Design of Bilateral Hand Movement Device using Design Thinking and Quality Function Deployment to Increase the Motoric Function of the Non-Dominant Hand

Novie Theresia Br. Pasaribu[1][a], Vivi Arisandhy[2][b], Christina[2][c], Elty Sarvia[2][d], Rainisa Maini Heryanto[2][e], Erwani Merry Sartika[1][f], Audyati Gany[1][g], Olga Catherina Pattipawaej[3][h], Richard Setiawan[1][i] and Jessica[2][j]

[1]*Bachelor Program in Electrical Engineering, Universitas Kristen Maranatha, Bandung, Indonesia*
[2]*Bachelor Program in Industrial Engineering, Universitas Kristen Maranatha, Bandung, Indonesia*
[3]*Bachelor Program in Civil Engineering, Universitas Kristen Maranatha, Bandung, Indonesia*

Keywords: Bilateral Movement, Design Thinking, Quality Function Deployment.

Abstract: Maintaining the balance of the body to prevent falls and injury can be done by doing one of the physical activities to train arm muscle strength. Bilateral movement exercise will get better results comparing to unilateral movement in increasing muscle strength. This research used Design Thinking, which consisted of empathize, define, ideate, prototype, and test. On the empathize stage, the customer needs were identified by doing the interview and observation. On the define and ideate stage, Quality Function Deployment was used to deploy the customer needs into technical requirements in the Product Planning Matrix and critical part requirements in Part Planning Matrix to make the detailed design. The prototype stage was realized by 3D Modelling. In Part Planning Matrix, there were top 2 contribution values: notice and Virtual Reality (VR). This research had an outcome of a device design that had the aim to increase the motoric function of the non-dominant hand, combined with VR to make it fun while doing the exercise. Future research might include vibration alert in doing the exercise, water flow to burden the rower, to make the exercise more real, continue the QFD with Process Planning Matrix and Production Planning Matrix.

1 INTRODUCTION

The covid-19 pandemic situation has made many changes in daily human life, including the change of physical activities (Rossa, 2020). The pandemic affected humans not doing physical activities globally in the late few months. Doing physical activities while at home can help our bodies to keep active and prevent diseases. Physical activities help the elderly to maintain the balance of the body to prevent falls and injury (Ramadhani, 2020).

One of those activities is for arm muscle strength. Arm muscle strength exercise does not just train endurance but also increases the muscles' mass.

[a] https://orcid.org/0000-0001-7774-9675
[b] https://orcid.org/0000-0001-9927-472X
[c] https://orcid.org/0000-0001-8033-5772
[d] https://orcid.org/0000-0003-3708-8723
[e] https://orcid.org/0000-0003-0808-538X
[f] https://orcid.org/0000-0003-3720-3584
[g] https://orcid.org/0000-0002-7389-6667
[h] https://orcid.org/0000-0002-7475-1726
[i] https://orcid.org/0000-0002-3857-9770
[j] https://orcid.org/0000-0002-9014-0167

Br. Pasaribu, N., Arisandhy, V., Christina, ., Sarvia, E., Heryanto, R., Sartika, E., Gany, A., Pattipawaej, O., Setiawan, R. and Jessica, .
Design of Bilateral Hand Movement Device using Design Thinking and Quality Function Deployment to Increase the Motoric Function of the Non-Dominant Hand.
DOI: 10.5220/0010747200003113
In *Proceedings of the 1st International Conference on Emerging Issues in Technology, Engineering and Science (ICE-TES 2021)*, pages 153-158
ISBN: 978-989-758-601-9

Muscles are part of the body that must be trained so the body can be moved well. If the muscles are less trained, there is a possibility to cause pain when doing a hard activity.

According to research, Range of Motion (ROM) exercises affected the increase of muscle power and functional ability (Astrid et al., 2011). The focus of the exercise to some weak parts of the body (unilateral exercise) and the exercise that was for both sides of the body (bilateral exercise) could increase the muscles power, but bilateral exercise could give better outcome compared to unilateral exercise (Cahyati et al., 2013).

Bilateral movement is when both limbs are used in unison to contract the muscles, which creates force and subsequently moves a given load (Fountaine, 2018). People would have a dominant hand that is used to do any activity, however, the motoric function of the non-dominant hand should be concerned to increase its productivity. Besides, the motoric function of the dominant hand could improve the motoric function of the non-dominant hand.

One of the physical activities that use hands to control is rowing. Rowing activity needs both hands to move simultaneously. Rowing simulation could be a choice to increase the motoric function of the non-dominant hand because the player was placed as a rower that rowed the paddles on each hand. The device was designed using rowing simulation movement. This research aim is to design a bilateral hand movement device for exercise program standard for both hands to increase the motoric function of the non-dominant hand.

2 METHODS

The design method that was used in this research was the Design Thinking Method that prioritized the human center approach. There were five stages are empathize, define, ideate, prototype, and test (Sándorová et al., 2020). The flowchart of the Methodology can be seen in Figure 1.

Empathize stage identified the customer needs and did the interview method and observation. The customer's age range was between 19-65 years old.

The next step was the define stage, which would do the problem interpretation so the things to be developed could be determined on the next stage.

The ideate stage was to determine the design idea by using many kinds of techniques and methods. At this stage, Quality Function Deployment (QFD) was used. QFD is typically used as a design tool. It could be used any time when customer needs have to be identified to determine technical requirements to determine priorities and setting targets (Erdil & Arani, 2019).

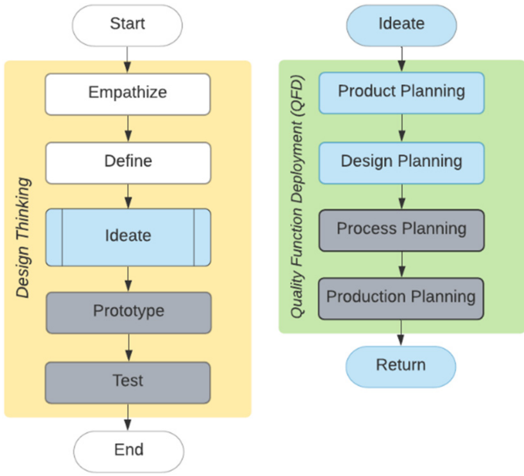

Figure 1: Flowchart of the Methodology.

There were 4 stages in the QFD, which were the Product Planning Matrix, Design Planning Matrix, Process Planning Matrix, and Production Planning Matrix. It was limited only to the Product Planning Matrix and Design Planning Matrix in this research because the goal of this research was to build the design ideas. The Product Planning Matrix, the customer needs, technical requirements, relationships, target values, and contribution values were needed. Based on the technical requirements of the Product Planning Matrix, it was determined the Critical Part Requirements and their Part Specifications and also the contribution values.

In making the design ideas, the anthropometric data would be used as the base to determine the exercise device measurement. Anthropometric data are essential for applying ergonomic principles to the design and improvement of a wide range of products for different users (Dianat et al., 2018). Anthropometric data are used for the proper design of a workstation, equipment, furniture, and so on to decrease awkward postures and stresses on the human body due to improper design (Jalil Mirmohammadi et al., 2006).

The anthropometric data that was used was the Indonesian community anthropometric data as the interpolation result of the British and Hongkong community to the Indonesian community (Nurmianto, 2004). For the body dimension that was not included in the anthropometric data, the anthropometric data in Chuan, et. al's research was used (Chuan et al., 2010).

After the ideate stage was done, the next stage was the prototype, based on those ideas. At this stage, the prototype was built in the 3D Modelling form using Blender Software.

The final stage of Design Thinking was the test, in which testing would be done on the prototype design. But this stage would not be done but would be suggested for future research.

3 RESULTS AND DISCUSSION

The first stage of the Design Thinking Method was empathize, which would identify the customer needs in doing the exercise program. The methods that were used were interviews and observation. Customer needs that were gathered were:

- Because of the Covid-19 pandemic, the customer did not want to do sports activities in public places such as fitness centers or together with others in their community.
- The customer did not want to go out too often.
- The exercise that would be done was low impact.
- The exercise that would be done was fun.
- The exercise that would be done, using both hands.
- The customer could do exercise without other people's help.

The second stage is define. The goal of this stage was to interpret the problems so the things that would be developed could be determined for the next stage. The problems were:

- The exercise device can be used with both hands.
- The exercise device is easy to be used.
- The exercise device can be used without other people's help.
- The exercise device is fun to be used.

The next stage is ideate. The goal of this stage was to determine the exercise device design ideas. Quality Function Deployment method was used, but limited only to Product Planning Matrix and Design Planning matrix.

The Product Planning Matrix can be seen in Figure 2. The customer needs were gained from the problems above, while the importance to the customer was assumed to have the same value for each variable. Relationship symbols were put to see the relationship between the customer needs and the technical requirements. The relationship symbols can be seen in Table 1 (Astuti et al., 2020).

Table 1: Relationship symbols.

Symbol	Definition	Value
●	Strong relationship	9
○	Moderate relationship	3
△	Weak relationship	1
No symbol	No relationship	0

At this stage, the technical requirements that had the 2 highest contribution values were the understanding rate to use and the independence rate of the user.

Technical requirements that had been determined including their contribution values were then transferred to the Part Planning Matrix. Part Planning Matrix can be seen in Figure 3.

In this Part Planning Matrix, critical part requirements were determined, which were the function detail to answer the technical requirement. Critical part requirements are divided into 4 categories, are additional, movement standard, an exercise device, fun facility. Critical part requirements needed the detailed design of its part, and anthropometric data was used to answer some of the technical requirements in this matrix.

Anthropometric data that were used are body dimensions for standing height, elbow height, elbow span, handbreadth, maximum grip diameter, and elbow-fingertip length. Body dimensions for exercise device design can be seen in Table 2:

Customer Requirement / Technical Requirement	An Exercise Program: Coordinating movement on two arms and hands	An Exercise Program: Hand Rhytmic Movement	Understanding Rate to Use	Independence Rate of the User	Fun Exercise	Importance to the Customer
Exercise tool can be used with both hands	●	●				0.25
Exercise tool is easy to be used			●	○		0.25
Exercise tool can be used without other people's help			○	●		0.25
Exercise tool is fun to be used					●	0.25
Contribution Scale	2.25	2.25	3	3	2.25	
Priority	3	4	1	2	5	
Operational goals/target	Bilateral Movement Exercise	Bilateral Movement Standard	95%	100%	Exercise Provided in a Game	

Symbol	Definition	Value
●	Strong relationship	9
○	Moderate relationship	3
△	Weak relationship	1
No symbol	No relationship	0

Figure 2: Product Planning Matrix.

Technical Requirement & Targets / Critical Part Requirement		Additional	Movement Standard		Exercise Tool										Fun Facility	Importance
		Notice	Forward Movement	Backward Movement	Height of the Pole	Height of the Paddle Center	Length between the Paddles	Length of the Paddle Stick	Diameter of the Paddles	Length of the Paddles	Material of the Poles	Material of the Hand Grips	Power of Paddling Stroke	Body Position of the User	Virtual Reality	
Understanding Rate to Use	95%	●														3
Independence Rate of the User	100%	●													●	3
Coordinating movement on two arms and hands	Bilateral Movement Exercise		●	●	●	●	●	●	●	●	●	●	●	●		2.25
Hand Rhythmic Movement	Bilateral Movement Exercise		●	●	●	●	●	●	●	●	●	●	●	●		2.25
Fun Exercise	Exercise Provided in a Game														●	2.25
Contribution Scale		54	40.5	40.5	40.5	40.5	40.5	40.5	40.5	40.5	40.5	40.5	40.5	40.5	47.25	
Priority		1	3	4	5	6	7	8	9	10	11	12	13	14	2	
	Part Specifications	A Manual Standard Sticked to the Tool	At the Same Time	At the Same Time	173.2 cm	95.7 cm	96 cm	7.9 cm	4.6 cm	40.9 cm	0.75 mm thickness Light Steel	Rubber Material	Left Stroke: 200.6 N and Right Stroke: 213.5 N	Standing Position	Oculus Quest 2	

Symbol	Definition	Value
●	Strong relationship	9
○	Moderate relationship	3
△	Weak relationship	1
No symbol	No relationship	0

Figure 3: Part Planning Matrix.

Table 2: Body dimensions for exercise device design.

Device dimensions	Body dimensions	Percentile	Gender	Dimensions (cm)
Height of the pole	Standing height	95th	Males	173.2
Height of the paddle center	Elbow height	50th	Females	95.7
Length between the paddles	Elbow span	95th	Males	96
Length of the paddles sticks	Handbreadth	50th	Males	7.9
Diameter of the paddles	Maximum grip diameter	50th	Females	4.6
Length of the paddles	Elbow-fingertip length	50th	Females	40.9

a. Height of the pole using the standing height body dimension with 95th percentile for males, which is 173.2 cm. The aim of using the 95th percentile for males was the flexible use of the device for tall users.

b. Height of the paddle center using elbow height body dimension with 50th percentile for females, which is 95.7 cm. The aim of using the 50th percentile for females was the suitability of the height of the paddle center measurement and the average body dimension for males and females.

c. Length between the paddles using elbow span body dimension with the 95th percentile for males which was 96 cm. The aim of using the 95th percentile for males was the flexible use of the device for big users.

d. Length of the paddles sticks using handbreadth body dimension with the 50th percentile for males which was 7.9 cm. The aim of using the 50th percentile was the suitability of the length of the paddles stick and the average body dimension for males and females.

e. Diameter of the paddles using maximum grip diameter with the 50th percentile for females which was 4.6 cm. The aim of using the 50th percentile was the suitability of the diameter of the paddles and the average body dimension for males and females.

f. Length of the paddles using elbow-fingertip length body dimension with the 50th percentile for females which was 40.9 cm. The aim of using the 50th percentile for females was the suitability of the length of the paddles and the average body dimension for males and females

Part Planning Matrix also had the same principles, as the Product Planning Matrix. At this stage, the critical part requirements that had the 2 highest contribution values were notice and Virtual Reality. By using all of the data from Part Planning Matrix, such as anthropometric data and its additional idea such as putting the notice and using the Virtual Reality, the design of the device was completed.

Virtual Reality (VR) was the simulation of the real world or the imaginative environment, could be felt in three dimensions, and also gave the visual interactive experience in the real-time movement with voice or any other feedback (Okechukwu & Udoka, 2011). VR has incorporated playing a game using a system capable of sensing movement (e.g., Xbox Kinect). VR has also been combined with traditional exercise tasks, such as stationary cycling treadmill running, and ergometer rowing (Murray et al., 2016). VR can be used as additional supporting tools as controller/joystick that enables the users to do variety movement, such as grabbing and throwing. These movements can help the motoric performance increasing process on the non-dominant hand.

The next step was making the prototype, using the design development with 3D Modelling using Blender Software. The result was shown in Figure 4 for the Front View, Figure 5 for the Top View and Figure 6 for the Side View. In Figure 7, the person's position when the rowing exercise is conducted, it is done using Bilateral Hand Movement Device.

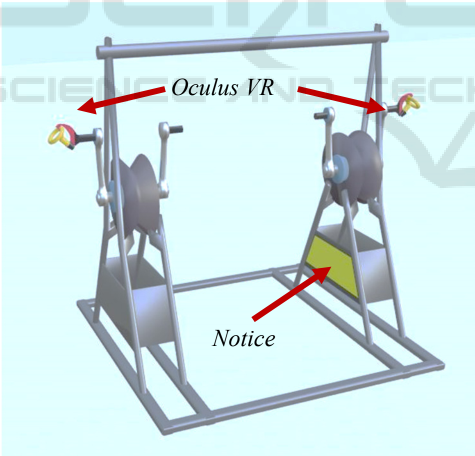

Figure 4: Design of Bilateral Hand Movement Device (Front View).

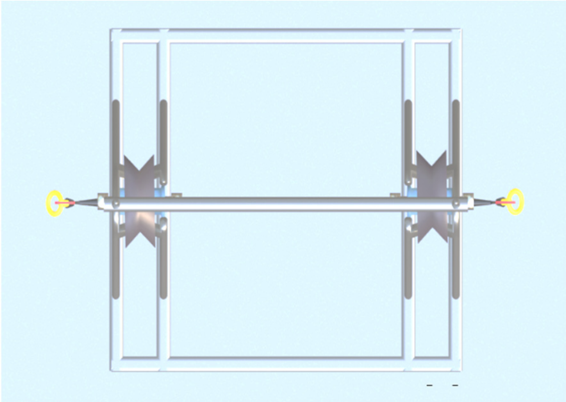

Figure 5: Design of Bilateral Hand Movement Device (Top View).

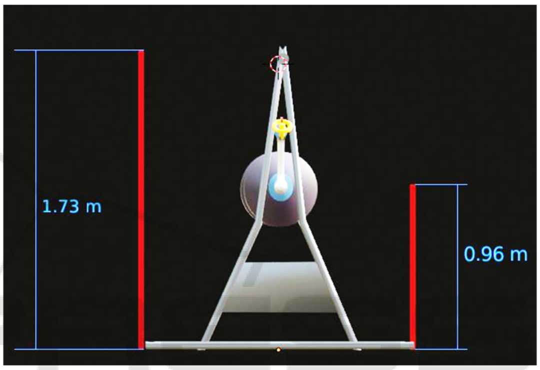

Figure 6: Design of Bilateral Hand Movement Device (Side View).

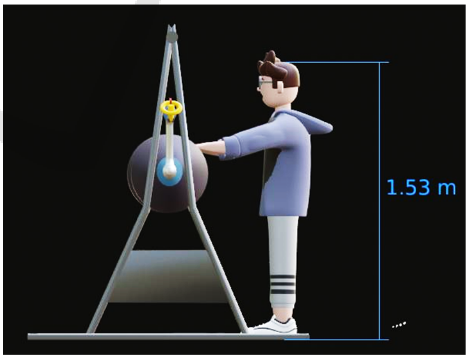

Figure 7: The Person's position while doing the rowing exercise.

The VR would be used while the person was doing the exercise using the device. The VR would be completed with the fun game as if the person was doing the rowing.

4 CONCLUSIONS

This research had an outcome of a design of a bilateral hand movement device that had the aim to increase the motoric function of the non-dominant hand. The device is combined with VR to make it fun while doing the exercise. The person who was doing the exercise would feel as if he was doing the real rowing, according to the game on the VR. It was related to previous researches that mentioned the use of VR was combined with traditional exercise tasks, such as stationary cycling treadmill running, and ergometer rowing, and related also to the exercise of bilateral movement. The device can be seen in Figure 4 to Figure 7.

In the Part Planning matrix, the critical part requirements that had the 2 highest contribution values were notice and Virtual Reality. Future research might include the vibration alert in doing the exercise, the water flow to burden the rower, to make the exercise more real. This research was early research of integrating the device with VR. For future research, it might continue the QFD with Process Planning Matrix and Production Planning Matrix. Other future research ideas are the material test to determine which material would be fit for the exercise tool, and the rowing game software that would integrate hardware, software, and experiment.

ACKNOWLEDGEMENTS

The authors would like to say thanks to Universitas Kristen Maranatha that has given fund research, and to all the respondents that were interviewed.

REFERENCES

Astrid, M., Elly, N., & Budiharto. (2011). Pengaruh Latihan Range of Motion (ROM) terhadap Kekuatan Otot, Luas Gerak Sendi dan Kemampuan Fungsional Pasien Stroke di RS Sint Carolus Jakarta. In *Jurnal Ilmu Keperawatan dan Kebidanan: Vol. 1(4)* (pp. 175–182).

Astuti, R., Thessalona, I., & Setiyawan, D. T. (2020). The Product Quality Improvement: An Example from a Rice Milling in Indonesia. *IOP Conference Series: Earth and Environmental Science*, *515*(1). doi:10.1088/1755-1315/515/1/012005

Cahyati, Y., Nurachmah, E., & Hastono, S. P. (2013). Perbandingan Peningkatan Kekuatan Otot Pasien Hemiparese Melalui Latihan ROM Unilateral dan Bilateral. *Jurnal Keperawatan Indonesia*, *16*(1), 40–46. doi:10.7454/jki.v16i1.18

Chuan, T. K., Hartono, M., & Kumar, N. (2010). Anthropometry of the Singaporean and Indonesian populations. *International Journal of Industrial Ergonomics*, *40*(6), 757–766. doi:10.1016/j.ergon.2010.05.001

Dianat, I., Molenbroek, J., & Castellucci, H. I. (2018). A review of the methodology and applications of anthropometry in ergonomics and product design. *Ergonomics*, *61*(12), 1696–1720. doi:10.1080/00140139.2018.1502817

Erdil, N. O., & Arani, O. M. (2019). Quality function deployment: more than a design tool. *International Journal of Quality and Service Sciences*, *11*(2), 142–166. doi:10.1108/IJQSS-02-2018-0008

Fountaine, C. J. (2018). Unilateral and Bilateral Exercise Movements: Considerations for Program Design. *ACSM'S Health & Fitness Journal*, *22*(3), 11–16. doi:10.1249/FIT.0000000000000390

Jalil Mirmohammadi, S., Houshang Mehrparvar, A., Jafari, S., & Mostaghaci, M. (2006). An Assessment of the Anthropometric Data of Iranian University Students. *International Journal of Occupational Hygiene*, *3*(2), 85–89. http://ijoh.tums.ac.ir

Murray, E. G., Neumann, D. L., Moffitt, R. L., & Thomas, P. R. (2016). The effects of the presence of others during a rowing exercise in a virtual reality environment. *Psychology of Sport and Exercise*, *22*, 328–336. doi:10.1016/j.psychsport.2015.09.007

Nurmianto, E. (2004). *Ergonomi: Konsep Dasar dan Aplikasinya* (2nd ed.). Penerbit Guna Widya, Surabaya, Indonesia.

Okechukwu, M., & Udoka, F. (2011). Understanding Virtual Reality Technology: Advances and Applications. *Advances in Computer Science and Engineering*, *March*. doi:10.5772/15529

Ramadhani, C. (2020). *Manfaat Aktivitas Fisik di Masa Pandemi Covid-19*. https://www.beritasatu.com/kesehatan/628363/manfaat-aktivitas-fisik-di-masa-pandemi-covid19

Rossa, V. (2020). *Terjadi Perubahan Aktivitas Fisik Selama Pandemi Covid-19, Apa Saja?* https://www.suara.com/health/2020/06/17/120231/terjadi-perubahan-aktivitas-fisik-selama-pandemi-covid-19-apa-saja?page=all

Sándorová, Z., Repáňová, T., Palenčíková, Z., & Beták, N. (2020). Design thinking - A revolutionary new approach in tourism education? *Journal of Hospitality, Leisure, Sport and Tourism Education*, *26*, 100238. doi:10.1016/j.jhlste.2019.100238