

Figure 2 presents the risk matrix heatmap employed in this user-centered risk assessment to evaluate and prioritize concerns raised by participants during the testing of a manually actuated standing wheelchair. This color-coded matrix provides a clear and intuitive visualization of risks based on two primary dimensions: the likelihood of a risk occurring and the severity of its potential impact. By systematically mapping each identified issue onto this matrix, the development team was able to discern which aspects of the product design posed the most critical threats to user safety, mobility, and physical engagement, and thus required immediate intervention.

The matrix is organized as a 5×5 grid, with severity on the horizontal axis and likelihood on the vertical axis. Each axis comprises five escalating categories that allow for nuanced and structured risk classification, reflecting both engineering judgment and lived user experience.

Likelihood of occurrence is defined as follows:

- **Rare (1):** The event is highly unlikely and may only occur under exceptional or extreme conditions.
- **Unlikely (2):** The event might occur under specific but uncommon circumstances.
- **Possible (3):** The event may occasionally arise during use.
- **Likely (4):** The event is expected to occur regularly across typical usage scenarios.
- **Almost Certain (5):** The event is anticipated to happen frequently or in most conditions of use.

Severity of consequence is categorized as:

- **Insignificant (1):** Negligible impact; easily recoverable and does not affect mobility or safety.
- **Minor (2):** Mild inconvenience or discomfort with minimal effect on functionality or user confidence.
- **Moderate (3):** Noticeable impact that may hinder usability or raise minor safety concerns.
- **Major (4):** Substantial reduction in mobility, comfort, or safety; requires intervention.
- **Catastrophic (5):** Severe functional failure, potential injury, or complete usability breakdown.

Cross-tabulating the two dimensions produces 25 risk scores, ranging from 1 (1×1) to 25 (5×5), interpreted using a color-coded heatmap for quick prioritization. The matrix employs a color-coded system:

- **Green zones (scores 1–10):** Represent low risk; both severity and likelihood are minimal. These risks are generally tolerable and may not demand immediate redesign.
- **Orange zones (scores 12–15):** Indicate moderate risk, where mitigation strategies are advisable depending on user needs, cost constraints, and design complexity.
- **Red zones (scores 16–25):** Highlight high to critical risk, which may directly affect user safety, hinder physical engagement, or discourage continued usage, necessitating urgent and targeted design interventions.

In this framework, any risk that is plotted within the red zone of the matrix, characterized by high severity and high likelihood, necessitates active mitigation. The objective of mitigation is to reduce the overall risk score by either decreasing the likelihood of the event occurring, lowering the severity of its potential consequences, or both.

Conceptually, this can be approached through various design, operational, or user-interface strategies. For example, reducing likelihood may involve improving product stability, enhancing user instructions, or simplifying control mechanisms to minimize operational errors. Reducing severity may involve incorporating redundant safety features, designing for passive protection during failure, or adjusting the system's physical properties to be more forgiving under adverse conditions.

The intended outcome of any mitigation strategy is to move identified risks from high-risk areas of the matrix toward lower-risk zones (green areas), thereby enhancing both user safety and product acceptability. This methodological approach allows for systematic refinement of assistive technologies in a way that centers user experience while aligning with established engineering risk management practices.

This structured matrix approach offers a rigorous yet adaptable tool to translate diverse user concerns into a clear risk prioritization model, particularly vital in assistive device development where the stakes for mobility and safety are high. By directly linking user insights to technical refinement pathways, this method enhances the credibility and social relevance of the design process, especially for people with disabilities seeking reliable and empowering mobility solutions.

Despite the careful planning and execution of the methodology, certain limitations were acknowledged. The sample size, though demographically varied, included only eight individuals, limiting statistical generalizability. Furthermore, the prototype tested was still a pre-commercial version, which may differ in weight, locking mechanisms, or component durability compared to eventual production models. Nonetheless, the detailed feedback and structured risk analysis offer important guidance for the refinement and potential scaling of this standing wheelchair technology.

3. Results

3.1. User Feedback on Standing Wheelchair Functionality

The feedback gathered through structured trials and interviews with eight diverse participants revealed both potential benefits and usability concerns associated with the standing wheelchair prototype. These findings were systematically categorized into risk types and paired with corresponding design recommendations, as summarized in Table 2. This user-centered mapping approach bridges qualitative insights with technical action and aligns directly with the study's goal: enhancing mobility and daily physical engagement for people with disabilities through a safe and inclusive standing wheelchair.

Participants from various stakeholder groups, ranging from individuals with physical disabilities to caregivers, therapists, and institutional representatives, consistently acknowledged the conceptual value of the standing function. Users noted that the ability to assume a vertical posture improved their sense of independence, enabled better social interaction at eye level, and provided easier access to objects placed at higher positions. These benefits were not only functional but also psychological, reflecting users' desire for dignity, autonomy, and active engagement in daily life.

However, several key challenges emerged, particularly regarding usability, comfort, and safety. Participant U01, a physiotherapist, highlighted concerns about the device's suitability for individuals with limited upper body strength. This observation was categorized under Manual Dependency, prompting a recommendation for assistive actuation mechanisms to reduce physical effort during operation.

Independent wheelchair users U02 and U03 expressed anxiety related to balance and exertion during standing transitions. These concerns were classified under Stability & Load and Physical Accessibility, respectively. Their feedback underscores the importance of addressing both mechanical stability and ergonomic access to ensure safe and confident operation.

Participant U04, a young female with a petite frame, described the chair as intimidating and too large, raising concerns about fit and perceived safety. This was categorized as User Perception & Fit, a risk type that reflects the psychological and aesthetic dimensions of design. Meanwhile, U05, an administrator from YPAC, recognized the product's potential but questioned its readiness for institutional or hospital use. This concern was classified under Institutional Readiness, highlighting the need for further development in documentation, training protocols, and regulatory alignment.

Table 2. Summary of qualitative user feedback

User ID	Detailed Feedback	Risk Type	Suggested Solution
U01	Great for users with strong arms; supports upper-body strength. Standing mechanism is promising	Manual Dependency	Add optional assistive mechanism (gas spring/electric)
U02	Fear of falling due to large body size. Worried about balance when standing	Stability & Load	Add safety harness and improve CG control
U03	Concern about leg strength; likened to sport wheelchair. Too hard to operate manually	Physical Accessibility	Reduce force requirement; add assisted standing system
U04	Scary design; weak legs and arms; fear of falling. Chair too big for petite users	User Perception & Fit	Soften aesthetic design; adjust size range
U05	Appreciated product; will help find user testers. Not ready for hospital environment	Institutional Readiness	Develop clinical-grade version with documentation
U06	Compared to electric wheelchair features. Chair looks weak, needs sturdier frame	Competitive Benchmarking	Improve structure; add optional powered features
U07	Worried about elderly use; checked door/classroom accessibility. Too risky for small children	Public Environment Fit	Add mobility stop-lock; test for public door clearance
U08	Needs sizing per user; design may not suit weak legs and arms. Product still not market ready	Personalization & Maturity	Develop modular sizes and test commercialization flow

3.2. Risk Scoring and Prioritization

Building on the categorized feedback presented in Table 2, each of the eight identified risk types was evaluated using a 5×5 qualitative risk matrix to systematically prioritize design responses. The risk matrix assesses each category based on two parameters—likelihood of occurrence and severity of impact—each rated on a scale of 1 (lowest) to 5 (highest), yielding composite scores from 1 to 25. These composite scores were translated into three priority levels: high, medium, and low, as summarized in Table 3.

Two risk categories emerged as high-priority concerns:

- **Stability & Load (score: 20):** This was the highest-rated risk, reflecting strong concerns from multiple users about tipping, imbalance, and frame instability—especially during the transition to a standing position. Such risks pose immediate safety threats and, if unmitigated, could render the product unusable for many target users.
- **Physical Accessibility (score: 16):** This category captures difficulties experienced by users with limited strength or range of motion, particularly during the manual actuation phase. The combination of physical exertion and unassisted operation can present significant barriers to adoption.

Addressing these high-priority risks is essential to fulfill the device's core objective: enabling upright mobility in a manner that is both empowering and safe. Proposed design responses include structural reinforcements at stress-prone joints, adjustment of the center of gravity for better balance, and the integration of assistive mechanisms such as gas-spring support to reduce the required physical effort.

Two risk types fell into the medium-priority category:

- **Competitive Benchmarking (score: 12):** indicates that the manual prototype, while innovative, is perceived as less robust than existing powered alternatives.
- **Personalization & Maturity (score: 12):** highlights the need for size variability and adaptability, particularly for users outside the average body profile or with multiple impairments.

While these medium-level risks are not immediately hazardous, they significantly influence user confidence, product attractiveness, and long-term satisfaction. Addressing them requires more than engineering refinement; it involves empathetic design choices such as modular sizing, aesthetic rebalancing, and intuitive interfaces to encourage user trust and psychological comfort.

The remaining four risk types: Institutional Readiness (score: 6), Public Environment Fit (score: 6), Manual Dependency (score: 9), User Perception & Fit (score: 9) were rated as low-priority risks in the context of current prototype testing. These categories reflect long-term considerations, such as readiness for hospital deployment or compatibility with indoor public infrastructure. Although not urgent in the development phase, they will become increasingly relevant as the product moves toward certification and broader implementation.

This structured scoring method offers multiple benefits. First, it ensures that the team focuses limited development resources on the most pressing issues, if left unresolved would compromise user safety and the product's core functionality. Second, it links qualitative user concerns directly to measurable, actionable design interventions. Third, it frames a development roadmap aligned not only with technical feasibility, but also with social inclusivity and user dignity.

More broadly, the risk matrix serves as a decision-support tool that aligns with the participatory and user-centered philosophy of the study. By translating lived user experiences into prioritized engineering challenges, the method avoids a purely technocratic or intuition-based development process. Instead, it integrates subjective concerns and contextual realities into a rigorous, structured approach to design refinement.

Figure **??** illustrates the distribution of eight identified risk types based on their assessed likelihood of occurrence and severity of impact, as reported by study participants. The matrix uses a standard 5×5 qualitative framework, where the vertical axis represents likelihood and the horizontal axis represents severity. Each risk type was plotted onto the matrix based on combined user feedback and expert judgment, allowing for immediate visual differentiation between low, medium, and high-priority concerns.

Table 3. Risk level of product concerns.

Risk Type	Likelihood (L)	Severity (S)	Risk Score (L × S)	Priority Level
Manual Dependency	3	3	9	Low
Stability & Load	4	5	20	**High**
Physical Accessibility	4	4	16	**High**
User Perception & Fit	3	3	9	Low
Institutional Readiness	2	3	6	Low
Competitive Benchmarking	3	4	12	Medium
Public Environment Fit	2	3	6	Low
Personalization & Maturity	4	3	12	Medium

The two highest risks —Stability & Load and Physical Accessibility—are clearly located in the red zone, representing high severity and high likelihood. These issues pose direct threats to user safety and device usability, and therefore require urgent design interventions. Medium-risk concerns such as Manual Dependency, User Perception & Fit, and Personalization & Maturity are situated in the yellow to orange zones, indicating notable but manageable concerns that warrant attention during iterative refinement.

Meanwhile, Institutional Readiness and Public Environment Fit appear in the green zone, reflecting their relatively low urgency at the current stage of development. However, their positioning does not diminish their relevance, particularly as the product approaches scaling, certification, and broader adoption.

The visual representation in Figure **??** reinforces the structured prioritization strategy employed in this study. It enables a shared understanding among designers, engineers, and stakeholders regarding which concerns to address first and how design decisions should be sequenced. This form of evidence-based risk visualization strengthens decision-making transparency and ensures that development efforts remain aligned with both user safety and contextual usability.

4. Discussion

The findings of this study reaffirm the core objective of developing a manually actuated standing wheelchair that not only enhances vertical mobility but also promotes daily physical engagement and psychological empowerment for people with disabilities. The structured feedback from a diverse group of users highlights that the ability to stand is not merely a mechanical function, it carries deep social and emotional significance. Participants expressed that standing facilitated eye-level interaction, improved their sense of independence, and enabled access to environments that are otherwise physically or socially restrictive.

Importantly, the use of a structured 5×5 risk matrix allowed this study to move beyond anecdotal insights by identifying, prioritizing, and addressing the most pressing design challenges. Two risk categories emerged as critical, Stability & Load and Physical Accessibility, each requiring distinct strategies to ensure safety and usability.

The Stability & Load category was consistently highlighted by users as a source of anxiety, particularly during the standing transition. Concerns included tipping risks, sudden movement, and structural imbalance under dynamic loading. These issues were especially pronounced for users with larger body sizes or those with previous negative experiences in unstable mobility aids.

In response, the development team implemented multiple design refinements aimed at reducing both the likelihood and severity of these risks. These include:

- Optimizing the center of gravity to lower the risk of tipping.
- Reinforcing structural joints and pivot points to withstand vertical and torsional loads during transition.
- Widening the wheelbase, particularly laterally, to improve balance.
- Integrating a mechanical damping system or gas spring to support a gradual, controlled standing motion.
- Adding redundant safety features such as adjustable thigh supports and secure body harnesses.

Through these measures, the matrix position of this risk category is expected to shift from the high-risk zone (score 20) to a medium-risk level (score 10) as shown in Figure 3. While the severity of consequences remains high, the likelihood of such events occurring can be significantly reduced through structural reinforcements, optimized geometry, and controlled actuation. This shows how a risk-based iterative design approach allows user input to directly guide technical improvements, reducing the chance of failure while still acknowledging the potential severity of the outcomes.

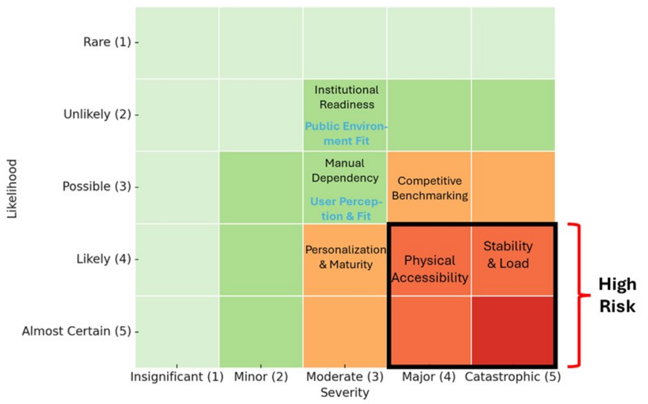

Figure 3. Risk evaluation after mitigation efforts

In contrast, the Physical Accessibility risk presents a more fundamental challenge. While the device is designed for manual actuation to preserve simplicity, cost-efficiency, and portability, this inherently limits usability for individuals with significant upper-body weakness. These users, such as those with high-level spinal cord injuries or neuromuscular disorders, may lack the strength required to operate levers, maintain balance, or safely initiate the standing motion unaided.

Although minor mitigations such as gas-spring support and ergonomic handle redesign have been proposed, these efforts are insufficient for users with very limited arm function. For this population, the risk remains high (Figure 3), and no feasible adjustments to the current mechanical design can adequately reduce it without introducing powered components or external assistance.

To accommodate different user needs, the team proposes a two-path development strategy:

- A manual version for independent users with moderate to full upper-body strength.
- A semi-powered version (in development) for users requiring additional mechanical assistance.

Such stratification allows the product line to grow inclusively without undermining safety, usability, or design simplicity. Additionally, caregiver-assisted usage has been explored by repositioning control levers to be operable from the rear or side, allowing a third party to aid in transition when necessary.

By recognizing the boundaries of manual technology, and clearly defining the target user profile, this study upholds both the practicality and ethical responsibility of inclusive design. It avoids the temptation to claim universal usability, choosing instead a thoughtful, layered approach that prioritizes user dignity and safety.

The structured risk analysis helped improve the design, and it also gave the team a clearer picture of the product's real limitations. The assistive technologies, by nature, must embrace limitations and specificity, rather than striving for universal applicability. The high-risk score associated with Physical Accessibility, particularly for users with severe upper-body weakness, demonstrates that this manual standing wheelchair, in its current form, is not appropriate for all user profiles. This is a critical realization that would have been easily overlooked in a purely mechanical or performance-focused evaluation.

Recognizing these limits helps the design team stay realistic about what the product can and can't do. It reminds us that assistive devices should not be forced to serve all needs through a single solution, especially when safety and dignity are at stake. Instead, they should be tailored unique to the abilities, environments, and contexts of each user. This aligns with the core philosophy of inclusive assistive technology: it is not about mass production, but about meaningful personalization.

Ultimately, this method encourages designers to move away from one-size-fits-all assumptions and toward a more responsive, ethically grounded innovation process. It also provides a powerful tool to communicate transparently with users and stakeholders, not only about what a product can do, but also about what it is not designed to do, and why that distinction matters.

5. Conclusions

This study has demonstrated the feasibility and challenges of implementing a manually actuated standing wheelchair through a user-centered and risk-based design approach. The results highlight that the standing function provides significant physical and psychosocial benefits. These include improved independence, better social interaction, and easier access to vertical space. However, its usability and adoption potential depend heavily on key factors such as stability, user strength, and perceived safety. Feedback from eight stakeholders led to the identification of eight thematic risk types, with Stability & Load and Physical Accessibility emerging as the most critical. Risk assessment showed that stability risks can be effectively reduced through structural refinement, lowering the likelihood of tipping. However, physical accessibility remains a high, unmitigated risk for users with severe upper-body weakness. This shows that a different version of the design is needed to meet the needs of users who require more support. The findings reinforce that innovation in disability devices must not rely solely on mechanical performance but must also respond to emotional needs, build user confidence, and support inclusive use across diverse real-world environments.

Conflicts of interest - If the authors have any conflicts of interest to declare.

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