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RESEARCH ARTICLE

Ergonomic Pad Design of IoT-Based Portable Electric Wheel-chair

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Abstract

Background and Aims: Wheelchairs are a basic necessity for people with disabilities, especially people with physical disabilities. Although conventional wheelchairs have aided the mobility of people with disabili-ties, they are limited in scope due to physical exhaustion and health problems from sitting in wheelchairs for a long time. This research is important to develop seatback and cushion features for Health Electric Wheelchair Portable IoT-Based wheelchairs, for easy and comfortable mobil-ity for people with disabilities. The development of wheelchairs aims to reduce the negative im-pact of prolonged immobilization on people with physical disabilities. **Methods:** Research & Development method. The development stage: 1). The development of pads for Health Electric Wheelchair Portable IoT-Based seatback and cushion needed by wheelchair users; 2). Development of expert-validated Health Electric Wheelchair Portable IoT-Based ergonomics and seatback in accordance with the needs of wheelchair users to improve physical independence; 3). Modify components and equipment for Health Electric Wheelchair Portable IoT-Based cushion and seatback. **Results:** The result of this development of this wheelchair pays attention to ergonomic design by developing seatback and chair features for Health Electric Wheelchair Portable IoT-Based wheelchairs to provide safety and comfort when using wheel-chairs, especially physical disability. **Conclusion:** The development of cushion and seatback on wheelchairs can reduce the negative impact of immobilization on people with physical disabilities and is able to provide broad access for users to mobilize on wheelchairs and can adjust to the ergonomics of each user's body.

Keywords
Ergonomic, Wheelchair, Cushion, Seatback, Physical Disability

INTRODUCTION

In 2018, it was known that the proportion of people with disabilities in Indonesia for ages 5-17 years was 3.3% and 18-59 years old was 22% (Pusdatın Kemkes, 2019). The proportion of people with disabilities is increasing so many tools must be developed to meet their needs (Moll & Cott, 2013). Of the approximately 49 wheelchair users, it was found that about 96% of people with disabilities wanted to have a wheelchair that was safe, comfortable, and inexpensive (Sunardi et al., 2021, 2023) to provide ease of mobilization for users in terms of usability, accessibility, safety, cost, stigma and participation from time to time (Labbé et al., 2020).

Difficulty in movement or mobility (Jatmiko, 2019; Jauhari &Wasesa et al., 2022) being one of the most commonly reported functional difficulties, a problem that is usually overcome by using special devices or equipment (Dudgeon et al., 2008) such as wheelchairs or crutches. Wheelchairs are crucial in the independence of people who have physical barriers (Dudgeon et al., 2008; Hsu et al., 2012). The World Health Organization (WHO) estimates that around 65 million people in the world use wheelchairs (electric or manual) (WHO, 2018), representing about one percent of the world's

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population (Armstrong et al., 2008). Using the right and suitable wheelchair will help wheelchair users to improve their quality of life (Iksal & Darmo, 2012; Setyaningsih & Gutama, 2016) and also their social conditions (Jatmiko, 2019). As stated in a discussion paper by the South African Revenue Services (SARS) in relation to persons with disabilities, infrastructure modifications need to be made to make certain structures accessible to persons with mobility disabilities so that they can function or carry out daily activities (Naidoo et al., 2014). If the wheelchair is not suitable or comfortable, the body will be injured (Yuan & Guan, 2014) So that mobility is limited, environmental exploration is also limited (Bray & Tudor Edwards, 2020; Davis, 2011).

About <75% of pad designs greatly affect a person's sitting posture (Dénes et al., 2020). Because, sitting posture and is an important factor that affects the function of the limbs (Sprigle et al., 2003) underlying bone function due to pressure or shift (Shechtman et al., 2001) underlying bone function due to pressure or shift (Hsu et al., 2018), decreased ability to relieve pressure by frequently changing their body position causing them to experience pressure sores or low back pain (Ma et al., 2017). In fact, the main purpose of using a wheelchair is to maximize the functional potential in people with physical disabilities (Shechtman et al., 2001) using a comfortable pad and seatback (Bhatia et al., 2022). Therefore, optimizing the design of the wheelchair pad that can be adapted according to the needs of the user (Defloor & Grypdonck, 1999) and ergonomics should be one of the main goals in designing a wheelchair (Li et al., 2020).

More than 200 models of wheelchair pillows/pads commercially available (Sprigle et al., 2003). As stated by (Garber & Krouskop, 1984) pads used in wheelchairs should be able to reduce the pressure of wheelchair users, which is currently used clinically (Rosenthal et al., 1996) and made with a wide variety of materials such as water, gel, foam, corrugated (egg crate), viscoelastic (Koo et al., 1996; O'Sullivan et al., 2012) and contoured pillows, which are shaped to fit the individual's body (Gil-Agudo et al., 2009).

From the facts above, it is very important to develop a portable pad that has been made in PUPT 2021 to support the independence of mobility for people with physical disabilities. The development of wheelchair pad standards will include means to measure and describe pad characteristics and performance. This study concentrated on the first, pad characteristics defined as physical features or attributes. Meanwhile, for pad performance, it relates to the way the pad functions in its role as a surface.

MATERIALS AND METHODS

Wheelchair Pad Design

Pad/pillow selection is not a trivial matter for many wheelchair users (Sprigle et al., 2001). Loss of motor or sensory function is a significant risk factor for low back pain that workers are exposed to during periods of time when they are sitting or not sitting, such as manual material handling or lifting activities, or psychosocial factors (De Carvalho et al., 2010). As stated by (Kamegaya, 2016) the ideal sitting posture for wheelchair users is with the pelvis pressed posteriorly on the ischium (sitting bone) sliding forward by 5 cm with a significantly greater posterior pelvic tilt during sitting. Factors such as manufacturing materials, shape or even mechanical and thermal responses from sitting can be potential contributors to the appearance of back and ischium pain (Williams et al., 2017).

Pad has become a complex topic for low back pain researchers because of the sitting position problems as shown in Figure 1 (Hobson, 1992) is one of the most expensive disorders found (Defloor & Grypdonck, 1999; Kelsey, 1975; Magora, 1975). Many investigations have focused their attention on the factors that cause injuries, especially on activities and events associated with the onset of symptoms in wheelchair users (Riihimäki, 1991).

Various positions and sitting characteristics of wheelchair users as shown in Figure 1 require pad support so that wheelchair users do not experience pain or shifts in bone construction (Kirby, 2016), thus providing comfort and security to users (García-Molina et al., 2021). The benefits of pads provide assistance in the form of pressure or redistribution to minimize these risks (Chai & Bader, 2013) with different pad characteristics (Lee et al., 2016).

To increase understanding of the factors that provide pad comfort in wheelchairs with foam hardness with bone posture and terrain commonly traversed by wheelchair users (Ebe & Griffin, 2001). Thus, the pad can provide the best cushioning and pressure according to the needs of each individual (Pellow, 1999).

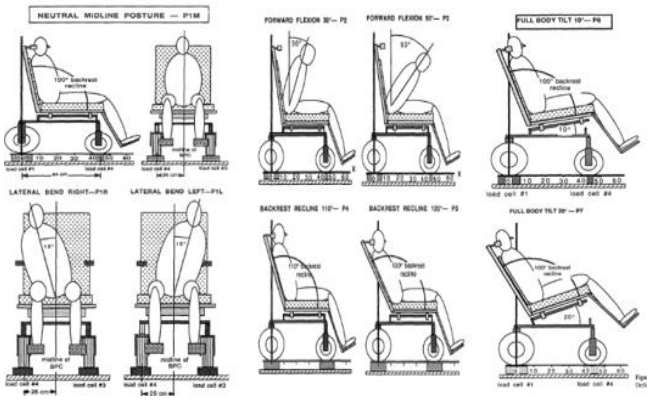

Figure 1. Wheelchair user's sitting posture (Hobson, 1992)

Wheelchair Pad Design

Surveys and studies show that more than 50% of respondents express the importance of ergonomic seating because proper ergonomic seating furniture with proper use can help reduce injuries and so-called cumulative trauma disorders (Parent-Thirion et al., 2007). From the point of view of ergonomics, high comfort is related to well-being, a feeling of security and a healthy sensation of the user (Dénes et al., 2020). The literature research process has identified 15 articles that contain that the material of the base and structure of the wheelchair is a factor in the discomfort of wheelchair users when using it (Syakura et al., 2021; Hostens et al, 2001) argued that an even distribution of pressure can be overcome after the ergonomic design of the seating system according to the needs with various anthropometric variations on foam cushions that have contour. Complies with many basic ergonomic requirements, health and level of dependency of the user (Diebschlag et al., 1988; Harms, 1990). Thus, creating better pressure than pads with flat foam.

In supporting ergonomics, anthropometry is needed, anthropometry plays an important role in the fields of industrial design, clothing design, ergonomics, and architecture (Sokhibi, 2017). In these areas, statistical data on the dimensional distribution of the body of a population are necessary to produce an optimal product (Kristanto & Saputra, 2019). Anthropometry will basically concern the physical size or function of the human body, including here linear size, weight, volume, space of movement, and others that will be very useful in planning work equipment or work facilities (Mardiana et al., 2020; Yudiantyo, 2020).

Method

The research method used is the Research and Development method (Gall et al., 2003). This method was used to develop research products that have been carried out previously, namely Health Electric Wheelchair Portable IoT-Based. The pad in the previous study will be re-designed, to be more suitable with the needs of wheelchair users and for embedding features related to ergonomics that follow bone construction. The initial stage of development is to conduct research on 1). the development of pads for Health Electric Wheelchair Portable IoT-Based seatback and cushion needed by wheelchair users; 2). development of expert-validated Health Electric Wheelchair Portable IoT-Based ergonomics and seatback in accordance with the needs of wheelchair users to improve physical independence; 3). modify components and equipment for Health Electric Wheelchair Portable IoT-Based cushion and seatback. The development procedure is described in Figure 2.

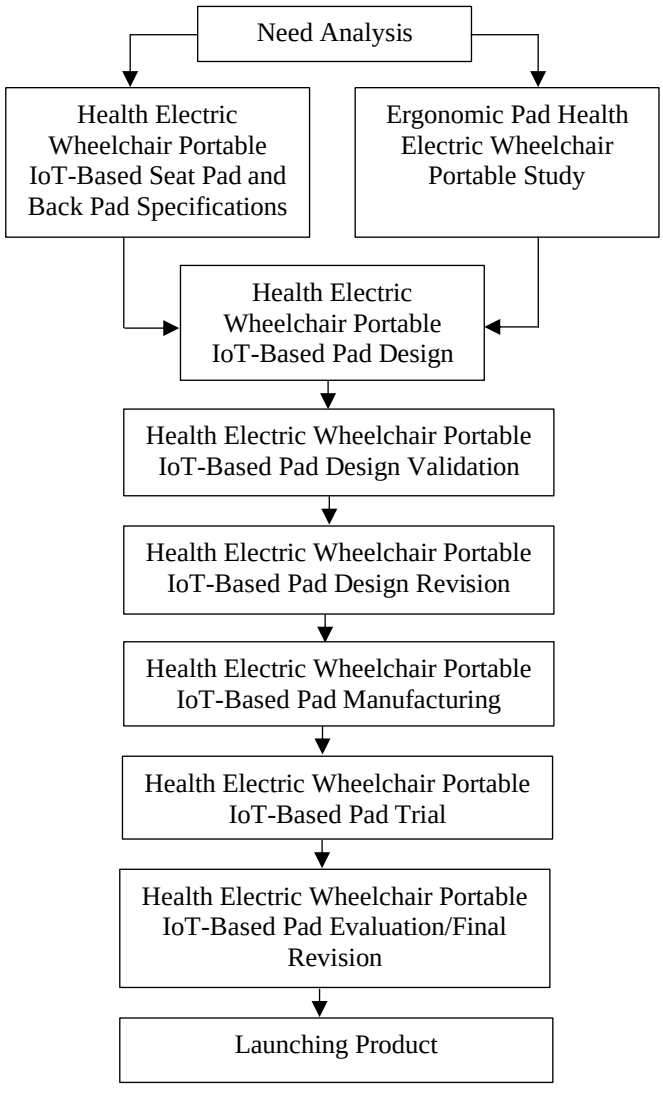

Figure 2. Development procedure

The method to be used to obtain research data is planned to use a survey method with a tool in the form of a questionnaire. In addition, it also uses the

interview method. For Health Electric Wheelchair Portable IoT-Based production equipment using existing equipment in the Laboratory of the Department of Mechanical Engineering, Automotive Engineering and the Physiology Anatomy Laboratory of Faculty of Sports and Health Sciences UNY.

RESULTS

The first step in developing wheelchair cushion and seatback needs features was to distribute a needs analysis questionnaire to people with disabilities and the questionnaire received responses from 49 wheelchair users. From the questionnaire, data was obtained that 1 respondent needed a sitting pad from a specific gel, so that if occupied for hours, he would not be sick to have the number of voters. The wide seating was chosen by 2 respondents. The soft seats was chosen by 15 respondents. The portable cushion feature in wheelchair seating was chosen by 16 respondents. Seats made of animal skins was chosen by 1 respondent. Seats that is permanently integrated with the wheelchair was chosen by 3 respondents. The feature of using a safety strap was chosen by 6 respondents. Features can be folded easily (portable) was chosen by 11 respondents. Temperature control feature (hot/cold) was chosen by 6 respondents. Head support feature in the seatback was chosen by 7 respondents with a voter percentage of 6%. Seat belt feature was chosen by 24 respondents with a voter percentage of 22%. A solid seatback feature with foam coating (padding) was chosen by 19 out of 24 respondents with a voter percentage of 17%. The height setting feature (portable) was chosen by 27 respondents with a voter percentage of 24%. The rear (right-left) thrust grip feature was chosen by 20 respondents with a voter percentage of 18%. The temperature control feature was chosen by 14 respondents with a voter percentage of 13%. The electronic form control feature was not chosen by 49 respondents. Portable features have the largest percentage with 37% with 38 voters from 49 respondents.

Based on data obtained from respondents, soft seatback and cushion were developed, ergonomic, adjustable and can be easily disassembled and installed on various types of wheelchairs (portable). The development and innovation of ergonomic design in this study focused on 3 main components, namely the cushion, back rest, and head rest. Based on data from the needs analysis questionnaire and reference studies related to ergonomics, the initial design and innovation of the 3 components were obtained:

Holder (Seat)

Innovation in wheelchair seats is adaptive (adjustable) using velcro, where the position of the hip support is adjusted, so that it can support and protect the Gluteus Maximus and Gluteus Medius muscles, which can then provide comfort for users.

Figure 3. Cushion

Seatback (Back Rest)

The innovation in the Back Rest is adaptive (adjustable) using a lever shift mechanism, which can be adjusted in height and stretch (width). This setting provides comfort and health in the shape of the user's body because it can support the waist, spine and back (lumbar support).

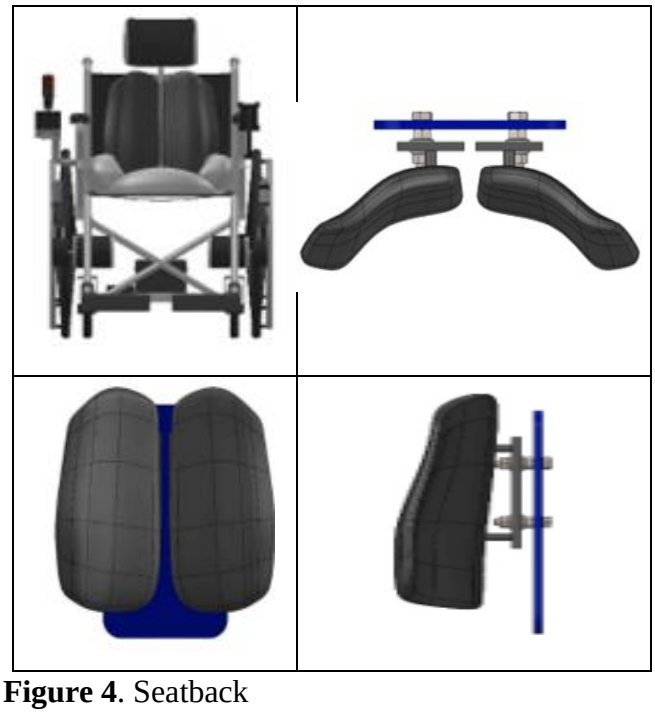

Figure 4. Seatback

Headrest

The innovation in the Head Rest is a shape that is adjusted to the anatomy of the head and the angle is adjusted for the comfort of the neck when

the head rests. Thus, wheelchair users with Head Rest will feel comfortable.

Figure 5. Headrest

DISCUSSION

Identifying the backrest and stand design required by the individual should be done as early as possible in the planning stages to ensure that the posture needs of the wheelchair user can be accommodated and used effectively (Horn, 2018). The use of pads on seatback and stands that are suitable for sitting posture can reduce maximum stress on muscles as well as bones (Ragan et al., 2002). Knowing the pressure on the pressure at the time of sitting is a logical method of assessing this factor (Akins et al., 2011). So that the pad on the cushion and seatback can improve balance significantly when the wheelchair user sits on a wheelchair (Aissaoui et al., 2001).

The symmetrical position and equal weight distribution of the subject on each pad measured by the interface pressure under the sacrum are further aspects that should be considered a priority (Reis, 2008). The wheelchair with a seatback tilt angle that can be adjusted according to needs and comfort can prevent decubitus ulcers . A greater tilt angle can facilitate circulation because the emphasis when sitting in a wheelchair is reduced. This additional component provides convenience to wheelchair users because it can reduce the effects of immobilization due to maintaining the fowler position for too long and prevent the occurrence of incorrect sitting posture on the wheelchair. Everyone has different anthropometry. Anthropometric differences in a person can cause differences in comfort in using the same seatback size. The adjustable seatback size will increase comfort for wheelchair users.

The development of wheelchairs can reduce the negative impact of immobilization on people with physical disabilities. The development of wheelchairs by adding pad seatback and cushion features for wheelchairs Health Electric Wheelchair Portable IoT-Based is useful to provide ease and comfort of mobility for people with disabilities and to reduce the negative impact of prolonged immobilization on wheelchairs. This wheelchair has the advantage of providing wide access for users to mobilize on a wheelchair and can adjust to the ergonomics of their respective bodies. It is very useful for people with physical disabilities because it can train muscle strength and nerve performance so that wheelchair users can minimize atrophy and severity of paralysis.

Conclusion

Wheelchairs are a basic need for people with disabilities, especially for physical disabilities. Although conventional wheelchairs have helped the mobility of people with disabilities, they are still limited in scope because they cause negative impacts in the form of physical fatigue and other health problems due to sitting in a wheelchair for too long. This research develops and innovates wheelchairs with attention to ergonomic design by providing Health Electric Wheelchair Portable IoT-Based wheelchair seatback and cushion features. The first step in developing wheelchair cushion and seatback features is to distribute a needs analysis questionnaire to people with disabilities and from the questionnaire response, soft, ergonomic, adjustable cushion and seatback are developed, and can be easily disassembled and installed on various types of wheelchairs (portable). The development and innovation of ergonomic design in this study then focused on 3 main components, namely the seatback, back rest, and head rest. The development of cushion and seatback on wheelchairs can in fact reduce the negative impact of immobilization on people with physical disabilities and is able to provide broad access for users to mobilize on wheelchairs and can adjust to the ergonomics of each user's body.

Conflict of Interest

During the development and publication of this work, the authors did not reveal any conflicts of interest.

Author Contributions

This research involved the participation of several contributors. Conceptualization, S,A.D,

Y.E, K.S and M.N.J; methodology, S, N.H and L.M.C.; design and development S, Y.E, T.T.P, anf S, validation, A.D, and K.S.; formal analysis, S, A.D and S.; investigation, S, N.H and L.M.C; writing original draft preparation, S, A.D, Y.E, S and E.P; writing review and editing, A.D, N.F and L.M.C visualization, Y.E, K.S, S, and T.T.P; supervision, S and Y.E

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