Development of A Walker for Fall Prevention

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ABSTRACT

This study explores the design and development of a simple, easily deployable walker aimed at preventing falls among adults and the elderly. They face challenges in regaining their ability to walk after experiencing a traumatic illness, an accident, a prolonged period of sickness, or simply being old and weak. This situation can create a vicious cycle: as their fear of falling increases and their physical activity decreases, they suffer an even greater loss of walking ability. Consequently, their quality of life worsens. The design is intended to support a body weight of 120 kg. In principle, the walker can support an adult without tipping over as long as the body's center of mass remains within the base of support. The walker has been designed, and its structural strength is simulated in SolidWorks. A customized inertial-measurement-unit (IMU) system is intended to be worn by the adult for the purposes of detecting falls, alerting users, and data acquisition. This paper demonstrates the design principles and procedure for a walker for fall prevention. The results indicated that the design could be revised repeatedly to meet the specified targets, and the trials confirmed the expected outcomes. Future enhancements could include additional straps to secure the body to the walker during a fall and the integration of IoT technology for remote alerts.

Keywords: Walker, fall prevention, IMU, alerting

1. Introduction

The global demographic landscape indicates that many countries are transitioning into aging societies, driven by increased life expectancy and declining birth rates [1]. As the proportion of older adults grows, the prevalence of age-related health issues, particularly falls, is expected to rise. Falls are among the leading causes of unintentional injury and mortality worldwide, with older adults being disproportionately affected [2]. Falls can occur in various locations, including slips while walking inside the home and outside the home [3]. Factors that increase the risk of falling include weakness in the lower body, vitamin D deficiency, difficulties with walking and balance, medication use, vision issues, foot pain, and hazards in the home [4].

Each year, millions of individuals require medical intervention due to fall-related injuries, which often result in fractures, head trauma, or long-term disability [5]. Beyond physical harm, falls are associated with significant psychosocial consequences, including loss of confidence, reduced participation in daily activities, and an increased fear of falling.

This fear-driven behavioral change often leads to reduced physical activity, initiating a detrimental cycle: decreased mobility contributes to muscle weakness and impaired balance, thereby increasing susceptibility to future falls [6]. Over time, this cycle exacerbates physical decline, accelerates frailty, and can lead to depression, social withdrawal, and diminished quality of life [7]. Collectively, the consequences of falls not only affect the individual but also impose considerable emotional, social, and financial burdens on families, caregivers, and healthcare systems [8].

Assistive devices have long served as essential tools to promote mobility, independence, and safety among the elderly. These devices can generally be classified into two categories: conventional and intelligent. Conventional devices, such as walking sticks and traditional walkers, are cost-effective and simple to use but provide limited protection against falls [9]. In contrast, intelligent assistive devices, enabled by advances in robotics, sensors, and artificial intelligence, offer enhanced safety features such as fall detection, stability control, and emergency notifications [10][11]. Despite these advantages, widespread adoption of intelligent devices remains constrained by factors such as affordability, portability, complexity, and maintenance. For many low- and middle-income households, cost continues to be the decisive factor when selecting mobility aids [12]. Among available assistive technologies, walkers are one of the most widely adopted solutions, offering varying levels of stability and support. They range from basic, lightweight frames to advanced models equipped with smart technologies. This study focuses on the development of an enhanced walker aimed at fall prevention. The design emphasizes the integration of security mechanisms and an alert system, with the ultimate objective of reducing fall-related risks, safeguarding independence, and improving the quality of life for elderly users.

2. Methodology

The methodology has two parts. Firstly, the walker and its design principle, and secondly, a customized accelerometric alert notification system.

The primary focus of this study is to enhance user safety when using a walker. Stability over the area of support is a measure of how resistant an object or person is to tipping over, with a wider base of support generally leading to greater stability. Stability is maintained as long as the object's center of gravity (or line of gravity) falls within its base of support. Instability occurs when the center of gravity falls outside the area of support, which can happen when the body leans too far beyond its supports, potentially leading to tipping over. The principle is illustrated in Figure 1, where the walker's base of support offers a larger area of stability for a person if they can maintain their balance during tipping or buckling. Several factors can enhance stability, including a wider base of support, a lower center of gravity, and increased body mass. These factors allow the center of gravity to shift further before causing instability. This means that the taller an individual is, the wider the base of support should be. For improved stability, the support area can be designed with additional lateral supports or a trapezoidal shape, as demonstrated in Figure 2. This study adopts the design as shown in Figure 2(a). The walker is constructed from pipe frames measuring 108 cm in height, 66 cm in length, and 62 cm in width. An additional support frame of 11 cm is added to both the left and right sides, as shown in Figure 3.

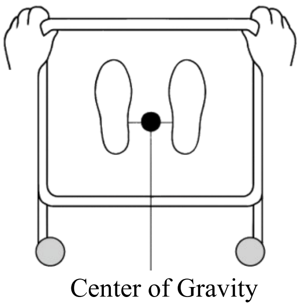


Figure 1. Key principle – Base of Support (Seen from top)

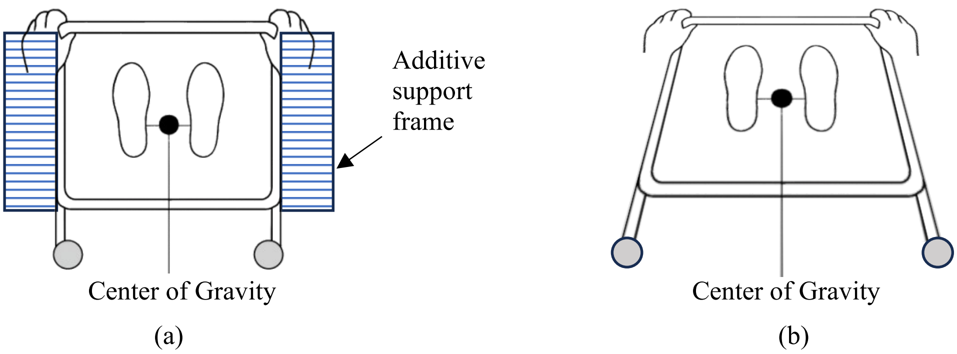


Figure 2. Design variants – (a) additive lateral supports, (b) trapezoid shape

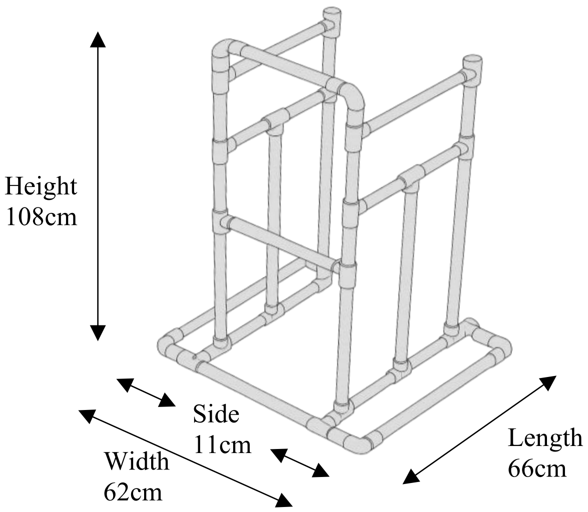


Figure 3. Design in SolidWorks

The second design is a customized accelerometric alert system. The electronic components in the walker consist of a microcontroller (Arduino Mega 2560), a triaxial accelerometer (ADXL335), a micro Secure Digital (SD) card module, a buzzer, and a push button to enable the system. The system is powered by a power bank. Figure 4 illustrates the block diagram of the accelerometric alert system, which will be constructed using these electronic components. Accelerometric gait data is collected for post-analysis. Fall detection occurs when there is any dynamic rise in any accelerometer axis, or when the accelerometric data indicates a shift from vertical to horizontal, either suddenly or in a pseudo-static or static state. The system is assembled and worn by a user using a pouch that is secured at the waist.

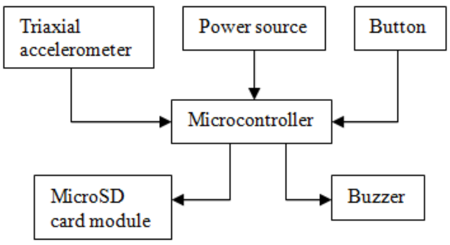


Figure 4. Block diagram of a customized accelerometric alert notification system

3. Results and Discussion

The walker must be capable of supporting the user's weight. For this project, a hollow PVC tube has been chosen for construction due to its affordability, lightweight nature, availability, and ease of assembly. (Note: Other stronger materials could also be used for construction.) The structural strength of the walker has been simulated using SolidWorks. Figure 5 presents the results of this simulation, while Table 1 displays the minimum and maximum stress levels for weights of 80 kg, 100 kg, and 120 kg. Stress analysis identifies the safe failure zone for specifying load stress. An illustration of the walker and a user is shown in Figure 6(a) and Figure 6(b) for normal and fall respectively.

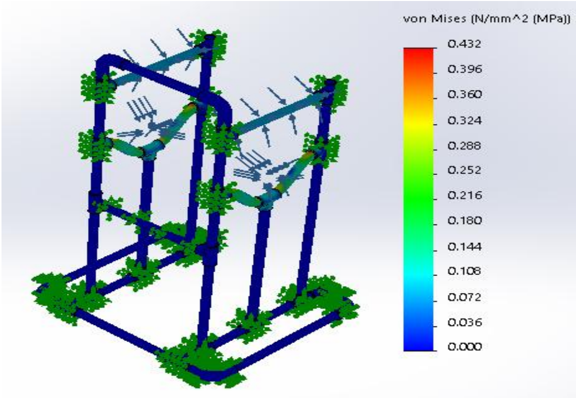


Figure 5. Stress analysis

Table 1. Force applied on walker

Load	120 kg (1177N)	100 kg (981N)	80 kg (785N)
Maximum	0.431502 N/mm^2 (MPa)	0.359625 N/mm^2 (MPa)	0.287742 N/mm^2 (MPa)
Minimum	4.24573e-019 N/mm^2 (MPa)	2.23545e-019 N/mm^2 (MPa)	2.80005e-019 N/mm^2 (MPa)

(a) (b)

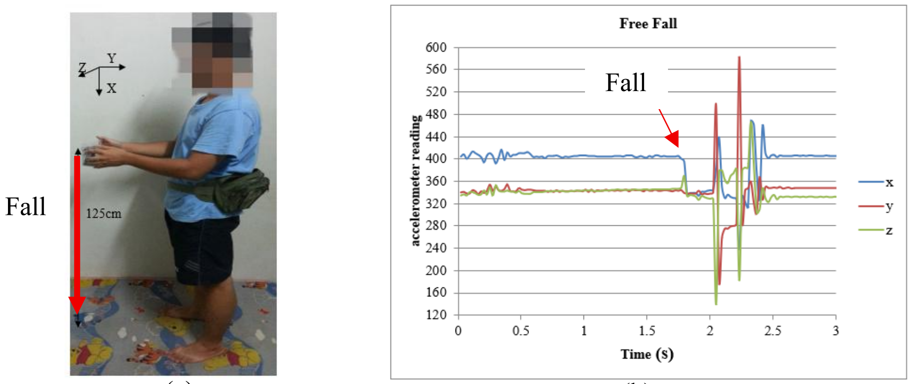
Figure 6. The walker and a user. (a) normal, (b) fall

The accelerometric alert system has been successfully assembled and programmed. To enhance portability, it is encased in a waist pouch. Calibration of the system is accomplished through two free-fall tests: the first involves dropping the device from a height, while the second entails a user wearing the pouch and falling into a seat. Multiple trials have been conducted.

Figure 7(a) illustrates the first free-fall test, where the system is dropped from a height of 125 cm, and Figure 7(b) displays the intensity recorded by the accelerometer across each axis. The graph clearly indicates a fall, marked by a sudden drop in the signal—most notably in the vertical axis (x-axis)—followed by spikes across all axes.

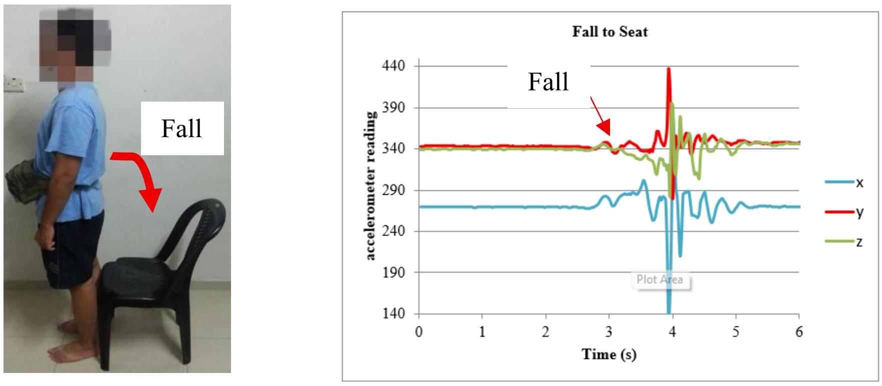
Figure 8(a) presents the free-fall test of a user falling into a seat, with Figure 8(b) showing the intensity recorded by the accelerometer across each axis. The graph indicates spikes in all axes; however, the change in the vertical axis (x-axis) at the moment of the fall is less pronounced than during the drop test. This may suggest that falling into a seat is a more controlled action.

The tests reveal that the axes effectively reflect the body's orientation, distinguishing between vertical and horizontal planes. During impacts with the ground or seat, jerks are identified as spikes. It is generally unnecessary to convert these measurements into 'g' units for assessing plane orientation and jerks. For alerting purposes, early detection of signal changes is impractical since these alterations occur too rapidly. Nevertheless, the jerks serve as a strong indicator of a fall. Additionally, a change in planes signifies that a user is lying on the floor.



(a) (b)

Figure 7. (a) Free fall test, (b) Accelerometric data



(a) (b)

Figure 8. (a) Fall to seat test, (b) Accelerometric data

4. Discussions

This paper highlights the base of support (BoS) as a critical factor in maintaining stability. The shape and area of the BoS can be tailored to meet the specific needs of the user. Ideally, a walker should be lightweight, portable, and capable of effectively supporting the user's body weight. Simulation plays a vital role in assessing the structural integrity of the product design. Data collected from accelerometers indicates that falls often occur very quickly in their early stages. The initial impact with the ground happens in a split second, making it unlikely that a caregiver will always be available to monitor and ensure a user's stability to prevent falls. Therefore, we propose a lightweight, affordable walker that can provide constant support and stability. For users with limited strength, it may be safer to include a body strap, such as a climber's safety vest, which connects to the walker for enhanced security during a fall. It minimizes fall injuries. Conversely, for healthier users, the body strap can be removed, allowing them to stabilize themselves during a fall using their hands, minimizing fall injuries.

5. Conclusions

Fall deserves our attention as it could cause financial cost and could deteriorate life quality. This paper demonstrates the design principles and procedure for a walker for fall prevention. The key working principle and the design procedure are highlighted.

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References

[1] United Nations, “World Population Prospects 2024: Summary of Results.,” New York, 2024.

[2] World Health Organization, “Falls.” https://www.who.int/news-room/fact-sheets/detail/falls (accessed Jul. 29, 2023).

[3] A. Ashari, T. A. Hamid, M. R. Hussain, R. Ibrahim, and K. D. Hill, “Prevalence, Circumstances, and Risk Factors of Falls Among Community Dwelling Members of University of the Third Age.,” *Front. public Heal.*, vol. 9, p. 610504, 2021, doi: 10.3389/fpubh.2021.610504.

[4] “Facts About Falls,” *US Centers For Disease Control And Prevention (CDC)*, 2024. https://www.cdc.gov/falls/data-research/facts-stats/index.html (accessed Sep. 10, 2025).

[5] E. L. S. Bally *et al.*, “Factors associated with falls among hospitalized and community-dwelling older adults: the APPCARE study,” *Front. Public Heal.*, vol. 11, Jun. 2023, doi: 10.3389/fpubh.2023.1180914.

[6] D. Lee and S. H. Tak, “A concept analysis of fear of falling in older adults: insights from qualitative research studies.,” *BMC Geriatr.*, vol. 23, no. 1, p. 651, Oct. 2023, doi: 10.1186/s12877-023-04364-5.

[7] S. Türkmen Keskin, E. Sönmez Sari, Ş. Canbulat, and F. Ö. Öztürk, “Fear of Falling Avoidance Behavior on Daily Living Activities and Physical Activity in Older Adults: A Cross-Sectional Study.,” *Nurs. Health Sci.*, vol. 27, no. 1, p. e70060, Mar. 2025, doi: 10.1111/nhs.70060.

[8] Y. K. Haddad *et al.*, “Healthcare spending for non-fatal falls among older adults, USA.,” *Inj. Prev. J. Int. Soc. Child Adolesc. Inj. Prev.*, vol. 30, no. 4, pp. 272–276, Jul. 2024, doi: 10.1136/ip-2023-045023.

[9] K. M. Goher and S. O. Fadlallah, “11 - Assistive devices for elderly mobility and rehabilitation: review and reflection,” N. K. Suryadevara and S. C. B. T.-A. T. for the E. Mukhopadhyay, Eds. Academic Press, 2020, pp. 305–341. doi: https://doi.org/10.1016/B978-0-12-818546-9.00016-6.

[10] M. Martins, C. Santos, A. Frizera, and R. Ceres, “A review of the functionalities of smart walkers,” *Med. Eng. Phys.*, vol. 37, no. 10, pp. 917–928, 2015, doi: https://doi.org/10.1016/j.medengphy.2015.07.006.

[11] R. Martins, M. M., Santos, C. P., Frizera-Neto, A., & Ceres, “Assistive mobility devices focusing on smart walkers: classification and review,” *Rob. Auton. Syst.*, vol. 60, no. 4, pp. 548–562, 2012.

[12] K. van Dam, M. Gielissen, R. Bles, A. van der Poel, and B. Boon, “The impact of assistive living technology on perceived independence of people with a physical disability in executing daily activities: a systematic literature review,” *Disabil. Rehabil. Assist. Technol.*, vol. 19, no. 4, pp. 1262–1271, May 2024, doi: 10.1080/17483107.2022.2162614.