Smart Walkers from an Ergonomics Perspective: A Review

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ABSTRACT

Walking is essential to our everyday lives, both socially and in our ability to perform basic everyday tasks. However, a significant number of people suffer from walking difficulties, especially people of older ages. Smart walkers are assistive devices that support independent living by extending the capabilities of four-wheeled walkers. The augmentative nature of this device means that there is a need for compatibility with the user’s gait and balancing needs. This aspect has not yet been fully explored as most previous studies have focused upon the technological features of smart walkers. This paper aims to highlight and elaborate upon some of the challenges associated with developing smart walkers from an ergonomics perspective.

Keywords: Assistive technology, Smart walkers, Ergonomics, Mobility aids, Human-machine interaction, Elderly

1. Introduction

Being able to move around freely and independently is fundamental to an individual’s well-being. Any impairment to this ability not only has severe consequences in terms of performing essential everyday tasks, but can also impede our ability to engage in meaningful social interactions (Rosso et al., 2013). However, ambulatory disability (difficulty in walking or climbing stairs) affects a large number of people (5.1% of working age people and 22.6% of elderly in the USA) (Kraus, 2017). The number of ambulatory disability sufferers are expected to rise substantially as the world population ages (United Nations, 2015).

It is not always possible to cure or prevent the occurrence of ambulatory disability, especially in the case of older adults. It is important for these people that there are assistive devices that can alleviate some of the difficulties of ambulatory disability and allow them to maintain a certain quality of life.

Today, many devices are available, including canes, crutches and walkers. However, these simple and passive devices often have high musculoskeletal and cognitive demands. While helpful, and even essential, in most cases, there are usually significant disadvantages to using them. For example, metabolic cost is significantly higher when walking with standard walkers (Priebe and Kram, 2011) and there is high risk of more severe injuries when using four-wheeled walkers (FWWs) (van Riel et al., 2014).

There is a need for better assistive devices and one promising approach is by incorporating mechatronic components. Taking this approach, smart walkers (SWs) improve and extend the capabilities of conventional FWWs using various sensors and actuators. SWs (also known as “robotic rollators” and “robotic walkers”) encompass a wide range of devices, each with its own unique combination and implementation of features (Fig. 1). These functions include obstacle avoidance for sight or cognitive impairments, power assistance for muscle weakness, and health monitoring to reduce workload of carers.

One of the main challenges in developing safe and effective SWs is that they are augmentative devices. These are devices which aim to supplement or enhance an existing human capability instead of replacing them (Martins et al., 2012). Therefore, there is a need for...
compatibility between the device and the existing function it is augmenting.

SWs are preferable to robotic wheelchairs because the user’s own legs are still used. A user continuing to walk can prevent further deteriorations in walking capability and may avoid the various health problems associated with remaining seated for long periods of time.

While there has been considerable research attention given to SWs, emphasis has largely been in the technology domain. Most research studies have focused upon proposing and developing new mechanical designs, controllers or algorithms (Martins et al., 2015). More studies are needed to better understand the needs and capabilities of potential SW users when designing SWs.

It is still not clear how to properly consider the needs and capabilities of potential SW users when developing SWs. This paper aims to highlight and elaborate on some of the challenges associated with developing SWs from an ergonomics perspective.

2. Ergonomics of Smart Walkers

2.1 Limitations of Four-wheeled Walkers

As mentioned earlier, FWWs form the basic structure from which SW functions build upon. It is important to understand the interaction with FWWs so that appropriate modifications can be made using mechatronic components of SWs. Although FWWs are widely used, detailed understanding of their functioning, and limitations of their design, is still lacking because most research has focused on prescriptive suitability and the risks and effects of use on a patient (Alkjaer et al., 2006; van Riel et al., 2014; Suica et al., 2016).

An FWW provides frontal plane balance by allowing the user to generate upper limb stabilizing moments. The primary force to generate these stabilizing moments is in the vertical direction (pushing downwards) (Tung et al., 2011). Although partial weight bearing support is provided, patients who require weight bearing support are often discouraged from using FWWs because these are viewed as being less stable relative to other mobility aids (Faruqui and Jaeblon, 2010; Bradley and Hernandez, 2011). Only minimal and unsteady sagittal plane support is provided by FWWs without the patient holding down the brakes.

2.2 Physical Interaction

Alternative and augmentative devices have much in common; both are human-machine systems which need to understand the intentions of its user, perform the desired actions, and provide appropriate feedback. However, there is an added dimension of physical interaction for augmentative devices, which needs to be considered (Fig. 2). “Physical interaction” here refers to the exchange of forces between the human and the device. For example, actuators in a robotic wheelchair do not directly interact with the human body, whereas force exchanges occur between the human body and an exoskeleton.

For SWs, the need for partial weight bearing of the user leads to the tight coupling of motion and significant physical interaction between the user and SW. The user has to counter the assistive force from an SW, or match the motion of the SW. In other words, the user cannot be moved without a postural change or stepping motion.

Therefore, the human-SW movement results from the combination of forces from the user and SW. Yet, the force generated by an SW leads to human adaptations which, in turn, affect user-generated force and the body

![Figure 2. Schematic of a general human-machine system showing the added dimension of physical interaction for augmentative systems.](image-url)
signals that the SW generated force is based on. This intertwined relationship between the system components mean that a good understanding of the effects of this tight coupling on the interaction is crucial in developing an intuitive and safe SW.

2.3 Sagittal Plane Support

The manual brakes installed in FWWs are the main source of sagittal plane support. This is normally only used when the user starts to fall. The passive or active actuators built into SWs provide an opportunity to improve stability by providing sagittal plane support without resorting to the discontinuous walking of standard walkers.

Previous studies have shown that it is possible to identify gait events based on inputs from handle forces or laser range sensors (Hirata et al., 2006; Abellan et al., 2010). However, the way to utilize this information to actuate an SW in order to achieve continuous stable gait is not known.

A more common approach in trying to provide continuous sagittal plane support is to provide it only when the user starts to fall. The SW will attempt to detect whether the user is falling as early as possible using various predefined parameters (Page et al., 2016). Once identified, most SW prototypes would stop moving, providing a stationary support for the user. The downside to this approach is that no support is available in the sagittal plane during normal use. This limits the SW’s user base to individuals who do not require sagittal plane support for walking, and have the strength to recover after starting to fall. While fall detection is helpful in reacting to unexpected events, it is preferable for the support provided to be continuous.

2.4 Motion Assist

Most SW prototypes have electric motors installed to provide motion assist. Users of SW are expected to be frail and would benefit from motion assistance. There are already FWWs available commercially which are equipped with motors to provide assistive force when used on slopes (RT.Works). However, there needs to be compatibility with the walking motion of the user as discussed in Section 2.1.

The center of mass for a human moves approximately sinusoidally during walking and its velocity varies about an average speed across the gait cycle (Kuo, 2007). In contrast, the velocity of motorized wheels is typically relatively steady. Consequently, an unnatural gait with compromised balance and/or an increase in metabolic cost would occur if the relationship between user and steady velocity of the SW is not considered when developing SWs. In addition, the push-pull capabilities of the user varies across the gait cycle (Bennett et al., 2008). The way this variation affects a user’s ability to generate stabilizing moments when walking is not known.

2.5 Posture

The body posture assumed when using an SW can affect an individual’s stability and likelihood of falling. It is often recommended that a user should maintain an upright posture when using an FWW (Liu et al., 2009; van Riel et al., 2014) as shown in Figure 3. This posture is preferred because it is more similar to natural walking and the center of mass of the user stays as close to the base of support as possible. In the stooped posture, the user’s balance is completely dependent upon the presence of hand reaction forces from the handles, and any unexpected motion from the FWWs can cause the user to fall.

However, an upright posture may be difficult to achieve without assistance for frail individuals because of the need to push the FWWs. The user’s center of mass needs to be in front of the user’s center of pressure when pushing in order to maintain postural balance. Users may tend to adapt a slightly forward leaning posture when having to push a device (Figure 3(a)). On the other hand, forcibly maintaining an upright posture while pushing a device could compromise the user’s balance.

2.6 Discussion

Physical interaction, sagittal plane support, motion assist, and posture, are closely interlinked and directly affected by the actuators in SWs. Many controllers have been proposed, based on various measurable parameters.
For example, JARoW continuously matches its center to the center of its user’s legs while ASBGo translates force in its handles to velocity (Lee et al., 2014; Martins et al., 2014). However, it is not known how well these SW prototypes achieve the four aspects discussed herein.

Shared control, where the SW helps with navigation through actuators, is common in SWs. SW motion will be less predictable to the user, making it harder for users to adapt and more important to consider the key factors described above.

4. Conclusion

It is important to study the interactions involved in human-SW systems, and the phenomena giving rise to these interactions, because there is a vital need for compatibility. In addition, a better understanding of the relationships between physical interaction, hand stabilizing moments, walking, and posture, is required to optimize the support and assistance from an SW.

Acknowledgments

This work was supported by JSPS KAKENHI Grant Number JP15K14619 and JP17H01454.

References


