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iTDAF IETI Transactions on Data Analysis and Forecasting

iTDAF | eISSN: 2959-0442 | Vol. 1 No. 3 (2023) | OPEN ACCESS

https://doi.org/10.3991/itdaf.v1i3.44039

SHORT PAPER

Meta-Analysis of Different Mobility Devices for Rehabilitation of Persons with Disabilities

Harshul Brahmbhatt(✉)

Gujarat Technological University, Ahmedabad, Gujarat, India

179999919015@gtu.edu.in

ABSTRACT

Loss of physical mobility poses significant challenges to full participation in daily activities and can even lead to complete limitations. In India alone, based on census data from 2011, there are over 5.5 million individuals with lower limb disabilities who rely on manually propelled wheelchairs for their mobility needs. While wheelchairs, crutches, and tricycles are commonly used mobility aids in India, this paper explores mobility technologies that have been conceptualized and developed in other parts of the world to assess their potential applicability in the Indian context.

KEYWORDS

assistive device, rehabilitation, mobility device, wheelchair, assistive technology

1 INTRODUCTION

Mobility refers to the ability of individuals to move their bodies within and across environments, including the manipulation of objects. It plays a crucial role in enabling individuals to pursue their chosen endeavors in life. However, impairments in bodily functions or structures can hinder a person's ability to perform mobility tasks successfully. Certain conditions, such as multiple sclerosis, gradually lead to impairments, while traumatic spinal cord injuries (SCIs), cerebral vascular accidents, and limb amputations result in sudden impairments [1].

Spinal cord injuries affect a significant number of people worldwide, with an estimated 250,000 to 500,000 new cases occurring each year [2]. Approximately 82% of individuals with SCI become dependent on wheelchairs for mobility. Disabled individuals constitute the largest minority group, totaling over 650 million people globally who experience some form of disability [3]. Restricted mobility has a profound impact on their daily functioning, quality of life, the mental health of caregivers, and employment rates [4].

Rehabilitation efforts encompass not only the restoration of movement but also individuals' independence in activities of daily living (ADL), active participation in

Brahmbhatt, H. (2023). Meta-Analysis of Different Mobility Devices for Rehabilitation of Persons with Disabilities. *IETI Transactions on Data Analysis and Forecasting (iTDAF)*, 1(3), pp. 83–89. https://doi.org/10.3991/itdaf.v1i3.44039

Article submitted 2023-07-14. Revision uploaded 2023-08-27. Final acceptance 2023-08-28.

society, maintaining a healthy lifestyle, engaging in sports, and access to public facilities such as toilets. The World Health Organization (WHO) has classified personal factors, such as cultural biases and gender, as also affecting rehabilitation outcomes [5].

Chronic impairment rehabilitation aims to restore locomotion, ambulation, and mobility in patients. It goes beyond simply restoring sensorimotor function and encompasses compensation and adaptability, often utilizing technology-based approaches. Wheelchairs are crucial assistive devices for individuals with lower limb limitations. Research in this field aims to improve function and mobility in chronic conditions [6].

According to the WHO, the global population aged 60 and above is projected to increase from 11% to 22% between 2000 and 2050. The number of individuals aged 60 or older is expected to rise from 605 million to 2 billion during the same period. Europe and North America have the second and third highest numbers of elderly individuals, respectively, comprising 22% of the global senior population. Worldwide, countries are transitioning to an aging demographic. Approximately 650 million people globally have disabilities, accounting for around 10% of the total population, with 80% of disabled individuals residing in developing countries [7].

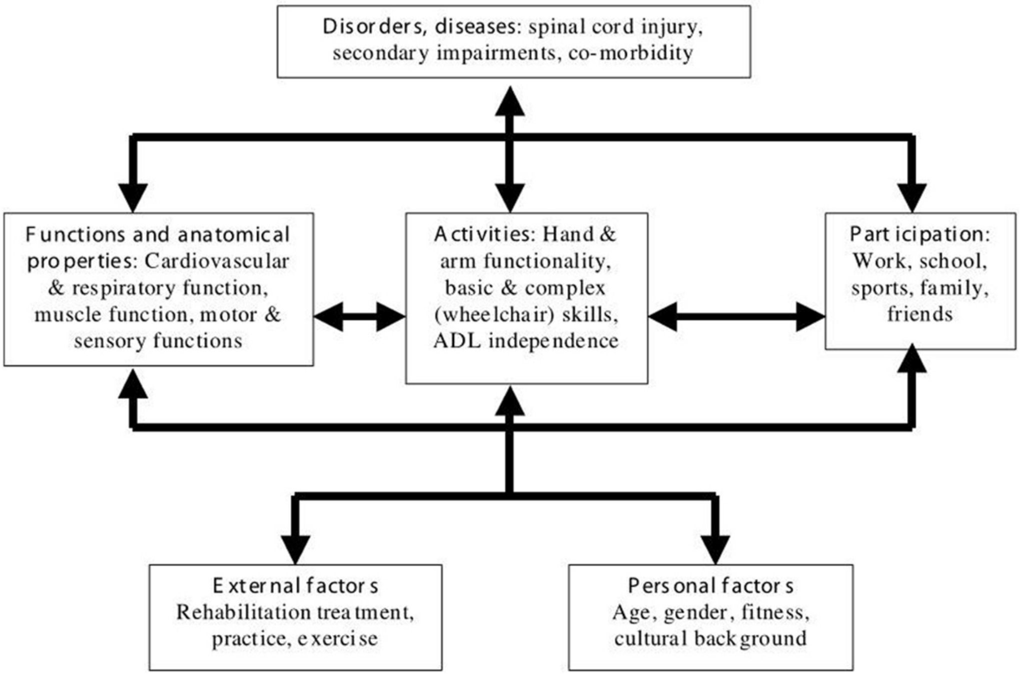


Fig. 1. The International Classification of Functioning, Disabilities and Health as developed by the World Health Organization and applicable to wheelchair-dependent person [8]

This paper aims to explore the relevance of different assistive technologies in promoting an active lifestyle for individuals in rehabilitation, particularly in developing countries.

2 DEVELOPMENT IN THE DOMAIN OF MOBILITY DEVICES

The utilization of harness crutches and saddle crutches for mountaineering was observed in the study. It highlighted the superiority of harness crutches over saddle crutches, as they transferred 18% more body weight among six out of eight non-impaired individuals [8]. This research sheds light on the potential of special-purpose crutches in enhancing functional capacity (Figure 2) and suggests their applicability in developing mobility devices for individuals with impairments.

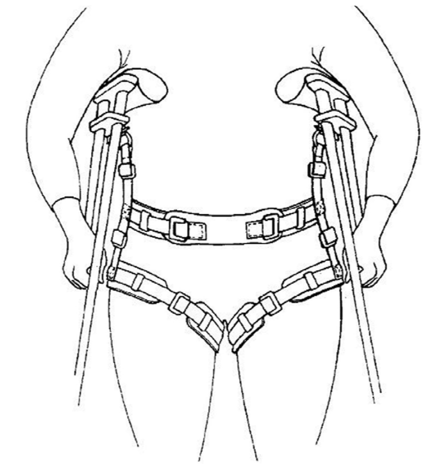


Fig. 2. The harness crutch [8]

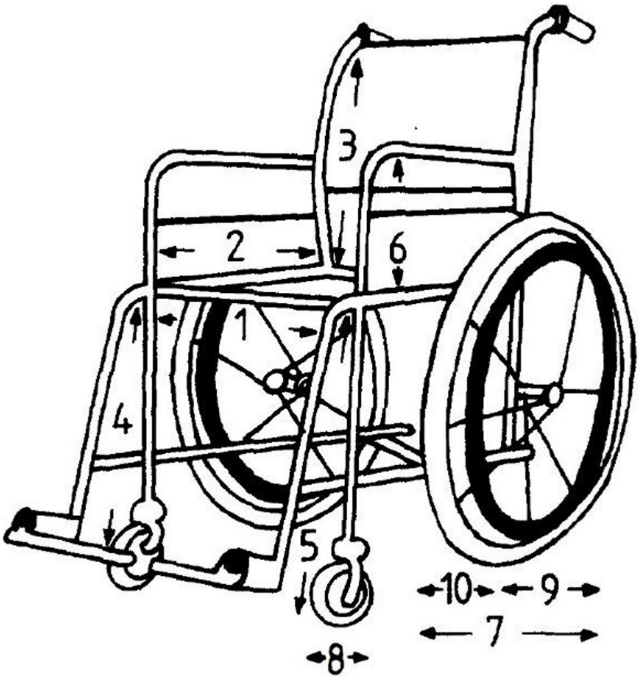
Crutches have been found to encourage higher levels of physical activity compared to many other mobility devices, leading to long-term health benefits for users. However, crutch gait is more demanding in terms of energy expenditure compared to unassisted gait (normal walking). To address this limitation, efforts have been made to improve crutch design, utility, materials, and features. Despite advancements, crutches remain slower and less efficient than normal walking, and they can cause strain and injury to the upper body, particularly the wrist and elbow. There are two main types of crutches: auxiliary and non-auxiliary (Figure 3). Auxiliary crutches provide rigid support with an underarm crosspiece, while non-auxiliary crutches have been used for nearly 5000 years and offer good control during gait (walking). However, non-auxiliary crutches require special training and skills, while auxiliary crutches lack flexibility and can lead to more strain with long-term use [9].

a) Axillary crutch or underarm crutch **b) Non-auxiliary or arm crutch**

Fig. 3. Crutches popular in India (www.seniority.in)

Manual wheelchairs are extensively relied upon by individuals with lower limb disabilities, or SCI, worldwide. In the mid-1980s, a study investigating different types of wheelchairs (Figure 4) found that Type A outperformed others in terms of engineering design and human-centric parameters. Additionally, the relationship between wheelchair rim diameter and cardiorespiratory response was established, indicating that smaller rim diameters result in lower cardiorespiratory exertion [10].

Wheelchairs have evolved from simple chromium-plated models to task-specific and utilitarian devices. Push-rim-activated power-assisted wheelchairs have emerged as a unique alternative to manual wheelchairs, each offering different advantages. Manual wheelchairs provide control over daily tasks, while power-assisted wheelchairs are more suitable for semi-outdoor mobility with increased torque. However, wheelchair users often experience issues such as neck pain, shocks and vibrations, and shoulder problems resulting from prolonged use [11]. The lack of appropriate skills and mobility options restricts users' daily activities and affects their overall quality of life [10].



Key		Wheelchair type A	B	C	D
1.	Seat width	42·0	41·0	44·0	44·0
2.	Seat depth	42·0	37·5	49·0	41·5
3.	Back rest ht.	40·0	28·0	38·5	40·5
4.	Seat to foot rest ht.	38·0	50·0	39·0	32·5
5.	Seat to ground ht.	51·5	56·0	53·0	47·0
6.	Seat to arm rest ht.	30·5	15·0	15·0	13·0
7.	Diameter of back wheel	62·0	64·0	58·0	58·0
8.	Diameter of front wheel	18·0	9·5	10·0	10·0
9.	Diameter of hand rim	56·0	54·0	44·0	44·0
10.	Clearance between rim and wheel	3·0	2·5	8·0	7·5
11.	Weight of wheelchair	23·0	25·0	26·0	25·0

Weight in kg, others in cm

Fig. 4. Pictorial view of a wheelchair and specifications of four types of wheelchairs (Goswami et al., 1986)

The design and configuration of wheelchairs used in sports such as basketball, rugby, and tennis have significantly contributed to athletes' performance. Sports wheelchairs consist of individual components, and even slight adjustments in their configuration can impact the ergonomics and mobility performance during wheelchair propulsion [12]. Much of modern wheelchair design has originated from wheelchairs used in sports practices (Figure 5).

Fig. 5. Different types of wheelchairs developed for person with lower limb impairment [6]

Exoskeleton systems have been extensively researched for mobility assistance, ranging from knee and hip support during normal walking to lower limb assistance during load lifting and carrying activities. However, a limitation of these systems is that they often move users on predetermined trajectories, making it challenging for individuals to practice their own movement patterns due to their unique needs [13].

3 CONCLUSION

In conclusion, addressing mobility challenges is crucial for enabling individuals to engage in activities and improve their quality of life. Advances in mobility technology, such as specialized crutches and wheelchairs, have shown promise for enhancing functional capacity. Further innovation is needed to overcome the limitations associated with current mobility devices. Collaboration between regions and personalized approaches to mobility assistance, including exoskeleton systems, can facilitate the adoption of effective solutions. Continuous advancements in mobility technology and inclusive design will empower individuals with disabilities to lead active, independent lives.

4 ACKNOWLEDGEMENTS

This research is conducted as a part of Doctoral research program affiliated to Gujarat Technological University, Ahmedabad. The PI is pursuing his Doctoral at Gujarat Technological University, Ahmedabad.

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6 AUTHOR

Harshul Brahmbhatt is a research scholar currently pursuing his doctoral studies at the Department of Mechanical Engineering, Gujarat Technological University, Ahmedabad, India. He holds membership with the prestigious Institution of Engineers (India), further underscoring his commitment to academic excellence and professional growth (E-mail: 179999919015@gtu.edu.in).