



Redesign walker for children with diplegic cerebral palsy using TRIZ method



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Children with cerebral palsy at rehabilitation centers had difficulty performing walking rehabilitation with the existing walker. The resulted in children with cerebral palsy feeling dissatisfied with existing walkers, and this dissatisfaction resulted in their interest in ongoing rehabilitation. The existing walker does not accommodate the needs of cerebral palsy children, resulting in lousy form and dissatisfaction when using a walker for rehabilitation and reduce their interest in rehabilitation. Therefore it is necessary to redesign the walker to prevent bad form and increase the satisfaction level of children with cerebral palsy. The QUEST 2.0 questionnaire was used as a reference for designing. Based on the dimensions from the QUEST 2.0 questionnaire, the walker design criteria were determined. Then use the TRIZ method to resolve any technical contradictions that occur at the design stage.

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1. INTRODUCTION

Cerebral palsy is a non-progressive disorder of the fetus or middle age brain [1] that affects the development of movement and posture [2]. This disorder affects activity limitations and dimensional health problems related to a person's motor signs. Problems with motor signs include primary neuromuscular defects and secondary musculoskeletal problems [3]. Children with cerebral palsy have brain disorders that affect motor function, reflect and balance [4], which will lead to poor physical abilities leading to difficulty carrying out daily activities and increased dependence on other people [5].

The incidence of cerebral palsy is 2-2.5 people per 1000 births [6]. Indonesia has 0.09% of children

aged 24-59 months experienced cerebral palsy in 2010 [7], divided into three types, namely spastic, athetoid, and ataxia [8]. The most common type of cerebral palsy [9]. The physical condition of the diplegic cerebral palsy child experiences body tightness in both legs, making it difficult to support the body when standing [10]. This disorder is permanent but can be minimized through the rehabilitation process to increase the ability and independence of children with cerebral palsy [11].

There are many types of therapy to help children with cerebral palsy to achieve independence and improve children's quality of life. Several types of therapy for children with cerebral palsy are namely exercise, gait training, constraint induced movement therapy, neurodevelopmental

therapy, cardiorespiratory training, electrical stimulation, etc. [12]. Moreau et al. [13] concluded that gait training appears to be the most effective intervention in increasing walking speed in children with cerebral palsy.

The walking gait rehabilitation process usually used a walker as an assistive device to help the child support their body [14]. However, the current walkers have not been able to accommodate the needs of children with cerebral palsy, resulting in them feeling dissatisfied after undergoing rehabilitation. Several things, such as the limited choice of walker sizes, cause dissatisfaction. They were forced to use a walker of the wrong size. The all-swivel walker wheel can rotate in any direction, making it difficult for the user to control the direction of the walker's motion. Prolonged use of the walker can cause injury. The absence of walker safety for users causes cerebral palsy children to fall because they cannot support their bodies.

Therefore, it is necessary to redesign the walker following the needs of children with cerebral palsy to increase children's satisfaction with cerebral palsy when using a walker. The satisfaction of using walkers can be measured using the Quebec User Evaluation of Satisfaction with Assistive Technology (QUEST 2.0) questionnaire, and the three dimensions of the QUEST 2.0 questionnaire are used as a reference for designing the walker [15]. The three dimensions are adjustment, safety, and simplicity of use.

The redesign of the walker used the TRIZ (Theory of Resolving Invention Contradictions) method. TRIZ provides product development solutions by paying attention to trends and aesthetic aspects or ingredients of a product [16], [17]. TRIZ has chosen to design tools based on aspects contradictory by considering the needs of children with cerebral palsy. This walker design consideration aims to make the rehabilitation process for cerebral palsy children easier.

2. RESEARCH METHODS

2.1. Identification of Problems

This research was motivated by the design of walking aids for children with cerebral palsy that has not been optimal in assisting the patient's rehabilitation process (Fig. 1). The existing walker still puts more weight on the back. Identify existing product problems using a cause-and-effect diagram to determine the root cause of the cerebral palsy user's dissatisfaction problem [18].



Fig. 1. Existing walker

The cause of walking aids still not satisfying users is that people with diplegic cerebral palsy have weak leg muscles not to support their body when walking using a walker (human factor). The material factor is the wheel used, which is the swivel type, which causes the wheel to easily rotate in all directions and change the direction of motion of the pedestrian. Metal frames rust easily due to a lack of maintenance of equipment, impacting easily damaged frames. The size factor is a walker whose size does not match the child's anthropometry. The method factor, namely the walking aid, has not accommodated the needs of children with cerebral palsy (Fig. 2).

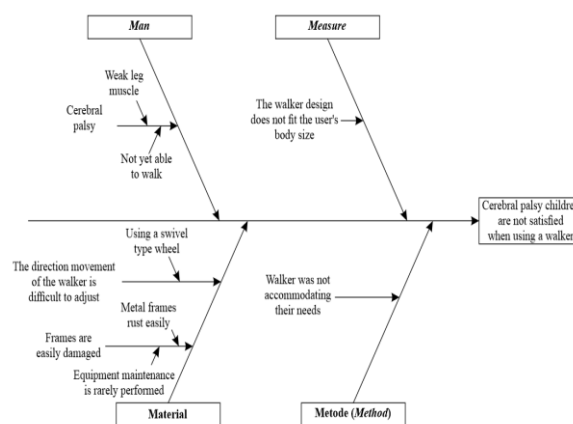


Fig. 2. Cause-effect diagram

2.2. Functional Analysis

The functional analysis model describes the relationship of each element in the walking rehabilitation process using existing walkers [19]. The functional analysis model formulates the actions taken to minimize the risks that occur [20]. The walker elements consist of a handle, frame, and wheels (Fig. 3). The handle serves to help the body, but it is still difficult to help control the walker's direction. Wheels help change direction but still have drawbacks related to difficulty controlling the direction of the walker.

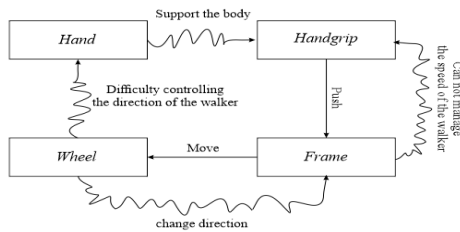


Fig. 3. Functional analysis

2.3. Design Criteria

Design criteria for a user are done using the QUEST 2.0 questionnaire. Based on QUEST 2.0, 3 dimensions were selected as a reference for determining the design criteria [11]. The selected dimensions are adjustment, safety, simplicity of use. Design criteria related to design adjustment, the walker function protects from possible falls that can cause injury, and the walker allows the user to move straight forward will be used as input for the conceptual design (Table 1).

Table 1. Design criteria

| QUEST 2.0 dimension | Design criteria |
|---------------------|--|
| Adjustment | The dimensions are adjusted according to the user |
| Safety | Walker protects the user from possible falls Use of a walker doesn't result in injury |
| Simplicity of use | The user easily pushes the walker to move straight forward |

2.4. Technical Contradiction

Technical contradiction is a stage of the TRIZ method which consists of technical requirement, improving feature, worsening feature, and inventive principle [21]. Technical requirements are the criteria for the needs of children with cerebral palsy on each element of the walker to improve product design by the technical requirements. The technical requirements are developing the functional analysis of the handgrip, frame, and wheel elements (Table 2).

Table 2. Technical Requirement

| Element | Technical Requirement |
|----------|--|
| Handgrip | Comfortable when held |
| Frame | The use of a walker doesn't cause injury It has an adjustable safety feature Strong and durable material |
| Wheel | Easily control the direction |

Improving feature is the stage to decide which features to be improved and selected by using 39 parameters that exist on TRIZ (Table 3). The worsening feature is the negative impact caused by the improving feature. The Worsening feature was selected based on the 39 parameters in TRIZ by considering the improving features (Table 4).

Table 3. Improving feature

| Element | Technical requirement | Improving feature |
|----------|---|---|
| Handgrip | Comfortable when held | Shape (12) |
| Frame | The use of a walker doesn't cause injury It has an adjustable safety feature | Reliability (27) Adaptation or versatility (35) Device complexity (36) Strength (14) |
| Wheel | Easily control the direction | Area of moving object (5) |

Table 4. Worsening feature

| Element | Technical requirement | Worsening feature |
|----------|---|--|
| Handgrip | Comfortable when held | Ease of operation (33) |
| Frame | The use of a walker doesn't cause injury It has an adjustable safety feature | Device complexity (36) Ease of operation (33) Device complexity (36) |
| Wheel | Strong and durable material Easily control the direction | Adaptation or versatility (35) Reliability (27) |

TRIZ method uses 40 inventive principles that have been compiled in a contradiction table of inventive principle to eliminate contradictions that occur when redesigning the walker. The inventive principle on the contradiction that occurs when redesigning the walker (Table 5).

Table 5. Inventive principle

| Element | Technical requirement | Inventive solution |
|----------|---|--|
| Handgrip | Comfortable when held | Color change (32) Dynamics (15)* Copying (26) |
| Frame | The use of a walker doesn't cause injury It has an adjustable safety feature | The other way round (13)* Parameter change (35) Segmentation (1) Dynamics (15)* Discarding and recovering (34) Segmentation (1) Partial or excessive action (16) Cheap short-living object (27) Preliminary anti action (9) Copying (26) Intermediary(24)* |
| Wheel | Strong and durable material Easily control the direction | Local quality (3)* Dynamics (15) Color change (32) Pneumatic and hydraulic (29) Preliminary anti action (9)* |

*selected inventive principle

2.5. Conceptual Design

Conceptual design has the concept of providing detailed information on the concept of a design [22]. Its design concept interprets the inventive principle of TRIZ [23], which can provide an effective solution by identifying user behavior or physical factors [24]. Walker's conceptual design dimensions will use anthropometric data of children with cerebral palsy as a reference. The conceptual design stage will compare the alternative solution with the most suitable solution to obtain a road aid design.

3. RESULTS AND DISCUSSION

The QUEST 2.0 questionnaire is used to determine indicators for the walker redesign process [25]. Then selected three dimensions from QUEST 2.0 are adjustment, safety, and simplicity of use. The adjustment dimension is the effect of

adjusting the tool to user needs. The safety dimension is the effect of tool safety on users. The simplicity of the dimensions of use is the effect of the tool's ease of setup and operation. The redesigned tool requires user anthropometric data to adjust the size of the walker to the user's body size [26]. The anthropometric dimensions of standing body height are elbow height standing, fingertip height standing, shoulder width, forearm length, hand width, and grip diameter (Table 6).

Table 6. Anthropometry dimension

| No. | Anthropometry dimension | Code |
|-----|---------------------------|------------------|
| 1 | Standing Body Height | D1 |
| 2 | Elbow Height Standing | D4 |
| 3 | Fingertip Height Standing | D7 |
| 4 | Shoulder Width | D17 |
| 5 | Forearm Length | D23 |
| 6 | Hand Width | D29 |
| 7 | Grip Diameter | D _{Max} |

The results of anthropometric measurements are used to determine the dimensions of the walker. Design the size of the walker by obtaining a product dimension from 4.13 (handgrip diameter) to 155.23 (walker height). The walker design used anthropometric dimensions with the 5th, 50th, and 95th percentiles (Table 7).

Table 7. Walker dimension

| No. | Walker dimension | Anthropometry dimension | Product dimension (cm) |
|-----|----------------------|-------------------------|------------------------|
| 1 | Walker height | D1 (P95) | 155.23 |
| 2 | Walker wide | D17 (P95) | 61.98 |
| 3 | Walker length | D23 (P50) | 35.13 |
| 4 | Handgrip height | D7 (P5) – D4 (P5) | 62.,35 – 75.44 |
| 5 | Handgrip diameter | D _{max} (P50) | 4.13 |
| 6 | Handgrip foam length | D29 (95) | 12.65 |

The evaluation results of the TRIZ method are used to improve the construction based on the main design criteria, namely adaptability, safety, and ease of use. The visualization design is adjusted to Fig. 4. The walker frame uses stainless steel, the rear wheels use standard 4-inch brake wheels, the front wheels use 4-inch rigid wheels, and the handle uses foam to grip the user.



Fig. 4. Walker redesign

Walker also uses a body harness attached to the child with cerebral palsy before using a walker to maintain body posture and protect against possible falls when using a walker. The height of the body harness can be adjusted to suit the user's ability to support their body to make it easier for the user with the wheel that can rotate 360 degrees to give the user freedom of mobility [27]. The use of the existing walker and the redesign walker show in Fig. 5 and Fig. 6.



Fig. 5. Use of existing walker



Fig. 6. Use of walker redesign

Based on the use of the existing walker and the redesign of the walker, a decrease in compression value was obtained on the L5S1 where the use of the existing walker provided compression of 3568 N and the use of the redesigned walker provided compression of 1985

N, where the allowable load limit was 3400 N [28]. The posture when using the existing walker and redesign walker is shown in Fig. 7.

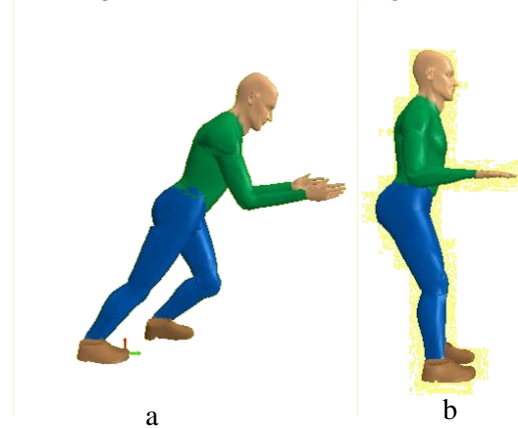


Fig. 7. (a) Posture existing walker (left)
(b) Posture using redesign walker (right)

4. CONCLUSION

They are redesigning walkers based on the three dimensions of the QUEST 2.0 questionnaire. The addition of hand pads to the grip position to provide a level of comfort. The level of alignment of the grip height with the user's height is designed to make it easier to achieve hand reach. The walker frame is designed using stainless steel because it is strong and does not require complicated maintenance. The wheel design is designed in one direction to make it easier to direct pedestrians. Walker uses body armor placed on a child with cerebral palsy before using a walker to maintain posture and protect against possible falls when using a walker. The height of the body harness can be adjusted according to the user's ability to support the body. The results of the redesign of this walker can maintain the child's posture so that children with cerebral palsy can train their leg muscles more optimally. This study still uses posture position parameters and requires further research. They are related to this design to minimize primary neuromuscular deficiencies and secondary musculoskeletal problems.

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