

# DESIGNING THE IRON SANDBAG FOR KNEE OSTEOARTHRITIS EXERCISE TOOL

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## Abstract

*One of major joint disease in Indonesia is knee osteoarthritis, but unfortunately, this condition is not well supported for the patients to do their treatment due to lack in accessibility of physical exercise therapy which required an expensive and big-sized equipment. In order to solve those problems, this research aims to make a concept of therapeutic aid that has an affordable price and portable size but still has its functionality to help patients with doubtful to moderate severity knee osteoarthritis do physical exercise to reduce their knee's pain. This research applied the stages of product design described by Ulrich and Eppinger (2012) and assisted by the House of Quality to determine the quality improvement of existing products. The results showed that the type of load used is the important factor that needs more attention. The final chosen concept in this research is a design of ankle weights with additional ties with a bag clip and have adjustable weight. This concept is also received good responses based on the result from willingness to pay (WTP) and willingness to use (WTU) which majority of participants would like to use and buy this therapeutic aid.*

**Keyword(s):** Product Design, Physical Exercise, Therapeutic Aid, Knee Osteoarthritis, House of Quality.

## 1. Introduction

Osteoarthritis (OA) is a disease that affects the musculoskeletal system that is not yet known clearly and precisely what causes it. Usually, this disease attacks old people (Ikeda, Tsumura, & Torisu, 2005). One of the most common joints affected by osteoarthritis is the knee-joint where the knee becomes stiff and painful when moved or given pressure and causes joint space become limited than usual (Buckwalter, Mankin, & Grodzinsky, 2005).

In Indonesia, OA is also the most common joint disease compared to cases of other joint diseases. Based on WHO (2017), around 8.1% of the total population is infected with osteoarthritis. However, only 29% of them do a doctor's examination directly, the rest only rely on themselves by consume pain-free drugs. This is because of their lack of knowledge related to the disease and the limitations of access in therapeutic tool for physical exercise to reduce pain due to osteoarthritis because of the high price and large size.

As explained by Zhang et al. (2013) this form of physical exercise may help prevent the progression of osteoarthritis. However, not all physical exercise can be carried out by most of the patients because usually only patients with the lowest to moderate severity of the disease can do it (Holland & Morrison, 2018). Prevention by doing physical exercise is considered to reduces levels of cytokines in the synovial fluid of the joints and inhibit the process of cartilage degradation and improve symptoms that arise. In other words, this form of therapy can also be carried out by a healthy person who has risk factors. The physical exercise consists of strengthening muscles, flexibility, and aerobics. There are several therapeutic devices which are usually used in hospitals in the city of Semarang which have been researched and proved to be beneficial in reducing knee-pain related to osteoarthritis, such as En-Tree (Kusumawati, 2003) sandbags, static bikes (Karman, 2016), *Theraband* (rubber band) and Quadricep Bench (Suriani & Lesmana, 2013). Based on an interview with one of the medical doctor, Dr. Hari Peni Julianti, Sp.KFR, M.Kes, there are some disadvantages from each tool such as the high cost of the tool and its large size, especially the En-Tree and static bicycles. Other than that, usually the problem is lack of attention to the comfort and safety factors in the

design, especially on the existing sandbag and rubber band tools, so that injuries to the user often occur. Those problem which occur on the existing tools encourages the need for a device that can be used with portable-size and at an affordable price, especially for patients of osteoarthritis with lowest to moderate severity. Both of these factors are expected to provide wider access to patients to be able to do physical exercise therapy better.

This study uses the stages of the product concept development phase by Ulrich and Eppinger (2012) which consists of 6 stages, i.e. identification of user needs, setting target specifications, conceptualization, concept selection, concept testing, and determining final specifications. Then in the stages of identifying user needs until the selection of the concept is assisted by using the House of Quality method which is part of Quality Function Deployment (QFD) stage (Ginting, 2013). As described by Harne and Deshmukh (2017). the HOQ method is expected to describe the needs and desires of consumers from patients, doctors or physiotherapists and define them into a more detailed form of product specifications for physical exercise tool. In concept testing phase, questions about Willingness to Use and Willingness to Pay are using the similar form that have been elaborated by Aumann et al. (2016) and Ulrich and Eppinger (2012) to participants targeted by consumers and users.

## **2. Methods**

This research uses descriptive research method in which the purpose of the research is to get a solution to the problem in the form of a concept design tool for knee-osteoarthritis based on problems from real situations that occur (Sugiyono, 2008). As explained previously, the method used is the House of Quality (HOQ) and use the development of product concepts based on Ulrich and Eppinger (2012) which have stages in detail as follows:

- a. Identification of user needs, this stage helps to find and get inspirations for product development that going to be made (Widodo, 2005) Data collection is done by collecting data from questionnaires and interviews related to the need for products.
- b. Established target specifications, this stage aims to redefine the needs of users based on the identification stages in the form of target specifications. Besides, this stage is helped by HOQ to determine the relative importance of product attributes, evaluates the attributes of existing products, creates a matrix of relationships between attributes and product characteristics, identifies relationships between technical characteristics and product attributes and relevant interactions among fellow technical characteristics, and determines the target to be achieved.
- c. Generate product concept, this stage aims to produce several alternative concepts by generating concepts using the Morphological Chart. Then, those possible alternatives are made into illustrations using Solidworks software. After that, each alternative has to be estimated at its price.
- d. Concept selection, this stage aims to filter the concepts that have been made using the Pugh Matrix based on the specified selection criteria.
- e. Concept testing, this stage aims to get information from participants related to the concept that has been made whether the product concept will be purchased and will be used (Aumann, Treskova, Hagemann, & von der Schulenburg, 2016) by the target user.
- f. Set final specifications, this stage aims to conclude the results of the previous stages related to which concepts and what changes are needed for the concepts to be realized later.

## **3. Findings**

### **Phase 1: Identification of Needs**

This stage was carried out by collecting data from questionnaires and interviews to determine the needs and the attributes of needs of knee osteoarthritis therapeutic tool for physical exercise. The needs identification questionnaire is divided into 2 stages. First, an open-question questionnaire consisting of questions related to the factors that need to be considered, how to use it, and the likes and dislikes of existing tools. The second questionnaire is a closed-question questionnaire that aims to see the responses of the attributes of the needs obtained from open questionnaires and also test it with the reliability and validity tests.

The participants involved in this stage questionnaire consist of 30 participants. This number was chosen based on a minimum number of samples for descriptive research stated by Gay and Diehl (1992) and also Mahmud (2011). The participants consist of patients, doctors, nurses, practitioners (elderly gymnastic instructor), and academics from public health.

The first questionnaire obtained primary attributes that shown in Table 1. These primary attributes are then break down based on the statement of needs obtained into more detailed form as secondary attributes that presented in Table 2. The description of the primary and secondary attribute is based on the statement of the participant.

Table 1. Primary Attribute of Needs

No	Primary Attribute(s)	Statement of Need(s)
1.	Comfort	Tools must be comfortable when used
2.	Safety	The tool is safe to use and does not cause injury
3.	Price	The tool has an affordable price and competes with existing products
4.	Dimension	The tool has a small size and lightweight
5.	Function	The tool is considered to have benefits to help therapy
6.	Ease of Use	The tool has an adjustment to the amount of weight used and ties that are easily worn and adjusted.
7.	Material	The tool is made with durable materials
8.	Load	The tool has a simple form of loading
9.	Aesthetics	The tool has a color that is not flashy with simple patterns

Table 2. Secondary Attribute of Needs

No	Secondary Attribute(s)	Statement of Need(s)
1.	Type of Tie	This type of ties can use velcro and can be adjusted with adjustable straps with bag clips
2.	Form of Load	The type of load can be in the form of iron sand bag or rubber band which can be adjusted in weight and have small size.
3.	How to Use	By tying the tool or the load on the lower leg
4.	Tool Color	The tool has neutral color (e.g: black, white or grey)
5.	Type of Material	The type of material that can be used is elastic, soft and has a strong durability
6.	Number of components	The number of components is made as little as possible and simple arranged so that the price is not expensive and does not take up much space
7.	Load Placement	Placement of the load is made so it is not easy to slide, detached, and not in contact with skin directly
8.	Form of Exercise	Form of exercise can be done by standing, sitting or sleeping and it is adjusted to the physical exercise guidelines or protocol for knee-osteoarthritis

Secondary attributes that shown in Table 2, then converted into questions and asked through closed questionnaires with 5-point rating scale to the same 30 participants. The result of the closed questionnaire shows that the questionnaire and attribute needs are valid and reliable with Pearson Correlation values,  $r_{count} > 0.361$  for each attribute needs and Cronbach's Alpha value  $0,694 > 0,6$ . Other than that, the responses from participants also show that all attributes that have been made get a good response based on its mode value for each attribute question.

### Phase 2: House of Quality (HOQ)

At this stage, five people were chosen as experts that representing a doctor, academics from public health, elderly gymnastics practitioners, male and female patients as a cross-function team with the reason that all participants were considered to have understood well how the therapy exercise in reducing pain on knee joint due to osteoarthritis is done, so that all of them are expected to provide a variety of viewpoints of answers (Tsai et al., 2008). These five participants assisted in making HOQ by filling out questionnaires about "Importance to Customer" and "Current Satisfaction Performance".

The final output of the House of Quality is shown in Figure 1, with the analysis and related explanation as follows:

#### a. Defining Technical Characteristics

This section is shown in the vertical column which contains the translation of the statement of need into metric specification. The technical characteristics consist of "Tie length", "Load weight", "Load size dimension", "Load compartment dimension", "Tool Dimension", "Material strength", "Number of components", and "Price"

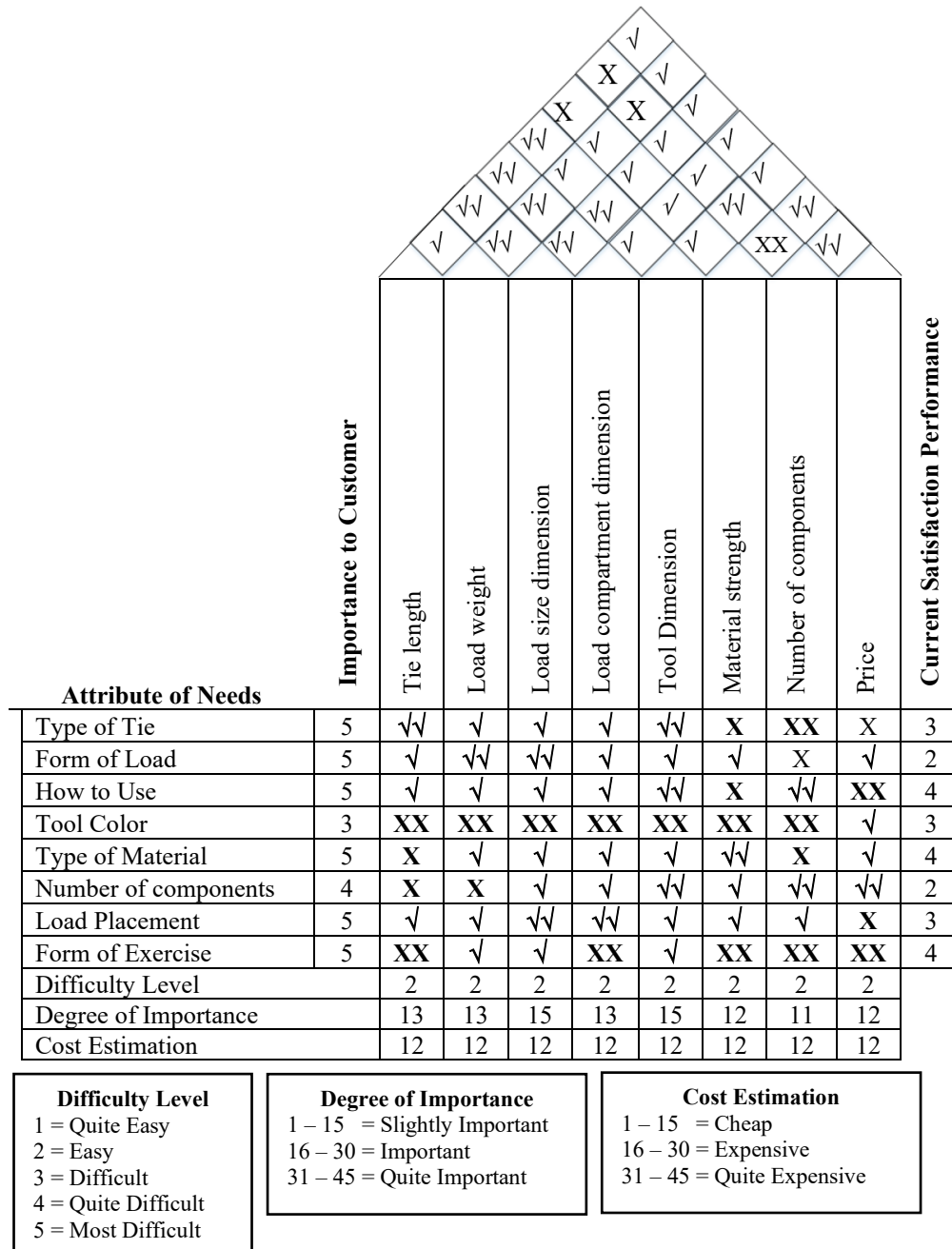


Figure 1. House of Quality

b. Importance to Customer

The importance level of product needs for HOQ is determined in the form of relative importance (Cohen, 1995) with a 5 point scale (Very unimportant, Unimportant, Neutral, Important, and Very Important). The assessment is based on the median value (Boone & Boone, 2012) of all participants' answers obtained from each attribute of the needs.

c. Current Satisfaction Performance

Similar to The Importance to Customer, the only difference is the 5-point scale description used. There are "Very Dissatisfied", "Dissatisfied", "Neutral", "Satisfied", and "Very Satisfied". The assessment is based on the median value (Boone & Boone, 2012) of all participants' answers obtained from each attribute of the needs.

d. Relationship between Attributes and Technical Characteristics

This step aims to assess the relationship between product attributes that placed on the horizontal part and the technical characteristics of the vertical edge on the top of HOQ. Then, the assessment is done by giving a score that aims to show how strong the level of relationship between both of them. The score written used a symbol as follows (Ginting, Ishak, & Widodo, 2019):

- √√ : 4 (Strong relationship)
- √ : 3 (Moderate relationship)
- X : 2 (Weak relationship)
- XX : 1 (No connection at all)

e. Relationship between Each of Technical Characteristic to another

This step aims to assess the relationship between one technical characteristic to another with the explanation of the relationship score as follows (Ginting et al., 2019):

- √√ : 4 (Strong relationship)
- √ : 3 (Moderate relationship)
- X : 2 (Weak relationship)
- XX : 1 (No connection at all)

f. Calculating The Performance Measures of HOQ

In this step, the performance measures of HOQ calculated consist of three aspects, i.e. Difficulty Level, Degree of Importance, and Cost Estimation (Ginting, 2013). These values are obtained based on the values that exist in the relationship in the matrix relationship of attributes with technical characteristics, as well as on the matrix of relationships between each of technical characteristics to another.

From the house of quality output (Figure 1). It could be said that “Form of Load” can be prioritized in the next step based on the score obtained which has highest gap score between “Current Satisfaction Performance” and “Importance to Customer”. The Performance Measures of HOQ shows that all of technical characteristics got “Easy” for the Difficulty Level, “Slightly Important” for the Degree of Importance, and “Cheap” for the Cost Estimation.

**Phase 3: Concept design**

This step starts by generating alternative concepts using the Morphological Chart (Ginting, 2013). The concepts are formed based on combinations of options on each product attribute that considered could fulfill the needs. This process obtained 2 concepts of footband with iron sandbag. The details shown in Table 3.

Table 3. Concept Obtained from Generating Concept Through Morphological Chart

Product Attribute	Concept Obtained from Morphological Chart	
	Concept 1	Concept 2
Form of Load	Iron sandbag	Iron sandbag
Type of Tie	Velcro	Velcro and Clip Bag
How to Use	Fastened on the lower-legs	Fastened on the lower-legs
Type of Material	Neoprene and Spandex	Neoprene and Spandeks
Load Placement	Placed on compartment(s)	Placed on compartment(s)
Form of Exercise	Sitting, standing, and sleeping	Sitting, standing, and sleeping
Tool Color	neutral color (e.g: black, white or grey)	neutral color (e.g: black, white or grey)

Those 4 concepts then made into illustration using Solidworks. The tool dimension was made based on anthropometric dimension data of Indonesian and Singaporean feet (shown in Table 4) from Chuan, Hartono, and Kumar (2010) and also dimension from existing tools.

Table 4. Anthropometric Dimension Data Used

No	Dimension Name	Percentile	Overall Dimension (cm)
16	Popliteal Height	50th	43
30	Foot Length	50th	26
31	Foot Breadth	50th	10

**Phase 4: Selection and Testing Concept**

This step is carried out from online questionnaire which contains information related to the description, illustration, using instruction of each product. The Participants on this step consist of 24 people who considered as market target who would like to use, buy or recommend it. Those criteria of participants are as follows:

1. Have/had knee-osteoarthritis
2. a medical staff(s)
3. Practitioner (e.g: instructor of elderly gymnastics)
4. Have relative or family who suffer from knee-osteoarthritis
5. Have a risk to suffer knee-osteoarthritis (based on age)

Participants then were asked about which concept is better based on attribute of needs and asked about how likely they want to try to use it and buy each of those concept (*Willingness to Pay* and *Willingness to Use*).

**Concept Selection**

This step is processed based on the information and responses obtained from the questionnaire. Pugh Matrix is used as form of selection approach method Ulrich & Eppinger (2012). The selection criteria used are from attribute of needs that considered can be described through questionnaire. The criteria consists of comfort, safety, ease of use, load, and price.

The selection process is carried out in each concept, where concepts 1 is used as reference concept because concept 2 can be considered as development of concept 1. Those concepts are rated by using a simple code (+ for “Better than”, 0 for “same as”, - for “worse than”). The concept selection matrix is shown in Table 5. The decision for the iron sand concepts is concept 2 with a final score of 1. This result is in line with the acquisition of data answers obtained where the majority of participants chose the concept 2.

Table 5. Concept Selection

Selection Criteria	Concepts	
	Tool of Iron Sandbag	
	1 (ref)	2
Comfort	0	+
Safety	0	+
Ease of Use	0	-
Load	0	0
Price	0	0
Sum of +		2
Sum of 0		2
Sum of -		1
Final Score		1
Decision?		Yes

In addition, based on the results of the questionnaire. Concept 2 was considered to be more comfortable and safer to use than the Concept 1. Since the concept 2 has additional ties with a clip bag that can be tighten more than the concept 1 that only using Velcro, and more suitable for person with bigger size of lower feet. But this additional ties for concept 2 make the concept was considered to be harder to use than the concept 1.

### Concept Testing

After all, off those concepts have been estimated at its price which concept 1 and 2 are estimated at 99,500 IDR to 105,000 IDR. This information then used in this stage to make sure that the estimated price is accepted by participants or not (willingness to pay, WTP). Other than that, participants are also asked about how likely they want to use (willingness to use, WTU) the concept or recommend it to their relatives or family. The result is shown in Figure 2.

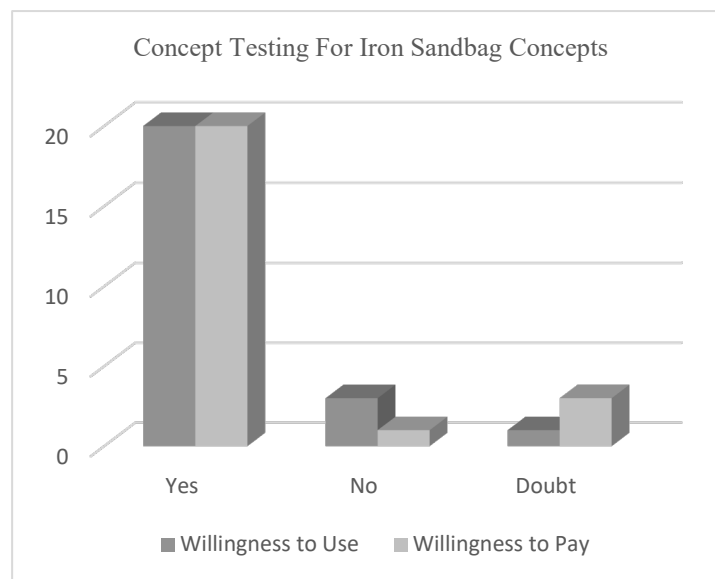


Figure 2. Bar chart of willingness to use (WTU) and willingness to pay (WTP)

Both WTU and WTP analysis can conclude that most of or majority of participants are willing to pay the all of the concepts and use them if it already available on market. More details on WTU, it is shown that 20 people (83,33%) answered “yes”, 3 people answered “no”, and 1 person answered “doubtful”. On WTP, it is revealed that 20 people answered “will buy or pay” (83,33%), 1 person “refuse to buy”, and 3 people are “doubtful”.

### Phase 5: Chosen Concept

Overall, based on the concept selection, concept 2 was obtained on the selected iron sand loading tool. The reason are the differences in how it is used which results in variations of exercise’s movements which has other side benefits compared to concept 2 besides from helping reduce knee joint pain due to osteoarthritis.

The illustration for concept 2 is shown on Figure 3 and 4. This concept uses the same working principle as concept 1 which is tool with iron sandbag placed in a plastic tube (polypropylene) with a diameter of 1 cm with a length of 10 cm and a weight of about 125 grams. So that the total weight load that can be given by the tool is around 1.25 kilograms (with 10 tubes). The ties are extended through clip bag to improve the strength of ties especially for people who have bigger diameter of lower feet. This tie can be adjusted its length like a bag strap.

## 4. Conclusion and Suggestion

From the results of the research that has been done, it can be concluded that the use of the HOQ can help to identify the needs related to tool for knee osteoarthritis therapy exercise. This step obtained 9 primary attributes and 8 secondary attributes. The translation of these attributes resulted in 8 technical characteristics. One of the results from the HOQ is that the type of load used was an important factor in the design of knee osteoarthritis therapy exercise tool.



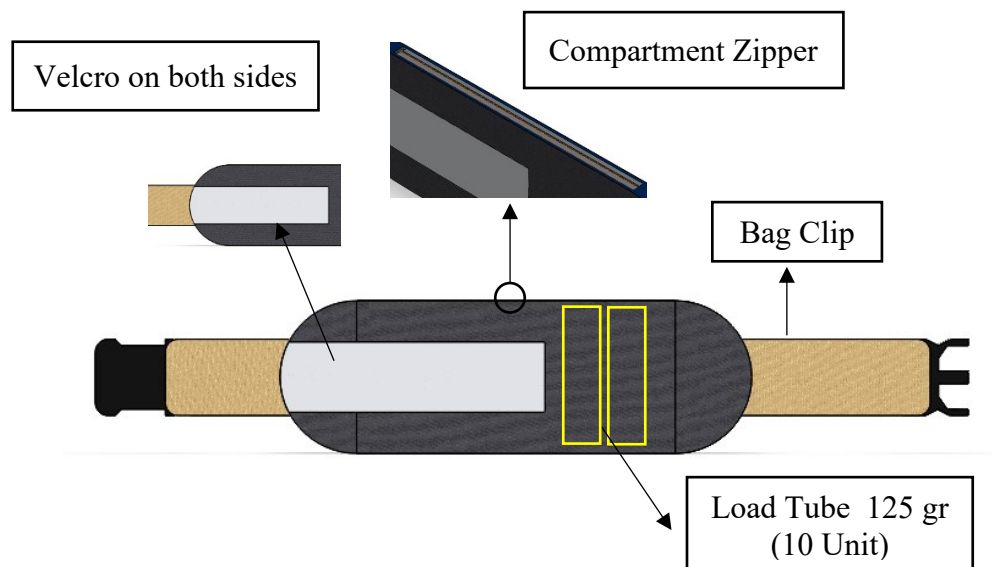


Figure 3. Illustration of Concept 2

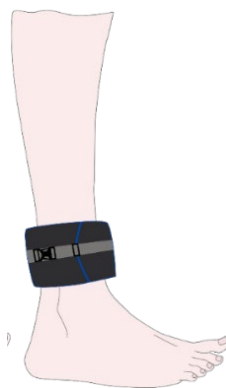


Figure 4. Illustration of Concept 2 when used

At the concept design stage, 2 concepts were chosen from generating concept through Morphological Chart because they are considered to be able to meet the needs of the user's statement. That concept are based on tools with iron sandbag loading

From the results of concept selection, it was found that concept 2 is the most appropriate to be continued in the form of prototype because it is considered to have better expectations to fulfill the needs of the concept, especially if it seen through its comfort and safety.

The test results show that the tool that have been made can be accepted by consumer target, indicated by the number of participants who are willing to buy and will try compared to those who are not or doubt.

Suggestion that can be given based on the implementation of this study is to involve more participants, especially for doctors and nurses who handle as physiotherapists. Then, make more appointments to go directly to see how physical therapy is is given to get a clearer and detailed picture related to determining restrictions such as the weight of the device that can be given and the ability of patients to perform physical movements. In addition, participants from groups of patients are better to be grouped first based on their severity of their knee osteoarthritis. This is useful to get the right information of the needs regarding the target users of osteoarthritis therapy tool exercise made.



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