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REDESIGN OF MOBILITY AIDS FOR SPASTIC DIPLEGIC CEREBRAL PALSY CHILDREN THROUGH COLLABORATION AMONG ACADEMICS - MEDICAL DEVICES INDUSTRY AND USER INTITUTIONS

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Abstract.Cerebral palsy (CP) children are part of the neuro disability spectrum in impaired brain function. The etiological understanding of CP children for primary prevention and early treatment can reduce the effects of damage to brain function. CP children with cerebral diplegia are motor developmental disorders caused by damage to the brain characterized by weakness in the lower limbs heavier than the upper limbs. The walker product is designed through a universal design approach to provide as much as possible mobility to CP children in general. A universal design approach to the walker products through the triple helix collaboration included academic, medical devices industry and user institutions. Three subjects with spastic CP cerebral diplegia children underwent gait training using walker. Gait performance (continuous walking distance, and maximum and comfortable walking speed) and energy expenditure are measured at the end of the 1-week training session. The purpose of the pediatric walker redesign is to facilitate mobilization the position of the child's body CP in the anterior and posterior positions. The walker design can be removed from the raft back and forth from both sides at the front. At a certain time, the walker can be positioned behind the user according to the recommendations of some physiotherapy practitioners. This design also facilitates the position of CP children in order to be more precise, reducing double support during ambulation and increasing walking speed. The anterior-posterior walker as ADVANCED walker for CP children provides the most appropriate position because it provides the best gait pattern and consumes less energy.

Keywords : Triple Helix Collaboration, Universar Design, Cerebral Palsy, Walkers, Energy Expenditure.

1. INTRODUCTION

This past year is a time to understand holistically in the field of developing activity aids for children with cerebral palsy (CP). Cerebral palsy cases appear early in infancy and continue throughout the life of the individual affected by this disorder, need to be thought about this condition and managed in the development of the child's growth, function and family role [1]. CP identified part of the spectrum of neuro disability, by understanding the etiological events, the potential for primary prevention and early treatment can reduce the effects of damage to brain function [2]. CP causes motor disorders accompanied by disorders in the form of sensation, perception, cognition, communication, and behavior, the influence of the emergence of epilepsy and secondary musculoskeletal problems [3]. The incidence of CP disorders in some countries according to some researchers found amount vary, such as 1.3 out of 1000 births in Denmark, 5 out of 1000 children in the United States, and 7 out of 100,000 births in America [4]. Data Center for Disease Control explains that in Indonesia, the prevalence of CP disorders is estimated to be around 1 to 5 per 1,000 live births [5]. The incidence of male sex more than female, the prevalence of events is more frequent in the first child. First births are more often due to stagnating births, resulting in a higher incidence than babies born with low weight and multiple births [4].

Whereas children with cerebral diplegia CP are motor developmental disorders in children due to brain damage that occurs in the period before, during and after birth [6]. This condition is characterized by weakness in the lower limbs becoming heavier than the upper limb. Characteristics of CP children such as high postural muscle tone especially in the lower trunk region towards the lower extremities. Therefore the need for CP child aids cannot be separated in daily activities with a multi-disciplinary approach including information ranging from orthopedic, urologic, neurological, and pediatric. Information assistance from paramedics is needed for engineers, physical therapists, and social workers to design aids according to the needs of CP children to be a holistic solution [2].

Mobility aids or known as pediatric walkers or walkers alone are recommended for children with CP [7]. The goal of mobility aids for CP children is to provide additional stability during ambulation. CP disorders in children produce very low productivity because they are limited in activities and rely on others as childminder and walkers to help every day. Generally, mobility aids for CP children in developing countries are widely used in anterior walker types. Located at Yayasan Pembinaan Anak Cacat (YPAC) Surakarta, how to improve the productivity of CP children is done by means of walk rehabilitation using the assistive devices? The design of the walker must meet the requirements of lightweight, easy to move, waist level, made of metal pipes, equipped with two handles that serve as a place to hold, and four legs for support [8]. At this time the walker used for rehabilitation of CP children walking at YPAC Surakarta is a simple anterior walker. The results of visualization observations on this walker can be concluded that the weight of the walker is still quite heavy, there is no handgrip, and the design is not a walker considering anthropometry and the user's walking position. Lack of anterior walker in YPAC Surakarta when used for walking activities, the user's body tends to lean forward while pushing the assistive walker. The use of anterior walkers results in an increase in weight load on the walker and increased hip flexion during gait [9].

Designers can choose all or some principles to evaluate existing designs, guide the design process about the benefits of universally designed products. The universal design approach for designing the walker products aims to make as much mobility as possible to CP children in general in the provision of social welfare services. Universal design is an approach where accessibility for people of all ages and abilities is included in the initial design [10]. The universal design of product functions must meet the man-machine engineering design method. As long as people use products, they must consider human-machine engineering and usage habits [11]. In addition, under the reason of meeting the comfort of the human body, the product design function must also consider the use of different population habits and special requirements, changes in the use of place and time [12]. This mobility aid will be redesigned so that CP children can be used for walking activities. The user's position towards the walker can be in the anterior and posterior areas. Walker design can be removed raft back and forth from the two sides of the front; the resulting walker product is called the ADVANCED Walker.

This collaborative multi-disciplinary approach in redesigning pediatric walker products involves academics - CV. Rigen Sarana Mukti Surakarta and CV. Yoga Mandiri Surakarta as a provider of medical devices and YPAC Surakarta as a Pengabdian Kepada Masyarakat (PKM). Both of these industries are limited partnership companies engaged in manufacturing and trading in medical equipment and precision-engineered. The basis of this collaboration is based on the principles of participatory among academics - producers and user institutions with the aim of moving together holistically to build the excellence of providers of medical devices. A universal design approach to walker products through triple helix collaboration among universities, industry, and user institutions. The triple helix collaboration is in accordance with system theory [13,14] as a set consisting of (1) components (academics, medical devices industry and user institutions), (2) relationships between components (collaboration and conflict moderation, collaborative leadership, substitution, and networking), and (3) function, is described as a process that occurs in what we call knowledge, innovation and implementation. The collaboration among academics, medical devices industry and user institutions in a triple helix system provides a clear view of innovation actors, the relationship between them and the flow of knowledge in the system, in a vision of a dynamic diachronic transition [15]. This collaboration provides an impact at the regional level, which aims to combine local resources to realize shared goals and new formats in the space of new knowledge, innovation, and implementation [16]. This analytical framework, empirical guidelines for policymakers, academics and business managers can be described, to strengthen the collaboration among the triple helix actors and enhance regional development [17].

The purpose of the walker redesign at YPAC Surakarta is to accommodate both the anterior and posterior positions so that the user can place the body in front and back positions. The posterior position for users who have been able to stabilize walking is recommended by some physiotherapists [18]. The results of the designed walker will facilitate the user's position to be more precise, reducing double support during ambulation and increasing walking speed. For children CP for posterior walkers is appropriate because it provides the best gait patterns and less energy consumption [19]. At the end of this collaboration activity will produce a new walker product designed to help and encourage CP children to learn to stand and walk with hands-free support. The benefit of walkers for CP children is to encourage them to increase their physical strength and endurance through increasing the body's load during ambulation.

2. METHODS

Children with CP always face changes in body energy capacity, low energy capacity and increased dependence on the needs of others and the same compensation for the device they find in the following days. Walker must provide solutions for CP children to overcome differences in capacities, abilities, and needs for daily life. Universal design is a concept that extends to the diversity of users who must interact with the surrounding environment [20]. Design activities include documentation of problem solving and communication between the parties involved in the collaboration. To achieve design goals effectively, individual participation to share information, responsibilities, and resources must be organized [21]. Therefore, this paper proposes a Useability, Safety, Efficiently Participatory (USEP) Model based on the triple helix collaboration. Also, case studies were carried out to design walkers and walker features with a participatory design session to test the conceptual design phase of the proposed model. There are five phases of the design model to transform concepts into design descriptions so that artifacts are able to produce agreed-upon functions. The phases of the USEP design model methodology are illustrated in Figure 1.

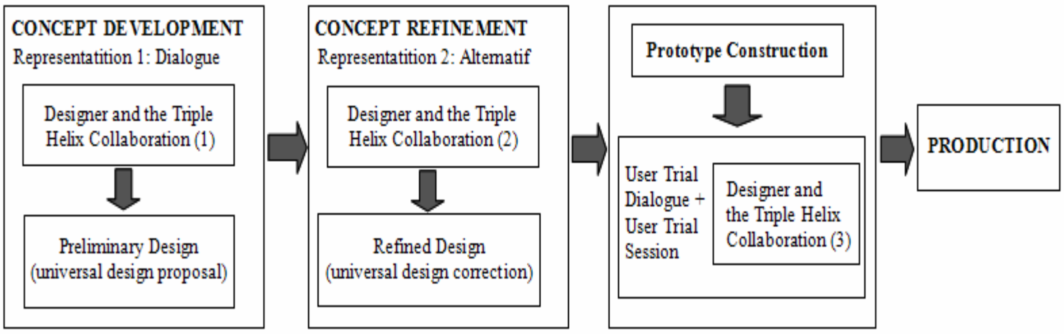

Figure 1 The phases of the USEP design model methodology

2.1 Concept development phase

In the first phase of the design model, where designers and childminder of CP children in YPAC Surakarta and parents of CP children and technicians in the medical devices industry were involved as many as 12 people, participatory design sessions are held with small groups. The techniques that apply in participatory design sessions are making scenarios [22], brainstorming, writing ideas and sketches, unstructured interviews and asking predetermined questions [23]. In this phase, participants generate ideas and determine their exact needs and preferences related to artifacts. Due to difficulties in extracting information from parents, participatory design sessions are a combination of brainstorming, scenario building, and unstructured interviews, with written and oral sections, sketches, or movements. The designer acts as an impartial moderator and the form of participation in this phase is active dialogue [23] where the designer does not make a proposal for the design at first but acts as a facilitator. A childminder of CP children are those who make proposals during the design process.

2.2 Concept refinement phase

In the second phase of the model, conceptual design solutions were introduced to childminder of CP children at YPAC Surakarta and parents of CP children in the second participatory session. During this session, childminder of CP children at YPAC Surakarta and parents of CP children were asked to criticize drawings, modify and make comments about design alternatives made by the designer. In this phase, the form of participation is an alternative [23]. The childminder of CP children at YPAC Surakarta and parents of CP children can see and feel the representation of the ideas and propositions they have made in the first phase and have been filtered through designer knowledge and interpretations based on USEP. The sketch was criticized, corrected and modified by the childminder of CP children at YPAC Surakarta and parents of CP children who acted as jury members. This phase tries to avoid misunderstandings and inaccurate interpretations from the designer, and reinforce the design description through the agreement of the caregivers of CP children at YPAC Surakarta and parents of CP children [24]. Designers are presenters and facilitators.

2.3 Prototype construction

The third phase is the manufacture of walker product planning, with the production of detailed technical drawings. In the end, the prototype walker will be produced. In this phase, the designer works as a team with ergonomists and technicians from the medical devices industry.

Furthermore, there are 3 main dimensions of the size of the walker, namely the height of the walker, the width of the walker and the length of the walker. Determination of walker height takes anthropology data of elbow height, to determine the width of the walker takes hip-width data and for the length of the walker uses anthropometric data of foot length [25]. This walker design concept uses 5 subject as anthropometric data with a 50% percentile. The anthropometric data from the subjects of walker users were measured as shown in Table 1.

Table 1 Anthropometric data on subjects of prospective pediatric walker users

Subject	Gender	High Elbow (cm)	Hip Width (cm)
Subject 1	F	95	33
Subject 2	M	100	37
Subject 3	F	82	34
Subject 4	F	74	27
Subject 5	F	70	24

Table 1 above explains the significant differences in size between subjects, which can be adjusted according to the size of the user. Walker length data is taken on the average length of the subject's feet which is about 22.5 cm because the length of the walker will later be adjusted to the ADVANCED walker design.

Interviews were conducted with therapists, CP children and parents of CP children to find information about walkers. Identification is done through articles and scientific journals by internet. This design requirement is carried out to determine the ADVANCED walker design criteria. This criterion will be chosen which criteria are suitable for the walker's design. These ADVANCED walker design criteria can be explained in Table 2.

Table 2 Criteria requirements for the ADVANCED walker design

No.	Pediatric Walker Design Criteria
1.	The height can be changed according to interests
2.	Reducing friction on the wheels
3.	The height is adjustable for comfortable walking
4.	Weight of the walker that matches the user's ability
5.	Can be folded, to be easily summarized taken outside the house
6.	If you need to add wheels or baskets
7.	Can maintain body balance when used
8.	There is protection to prevent falls
9.	Made of a strong and rust-resistant material
10.	There is a height adjustment mechanism
11.	Accompanied by basket or seat

Furthermore, this criterion is adjusted to universal design 7's principle and becomes the basis for making a questionnaire, as shown in Table 3.

Table 3 ADVANCED walker design requirements based on universal design

No.	Principles of	Questions of Pediatric Walker Design Needs
1.	Equitable in use	Can be used for all children
2.	Flexibility in use	Can be adjusted according to pediatric users
		The height that can be modified
3.	Simple and Intuitive use	Can be assembled
4.	Perceptible information	Easy to use
5.	Tolerance for error	Can maintain user balance
		No additional brakes are given
		Can protect users from falling
6.	Low physical effort	Use the wheels to reduce friction
		The material used is lightweight and sturdy
7.	Size and Space for Approach and Use	Handlers are made of rubber
		The size of the walker matches the user's size
		Not given additional features (chairs, baskets, etc.)

Table 3 is the basis for making a questionnaire to determine the needs to be developed. The questionnaire was given several statements about the criteria and compared with the condition of the walkers used every day as well as questions about some additional features needed.

2.4 User trial

The fourth phase is the testing of prototype artifacts that have been made by technicians from the medical devices industry to CP children. In this phase, participation takes the form of a user trial [23] combined with a form of participation dialogue. The team consists of a designer and an ergonomist who observes CP children who try prototypes while discussing designs. New comments and ideas from CP children's childminder at YPAC Surakarta and parents of CP children are recorded again to remember all the details and to create a domain of knowledge for similar projects in the future.

Furthermore, gait performance parameters were assessed at the end of the 1-week training program for a anterior walker initial and ADVANCED walker including distance and walking time; and comfortable walking speed [26]. For walking distances, participants are instructed to walk, without rest, at a comfortable pace of their own choosing until they are exhausted. Oxygen consumption and energy expenditure [27] are calculated according to the following equation,

$$VO_2Max = 0{,}019\ HR - 0{,}024\ h + 0{,}016\ w + 0{,}045\ \alpha + 1{,}15\ (liter/minute) \quad (1)$$

$$1\ liter\ O_2 = 5\ kkal \quad (2)$$

2.5 Production

The production phase is the final phase of implementation in product planning into product artifacts to be produced and made available to consumers.

3. RESULTS AND DISCUSSION

3.1 The Triple Helix Collaboration Models

The triple helix collaboration embodies a potential for innovation and economic development in the knowledge society lies in a more prominent role for academics. Hybridization of organization of elements included academia, industry and user instutions to produce collaboration and social formats for the production, transfer and application of new knowledge. Creative synergies emerge and drive the process of "innovation in innovation", the creating new interactions and formats, because individual actors and organizations not only perform their own roles. This creative process, the relationship among academic, medical devices industry and user institutions continues to improve innovation, bringing forth new technologies, new companies and new types of relationships in a sustainable manner [16]. The main objective of triple helix collaboration is to create an atmosphere suitable for two-sided and tri-lateral relations so that knowledge sharing can occur among industry, laboratories, and research groups, as in Figure 2.

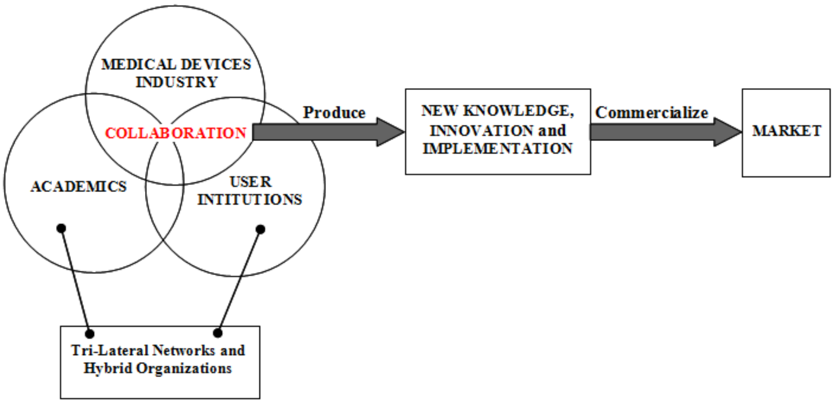

Figure 2 The triple helix collaboration models (academic, medical devices industry and user institutions)

With reference to Figs. 1 above, the triple helix collaboration will produce new formats in the space of new knowledge, innovation, and implementation and then be used to produce competitive advantages. The process for generating new knowledge, innovation, and implementation itself is not linear. Human skills are basic requirements in the production of new knowledge or enhancement of existing knowledge. New knowledge can be generated in a team by its members [28]. Therefore, the collective knowledge of team members (academics) is combined for knowledge users (medical devices industry). Knowledge is produced by three different modes, Mode 1, Mode 2 and Mode 3. In Mode 1, knowledge is produced by each party without collaboration with others (for example, academics), in Mode 2 knowledge is generated through short-term collaboration with other parties (for example, industry), while Mode 3 knowledge is generated through long-term collaboration with other parties to solve certain problems. The collaboration between organizations facilitates the sharing of resources and the creation and transfer of new knowledge, thus helping to produce synergistic solutions [29]. Thus, collaboration not only supports the creation of new knowledge, but also the improvement of skills for effective and efficient innovation [30].

3.2 Universal Design in Advanced Walker Design

In making the design of the questionnaire refers to the principle of product design based on universal design. This concept was chosen to develop products that can be used effectively by everyone. Questionnaire measurements are calculated through the average value of each universal design principle. The calculation results can be known from each universal design principle that has a low rating from user respondents, as can be explained in Table 4.

Table 4 Average results of testing the ADVANCED walker design questionnaire

No.	Principles of universal design	Questions	Average	Sum of Average
1.	Equitable in use	Q10	1.75	1.75
2.	Flexibility in use	Q11	1.75	2.00
		Q9	2.25	
3.	Simple and intuitive use	Q8	2.75	2.75
4.	Peceptible information	Q5	5.50	5.50
5.	Tolerance for error	Q6	6.00	5.60
		Q13	5.25	
		Q7	5.50	
6.	Low physical Effort	Q2	6.00	4.80
		Q1	3.50	
7.	Size/space, approach/use	Q3	2.25	3.80

The value generated from the questionnaire according to the universal design principle can be seen that low values such as the principle of equitable use, flexibility in use and simple and intuitive use, all three attributes of the universal design principle have an average total value of 1.75, 2.00 and 2.75. Equitable in use attribute has the lowest value so that the use of equitable in use has not been felt by the user. The principle of equitable use which is the main focus in designing walkers together with principles that have a low mean value is flexibility in use and simple and intuitive use.

3.3 Making Advanced Walker at Medical Devices Industry

The design phase of the ADVANCED walker starts with comparing a number of reference walkers in the market followed by the design phase. Information from the design reference and comparing the previous walker then made ADVANCED walker that is able to meet user needs. The assistive walkers designed with user anthropometric measurements, so that the walker is made according to the user's posture size so that when used the walker feels more comfortable. The results of anthropometric measurements obtained by ADVANCED walker specifications are height (750 cm), width (550 mm), length (600 mm), weight (7 kg), front-wheel diameter (7 cm), and rear-wheel diameter (14 cm). The advantage of this ADVANCED walker is that it can be used anteriorly and posteriorly, thus adjusting the user's pediatric. This design is divided into four main sections and these parts are connected by bolts, can be assembled and can be folded as shown in Figure 3.

Figure 3 The prototype ADVANCED walker is designed with the universal design principles

Based on Figure 4 above, the frame structure is the main part of the walker that forms the overall construction of the walker. The frame walker made through the process of bending and drilling for mounting nuts and bolts, the bottom for walker's feet and mounted wheels. Right and left frame, this frame consists of two separate parts. This frame is connected to the mainframe using bolts. The top of the frame functions as a hand handle when used, and then the bottom of the frame functions as a walker's legs and is given a pair of wheels. Walker is design with wheels that serves to reduce the friction when used. Wheels are used as many as four, where the size of the front wheels and rear wheels are the same size. The front wheels function as a steering wheel, counterweight and so that the walker is lighter when turning. After the ADVANCED walker design process with the material in making this tool is to use aluminum pipe iron with a diameter of 16 mm. The choice of aluminum material as material in the process of making this tool is because aluminum has properties including rigid, lightweight and not easy to rust.

3.4 Testing Gait Performance in CP Children

After the manufacturing process, the ADVANCED walker is tested which aims to evaluate so that when testing aids walk smoothly and get good results. ADVANCED walkers are anterior-posterior walkers with four wheels. ADVANCED walkers are anterior-posterior walkers with four wheels. The ADVANCED walker prototype test is done by comparing the previous walker with gait performance parameters is how much energy consumption. All subjects tested can walk independently without the help of an assistant, and can use a walker. Under the guidance of a physical therapist at YPAC Surakarta, ambulation with an anterior-posterior walker is carried out with this type of walking aid. The test of the design of the walker design was carried out on 3 subjects with an age range between 12-13 years, as shown in Table 5.

Table 5 Demographics of test subjects walking in using a walker

Subject	Gender	Height (cm)	Weight (kg)	Age (yr)
Subject 1	F	110	33	12
Subject 2	F	120	38	13
Subject 3	F	115	35	12

They walk with or without orthosis feet with hinged joints at a comfortable pace of their own choosing. After each test, the children rest at least 15 minutes so that their heart rate returns to the basal level. The purpose of this test is to analyze the energy consumption of CP children when walking straight as far as 2 meters.

Figure 4 Anterior walkers initial

The results were compared between using an anterior walker initial and an ADVANCED walker, as shown in Figure 4 above and Table 6.

Table 6 Results of measurements of oxygen consumption in using a walker

Subject	Anterior Walker Initial (liter/minute)	ADVANCED Walker	
		Anterior Walker (liter/minute)	Posterior Walker (liter/minute)
Subject 1	1,193	1,098	0,984
Subject 2	0,945	0,830	0,736
Subject 3	1,390	1,257	1,143

Table 7 is a comparison of energy expenditure results in using a walker between using an anterior walker initial and ADVANCED walker.

Table 7 Results of energy expenditure measurements in using a walker

Subject	Anterior Walker Initial (kkal)	ADVANCED Walker	
		Anterior Walker (kkal)	Posterior Walker (kkal)
Subject 1	5,96	5,49	4,92
Subject 2	4,73	4,15	3,68
Subject 3	6,95	6,28	5,70

The results explained in Table 6 and Table 7 show that energy consumption and energy expenditure show that using a posterior walker, where subjects require less energy expended than using an anterior walker initials. The use of ADVANCED walkers during testing is done that subjects are more comfortable The anterior intestinal walker causes an increase in body weight against the walker and an increase in hip flexion during the walking gait. Posterior walkers in most CP children are the most appropriate because the best walking gait pattern and less spending on body energy consumption. Options for rehabilitation for CP children of walked in cases where extensor spasticity predominates. CP children have problems with posterior balance and tend to fall backwards. In this case, it will benefit from the posterior walker as an aid to improve its balance.

4. CONCLUSION

The triple helix collaboration among academics, medical devices industry and user institutions to redesign walkers for CP children, especially in the city of Surakarta in the province of Central Java, is important because of knowledge-based innovation. Our collaborative process models among academics, medical devices industry, and user institutions are designed to highlight the roles and responsibilities of each actor at different stages in generating knowledge and commercialization. The government in Indonesia funds projects at universities and thus creates a research environment that meets flexible industry requirements and policies. In such collaborations, academics and research groups can use resources such as skilled personnel, laboratories, and equipment to complete assignments within a specified time period. The participatory design model is proposed using a universal design approach in designing safe and functional walkers that will promote and sustain the lives of CP children independently. Collaboration among academics, medical devices industry, and user institutions is a suitable way to incorporate the needs of CP children into the design process. The use of the USAP methodology model has proven to be a potential source for designers to be able to explore more deeply. ADVANCED walkers are designed to help individuals with CP children with spastic diplegic. The results show the effectiveness of a better ADVANCED walker, relative to the initial anterior walker, with respect to comfort and provide the best gait pattern and consume less energy.

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