JOINT-DEVELOPMENT OF MOBILITY ASSISTIVE DEVICES FOR PATIENTS WITH SPECIAL TREATMENT

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Abstract

The skeletal, muscular and nervous systems in human body works together to enable specific movement or posture. Abnormalities in any of these systems may cause this functionality to degrade. Some examples of such diseases are spinal muscular atrophy and cerebral palsy. Patients who suffer from these diseases may require assistive devices designed specifically to their anatomy for supporting their posture and mobility. Bioteknik Design in Bandung, is a small local company focusing in the development of assistive device for helping such patients. A collaboration between SGU and Bioteknik was made to help Bioteknik in designing some of their supportive devices. A student internship was assigned in Bioteknik Design to conduct various tasks related to developing assistive devices based on the need of the patient. These tasks include patient anatomy measurement, design and production of the assistive devices suitable for the patient. These tasks are directed towards giving the patient the mobility and the posture needed, so that the opportunity for the patient to move, explore, and connect to their surroundings could be improved. In this project, several assistive devices, e.g. electrical wheelchair (Go-Roll), specific wheel chair with footrest, and feet-controlled wheelchair, have been measured, design and implemented at various stages.

Keywords : Assistive Devices, Specific Treatment, Wheelchair; Spinal Muscular Atrophy, Cerebral Palsy

INTRODUCTION

The human body is a complex integrated system in which all aspects contribute towards creating a complete individual. The skeletal system, muscular system, nervous system works together as the pillar in order to create the specific movement and posture that the human body requires. In certain cases, abnormalities arouse in one or some of those pillars and could entice health problems towards the diseased person. These diseases can affect the ability of the body to create movement and maintain posture. These diseases have a wide variety, a few of the varieties are spinal muscular atrophy (Coovert, 1997; Martinez, 2012; Lefebvre, 1997; Lorson, 1999, 2010; Lunn, 2008) and cerebral palsy (Bax, 1964; Nelson, 1982; Nelson, 1999; Krigger, 2006, Odding, 2006).

Bioteknik is a local company located in Bandung that concentrates in the research and development field (Bioteknik website). The company was built in 2006 by Miss Lydia Kidarsa. The company mainly focuses on designing and creating assistive devices for patient that are in need for postural and mobility support (Day, 2001). The assistive device ranges from wheelchairs, standers, seats, crutches, walkers, etc. Those devices are mostly aimed towards children that needs to be specially supported (Thomson, 2005), and even some is needed to be individually designed and created based on the patient's needs (Bateni & Maki, 2005, Damiano, 2006).

To assist the development of this assistive device, an internship student from the Biomedical Engineering department of Swiss German University (SGU) was assigned to Bioteknik Design. This internship created a mutual collaboration between the two institutions. The purpose of this internship is to assist in the production of assistive devices at the Bioteknik Workshop. As a Biomedical Engineering student, this internship program has a purpose to give the students the chance and opportunity to gain experience and knowledge within their faculty's working environment. Biomedical engineering is a versatile major that can work in various concentrations in their working environment. In this internship, the ability to design and create is essential, therefore critical thinking and creativity is required to accomplish the task. Overall, this internship could enhance the students by deepening their knowledge, give the perspective in the working environment, and techniques required in the future.

The main task given during the internship program in Bioteknik is to measure and analyze the patient, design the parts that is required for the devices in Solidworks and then create from the design at the Bioteknik's workshop. Some obstacles were encountered during the internship, such as the need to adapt to work environment, unfamiliarity in using mechanical tools, and unfamiliarity in using applications and programs required.

METHODS

1. General Methods

The primary steps that are used for production in the Bioteknik company are diagnostics, measurements, designing, making, and then finally fitting. Diagnostics are usually conducted with the help of doctors. Majority of the patient usually suffer from either Spinal Muscular Atrophy (Coovert, 1997, Martinez, 2012, Lefebvre, 1997, Lorson, 1999, 2010; Lunn, 2008) or Cerebral Palsy (Bax, 1964, Nelson, 1982; Nelson, 1999; Krigger, 2006, Odding, 2006). The patient is then measured based on the existing procedure sheet, and any special treatments are also considered and measured (Thomson, 2005). After the measurement is complete, components and parts for the assistive device are then designed using Solidworks application, all based on the measurement that had been conducted.

After the design is complete, it is then composed into a 2D engineering drawing and then sent to the workshop. The materials such as metal pipes, stainless pipes, metal sheets, etc., that are needed are ordered and bought first. Then the assistive device is made according to the engineering drawing. The making process usually takes about 2 – 3 weeks of work. The making process consists of bending metal pipes, shaping metal, welding, soldering if electrical components are required, painting, etc. An assistive device product called Go – roll requires the usage of Arduino and other electrical components, therefore coding and soldering is required. Once the assistive device is complete, the patient is then finally called for fitting (Day, 2001).

2. Problem Assessment and Diagnostic

During the period of the internship at Bioteknik, there are a few number of assistive device productions that the student partly contributed in. An electrical wheelchair, or *Go – Roll* for Patient A and Patient B, a *wheelchair* for Patient C, a *seat* for an Patient D, and a foot powered electrical wheelchair for Patient E. The production of these assistive devices requires creativity and various practical mechanical techniques such as using metal grinder, wood cutter, welding tools, soldering, the ability to read engineering drawing, and also the knowledge and ability to create and construct the parts in solidworks.

RESULTS AND DISCUSSION

1. Go – Roll Patient A

A Go – roll is an electrical wheelchair designed by Bioteknik that uses two motors that are connected to the tires of the wheelchair to provide movements. The movement of the wheelchair are coded using Arduino. A joystick is used to control the movement of the wheelchair. In figure 1 below shows the framework structure for the wheelchair in progress. The frame of the wheelchair is made based on the engineering drawing. The metal or stainless pipes are bent and welded together.

Figure 1. Frame for Go-Roll

The seat, armrest, headrest, and others are made using a plank of wood. All of the wood frames are made in the workshop. Then the wood frames will then be covered by foam at a local store near the workshop. Firstly, the shape is drawn using a marker onto the wood plank, and then cut using a wood cutter at the workshop. Figure 2 (left) shows one of the wood frame shapes of the arm rest for the Go – Roll wheelchair made in the workshop. Figure 2 (right) shows the completed arm rest after the foam is put on.

Figure 2. Arm Rest Wood Frame (left); and Arm Rest Go-Roll (right)

Holes were made accordingly and T-nuts were placed onto the holes for screw placement during the assembly. The wood frames were also smoothen out if any sharp and rough edges are present using a wood grinder in order to avoid any splinters. As for the foot rest of the Go – Roll, the wood frame can be seen in Figure 3 (left), and the completed foot rest can be seen in figure 3 (right).

Figure 4 shows the wood frame and the completed postural support respectively, where the postural support that is used on the wheelchair to maintain a good posture for the patient. 4 holes were drilled on the wood frame where the T-nuts were put. In total, there are 2 pairs of these supports that are made. The supports are not yet assembled to the wheelchair as it requires the patient to be present for fitting.

Figure 3. Foot Rest Wood Frame (left) and after completed for Go-Roll (right)

Figure 4. Postural Support Wood Frame (left) and after completed for Go-Roll (right)

The joystick for the Go – Roll is made using 3D Printing and some components had to be soldered. The Joystick consists of the joystick control, a safety button, and 3 points switch to control the velocity of the Go – Roll. The joystick can be seen in Figure 5. The joystick had to be replaced once because the first joystick was broken or burned and it was causing difficulties to control the movement of the Go – Roll.

The Go – Roll has already been finished and already assembled. However, the patient has not yet gone through fitting for the wheelchair due to the patient currently unable to come. The assembled Go – Roll can be seen in Figure 6.

Figure 5. Joystick for Go-Roll

Figure 6. Completed Go-Roll

2. Kuron Ata for Patient B

Kuron Ata is a wheelchair that can be controlled by the user manually on the wheels using their hands. Patient B was assigned to kuron ata due to the patient still having the ability and strength to move the wheelchair using their own hands. Therefore it is best that the muscle on the arms are always routinely used as possible, so the muscle does not experience atrophy. The assistive device is planned to be designed in such a way that it does not obstruct the motion of the hands when controlling the kuron ata. The design is ought to lower the height of the arm rest. The assistive device Kuron Ata for Patient B has not yet been made. However, measurements of patient B has already been done at Hasan Sadikin Hospital on Tuesday, 28 January 2020. Patient B suffers from Spinal Muscular Atrophy and requires a wheelchair with postural support to support and maintain a good posture for his body. The patient also suffers from scoliosis and a hump is present at the back of the patient due to the bad posture. Therefore, the back rest of the wheelchair is planned to have a hole that will be covered by foam, so the hump of the patient won't experience a big pressure. By creating a hole, it creates a larger area for the hump, in return it lowers the pressure created. The shape of the bottom half of the patient are also made using gypsum. The measurement result of Patient B can be seen in table 1 and table 2 below, where table 1 is a seated measurement and table 2 is a standing measurement.

Table 1. Seated Measurement of Patient B

Patient		B
Date of Measurement		28-Jan-20
Diagnosis		SMA
No.	Variable Measured	Result (cm)
1	Patient's height	121
2	Patient's weight	25
3	Waist width	32
4	Chest width	25
5	Shoulder width	32
6	Left upper limb length	32
7	Right upper limb length	32
8	Left lower limb length	31
9	Right lower limb length	31
10	Sitting bone distance	30
11	Back rib bone height (left/right)	16 / 15
12	Scapula bone height	32
13	Armpit height	36
14	Shoulder height (left/right)	37 / 36
15	POE height	47
16	Fontanel bone height	57
17	Armrest height	17
18	Abductor width	-
19	Adductor width	-

3. Wheelchair Patient C

During the late period of the internship, the assistive device for Patient C has just started to be constructed. To comply for the consumer's requirements, slight modifications on the foot rest has to be made, where the footrest can be opened and closed. This feature allows for the patient to be easily moved around if needed. Using Solidworks, the design of the new footrest is to be made.

Patient		B
Date of Measurement		28-Jan-20
Diagnosis		SMA
No.	Variable Measured	Result (cm)
1	Height	121
2	POE	109
3	Shoulder	101
4	Armpit	92
5	Floating Ribs (left/right)	80 /78
6	Front Ribs	78
7	Apex Lumbar	73.5
8	Elbow	82
9	SIPS	68
10	Trochanter Major (left/right)	61 / 66
11	Back of Knee	32.5

Table 2. Standing Measurement of Patient B

The first early design that was made in solidworks consist of a connector that connects the footrest to the wheelchair, a pivot, and a metal plate for the foot. This early design can be seen in figure 7 (left). However, there are some issues regarding the metal plate that was used for the foot to rest, as it won't be strong enough to hold the foot. Therefore, changes on the initial design was made where the metal plate was changed into two metal strips that will be the site for the wood frame. Figure 7 (right) shows the second design of the foot rest.

The second design was changed as the metal strips will not be strong enough to hold the wood frame. The third design involves the addition of metal pipes underneath the metal strip for extra support. The third design can be seen on figure 8 (left). In the third design, the wood frame where the foot rest will be used as the stopper to stop the foot rest from falling. However, the wood frame will not last long as the stopper and will easily break. Therefore, the fourth design of the foot rest, a metal pipe was added to the foot rest for the stopper as it is stronger and sturdier as a stopper than having the wood frame as the stopper. A metal plate circle shaped is also added and will be welded on the end of the pipe. The addition of the circular metal plate is to add more strength to the stopper and to stop it from getting flat. The stopper in the fourth design was placed under the pipe for the wood frame. The fourth design can be seen in figure 8 (right).

Figure 7. Foot Rest First (left) and Second (right) Design

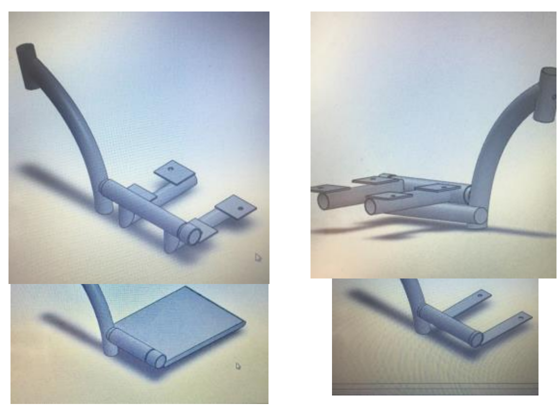

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Figure 8. Foot Rest Third (left) and Fourth (Right) Designs

The final design for the foot rest has a similar design towards the fourth design. Minor changes include the reduction of metal plates from four to two. Major change for the design changes the placement of the wood frame site onto the stopper. This change allows for a thinner foot rest compared to the fourth design. The pivot on the final design are also brought out. The final design of the foot rest for the wheelchair can be seen on figure 9. The scale of the foot rest is not in real life scale yet.

A few wood frames for the wheelchair has already been cut, and can be seen in figure 10 (left). The metal connector has already been bent and painted, and can be seen in figure 10 (right). The metal connectors are made 4 in total.

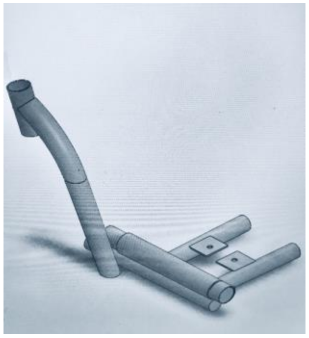

Figure 9. Foot Rest Final Design

Figure 10. Wood Frames for Wheelchair (left); and Metal Connector (right)

The measurement result of Patient C can be seen in table 3, where the type of measurement performed is the seated measurement.

4. Seat Patient D

This assistive device is a seat for an elder person for daily activities. The elder person suffers arthritis on both knee joints that in consequent, causes the person to have difficulties to stand up from a seated position. Therefore, the seat is purposely made higher. The chair is made based on the engineering drawing already provided. The frame of the chair is made by measuring, bending, cutting, and welding metal or stainless pipes. An important feature in this chair is the leg support that can be adjusted accordingly to the patient's needs. The higher height of the seat as well as the addition of the leg support allows a more ease movement for the patient to stand up. The seat is already nearly complete, and can be seen on figure 11.

Table 3. Seated Measurement of Patient C

Patient		C
Date of Measurement		27-Jan-20
Diagnosis		Old age
No.	Variable Measured	Result (cm)
1	Patient's height	150
2	Patient's weight	55
3	Waist width	38
4	Chest width	31
5	Shoulder width	40
6	Left upper limb length	42
7	Right upper limb length	41
8	Left lower limb length	41
9	Right lower limb length	40
10	Sitting bone distance	29
11	SIPS bone height	13
12	Back rib bone height	25
13	Scapula bone height	35
14	Armpit height	39
15	Shoulder height	50
16	POE height	62
17	Fontanel bone height	83
18	Armrest height	13
19	Abductor width	20
20	Adductor width	42

5. Foot Powered Electrical Wheelchair for Patient E

A new design of Go – Roll for patient E is requested to be made, where the wheelchair will be controlled using the feet. A quick research is made to determine the method and design of the controller that will be used to control the wheelchair. Afterwards, a miniature design of the controller was made using sheets of Styrofoam as a sample for the patient to try. A research is also conducted to find a few alternatives of the pedals that can be used to control the wheelchair. In total, there are 3 different alternatives on the design of the controller, and can be seen on figure 12.

Figure 11. Assembled Chair for Patient D

Figure 12. Alternative Pedal Designs for Patient E: first (upper left), second (upper right) and third (bottom) design.

The patient was diagnosed with Cerebral Palsy, and had already been measured on Friday, 14th February 2020. During the patient measurement and assessment, the pedal's placement on the foot rest was modified to suit the patient's needs and comfort. The final placement of the pedal can be seen on Figure 13, and the measurement of the patient can be seen in table 4 below.

Figure 13. Final Pedal Placement

6. Societal Impact of the Internship

The attachment of the biomedical engineering student to Bioteknik has enriched Bioteknik with more diverse human resource that could provide design- and service-level assistance to Bioteknik's line of work. Previously, most of the service- and design-level jobs at Bioteknik were conducted by Ms. Lydia Kidarsa herself as the founder and manager of Bioteknik. By attaching an intern students, some of these jobs has been carried out by the internship students. As a results, more service can be done within the limited time for patients that need special treatment. Within a period of 6 weeks, five devices have been designed and fabricated, and some even got tested with the patients. Thus, more people reap the benefit of this joint development. From the attached student's perspective, the student gained first hand experience on communicating with patients, and communicating with technicians and workers. The students also learnt how to implement their knowledge and skills to solve real world biomedical engineering problems.

CONCLUSION

In conclusion, there are 5 steps in creating the assistive devices in Bioteknik. These steps include diagnosing, measuring, designing, creating, and then fitting. During diagnosing, the requirements and measurement are also conducted. The designing task are mainly done using Solidworks application. The creation of the assistive device are done at the workshop that includes welding, cutting, bending, metal, and others. And finally at the fitting, the assistive device is fitted to the patient.

During this internship, there are 2 assistive devices that are almost complete, the Go – Roll for Patient A and the seat for Patient D. Meanwhile the other three assistive devices have just undergone patient measurements, early research, or initial framework.

Uncompleted procedures from diagnosing to fitting are caused by a few interferences. In production, interferences include repairs needed to be done, bad weather, change of design, difficulties in machining. After production, mainly the difficulty is patient unable to come for fitting due to tight schedule or others.

From the student's perspective, the internship in Bioteknik has allowed further developments on student's skills such as, creativity, machining, critical thinking, the ability to work in a team, and, mechanical techniques. Those skills are definitely useful for the upcoming internship, assignments, or future jobs to come.

We recommend that this internship practice for joint development of assistive device be extended for the next period of students' internship. Hence, more patients can also reap the benefit of this joint development via student internship program.

Table 4 Seated Measurement of Patient E

Patient		E
Date of Measurement		14-Feb-20
Diagnosis		Cerebral Palsy
No.	Variable Measured	Result
1	Patient's height	140
2	Patient's weight	40
3	Waist width	32
4	Chest width	27
5	Shoulder width	34.5
6	Left upper limb length	46.5
7	Right upper limb length	46.5
8	Left lower limb length	38
9	Right lower limb length	38
10	Sitting bone distance	28
11	SIPS bone height	15
12	Back rib bone height	26
13	Scapula bone height	46
14	Armpit height	40.5
15	Shoulder height	49
16	POE height	60
17	Fontanel bone height	75
18	Armrest height	21
19	Abductor width	15

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