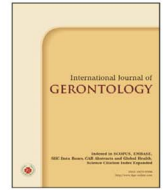




International Journal of Gerontology

journal homepage: <http://www.sgecm.org.tw/ijge/>



Original Article

Usability Test for the Development of a Walking Assistive Device: A User Needs Analysis

Eun Pyeong Choi, Daon Hwang, Ki Hun Cho *

Department of Physical Therapy, Korea National University of Transportation, South Korea

ARTICLE INFO

Accepted 8 September 2025

Keywords:

aged,
ergonomics,
personal satisfaction,
stroke,
walking

SUMMARY

Background: In a super-aged society, there is increasing interest in the ‘silver industry’, leading to the development of various products. This study aims to conduct a usability test exploring consumers’ walking assistive device (WAD) needs.

Methods: Usability tests (satisfaction survey and an in-depth interview) were conducted with 10 older adults and three stroke survivors, using four types of commercialized WADs (walking frames, rollators [Types A and B], and walking tables). Participants walked four courses (straight, obstacle, S-curve, and ramp) using the four types of commercialized WADs, after which they completed a satisfaction survey and participated in an in-depth interview. The satisfaction survey comprised six items covering stability, convenience, and functionality. All items were rated on a 5-point Likert scale (1 = not at all / no discomfort, 5 = very severe). Qualitative data from the interviews were analyzed using conventional content analysis.

Results: Both older adults (2.05 point) and stroke survivors (2.22 point) were preferred the rollator Type A. Older adults requested structural and functional improvements to enhance stability and convenience, while stroke survivors emphasized improvements that considered the characteristics of their condition.

Conclusion: Needs varied according to participant’s physical characteristics, highlighting ergonomic designs tailored to individual users in the development of future WADs.

Copyright © 2026, Taiwan Society of Geriatric Emergency & Critical Care Medicine.

1. Introduction

In 2023, 18.4% of South Koreans were aged 65 or older, classifying the country as an aged society. This figure is expected to reach 20.6% by 2025, transitioning it to a super-aged society.¹ Thus, increasing attention is being paid to the ‘silver economy’, which promotes products that support older adults’ independence and community participation.² Aging is associated with declines physical function, including motor skills, endurance, sensory abilities, and balance.³ Notably, individuals in their 80s experience up to a 40% reduction in lower-limb strength compared to those in their 30s and a 70% reduction in ambulatory capacity compared to those in their 20s.⁴ Declines in strength and ambulatory capacity increase the risk of falls and reduce independence, ultimately diminishing quality of life.²

Walking assistive devices (WADs) mitigate mobility limitations and promote independence, enabling older adults to lead more active and independent lives.⁵ WADs also reduce caregiving burdens^{6,7} and support physical rehabilitation.^{8–10} International Organization for Standardization (ISO) 11199-1, 2, and 3 classified WADs for older adults into three types — walking frames, rollators, and walking tables — and specified key structural features, dimensions, handle designs, weight limits, and braking systems.¹¹ South Korea similarly

classifies WADs under its national safety standards (Safety Standard, Annex 20),¹² however, rollators are classified into Type A (with a backrest) and Type B (without a backrest).² Furthermore, the Support Center for Senior-Friendly Industry under the Korea Health Industry provides usability testing guidelines to minimize errors and ensure safe and effective performance of WADs.¹³

Despite safety standards and usability testing guidelines, WADs market in South Korea remains insufficiently developed.¹⁴ Assistive devices within the silver economy are dominated by inexpensive imported products, with systematic research and development deterred by perceived low profitability relative to development costs.^{2,15} Additionally, products often fail to align with specific mobility environments or the body dimensions of Korean users and thus offer limited safety and usability.²

To revitalize the WADs market, it is essential to evaluate usability that incorporate the biomechanical characteristics of the human body, and apply ergonomic principles to meet user needs.¹⁶ The COVID-19 pandemic further accelerated the adoption of home-use medical technologies, heightening the need for rigorous usability evaluation in healthcare settings.¹⁷ Previous study proposed a rapid methodological framework integrating wearable sensors, telemonitoring, and televisits for heart failure patients, demonstrating that structured usability test can markedly improve user experience.¹⁸ Additionally, recent study noted that several usability issues still arise in commercially available home medical devices and emphasized usability testing to improve device design and safety.¹⁹ Despite

* Corresponding author. Department of Physical Therapy, Korea National University of Transportation, 61 Daehak-ro, Jeungpyeong-gun, Chungbuk 27909, Republic of Korea.
E-mail address: mamiya34@gmail.com (K. H. Cho)

the importance of usability tests in the initial stages of development, many WAD projects in South Korea have lacked user-centered information and usability analysis. Often, these projects relied solely on limited data, such as anthropometric measurements, to inform product design.² Thus, this study aimed to conduct usability tests for commercialized WADs available to community-dwelling older adults and individuals with stroke in South Korea to analyze user needs and inform future developments of WADs.

2. Patients and methods

2.1. Participants

Thirteen participants (10 older adults and three stroke survivors) enrolled in this study. Sample size was determined based on the exploratory nature of this study and in alignment with prior studies on assistive device usability.^{20,21} Community-dwelling participants were recruited using posters at local senior welfare centers. Participation was voluntary, and all individuals who met the inclusion criteria and provided informed consent were included. Inclusion criteria for older adults were: (1) A Mini-Mental State Examination–Korean Version (MMSE-K) score of 24 or higher and (2) ability to walk independently using a WAD. Inclusion criteria for stroke survivors were: (1) community-dwelling individuals at least two years post-stroke, (2) MMSE-K score of 24 or higher, and (3) the ability to walk independently using a WAD. Exclusion criteria for older adults and stroke survivors were: (1) inability to understand the informed consent form or follow the study procedures and (2) unstable joints due to osteoporosis or joint replacement. Table 2 summarizes participants characteristics.

2.2. Usability test

This usability test was approved by the Korea National University of Transportation Institutional Review Board (KNUT-2024-HR-18-15). All patients provided informed consent in accordance with the Declaration of Helsinki before commencing the study.

Participants walked four courses using four types of commercialized WADs (Figure 1), after which they completed a satisfaction survey and participated in an in-depth interview. The usability test was conducted in a 205.02 m² auditorium free of obstructions, with overhead lighting at approximately 700 lux, background noise ranging from 40–60 dB, ambient temperature maintained between 18–23 °C, and relative humidity between 50–55%. The floor consisted of flat, non-slip PVC vinyl with a wood grain finish, and colored cones marked the walking courses. Participants wore comfortable athletic shoes that they normally wear and were instructed on how to use each device and navigate the courses. Ample time was given to familiarize themselves with the devices and courses.

Participants' stability, efficiency, and convenience were evaluated during their ambulation (Figure 2). To minimize potential order effects, both the sequence of the four WADs and four walking courses were randomized using a draw-lots method. Each participant tested all devices on all courses, however, the starting device and course order varied. Short rest periods were provided between trials to reduce fatigue effects. The straight course was designed to move a straight 5-meter distance; the obstacle course was designed to cross a 10 mm doorsill; the S-curve course was designed to be ridden in an S-shaped section; and the ramp course is designed to walk on a 7° slope (1 m distance). Two trained research assistants roles were standardized to include walking alongside the participant at a safe dis-



Figure 1. Four types of commercial WADs (A: Walking frame, B: Rollators (Type A), C: Rollators (Type B), and D: Walking table).



Figure 2. Four types of walking courses (A: Straight course, B: S-shaped course, C: Obstacle course, and D: Ramp course).

tance, monitoring for safety, and providing verbal instructions only when necessary.

Although standardized usability assessment tools such as the Quebec User Evaluation of Satisfaction with Assistive Technology (QUEST 2.0) are widely used for evaluating assistive devices,²² this study considered the specific characteristics of WADs and need for clarity and accessibility for older adults and stroke survivors. Accordingly, a satisfaction questionnaire was developed by modifying and supplementing the usability test guidelines provided by the Korea Health Industry Development Institute’s Support Center for Senior-Friendly Industry,¹³ ensuring that items reflected device-specific functions such as slope walking, storage method, and brake performance. The satisfaction survey comprised six items covering stability, convenience, and functionality. All items were rated on a 5-point Likert scale (1 = not at all / no discomfort, 5 = very severe; Table 1). One-on-one interviews explored participants’ preferred type of WAD, the strengths and weaknesses of each device, and areas for improvement to guide future product development. Qualitative data from the interviews were analyzed using conventional content analysis. Interviews were audio-recorded, transcribed verbatim, and independently reviewed by two researchers. Researchers reviewed the transcripts, coded recurring concepts, and grouped them into categories representing key themes. Disagreements in coding were resolved through consensus meetings. Finalized themes were organized according to the four types of devices and categorized separately for older adults and stroke survivors to enable comparative analysis.

2.3. Data analysis

Statistical analysis was performed using SPSS (version 27.0; IBM Corp., Armonk, NY, USA). Participants’ general characteristics were presented using descriptive statistics and frequency analysis. The satisfac-

tion survey results were presented as mean and standard deviation.

3. Results

3.1. Satisfaction with WADs

Table 3 presents participants’ satisfaction levels when using four types of WADs across four courses. Older adults rated their satisfaction highest with the rollator Type A (mean satisfaction score = 2.05) and lowest with the rollator Type B (mean satisfaction score = 3.58). Similarly, stroke survivors gave the highest satisfaction rating to the rollator Type A (mean satisfaction score = 2.22) and the lowest rating to the walking frame and walking table (mean satisfaction score = 3.94). Overall, both groups reported the highest satisfaction with rollator Type A compared to the other devices.

Table 2. Participants characteristics (n = 13).

Parameters	Older adults (n = 10)	Stroke survivors (n = 3)
Sex (male/female)	3/7	1/2
Age (years)	83.30 ± 1.89	75.33 ± 5.03
Height (cm)	152.24 ± 2.46	166.67 ± 11.55
Weight (kg)	59.80 ± 9.04	61.67 ± 17.56
BMI (kg/m ²)	25.85 ± 4.25	21.90 ± 3.80
Duration of walking aid use (years)	3.17 ± 3.53	11.00 ± 8.54
Affected side (right/left)	-	1/2
U/E MAS (1/1+)	-	1/2
L/E MAS (1/1+)	-	1/2
BBS (score)	38.45 ± 5.12	30.00 ± 7.94
10MWT (m/s)	0.41 ± 0.14	0.35 ± 0.15

Values are expressed as mean ± SD.

BBS: Berg Balance Scale, BMI: body mass index, L/E: lower extremity, MAS: Modified Ashworth Scale, U/E: upper extremity, 10MWT: 10-meter walking test.

Table 1 Usability questionnaire.

Section	Item	Question	Scale				
Safety	Fear of falling	Please indicate the degree of fear of falling	①	②	③	④	⑤
	Anxiety during walking	Please indicate the level of anxiety during walking	①	②	③	④	⑤
	Discomfort on slopes	Please indicate the level of discomfort when walking on a slope	①	②	③	④	⑤
Convenience	Storage inconvenience	Please indicate the level of discomfort regarding storage method	①	②	③	④	⑤
	Discomfort during use	Please indicate the level of discomfort during walking	①	②	③	④	⑤
Functionality	Brake function	Please evaluate the functionality of the brake	①	②	③	④	⑤

Please respond using a 5-point Likert scale: ① = Not at all / No discomfort, ② = Slight, ③ = Moderate, ④ = Severe, ⑤ = Very severe.

Table 3 WADs satisfaction scores (n = 13).

Subjects	Items	Walking frame	Rollator (Type A)	Rollator (Type B)	Walking table
Older adults (n = 10)	Fear of falling	2.40 ± 1.43	1.60 ± 1.07	4.50 ± 0.71	2.10 ± 1.37
	Anxiety during walking	1.40 ± 0.70	1.30 ± 0.67	2.90 ± 1.66	2.30 ± 1.64
	Discomfort on slopes	4.00 ± 0.67	2.20 ± 1.69	4.20 ± 1.23	3.90 ± 1.20
	Storage inconvenience	2.07 ± 1.57	2.10 ± 1.45	2.90 ± 1.73	3.70 ± 1.57
	Discomfort during use	3.30 ± 1.25	2.90 ± 1.85	4.40 ± 1.26	3.60 ± 1.35
	Brake function	3.50 ± 1.51	2.20 ± 1.75	2.60 ± 1.78	3.80 ± 1.55
	Average	2.88 ± 1.46	2.05 ± 1.50	3.58 ± 1.60	3.23 ± 1.58
Stroke survivors (n = 3)	Fear of falling	4.00 ± 1.00	1.67 ± 1.15	2.67 ± 1.15	3.00 ± 1.73
	Anxiety during walking	3.67 ± 0.58	1.67 ± 1.15	2.67 ± 1.15	3.33 ± 1.15
	Discomfort on slopes	3.67 ± 1.15	2.33 ± 1.15	3.00 ± 1.00	4.33 ± 0.58
	Storage inconvenience	3.67 ± 0.58	3.33 ± 2.08	3.00 ± 1.73	4.33 ± 0.58
	Discomfort during use	4.33 ± 0.58	2.67 ± 1.53	3.00 ± 1.73	3.67 ± 1.53
	Brake function	4.33 ± 0.58	1.67 ± 1.15	2.00 ± 1.73	5.00 ± 0.00
	Average	3.94 ± 0.73	2.22 ± 1.35	2.72 ± 1.27	3.94 ± 1.16

Values are expressed as mean ± SD.

1 = Not at all / No discomfort; 2 = Slight; 3 = Moderate; 4 = Severe; 5 = Very severe.

3.2. In-depth interview results

Table 4 presents participants' recommended improvements for each WAD. Both groups expressed a clear preference for the rollator Type A. Older adults highlighted the need for a larger seat for resting, increased weight for improved stability, larger wheels to navigate obstacles more effectively, and enhanced brake functionality. Stroke survivors emphasized the importance of structural features that enable single-handed weight support and mobility, as well as one-hand folding, a wider frame to prevent tripping, a stable design to support sufficient weight, and motorized assistance for navigating uphill inclines.

4. Discussion

The satisfaction survey revealed that both groups expressed the highest satisfaction with rollator Type A. Older adults reported the lowest satisfaction with rollator Type B, and stroke survivors reported the lowest satisfaction with the walking frame and walking table. These results are thought to be due to differences in mobility and stability depending on the type of WADs. Research on WAD stability and maneuverability indicates that smaller wheels require greater effort to navigate doorsills or obstacles, while larger wheels improve ease of movement on inclines.²³ Devices that can support more weight also enhance user stability and reduce the fear of falling.²⁴ Rollator Type A is equipped with four large wheels that likely provide greater convenience during use, and its A-shape frame design (a wider base compared to the top) enhances stability for weight bearing, minimizing fears of falling. This is evident in the survey results, where older adults (1.60 points, No discomfort) and stroke survivors (1.67 points, No discomfort) rated their satisfaction highest for the "fear of falling" category.

The satisfaction survey results of stroke survivors can be inferred from the disease characteristics. Hemiplegia is a neurological symptom of stroke, and survivors primarily use their non-paralyzed upper limbs to support their weight and use WADs.²⁵ During the walking courses, walking frames and tables presented difficulties in directional control when used with only one hand (non-paralyzed upper limbs), while rollators (Type A and Type B) were easy to operate with one hand. Specifically, the large wheels on the rollator Type A likely contributed to a smoother and more stable walking experience. A previous study found that a rollator Type A structure was effective for subacute stroke patients who face challenges in gait train-

ing.²⁶ Additionally, a study evaluating a design comparable to rollator Type A reported improved stability during downhill walking compared to standard WADs.²⁷ These findings suggest that the advantages of rollator Type A, such as ease of maneuvering and stability, should be actively incorporated in future development of WADs for stroke survivors. Study findings align with growing emphasis on integrating advanced technologies into WADs to improve usability, safety, and user satisfaction. Recent studies on smart walkers and robotic assistive devices demonstrated that systematic usability evaluations can effectively identify design limitations and guide targeted improvements.^{28,29} This underscores embedding iterative usability testing throughout the design process to ensure that WADs meet functional requirements and optimize overall user experience.

During in-depth interviews, older adults emphasized structural and functional improvements for safer and more convenient use, such as increasing seat size for resting, increasing device weight for greater stability, enlarging wheels to overcome obstacles easily, and improving brake functionality. Stroke survivors primarily requested functional improvements that considered disease characteristics (hemiplegia), such as supporting weight and assisting walking with only one hand and assistive motor power when walking (especially uphill).

These improvements highlight ergonomically designed WADs that consider individual physical conditions rather than simply providing basic weight support. A design that balances optimal stability and mobility remains a complex challenge,²³ and integrating advanced technologies such as robotics holds promise for developing devices that meet diverse user needs.^{9,30} Future designs should focus on both aesthetics and intuitive functionality.³¹ A user-friendly appearance can reduce psychological resistance, while simplifying operation can enhance usability for older adults and people with physical or cognitive impairments.^{9,32}

4.1. Limitations

This study has several limitations. First, the small sample size limits the statistical generalizability of the findings, particularly for the stroke group ($n = 3$), which restricts the interpretation of results beyond qualitative insights. Although the sample size aligns with prior usability research norms for exploratory studies,^{20,21} larger and more diverse participant groups are needed in future research for robust statistical comparisons and broader applicability of the results. Second, the usability test focused solely on older adults and stroke survivors; hence, there was no input from users with other

Table 4

Key findings of in-depth interviews ($n = 13$).

Walking assistive devices	Older adults ($n = 10$)	Stroke survivors ($n = 3$)
Walking frame	<ul style="list-style-type: none"> Enhanced brake functionality (slippage issues observed) Need larger seats 	<ul style="list-style-type: none"> Difficult to use with one hand Small wheels make it challenging to overcome obstacles
Rollator (Type A)	<ul style="list-style-type: none"> Foldable design for easier storage Larger seat 	<ul style="list-style-type: none"> Design allowing one-handed use and storage Motorized assistance for uphill mobility Wider frame to prevent tripping Larger seat
Rollator (Type B)	<ul style="list-style-type: none"> Heavier weight needed for safety during weight support (currently feels unstable) 	<ul style="list-style-type: none"> Fear of falling when bearing weight Feels unsafe for seated resting
Walking table	<ul style="list-style-type: none"> Adequate for weight support, but small wheels make obstacle navigation difficult Design improvements Enhancements for more convenient seat use Brake mechanism should be improved (suggest hand-applied brake system) 	<ul style="list-style-type: none"> Difficult to use with one hand Challenging to adjust handle height Need hand-operated brakes Difficulty navigating over obstacles

physical conditions who rely on WADs. Third, all assessments were conducted exclusively indoors under controlled laboratory conditions, without considering contextual factors such as environmental challenges (e.g., uneven terrain), social influences (e.g., public perception), and functional demands of real-world use. Thus, the generalizability of the findings to community and outdoor environments is limited. Finally, the study's short duration precluded analysis of long-term usability, durability, and adaptation processes associated with these devices. Future research should include evaluations in diverse outdoor and community settings to inform the development of WADs that better address the needs of a broader range of users.

5. Conclusion

This study assessed the usability of four types of commercialized WADs through satisfaction surveys and in-depth interviews to analyze user needs for future device development. Findings revealed that users' physical characteristics influenced their structural and functional requirements, underscoring the importance of ergonomic designs tailored to individual needs. These results can serve as foundational material for WAD development and direct future design efforts.

Funding/support statement

This research was supported by the U-LAB Program of the National University Development Project (2025) funded by Korea National University of Transportation. This research was supported by the Regional Innovation System & Education (RISE) program through the Chungbuk Regional Innovation System & Education Center, funded by the Ministry of Education (MOE) and Chungcheongbuk-do, Republic of Korea. (2025-RISE-11-004-02). In addition, this research was supported by the Assistive Technology Commercialize R&D Project for Independent Living for People with Disability and Older People of the Ministry of Health & Welfare, Republic of Korea (grant number: RS-2024-00431203).

Conflicts of interest

The authors have no conflicts of interest to declare.

References

- KOSIS KOREAN Statistical Information Service. Projected Population by Age Group (Korea). Accessed December 17, 2024. https://kosis.kr/statHtml/statHtml.do?orgId=101&tblId=DT_1BPA003&conn_path=I2&language=en
- Jung GH, Park JH. Classification and structural analysis of human-centric pedestrian assistance products in South Korea. *J Ergon Soc Korea*. 2023; 42(6):549–569. doi:10.5143/JESK.2023.42.6.549
- DiPietro L. Physical activity in aging: changes in patterns and their relationship to health and function. *J Gerontol A Biol Sci Med Sci*. 2001; 56(suppl_2):13–22. doi:10.1093/gerona/56.suppl_2.13
- Roh CG, Park BJ. A study on the design criteria of pedestrian facility (slope) by motion analysis of walking parameters in the elderly. *J Korean Soc Transp*. 2018;36(5):383–391. doi:10.7470/jkst.2018.36.5.383
- Hwang D, Cho KH. Usability test for motion tracking gait assistive walker. *J Korean Phys Ther Sci*. 2023;30(4):1–8. doi:10.26862/jkpts.2023.12.30.4.1
- Arefin P, Habib MS, Arefin A, Arefin MS. A comparison of mobility assistive devices for elderly and patients with lower limb injury: narrative review. *Int J Aging Health Mov*. 2020;2(1):13–17. doi:10.6084/m9.figshare.12318608
- Park DC, Jung JH, Kim WD, Son IH, Lee YJ, Lee GC. Comparison of gait ability according to types of assistive device for ankle joint of chronic hemiplegic stroke survivors. *J Korean Phys Ther Sci*. 2021;28(2):30–39. doi:10.26862/jkpts.2021.09.28.2.30
- Hesse S, Uhlenbrock D, Sarkodie-Gyan T. Gait pattern of severely disabled hemiparetic subjects on a new controlled gait trainer as compared to assisted treadmill walking with partial body weight support. *Clin Rehabil*. 1999;13(5):401–410. doi:10.1191/026921599673896297
- Martins M, Santos C, Frizera A, Ceres R. A review of the functionalities of smart walkers. *Med Eng Phys*. 2015;37(10):917–928. doi:10.1016/j.medengphy.2015.07.006
- Sousa CO, Barela JA, Prado-Medeiros CL, Salvini TF, Barela AM. The use of body weight support on ground level: an alternative strategy for gait training of individuals with stroke. *J Neuroeng Rehabil*. 2009;6:43. doi:10.1186/1743-0003-6-43
- ISO 9999:2022(en) Assistive products – Classification and terminology. Online Browsing Platform (OBP) Accessed December 30, 2024. <https://www.iso.org/obp/ui/#iso:std:iso:9999:ed-7:v1:en>
- Korean Agency for Technology and Standards. Korean Standard Notification No. 2017-032, Annex 20: Walking frames, Rollator and Walking Table for Walking Support. Accessed December 19, 2024. https://kats.go.kr/content.do?cmsid=527&sf_cat1=CWS485&cat1_0=CWS485&sf_cat2=CWS496&mode=view&page=2&cid=19144
- Korea Health Industry Development Institute. Guidelines for Usability Evaluation of Senior-Friendly Products. Accessed December 17, 2024. <https://www.khidi.or.kr/board?menuId=MENU00310&siteId=SITE00003>
- Seong KE, Lee DT. A study on the future scenario of futuristic walker design to improve activity of senior-focused on the women active senior in baby boom generation. *J Basic Des Art*. 2016;17(1):295–306.
- Kim JS, Im SH, Shin YJ. A study on crutched walking frame with one-wheel drive. *J Korean Soc Mech Technol*. 2013;15(3):351–356. doi:10.17958/ksmt.15.3.201306.351
- Kim YJ, Chae SW. Human-centered product innovation research center. Article in Korean. *CDE Review*. 2008;14(3):37–48.
- Barsom EZ, Meijer HAW, Blom J, Schuurings MJ, Bemelman WA, Schijven MP. Emergency upscaling of video consultation during the COVID-19 pandemic: contrasting user experience with data insights from the electronic health record in a large academic hospital. *Int J Med Inform*. 2021;150:104463. doi:10.1016/j.ijmedinf.2021.104463
- Savoldelli A, Vitali A, Remuzzi A, Giudici V. Improving the user experience of televisits and telemonitoring for heart failure patients in less than 6 months: a methodological approach. *Int J Med Inform*. 2022;161:104717. doi:10.1016/j.ijmedinf.2022.104717
- Tase A, Buckle P, Ni MZ, Hanna GB. Usability of home-use medical technology: the patient perspective. *J Patient Saf Risk Manag*. 2024;29(2):83–91. doi:10.1177/25160435241230143
- Virzi RA. Refining the test phase of usability evaluation: how many subjects is enough? *Hum Factors*. 1992;34(4):457–468. doi:10.1177/001872089203400407
- Faulkner L. Beyond the five-user assumption: benefits of increased sample sizes in usability testing. *Behav Res Methods Instrum Comput*. 2003; 35(3):379–383. doi:10.3758/BF03195514
- Aledda S, Galeoto G, Fabbrini G, et al. A systematic review of the psychometric properties of Quebec user evaluation of satisfaction with assistive technology (QUEST). *Disabil Rehabil Assist Technol*. 2024;19(4):1228–1235. doi:10.1080/17483107.2022.2161648
- Anslow R, Pinnington LL, Pratt DJ, Spicer J, Ward CD, Weyman N. Stability and manoeuvrability of wheeled walking frames. *Physiotherapy*. 2001; 87(8):402–412. doi:10.1016/S0031-9406(05)65459-4
- Thies SB, Russell R, Al-Ani R, et al. An investigation of the effects of walking frame height and width on walking stability. *Gait Posture*. 2020;82:248–253. doi:10.1016/j.gaitpost.2020.09.017
- Van Hook FW, Demonbreun D, Weiss BD. Ambulatory devices for chronic gait disorders in the elderly. *Am Fam Physician*. 2003;67(8):1717–1724.
- Morone G, Annicchiarico R, Iosa M, et al. Overground walking training with the i-Walker, a robotic servo-assistive device, enhances balance in patients with subacute stroke: a randomized controlled trial. *J Neuroeng Rehabil*. 2016;13(1):47. doi:10.1186/s12984-016-0155-4
- Han K, Ko BW, Shin JH, Cho W, Song WK. Usability testing of smart mobile walker: A pilot study. In: *2014 11th International Conference on Ubiquitous Robots and Ambient Intelligence (URAI 2014)*. IEEE; 2014: 112–115.
- Zhang B, Wang Z, Li Z. Mobility Aid Design for the Elderly (MADE): a de-

- sign thinking approach using a smart walker as a case study. *Humanit Soc Sci Commun*. 2024;11:1469. doi:10.1057/s41599-024-04007-z
29. Sierra M. SD, Harris N, Múnera M, Cifuentes CA. Socially assistive walker for daily living assistance in older adults. *Front Robot AI*. 2024;11:1401663. doi:10.3389/frobt.2024.1401663
30. Demiral DG. Emerging assistive technologies and challenges encountered. In: Calp MH, Butuner R, eds. *Current Studies in Technology, Innovation and Entrepreneurship*. ISRES Publishing; 2023:1–21.
31. Wu CC, Lin WL. Development of evaluation indicators for senior-friendly restaurants. *Br Food J*. 2023;125(4):1453–1468. doi:10.1108/BFJ-11-2021-1264
32. Cowan RE, Fregly BJ, Boninger ML, Chan L, Rodgers MM, Reinkensmeyer DJ. Recent trends in assistive technology for mobility. *J Neuroeng Rehabil*. 2012;9:20. doi:10.1186/1743-0003-9-20