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The Innovation of an Ergonomic Walker using ARIZ

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Abstract: Devices such as walkers can sometimes cause secondary injuries to patients if not used properly. Although, there are existing redesigned walkers which prevent falls from happening, it appears that there is still room for improvement towards developing a more innovative and ergonomic walker. Hence, this study aims to design and develop an innovative walker for improved usability using ARIZ. ARIZ which is an algorithm for inventive problem solving is widely used for complex problem solving with minimal changes to the system. The ARIZ approach in this study proposed three inventive principles to be used namely dynamicity, asymmetry and nested doll. The solution involved a double slider crank mechanism which enabled the newly designed walker to effectively support gait movement and stair-climbing. Overall, researchers of this study successfully designed and developed a unique and innovative ergonomic walker for the elderly and disabled people with intentions to prevent further injuries or accidents.

Key words: ARIZ, innovative design, TRIZ, ergonomics, walker, dynamicity

INTRODUCTION

Studies conducted by D'Angelo *et al.* (2011) show that 50% of people between the age of 40 and 45 years old are more prone to be affected by musculoskeletal disorders. Therefore, in order for elderly people to be able to live independently, a mobility aid is needed to assist them to improve their quality of life (Martins *et al.*, 2012). According to Epstein (1937), the walker has been used for many years by patients with a variety of musculoskeletal problems. In addition, it was found that 10% of patients who had hip fractures did not gain independence from using walkers after a period of 9 weeks from the surgical fixation of the hip fracture (Cheng *et al.*, 1989). Moreover, suggested that walkers are designed to improve the pathological gait walking of elderly people through the support base of the upper limbs which improves the balance of the individuals.

Literature review: About 71% of 1.5 million people occupying the nursing homes in the US require some form of mobility assistance (Ficke, 1991). In addition to that according to D'Angelo *et al.* (2011) about 50% of people between the age of 40 and 45 years are more prone to be affected by musculoskeletal diseases with the females having a slightly higher tendency compare to males. Due to aging, the ability of elderly people in maintaining balance and posture deteriorates with time. This is evident in the statistics done by Gillespie *et al.* (2003) which proved that elderly people over the age of 65 have a one in three chances to fall each year with those odds increasing to one in two for those over the age of 85. In addition, the findings of O'Hare *et al.* (2013) suggested that it was difficult to support or reject the use of walkers about whether they worsen or improve the situation for elderly people though the findings of Bradley and Hernandez (2011) do support that the most commonly reported accidents related to the use of walker were falls. A conventional walker works exactly like a walking stick, only that it provides extra stability with its additional two/three legs. Studies show that conventional walkers do have their adverse effects like higher energy consumption and discontinuous gait movement among recovering patients (Bateni *et al.*, 2004). Though there have been existing redesigned walkers up to date that prevent falls from happening, it appears that there is still room for improvement towards developing a more innovative and ergonomic walker. Hence, this study aims to design and develop an ergonomic walker for improved usability.

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MATERIALS AND METHODS

For this project ARIZ was used. ARIZ is a Russian abbreviation for the term Algorithm for inventive problem solving. It is a type of tool used in TRIZ which is a Russian acronym for The theory of inventive problem solving. ARIZ is used to solve complex problems that cannot be solved by other TRIZ tools by instigating a multi-step process which integrates different pieces of TRIZ (Yeoh, 2014).

Two stages of problem solving were carried out. Stage 1 involved using ARIZ to solve the first problem statement which involved the difficulty of patients to walk with continuous gait movement on regular flat surfaces using a conventional walker. Stage 2 involved using ARIZ to solve the second problem which was the difficulty in patients going up and down the stairs using a conventional walker.

ARIZ Stage 1 (difficulty in walking with continuous gait movement on levelled surfaces): In ARIZ, the first step requires researchers to identify the problem which desires to create a walker that improves assistive walking. Hence, the engineering system would involve holding the person. This engineering system would consist of parts like the walker, frame legs, ground and person. With respect to the system's ability to hold the person, two types of engineering contradictions are developed.

EC-1: If the walker is grounded, then walker can hold the person but the walker blocks the person from moving.

EC-2: If the walker is lifted then the walker would not block the person from moving but the walker cannot hold the person.

Based on the a fore mentioned contradictions, it would then be necessary to allow the walker to hold the person without it blocking the person from moving with minimal changes to the system. Having said that the tool of the system would then be the walker whereas the product of the system would be the person. Furthermore, based on the identified contradictions (EC-1 and EC-2), it can also be deduced that there are 2 states of the system to be observed namely the state where the walker is grounded (State 1) and the state where the walker is lifted (State 2). Based on the contradictions, the situation where the main function is delivered better involves the first contradiction (EC-1).

At this point, the product would still be identified as the person while the tool can be identified as the walker. An engineering contradiction with an aggravated state would then be required. Based on the basic engineering contradiction identified, the aggravated basic contradiction can be designed as such; if the walker is totally grounded then walker can completely hold the person but the walker totally blocks the person from moving. According to the techniques in ARIZ with the understanding that the product is the person and the tool is the walker, it would be necessary to introduce an X-factor that preserves the ability of the walker to hold the person without it blocking the person from moving with minimal changes and without any harmful consequences. Hence, an analysis of the problem model can be done and the operating space (space where a conflict is happening) can be defined as the interface between the person and the walker.

The operating space provides a clearer understanding in terms of defining the operating time which can be categorised as T1-3 where T1 represents the time before the conflict, T2 represents the time during the conflict and T3 represents the time after the conflict. Hence, there would be time to improve the situation in advance (T1) and also time to improve the situation during the conflict (T2), though the time to improve the situation after the conflict (T3) would not exist.

When analysing the Resources of Substances and Fields (SFR), the observation of three major elements in the operating space would be required. These three elements include the substances, parameters and fields. The operating space in this scenario would consist of the tool (walker) and the product (person). The substance of the tool refers to the material of the walker in which its parameters would include shape and size within a mechanical field. The substance of the product refers to the material of the person in which its parameters would include weight, age and height within a mechanical field as well.

Upon the identification of the SFRs, the Ideal Final Result (IFR) of the solution and a physical conflict which disallows the achievement of the IFR are required to be defined. Based on how the X-factor, operating time and operating space were introduced in the preceding paragraphs, the IFR for this study can be defined using the following statement; the X-factor itself preserves the ability of the walker to hold the person without it blocking the person from moving in between the walker legs and the flat ground during T1 and T2 without making the system more complex and without any harmful consequences. With the IFR defined, there would be a need to introduce limitations where the use of foreign, new fields and substances would not be allowed. In this case, the X-factor can be substituted with all the SFR parameters of the operating space. There were only two parameters identified which include shape and size. As such the two IFRs with physical conflicts can be expressed as such.

Shape of the frame: Itself preserves the ability of the walker to hold the person without it blocking the person from moving in between the walker legs and the flat ground during T1 and T2 without making the system more complex and without any harmful consequences.

Size of the frame: Itself preserves the ability of the walker to hold the person without it blocking the person from moving in between the walker legs and the flat ground during T1 and T2 without making the system more complex and without any harmful consequences.

Based on the two IFRs defined, two physical contradictions can be created on a macro level. For the first contradiction, the shape of the frame needs to be arched to not block the person from moving and the shape of the frame needs to be straight to hold the person. The aforementioned physical contradiction would involve the principle of "separation in time" (Yeoh, 2014). Based on the considerations of cost, availability of materials and performance delivery, the inventive principle of dynamicity (#15) was chosen out of the 40 inventive principles of TRIZ to resolve this physical contradiction. The idea used based on this principle was to alter the currently rigid shape of the frame to be more flexible by substituting certain bars (such as the one in front of the frame which blocks the person) with flexible chains, belts or other flexible elements to extend the walking distance.

For the second physical contradiction, the size of the frame needs to be small to not block the person from moving AND the size of the frame needs to be big to hold the person. The aforesaid physical contradiction would involve the "separation in space" principle (Yeoh, 2014). With consideration of several important factors such as usability, practicality, cost and availability of materials, the inventive principle chosen to resolve this physical contradiction was the nested doll principle (#7). Based on this principle, the idea was to create a function which allowed the front legs of the frame to collapse (retract) inwards to reduce the frame size while retaining some support from the handle so that the person could cross a certain distance without being blocked (much like the parallel bars used for the rehabilitation of people with walking disabilities). After crossing a certain distance, the frame can resume its normal height with extendable legs.

ARIZ Stage 2 (difficulty in ascending and descending stairs): The second stage of ARIZ involves resolving the problem of the walker's difficulty in ascending and descending the stairs. At this stage, the problem model would still involve an engineering system for holding a person. This system would consist of the walker, stairs and person. The two engineering contradictions can be developed as such.

EC-1: If the walker is rigid then the walker can effectively hold the person but the stairs would block the walker.

EC-2: If the walker is flexible then the stairs would not block the walker but the walker cannot hold the person effectively.

Based on the engineering contradictions, it is found that it would be necessary for the walker to effectively hold the person without stairs blocking the walker with minimal changes to the system. Hence, the tool for the system would be the walker while the product would be the person. The first state would require the walker to be rigid (as per EC-1) while the second state would require the walker to be flexible (as per EC-2). Based on the contradictions, EC-1 can be chosen as the basic contradiction since it involves the main function being delivered better. Thus, the aggravated basic contradiction can be expressed as such; if the walker is extremely rigid, then the walker can completely hold the person but the stairs would completely block the walker.

By the identification of the aggravated basic contradiction, it would then be necessary to introduce an X-factor that preserves the ability of the walker to hold the person effectively without the stairs blocking the walker with minimal changes and without any harmful consequences. The analysis of the problem model would identify the operating space as the interface between the walker legs and the stairs.

Based on the operating space, there would appear to be time to improve the situation in advance (T1) and also time to improve the situation during the conflict (T2), though the time to improve the situation after the conflict (T3) does not exist. For substances and fields, the parameters for the tool include shape, size and angle.

In order to achieve the Ideal Final Result (IFR), the following statement using the X-factor was produced; the X-factor itself preserves the ability of the walker to hold the person effectively without the stairs blocking the walker in the interface between the walker legs and the stairs during T1 and T2 without making the system more complex and without any harmful consequences.

The goal was to introduce the SFR parameters of the operating space into the X-factor in order to produce limitations and physical conflicts within the IFR. Hence, the IFRs with physical conflicts were proposed as.

Size of the frame: Itself preserves the ability of the walker to hold the person effectively without the stairs blocking the walker in the interface between the walker legs and the stairs during T1 and T2 without making the system more complex and without any harmful consequences.

Shape of the frame: Itself preserves the ability of the walker to hold the person effectively without the stairs blocking the walker in the interface between the walker legs and the stairs during T1 and T2 without making the system more complex and without any harmful consequences.

Angle of the frame: Itself preserves the ability of the walker to hold the person effectively without the stairs blocking the walker in the interface between the walker legs and the stairs during T1 and T2 without making the system more complex and without any harmful consequences.

When defining the physical contradictions on a macro level, a total of 3 physical contradictions can be developed. For the first physical contradiction, the angle of the frame needs to be small to prevent stairs from blocking the walker and angle of the frame needs to be big to hold the person effectively. This physical contradiction involved the "separation in space" principle where the suggested inventive principle chosen was the nested doll principle (#7). Based on this principle, the idea was to get the legs of the frame to be extendable and retractable at both ends in order to fit the stairs effectively. This could be achieved by perhaps using disc bearings or spring-induced mechanisms (much like the ones used in tracking poles).

For the next physical contradiction, the size of the frame needs to be small to prevent stairs from blocking the walker AND size of the frame needs to be big to hold the person effectively. The aforesaid physical contradiction involved the "separation in time" principle where the inventive principle of dynamicity (#15) was used. The idea based on this principle was to mechanise the frame legs to create back and front legs that move in and out simultaneously to fir the higher and lower stairs. In this case, the use of springs, gears or disc bearings could possibly allow these movements.

Finally, for the final physical contradiction, the shape of the frame needs to be asymmetrical to prevent stairs from blocking the walker and shape of the frame needs to be symmetrical to hold person effectively. The above-mentioned contradiction involved the principle of "separation in space" whereby the inventive principle selected to resolve the contradiction was the asymmetry principle (#4). The idea was to allow the centre point of the frame to be flexible so that the frame had a larger degree of flexibility in the middle. This would make the frame not as symmetrical as it used to be and allow it to reach within the steps of the stairs.

RESULTS AND DISCUSSION

The results and discussion for this study involved the proposal of the solution based on the inventive principles identified from the ARIZ process. This study involved 3 major parts where the first two parts discussed about how the principles were used to output the design and the last part discussed about the estimated cost.

Dynamicity and nested doll principle: Using the principle of dynamicity, a mechanical linkage was installed on the walker legs and connected to a disc to create a slider crank mechanism. In order to function on two different elevated surfaces such as stairs, the front and hind legs of the walker must translate together at a single time. Therefore, a double slider crank mechanism was introduced to overcome this problem. As the rotating crank rotates, one side of the rod will push the slider forward and vice versa for the opposite side of the crank with the rod pushing the slider backwards as the crank completes a full revolution.

For the process of ascending a flight of stairs, the front legs of the walker are shortened by compressing them on the first step in order to compensate for the elongation of the hind legs. This would turn the disc, causing a transmission of motion to the hind legs of the walker. Figure 1 shows how to use the walker while climbing a flight of stairs.

For the process of descending a flight of stairs, the process is directly opposite of how the ascending works with the hind legs of the walker shortening first while the rotating motion of the disc transmit the force exerted to the front legs to elongate it so that is reaches the lower surface and create a balance platform for the user to support while shifting their weights.

Dynamicity and asymmetry principle: Using the double slider mechanism, the walker is not only capable of ascending and descending the stairs but also improving regular gait movement. By allowing the bar that connects the two frame legs to be flexible along with the help of the double slider, the gait movement can be performed

Fig. 1: Steps on ascending stairs: a) Hold the walker level on the ground; b) Carry it onto the first step; c) Exert a force downwards so the hind legs would elongate and d) Shift the weight of your leg forward with the handle support and repeat everything on the following steps

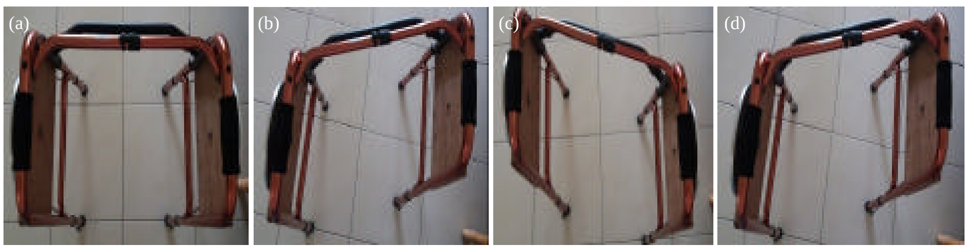

Fig. 2: Step by step instructions on using the walker for levelled surfaces: a) Make sure both sides of the walker is aligned; b) Move one side of the walker forward while having full support from the other side when shifting weight; c) Repeat the same step as part (b) for the other side and d) Repeat part (b) and (c) to continue moving forward

smoothly without having to lift the frame up unsupported. Figure 2 shows the steps of using the walker on a levelled ground.

CONCLUSION

All in all, the innovative ergonomic walker is indeed a unique product solution for elderly people, disabled people and rehabilitating people with intentions to prevent further injuries or accidents from occurring. It has the potential to improve the quality of life by allowing patients to move from one place to another independently with support. It is also a product designed uniquely with functions that precedes all its predecessors. It is capable of allowing users to ascend/descend the stairs and promotes a more natural and continuous gait movement when the user is walking on levelled surfaces. Eventually, this new product can be innovated further in the future to be commercialized in the open market for all people.

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