Redesign paediatric walker for children with spastic cerebral palsy using TRIZ Method

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Abstract. Cerebral palsy is a type of disability, which is related with movement and posture. Statistical data shows the number of CP in Indonesia from 2010 contributed 0.09 percent of children 24-59 months. Types of CP that are commonly found are Diplegic Cerebral Palsy (DCP) and Hemiplegic Cerebral Palsy (HCP). Percentage of DCP about 30 to 40 percent and HCP about 20 to 30 percent. The physical condition of a DCP has weak hip, so there is no strength to lift the body and physical condition of an HCP has one spastic hand down and swings to exhortation. Rehabilitation for them must be continuing to maximize the walking ability and increase physical mobility. Walker used to improve children's walking. Nowadays, walker is still too heavy, walker dimensions have not considered the size of anthropometry's children, and walkers have not accommodated users. Therefore, a walker was designed based on concept of DCP and HCP using TRIZ method. The aim is choosing design that accommodate the needs of children for supporting rehabilitation. The results of products dimension are maximum height 107.3 cm, minimum height 60.0 cm, length of walker 71.7 cm, length of handgrip 10.4 cm, and diameter of hands pad 3.3 cm.

1. Introduction

Physical activity is a physical movement carried out by the body muscles and supporting systems [1]. Humans do physical activity at all times, such as walking movements to move places. Walking ability can be seen from the growth and development of children. The discipline that studies about child development is pediatric. Pediatric is a discipline that deals with biological, social, and environmental influences on the developing child and the impact of disease and dysfunction on development [2]. Disease and dysfunction of child development can occur before birth (pre-natal) and after birth (post-natal) and the first two years of development of a child. Children who experience growth disorders often experience limited mobilization.

Mobilization or mobility is an individual's ability to move freely, easily, and regularly with the aim of fulfilling their activities and at the same time maintaining their health [3]. In maintaining optimal physical mobility, the nervous, muscular, and skeletal systems must remain intact and functioning [3]. Impaired physical mobilization (immobilization) is defined by the North American Nursing Diagnosis Association (NANDA) as a condition when individuals experience or risk experiencing limited physical movement [3]. Problems commonly associated with immobility include weakened muscles, joint contractures, and deformities. Cerebral palsy is a type of immobilization or disability, which is related with movement and posture. CP according to The American Academy of Cerebral Palsy is a variety of changes in movement or abnormal motor functions that arise as a result of accidents, injuries or diseases of the nervous system found in the skull cavity. The type of CP that is commonly found is Diplegic Cerebral Palsy (DCP) and Hemiplegic Cerebral Palsy (HCP). The percentage of DCP events is 30% to 40% and HCP is 20% to 30% [4]. The incidence of CP in each country is different, statistical data shows that the number of CP patients in Indonesia from 2010 was 0.09% in children aged 24-59 months [5].

CP cannot be cured but through rehabilitation will improve patient's life skills [6]. Many CP children after adults have the possibility to walk, where 60% with no assistive devices, 10% walk with assistive devices, 30% use wheelchairs or ambulatory aids. But without medical training and rehabilitation, patients with CP can experience physical impairment [7]. The period of rehabilitation for CP children must be sustainable to maximize their walking ability in order to increase physical mobility. Walker is a tool commonly used for the rehabilitation of walking DCP and HCP children. The lack of walkers now is that they are still too heavy to be used by children, handgrips and walker design dimensions have not considered the size of the anthropometry of children, and walkers have not accommodated DCP and HCP patients.

The design of a walker is based on the concept of pediatric users in cases of children with DCP and HCP. The dimensions of the walker's design are made taking into account the results of the design development based on the TRIZ method. TRIZ (Teoriya Resheniya Izobreatatelskikh Zadacth) is theory of inventive problem solving (TIPS) developed in the Soviet Union starting [8]. TRIZ was chosen to develop a walker design in accommodating cases of DCP and HCP children. The design of walkers by considering the needs of different DCP and HCP children based on aspects of contradiction. The consideration of the walker's design aims to make the process of rehabilitation for children of DCP and HCP easier.

2. Methodology

2.1. Identification problem

The background of the problem is how to redesign the pediatric walker for children with DCP and HCP cases to accommodate rehabilitation in one device. The problem is solving by cause effect diagram. Cause effect diagram is a graphical technique to show the several causes of a specific event or phenomenon [9].

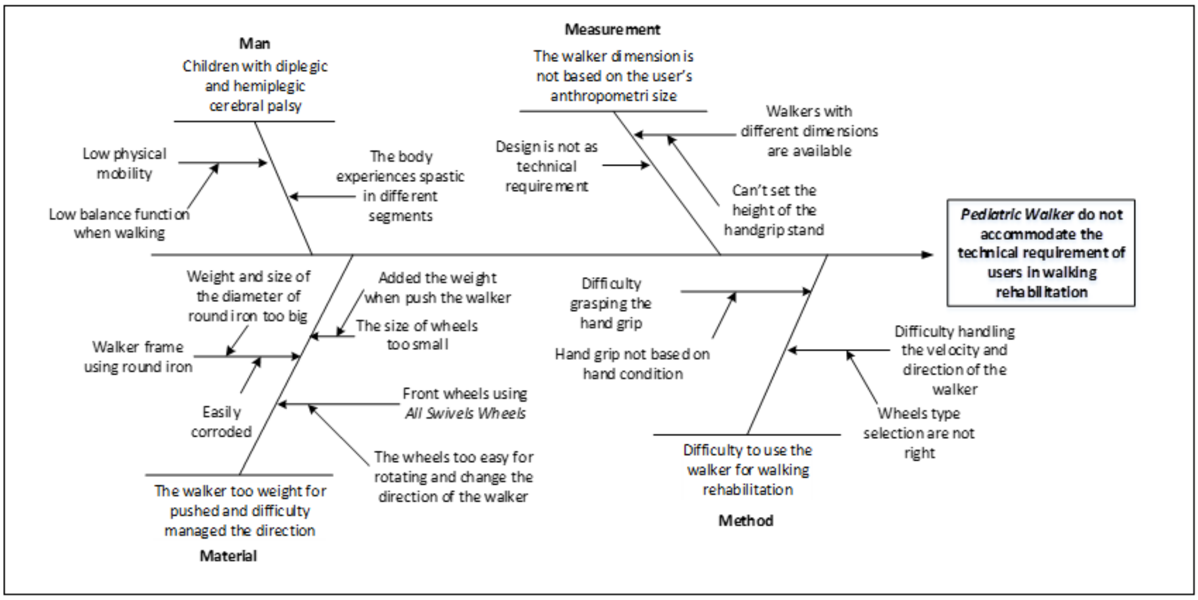

Figure 1. Cause effect diagram.

The man factor is that children with DCP and HCP cases have special needs from their limited physical condition. This situation makes children DCP and HCP have a different way of walking (gait). Human gait is an attractive modality for recognizing people at a distance [10]. The measurement factor is the walker dimension which is currently not adjusted to the anthropometric size of DCP and HCP children. The material factor is the round hollow iron which makes the tool weigh as much as 7 kg, so users need more power to drive the walker. The method factor is the difficulty of using a walker caused by the design of the walker that does not fit the user's needs.

Figure 2. Existing pediatric walker.

The following are the results of observations of gait with locomotion parameters children with spastic DCP and HCP cases using the existing walker for walking rehabilitation as shown in Table 1 [11].

Table 1. Parameter locomotion existing walker.

No	Parameters	Mean ± σ	
		Mean + σ	Mean - σ
1	Velocity (m/s)	0.07	0.06
2	Cadence (steps/min)	50	31
3	Single Support (s)	0.12	0.05
4	Double Supports (s)	0.55	0.48
5	Step Length (m)	0.23	0.17
6	Stride Length (m)	0.45	0.34

2.2. Identification design requirement

The identification design requirement for a user is done using a questionnaire [12]. Criteria that are used as input for conceptual design. In this case, a questionnaire was given to parents of the subject. After the questionnaire is filled out then the output as an input to determining design criteria.

2.3. Determination of criteria

The parameters for the design criteria for a pediatric walker are based on tool functions, easy to use, safety, materials, and aesthetics. The output of the criteria proposed in the questionnaire was tested for reliability and validity. After that, an analysis and description of the requirements of the pediatric walker design are carried out.

Table 2. Criteria hierarchy.

No.	Criteria	Statement
1	Function	Walker according to the anthropometry of the user
2		Walker keeps the user functional balance
3		Walker is used for walking rehabilitation
4		Walker has a stable base support
5	Easiness	Walker is used easily by the user
6		Walker has an adjustable height
7	Safety	Walker has a handgrip design according to the condition of the hand
8		Walker uses a material that is safe for users
9		Walker protects users from falling
10	Material	Walker has lightweight material
11		Walker uses small friction wheels
12	Aesthetics	Walker has an attractive appearance for users

2.4. Functional analysis

The functional analysis explains the elements or parts of the pediatric walker both the function and the problem of the tool. Elements consist of the handgrip, high adjustable, base support, front wheels, and back wheels.

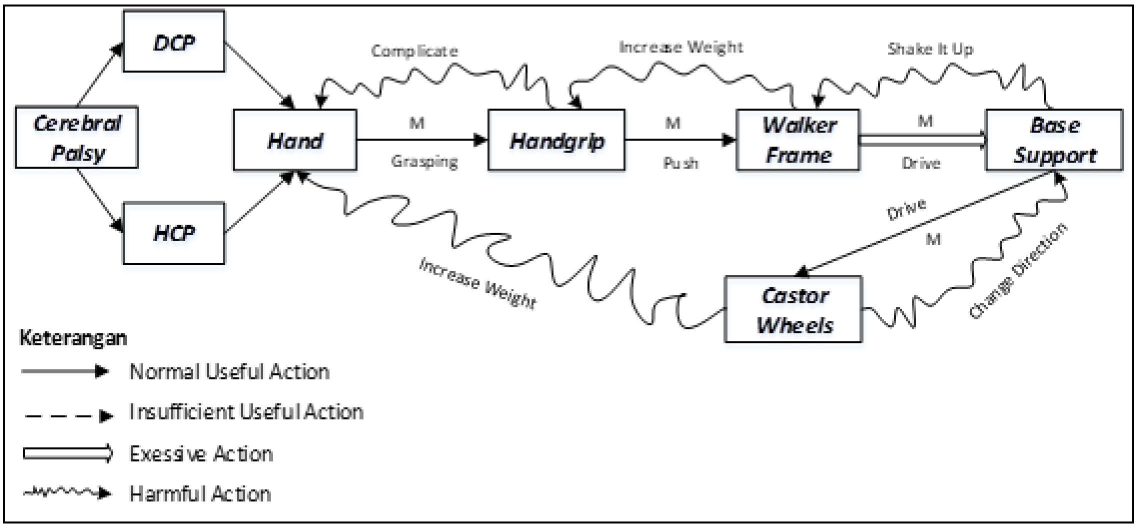

Figure 3. Functional analyse model of paediatric walker.

2.5. Technical contradiction (TRIZ)

2.5.1. Technical requirement. Technical requirements are criteria for technical needs which are the needs of children with DCP and HCP cases so that the design can accommodate both CP cases. Technical requirements are obtained from observation and functional analysis as shown in Table 3.

Table 3. Technical requirement.

No	Part	Technical Requirement	Source
1	Handgrip	Design according to hand conditions	Observation
		Easy to hold	Functional Analysis
		Dimension according to anthropometry	Observation
2	Walker Frame	Lightweight material	Functional Analysis
		Protect users in walking	Observation
		The size can be adjusted by the user	Observation
		Maintain a walking balance	Observation
3	Base Support	Able to hold user weight	Functional Analysis
		Able to maintain stability	Functional Analysis
4	Castor Wheels	Able to hold user weight	Functional Analysis
		Small friction	Observation

2.5.2. Improving feature. Improving feature is a classification stage based on technical requirements using 39 problem parameters used in development product based on TRIZ method as shown in Table 4.

Table 4. Improving feature.

No	Part	Technical Requirement	Improving Feature
1	Handgrip	Design according to hand conditions	Shape (12) Ease of operation (33)
		Easy to hold	Reliability (27) Harmful side effect (31)
		Dimension according to anthropometry	Length of stationary object (4) Measurement accuracy (28)
2	Walker Frame	Lightweight material	Weight of moving object (1)
		Protect users in walking	Harmful side effect (31)
		The size can be adjusted	Length of stationary object (4) Measurement accuracy (28) Ease of operation (33)
		Maintain a walking balance	Reliability (27)
3	Base Support	Able to hold user weight	Strength (14) Stress of pressure (11)
		Able to maintain stability	Stability (13)
4	Castor Wheels	Able to hold user weight	Strength (14)
		Small friction	Durability of moving object (15) Power (21)

2.5.3. Worsening feature. The worsening feature is determined by considering the improving feature matrix. The determination of the worsening feature is taken based on 39 problem parameters in the TRIZ method and considers the impact that occurs as a result of improving the applied criteria as shown in Table 5.

Table 5. Worsening feature.

No	Part	Technical Requirement	Improving Feature	Worsening Feature
1	Handgrip	Design according to hand conditions	Shape (12) Ease of operation (33)	Loss of Energy (22) Weight of moving object (1)
		Easy to hold	Reliability (27) Harmful side effect (31)	Ease of operation (33) Power (21)
		Dimension according to anthropometry	Length of stationary object (4)	Manufacturing precision (29)
			Measurement accuracy (28)	Ease of manufacture (32) Ease of operation (33) Durability (15)
2	Walker Frame	Lightweight material	Weight of moving object (1)	Strength (14) Power (21) Loss of Energy (22)
		Protect users in walking	Harmful side effect (31)	Productivity (39)
		The size can be adjusted	Length of stationary object (4)	Manufacturing precision (29)
			Measurement accuracy (28)	Ease of manufacture (32)
			Ease of operation (33)	Adaptability or versatility (35) Ease Repair (34)
		Maintain a walking balance	Reliability (27)	Productivity (39)
3	Base Support	Able to hold user weight	Strength (14)	Shape (12) Area of moving object (5)
			Stress of pressure (11)	Power (21)
		Able to maintain stability	Stability (13)	Harmful side effect (31)
4	Castor Wheels	Able to hold user weight	Strength (14)	Productivity (39)
		Small friction	Durability of moving object (15)	Speed (9)
			Power (21)	Loss of Energy (22)

2.5.4. Contradiction elimination. To resolve and eliminate the contradictions that occur in the design of a paediatric walker, the TRIZ method provides tools in the form of 40 inventive principles to help resolve existing contradictions as shown in Table 6.

Table 6. Inventive solution.

No.	Part	Technical Requirement	Inventive Solution
1	Handgrip	Design according to hand conditions	Spheroidality (14)
			The other way round (13)
		Easy to hold	Moving to a new dimension (17)
			Parameter Change (35)
			Composite material (40)
		Dimension according to anthropometry	Preliminary action (10)
			Universality (6)
			Self service (25)
			Segmentation (1)
			Another Dimension (17)
2	Walker Frame	Lightweight material	Composite materials (40)
			Porous materials (31)
			Discarding and recovering (34)
		Protect users in walking	Convert harm into benefit (22)
		The size can be adjusted	Preliminary action (10)
			Universality (6)
			Parameter change (35)
			Segmentation (1)
			Equipotentiality (12)
		Maintain a walking balance	Parameter changes (35)
3	Base Support	Able to hold user weight	Composite materials (40)
			Local quality (3)
			Composite materials (40)
			Spheroidality (14)
		Able to maintain stability	Parameter changes (35)
4	Castor Wheels	Able to hold user weight	Parameter changes (35)
		Small friction	Local quality (3)
			Preliminary action (10)

2.6. Conceptual design

2.6.1. Anthropometry dimension. Anthropometry measurement is done by direct observation using a roll metline, vernier calliper, and 3D printed cone to measure the grip diameter. Figure below is the measuring instrument used and Table 7 is the dimension of anthropometry that measure.

Figure 4. Roll metline.

Figure 5. Vernier calliper.

Figure 6. 3D printed cone.

Table 7. Anthropometry dimension.

No	Anthropometry Dimension	Code
1	Height	TB
2	Shoulder width side	D17
3	Hip width	D28
4	Elbow height	D4
5	Knee height	D15
6	Length of metacarpal length	PTm
7	Length of the little finger	JIJK
8	Hand width to thumb	LTIJ
9	Maximum grip diameter	DMak

2.6.2. Design dimension
Based on anthropometric measurements that have been processed, the next step is to determine the size of the paediatric walker design. The following is a design measure for paediatric walked using dimension of anthropometry and allowance as shown in Table 8.

Table 8. Equation of dimension.

No	Size	Equation (cm)
1	Width of the top walker	D17 (P95)
2	Width of base support	D28 (P95) + 8.5
3	Maximum height walker	D4 (P95) + 2.5
4	Minimum height walker	D4 (P5) + 2.5
5	Length of walker	D15 (P95) x 1.5
6	Width of handgrip	PTm (P5)
7	Length of handgrip	JIJK (P95)
8	Length of rubber HG	LTIJ (P95)
9	Diameter of rubber HG	DMak (P50)

3. Results and discussions
The results of the questionnaire are used as a tool to find out the needs that need to be developed in the paediatric walker redesign process. Design requirements are obtained through the average value of each criterion. Based on these calculations, the criteria that have a low rating for the user are obtained, it can be seen in Table 9.

There are 5 criteria processed in the questionnaire namely function, convenience, safety, material, and aesthetics. The average chart of criteria values shows that the security criteria has the lowest value of 3.58, material criteria of 4, function criteria of 4.38, ease criteria of 4.5, and aesthetic criteria of 5.25. Therefore, in the research development of paediatric walker design focused on the 3 lowest criteria, namely safety, material, and function of the tool.

Table 9. Criteria hierarchy.

Criteria	Statement	Mean	∑ Mean
Function	Q1	3.75	4.38
	Q2	3.75	
	Q3	4.75	
	Q4	5.25	
Easiness	Q5	5	4.5
	Q6	4	
Safety	Q7	4	3.58
	Q8	5	
	Q9	1.75	
Material	Q10	3.75	4
	Q11	4.25	
Aesthetics	Q12	5.25	5.25

Based on Table 8, The dimension of product can be calculated as shown in Table 10.

Table 10. Dimension of product.

No	Size	Equation (cm)	Dimension of product (cm)
1	Width of the top walker	D17 (P95)	42
2	Width of base support	D28 (P95) + 8.5	51.1
3	Maximum height walker	D4 (P95) + 2.5	107.3
4	Minimum height walker	D4 (P5) + 2.5	60.6
5	Length of walker	D15 (P95) x 1.5	71.7
6	Width of handgrip	PTm (P95)	10.5
7	Length of handgrip	JIJK (P95)	17.3
9	Length of handspad	LTIJ (P95)	10.4
10	Diameter of handspad	DMak (P50)	3.3

The results of the evaluation will be the main development improvement and the main criteria that form the basis of design are function, convenience, safety, material, and aesthetics. The following Figure 7 is a visualization design that is adapted to the previous criteria.

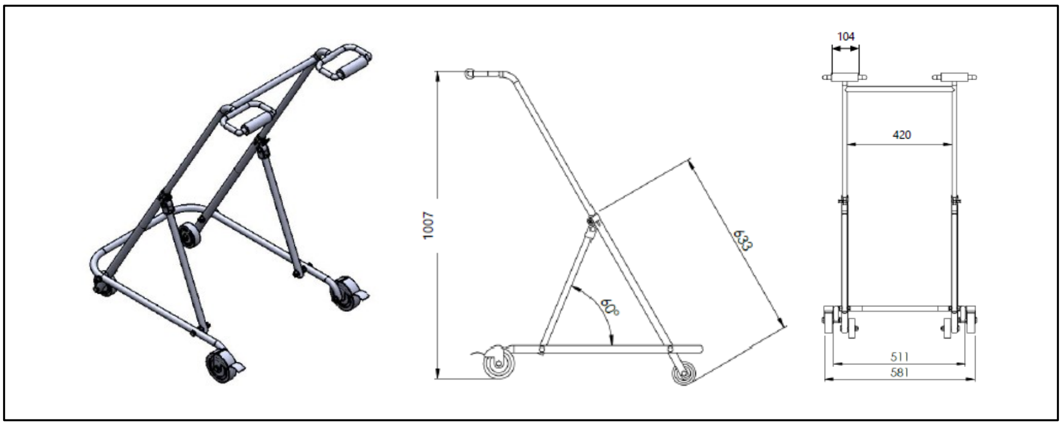

Figure 7. Conceptual design of pediatric walker.

Chia Pao Chang and Yin Hsiang Lin have done research about applying TRIZ to improve the structure of walkers. A walker is used for the patient of weak or lack of balance and mobility. It is dangerous when walkers are pulled up and easily feel sore on both arms of the user. They apply TRIZ theory to solve about problems. They add four ball bearings to the new spring structure. While needs moving, the user may push walker lightly via ball bearings. In this reseacrh the walker for accommodate children with spastic diplegic and hemiplegic cerebral palsy. The walker using stainless steel for the frame, front wheels using rigid wheels 3 inch, back wheels using normal brake wheels 4 inch, handgrip using leather black for the handspad, and handgrip support with velcro strap for binding the hand of users.

4. Conclusions

The redesign of the paediatric walker based on five hierarchical criteria. In the latest design, the handgrip is equipped with a velcro strap that is useful for binding the user's hand that cannot hold. The handgrip is designed to accommodates DCP and HCP children. The handgrip is equipped with hand pads for comfort when holding. The height of the handle is designed to be adjusted to the user's height so that the reach of the hand is reached. The walker frame can be folded to make the tool move more easily. The caster wheel design to minimize the friction that occurs so users have no trouble using it because of the slippery surface. The caster wheel design is made in one direction to help steer. The basic support design is made to support the stability of the tool when used for ongoing rehabilitation so that the tool is stable when in use.

5. References

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