Application of the Total Ergonomics in Designing Functional Prosthetic Ankle with Low Cost in Indonesia

L Herdiman¹, S Susmartini² and I Priadythama³

¹²³Industrial Engineering Department, Universitas Sebelas Maret, Kentingan, Solo, Indonesia

E-mail: lobesh@gmail.com

Abstract. Prosthetic foot is an amputee's need to fulfill their functional activities. In Indonesia, prosthetics with functional ankle foot are still imported from developed countries. The purpose of this paper is how to apply the total ergonomics in designing prosthetic ankles for below-knee amputee as functional at a low-cost. The total ergonomics is applied to produce prosthetic ankle designs by integrating design needs through a systemic and holistic approach, and manufacturing needs through an interdisciplinary and participatory approach. The qualitative research method with Focus Group Discussion (FGD) to discuss the design of prosthetic ankles through several questions discussed. Participants in the discussion, according to their respective fields of expertise were 14 people, including 1 orthopaedics doctor, 2 experts in making prosthetics, and 7 people using below-knee prosthetic foot, 2 product designer experts, and 2 metal workshop experts. All participants were asked to provide input on the prosthetic ankle design requirements. This study produced a prosthetic ankle design in cases of below-knee amputee that has a multi-axis capability, energy store-return, according to local conditions, culture, economy, and available materials, allowing them to increase their mobility.

1. Introduction

The lack of one foot due to amputation makes a person's life an amputee [1]. In the case of below-knee amputee with an important part of the prosthetic foot component, it's namely the sole of the foot or SACH (Solid Ankle Cushioned Heel), shank and prosthetic socket [2]. Prosthetic soles are made of neoprene crepe or polyurethane foam which is shaped to resemble the sole of a human foot [3]. The foot shank system is made from pylon, which is installed vertically to hold the user's body weight [4]. Prosthetic socket components fit around the leg or stump [5]. Through the socket allows the user when using a prosthetic foot to make changes according to alignment when starting to walk [6]. Medically, SACH foot is needed to replace the missing anatomical shock absorber mechanism, to reduce the force transferred to the amputated foot and pressure on the proximal joint during walking [7]. Functionally, there are many suggestions for several SACH foot designs ranging from passive to active offered by prosthetic foot developers.

SACH foot can help an amputee in reducing the impact load during the phase of the heel strike, storing and releasing a little elastic energy from the selection of material, potentially helping to increase gait [8]. An amputee in walking experiences differences compared to not amputee even at the same speed [5]. South et al. [7], to explain this difference arises when mobility with a number of problems with biomechanics include changing walking speed, variations of muscle excitation patterns between two legs, increased gait asymmetry, and force loading on intact feet. Hafner et al. [8], to explain that during mobility prosthetic ankles should be able to store elastic energy during the stance.
phase, and release some energy in the toe-off phase to help push and initiate foot swing. Many prosthetics foot have been designed and manufactured using carbon fiber materials, composite materials with high strength and light weight, enabling the success of ankle foot with energy stores and returns to support mobility.

On the other hand, on users in Indonesia, that the factors that influence an amputee or his family in choosing a prosthetic foot characteristic depend on their purchasing power. In 2014, Indonesia was a developing country with an income of approximately US $ 11.905 [9]. Supported by the results of a household survey on health and disability in the population aged > 18 years, which explains the prevalence of social strata Q1 (poorest) and Q2 higher than other quartiles [10]. A threshold value of 40, which is 22.4, is a person with a disability who experiences significant difficulties on a daily basis, a threshold value of 50, which is 3.6, has significant difficulties [11]. In general, amputee social strata in the country of Indonesia are in Q1 and Q2 quartiles with low purchasing power. In this condition, they prefer to use passive prosthetic foot at low prices even though the design is simple without any flexible parts or no articulated, more cosmetic considerations. This it’s prosthetic foot, functionally less supportive of the user and looks stiff to walk. All of this information is important in cases of amputation below-knee in designing functional prosthetic foot at a low cost to meet the needs of various social strata. It is the use of nylon polymer materials and available in developing countries for manufacture of prosthetic ankles at a low cost.

To date, there have been no systematic studies in identifying the need for prosthetic ankle design in cases of below-knee amputee in a subjective way. The total ergonomics is used in solving this problem in designing prosthetic ankles with a focus on multidisciplinary ways of thinking and acting [12]. The total ergonomics is carried out through FGD through the SHIP approach (Systemic, Holistic, Interdisciplinary, and Participatory) and applying appropriate technology to design [13,14]. The implementation of this activity is carried out with consideration that is practiced in implementation, time, and cost [15]. The SHIP approach is a problem-solving effort in the case of the stages of designing prosthetic ankles for below-knee amputee, related to manufacturing needs in the process of making prosthetic foot at a low cost [16]. The application of appropriate technology through simple but advanced technology [17], as a consideration in designing prosthetic ankles in cases of below-knee amputee that does not require excessive care, relate to local culture, availability of resources, can overcome problems, has functional and cosmetics that are good, and reach a better usability to be used amputee. The aim of study is to seek input through the application of the total ergonomics to design prosthetic ankles for the below-knee amputee. The results are expected from study to obtain describe that has the ability to multi-axis motion, energy store-return, and lighter prosthetic foot weight. Thus, the design of prosthetic ankles in this study by applying appropriate technology to enable manufacturing processes that are precise, cost effective and functional to meet the needs of users.

2. Methodology

Ethics and R&D approval was obtained from the Research Ethics Committee of Universitas Sebelas Maret Surakarta and Orthopaedic Hospital Prof. Dr. Suharso Surakarta. Cause of the limitations of research time, convenience sampling method is used to recruit participants [18]. Participants in the discussion represented 14 areas of expertise, including 1 medical rehabilitation doctor, 2 experts in making prosthetics, 7 people below-knee amputees with prosthetic foot users, 2 product designer experts, and 2 metal workshop experts. A qualitative approach to the total ergonomics is carried out to answer structured questions, conveyed by interviewers in Focus Group Discussions. Data collection is through the views of each participant based on their experiences and expectations. The application of total ergonomics includes the implementation of the SHIP approach through questions with a questionnaire of 20 items, and how to apply appropriate technology to design prosthetic ankles is done through questions with a questionnaire of 7 items. Therefore, the FGD method is used as a tool to obtain perceptions from medical parties and young adult participants, experiencing amputations below the knee. Implementation of the total ergonomics with several steps as described in Figure 1.
The application of the total ergonomics begins with (1) identifying the problem of ambulation in below-knee amputee by evaluating all eight aspects of ergonomics; (2) problem analysis using the SHIP (Systemic, Holistic, Interdisciplinary and Participatory) approach, the resulting outcomes are the priority scale of completion; (3) designing prosthetic ankles by applying appropriate technology; (4) making work drawings for working on prosthetic ankles; (5) the manufacturing process and constructs between prosthetic ankles and other prosthetic components; (6) assemble prosthetic ankles and other prosthetic components into below-knee prosthetic foot.

3. Result and Discussion

The group division in the interview was divided into 2 discussion groups from the 14 people involved. In the first FGD as Group 1, it was held at Orthopaedic Hospital Prof. Dr. Soeharso Surakarta, the participants came from the hospital as much as 7 people consisting of 1 medical rehab doctor, 2 experts making prosthetics, 2 product designer experts, and 2 metal workshop experts. Participants discussed their hopes for the rehabilitation process, such as how long they thought it would take, who they thought would be involved, what the process might be and when certain problems would occur during the process. Followed by the second FGD as Group 2 held at the prosthetic workshop CV. Yogamandiri Surakarta, attended by 7 people from prosthetic foot below-knee users, where 5 participants came from the Balai Besar Rehabilitasi Sosial Bina Daksa Fisik Prof. Dr. Soeharso Surakarta and 2 independent participants. In the second FGD all participants involved were below-knee amputee with consideration to meet the needs of below-knee prosthetic foot. Participants were given written information about the purpose of the focus group, the consent form and a brief questionnaire the researchers designed, gathering demographic details and initial information. Before the interview, all FGD participants filled with a number of demographic questions, such as age, cause of amputation, medical history, social acceptance, product price expectations, and could accommodate users. Then the discussion participants were asked about what they thought about prosthetic foot they might receive, with questions that focused on the expectations, aesthetics, comfort, use, and acceptance of limbs when using prosthetic foot. At the end of this session, participants were asked about their life expectancy with a prosthetic foot such as their independence in their daily activities.

An amputee who participated in this study, they were aged between 19 to 32 years, had amputated in the last 2 weeks, had been referred to prosthetic foot; interviewees involved were those who had amputations due to traffic accidents. Characteristics of the subjects are male, age range (22.14±4.60) years, body weight (67.15±10.56) kg, body height (165.00±10.24) cm, length of time using prosthetics foot between 1 to 9 years, good nutrition indicated by a normal body mass index (18.61 to 24.5 kg/m²), four amputees living with family, two amputees living with their wives, and one amputee staying independent, as explained in Table 1.
Table 1. Demographic characteristics of participants from amputee

| Participants | Gender | Age (years) | Level of Amputation | Position Leg Amputation | Prosthetic Wearing (years) | Cause of Amputation | Social Situation       |
|--------------|--------|-------------|---------------------|-------------------------|---------------------------|---------------------|-----------------------|
| AT1          | Male   | 32          | below-knee          | Right                   | 9                         | Traffic accident    | Lives with wife       |
| AT2          | Male   | 22          | below-knee          | Left                    | 5                         | Traffic accident    | Lives with family     |
| AT3          | Male   | 19          | below-knee          | Right                   | 2                         | Traffic accident    | Lives with family     |
| AT4          | Male   | 19          | below-knee          | Right                   | 1                         | Traffic accident    | Lives with family     |
| AT5          | Male   | 20          | below-knee          | Right                   | 2                         | Traffic accident    | Lives with family     |
| AT6          | Male   | 20          | below-knee          | Right                   | 1                         | Traffic accident    | Lives alone           |
| AT7          | Male   | 23          | below-knee          | Right                   | 1                         | Traffic accident    | Lives with wife       |

The implementation of this FGD is to obtain in-depth information about the perceptions, attitudes and experiences of the participants. Furthermore, this information to be further understood by researchers in solving the desired problem from the diversity of perspectives between groups. Researchers need additional information on quantitative data, involving technical issues and broad implications. Participants express their opinions and input in order to obtain a good, accurate value because they hear directly from the research subject as explained in Figure 2.

The SHIP approach is an attempt to seek input in designing active prosthetic ankles. This input is useful to measure how important the planned ankle, which has the ability of dorsi flexion-plantar flexion, inversion and eversion, and is able to store and return energy for requirements below-knee prosthetic foot to be comfortable. Systemic and holistic elements are extracting information about the voice of design (VoD) from medical, prosthetic & orthotic experts. Meanwhile, interdisciplinary and participatory elements are extracting information about the voice of manufacture (VoM) from metal workshop experts, manufacturing designers, and amputees. The SHIP approach brings new ideas in a balanced way between the fulfilsments of prosthetic foot product designers and the ease in the manufacturing process based on extensive manufacturing experience. Another consideration for making prosthetic ankles with the low cost can provide value at the beginning of the process, mainly through two aspects, namely design for value and design for cost, the diagram in Figure 3.

Systemic and holistic are the design attributes in the process of finding out what is needed, brainstorming possible ideas, and creating prototype descriptions of new products. Interdisciplinary role is to determine the technical feasibility of technology in the cost of manufacturing products and the cost of commercialization. Participatory that all the participants involved in problem solving are
involved to achieve maximum results. The SHIP approach in its implementation aside from gathering information from participants in the FGD but requires more exploring creative ideas in innovation, better products, new ideas, being able to respond to challenges, wider manufacturing experience, better design capacity, and ensuring work done.

Figure 3. SHIP approach in designing prosthetic ankles

Evaluation of the SHIP approach using a questionnaire, designed with 20 questions with a Likert 4 scale (disagree to strongly agree), as described in the Appendix. All question items are proposed to determine how much the reliability and validity of each question submitted. The correlation test results show that each assessment group \( n = 7 \) with the value of \( r \) table (0.754) at the level of 95% or 5% level of significance, indicates a good correlation. Group 1 gives Cronbach Alpha (\( \alpha \)) 0.901 and Pearson Correlation (\( r \)) with \( r > r \) table and sig. (2-tailed) < 0.05 which shows that the questionnaire is reliable and valid for Group 1. In Group 2 gives Cronbach Alpha (\( \alpha \)) of 0.962 and Pearson Correlation (\( r \)) with \( r > r \) table and sig. (2-tailed) < 0.05, which shows the same results as Group 1.

Group 1 gave a positive response with a scale value of 2.71, this shows that prosthetic ankles for below-knee prosthetic foot must meet the minimum requirements in improving the ability of amputee namely comfort while walking, walking balance, satisfaction while walking, self-confidence, meeting technical standards in biomechanics, modern technology, involving medical rehab doctors, always involving physicians, the application of this technology has been always experts in prosthetic workshops, and the application of this technology always involves material experts. Conversely, prosthetic ankles must also be met with maximum requirements with a scale value of 3.43, where the technology designed is to improve walking, provide a sense of security, be in accordance with amputee characteristics, must pay attention to anthropometry, and this technology is sufficient with materials obtained in the market. Whereas, Group 2 gave a positive response with a scale value of 2.29, this shows that prosthetic ankles must meet the minimum requirements is the application of this technology can increase satisfaction while walking. Conversely, prosthetic ankles must also be met with the maximum value of a scale value of 3.14, where this technology must be in accordance with the needs of the below-knee amputee.

An amputee with a prosthetic foot for, will, during walking must be understood as a system, exerting influence on the condition and ability of the amputee. In meeting the needs of prosthetic ankle design was, according to the questionnaire questions submitted by FGD participants. This design aims to provide absorption, equivalent to normal ankles without the use of articulated ankle joints. The prosthetic ankle function is designed so that the amputee can walk more naturally and ergonomically starting the swinging phase of the prosthetic foot and the initial foot, supported by minimal contraction of the leg muscles. Su et al. [19] explain that prosthetic ankle movements can improve swinging walking movements and are easy to control when walking. The application of ankle design with appropriate technology is representative of social and cultural innovation, the usefulness or value of a technology must be consolidated by the social, cultural, economic environment in which the
technology is used. A publication of the results of the consensus conference International Society for Prosthetics and Orthotics (ISPO) about orthopaedic technology that is appropriate for low-income countries, that needs prosthetic endure at least 3-5 years [20].

The appropriate technology questionnaire was distributed to two assessment two groups. Appropriate technology with 7 characteristics is divided and converted into 26 question items; it can be shown in Appendix. The questionnaire on appropriate technology was designed with 26 questions with a Likert scale of 4 (disagree to strongly agree). The items in question were all about the technological criteria used in the design of the proposed prosthetic foot that had fulfilled the requirements of each technological characteristic. Questions from the appropriate technology questionnaire for each characteristic item are divided into 6 questions for technical feasibility, 4 questions for economics, 6 questions to meet ergonomic / health requirements, 4 questions for social and cultural acceptance, 2 questions for energy savings, 2 questions for friendliness environment, and 2 questions for trendy.

Correlation test results from the questions on the appropriate technology questionnaire showed that all assessment groups \( n = 7 \) with the value of \( r \) table \((0.754)\) at the level of 95% or 5% level of significance, indicating a good correlation. Group 1 gives Cronbach Alpha (\( \alpha \)) 0.955 and Pearson Correlation (\( r \)) with \( r > r \) table and sig. (2-tailed) < 0.05 which indicates that the questionnaire was reliable and valid for the first group. Group 2 gave Cronbach Alpha (\( \alpha \)) of 0.930 and Pearson Correlation (\( r \)) with \( r > r \) table and sig. (2-tailed) < 0.05 which shows the same results as Group 1.

The results of the application of the appropriate technology questionnaire for prosthetic ankle design showed that in group 1 giving responses in the third characteristic section (fulfilling ergonomic / health requirements) obtained a scale value of 2.69, indicating that multi-axis movement capability and energy store-return prioritize amputee balance in walking to achieve a trendy design, where ratings are low (2.50). Meanwhile, the scale value of 2.93 in the technical feasibility section shows that granting a size tolerance (0.01 mm) to facilitate local manufacturing engineering. Group 2 gave responses on the third characteristic section (fulfilling ergonomic / health requirements) getting a scale value of 2.81, indicating that the ability of multi-axis movement and store-return energy prioritizes the amputee balance in walking to achieve a trendy design. Whereas, it the scale value of 2.93 in the technical feasibility section shows that the material used in designing prosthetic ankles prioritizes easily obtained in the local market. The results of responses from both groups can be explained in Figure 4.

![Figure 4. Perception between Group 1 and Group 2 in the application of appropriate technology](image-url)
The difference in perception between Group 1 (medical rehab and prosthetic foot developer) and Group 2 (amputee), allows researchers to describe technical needs. Medical rehabilitation and prosthetic developments in Group 1 is emphasized more on technical feasibility, and amputee in Group 2 is emphasized trends and technical feasibility. Furthermore, how appropriate technology can be distributed and used depends on several parameters, namely designer skills, manufacturing processes, and the purchasing power of people, especially the poor, because this constitutes the majority of the population in low-income countries. Applying appropriate technology is considering the ability of all people with disabilities with the conditions of their social strata.

Describing the design needs by identifying the design needs into technical requirements, there it’s 2 mains information. First, this information starts from the use of materials for manufacturing prosthetic ankle joints which is grey HDPE plastic (nylon polymers). This material selection is mainly to support the completion of all low-cost manufacturing process operations in order to obtain a price that can be purchased by the user. This material has a lighter weight ratio than aluminium (Al 6061), commonly used as a prosthetic foot component in developing countries. This material is also easily formed with conventional machine tools in the end at low cost for production costs. Furthermore, the second information is prosthetic ankle design to meet the requirements of the biomechanics of movement, store-return energy function, it is possible to use 4 springs (2 fronts and 2 behind) to activate the quadriceps and hamstring muscles in the femur to regulate movement hip joint when walking. Prosthetic ankles are designed in the direction of the dorsi flexion-plantar flexion and eversion-inversion through a spherical plain bearing component mechanism that is placed in the centre of the SACH foot axis, so that it can adjust automatically during walking on the floor surface even though there are different heights, the technical requirements can be illustrated in Figure 5.

![Figure 5](image_url)

**Figure 5.** Perception between Group 1 and Group 2 in the application of appropriate technology

In Figure 5 explains where two functional components for prosthetic ankle, the use of four springs and one spherical plain bearing, are placed between the bottom adapter and the upper adapter.

4. Conclusions

New challenges in designing ankles by applying the total ergonomics in developing countries such as in Indonesia, given the conflicting design requirements, such as questionnaires submitted in discussions at the FGD. The ankle component must meet the functional qualifications, because it will be more widely used by active young adult individuals. However, at the same time the technology applied must take into account price, durability, and culture and environment. Applying appropriate technology provides opportunities to overcome prosthetic limitations, but more research and development is needed. These include increasing the durability of the external cosmetic features of the prosthetic foot, developing a more functional prosthetic ankle joint, and simplifying manufacturing techniques to improve yields with socket fittings and alignment of the prosthetic foot area.
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Appendix

The SHIP approach questionnaire and The Appropriate Technology questionnaire

| No. | Questions in the SHIP Approach | 1 | 2 | 3 | 4 |
|-----|---------------------------------|---|---|---|---|
| 1   | How do you assess the need for prosthetic ankle design in order to obtain the ability of dorsiflexion-plantar flexion, evertion-diversion, and be able to store and return energy, so as to improve walking as natural as possible? | Disagree | Quite Agree | Agree | Strongly Agree |
| 2   | How do you assess prosthetic ankle design needs in order to obtain the ability of dorsiflexion-plantar flexion, evertion-diversion, and be able to store and return energy, so as to provide a sense of security in use while walking? | Disagree | Quite Agree | Agree | Strongly Agree |
| 3   | How do you assess prosthetic ankle design needs in order to obtain the ability of dorsiflexion-plantar flexion, evertion-diversion, and be able to store and return energy, so as to provide efficient running/marching? | Disagree | Quite Agree | Agree | Strongly Agree |
| 4   | How do you assess prosthetic ankle design needs in order to obtain the ability of dorsiflexion-plantar flexion, evertion-diversion, and be able to store and return energy, so as to minimize the characteristics of the walking gait? | Disagree | Quite Agree | Agree | Strongly Agree |
| 5   | How do you assess the need for prosthetic ankle design in order to obtain the ability of dorsiflexion-plantar flexion, evertion-diversion, and be able to store and return energy, so as to increase wear satisfaction while walking? | Disagree | Quite Agree | Agree | Strongly Agree |
| 6   | How do you assess the need for prosthetic ankle design in order to obtain the ability of dorsiflexion-plantar flexion, evertion-diversion, and be able to store and return energy, so as to improve the balance of walking while walking? | Disagree | Quite Agree | Agree | Strongly Agree |
| 7   | How do you assess the need for prosthetic ankle design in order to obtain the ability of dorsiflexion-plantar flexion, evertion-diversion, and be able to store and return energy, so as to increase wear satisfaction while walking? | Disagree | Quite Agree | Agree | Strongly Agree |
| 8   | How do you assess prosthetic ankle design needs in order to obtain the ability of dorsiflexion-plantar flexion, evertion-diversion, and be able to store and return energy, so as to increase the fulfillment of all activities? | Disagree | Quite Agree | Agree | Strongly Agree |
| 9   | How do you assess prosthetic ankle design needs in order to obtain the ability of dorsiflexion-plantar flexion, evertion-diversion, and be able to store and return energy, so as to increase confidence in communication? | Disagree | Quite Agree | Agree | Strongly Agree |
| 10  | How do you assess the need for prosthetic ankle design in order to obtain the ability of dorsiflexion-plantar flexion, evertion-diversion, and be able to store and return energy, so as to increase confidence in communication? | Disagree | Quite Agree | Agree | Strongly Agree |
| 11  | How do you assess the need for prosthetic ankle design in order to obtain the ability of dorsiflexion-plantar flexion, evertion-diversion, and be able to store and return energy, so as to increase confidence in communication? | Disagree | Quite Agree | Agree | Strongly Agree |
| 12  | How do you assess the need for prosthetic ankle design in order to obtain the ability of dorsiflexion-plantar flexion, evertion-diversion, and be able to store and return energy, so as to increase confidence in communication? | Disagree | Quite Agree | Agree | Strongly Agree |
| 13  | How do you assess prosthetic ankle design needs in order to obtain the ability of dorsiflexion-plantar flexion, evertion-diversion, and be able to store and return energy, so as to increase wear satisfaction while walking? | Disagree | Quite Agree | Agree | Strongly Agree |
| 14  | How do you assess prosthetic ankle design needs in order to obtain the ability of dorsiflexion-plantar flexion, evertion-diversion, and be able to store and return energy, so as to increase wear satisfaction while walking? | Disagree | Quite Agree | Agree | Strongly Agree |
| 15  | How do you assess prosthetic ankle design needs in order to obtain the ability of dorsiflexion-plantar flexion, evertion-diversion, and be able to store and return energy, so as to increase wear satisfaction while walking? | Disagree | Quite Agree | Agree | Strongly Agree |
| 16  | How do you assess prosthetic ankle design needs in order to obtain the ability of dorsiflexion-plantar flexion, evertion-diversion, and be able to store and return energy, so as to increase wear satisfaction while walking? | Disagree | Quite Agree | Agree | Strongly Agree |
| 17  | How do you assess prosthetic ankle design needs in order to obtain the ability of dorsiflexion-plantar flexion, evertion-diversion, and be able to store and return energy, so as to increase wear satisfaction while walking? | Disagree | Quite Agree | Agree | Strongly Agree |
| 18  | How do you assess prosthetic ankle design needs in order to obtain the ability of dorsiflexion-plantar flexion, evertion-diversion, and be able to store and return energy, so as to increase wear satisfaction while walking? | Disagree | Quite Agree | Agree | Strongly Agree |
| 19  | How do you assess prosthetic ankle design needs in order to obtain the ability of dorsiflexion-plantar flexion, evertion-diversion, and be able to store and return energy, so as to increase wear satisfaction while walking? | Disagree | Quite Agree | Agree | Strongly Agree |
| 20  | How do you assess prosthetic ankle design needs in order to obtain the ability of dorsiflexion-plantar flexion, evertion-diversion, and be able to store and return energy, so as to increase wear satisfaction while walking? | Disagree | Quite Agree | Agree | Strongly Agree |
| 21  | How do you assess prosthetic ankle design needs in order to obtain the ability of dorsiflexion-plantar flexion, evertion-diversion, and be able to store and return energy, so as to increase wear satisfaction while walking? | Disagree | Quite Agree | Agree | Strongly Agree |
| 22  | How do you assess prosthetic ankle design needs in order to obtain the ability of dorsiflexion-plantar flexion, evertion-diversion, and be able to store and return energy, so as to increase wear satisfaction while walking? | Disagree | Quite Agree | Agree | Strongly Agree |
| 23  | How do you assess prosthetic ankle design needs in order to obtain the ability of dorsiflexion-plantar flexion, evertion-diversion, and be able to store and return energy, so as to increase wear satisfaction while walking? | Disagree | Quite Agree | Agree | Strongly Agree |
| 24  | How do you assess prosthetic ankle design needs in order to obtain the ability of dorsiflexion-plantar flexion, evertion-diversion, and be able to store and return energy, so as to increase wear satisfaction while walking? | Disagree | Quite Agree | Agree | Strongly Agree |
| 25  | How do you assess prosthetic ankle design needs in order to obtain the ability of dorsiflexion-plantar flexion, evertion-diversion, and be able to store and return energy, so as to increase wear satisfaction while walking? | Disagree | Quite Agree | Agree | Strongly Agree |
| 26  | How do you assess prosthetic ankle design needs in order to obtain the ability of dorsiflexion-plantar flexion, evertion-diversion, and be able to store and return energy, so as to increase wear satisfaction while walking? | Disagree | Quite Agree | Agree | Strongly Agree |

| CRITERIA | PARTICIPATORY QUESTIONS ABOUT APPROPRIATE TECHNOLOGY |
|----------|------------------------------------------------------|
| 1. Technical | 1. Agrees the technology of this prosthetic ankle material according to market standards (for example, HCPs materials). |
|           | 2. Agrees that this prosthetic ankle material technology is always obtained in the market. |
|           | 3. Agrees manufacturing engineering technology to make prosthetic ankles help the manufacturing process. |
|           | 4. Agrees that the manufacturing engineering technology applied to make this prosthetic ankle help in the manufacturing process. |
|           | 5. Agrees this prosthetic ankle technology provides low maintenance costs for users. |
|           | 6. Agrees this prosthetic ankle technology provides ease of care for users. |
| 2. Economic | 7. Agrees the economic costs incurred for prosthetic ankle technology can be reached by users. |
|           | 8. Agrees investment costs for prosthetic ankle technology can be reached by prosthetic repair shops. |
|           | 9. Agrees the cost of repairs incurred for prosthetic ankle technology can be implemented by the user. |
|           | 10. Agrees the cost of repairs incurred for prosthetic ankle technology can be done by prosthetic repair shops. |
| 3. Ergonomic/Health | 11. Agrees that prosthetic ankle technology that matches aspects of ergonomics and body health risks to provide a balance of walking between normal legs and prosthetic feet. |
|           | 12. Agrees that prosthetic ankle technology that is in accordance with ergonomic aspects and the rules of health the body can maintain a stable energy consumption in the body constantly. |
|           | 13. Agrees that prosthetic ankle technology that is in accordance with ergonomic aspects and the rules of health the body can maintain a stable energy consumption in the body constantly. |
|           | 14. Agrees that prosthetic ankle technology that matches aspects of ergonomics and body health principles to provide comfortable walking. |
|           | 15. Agrees that prosthetic ankle technology that matches aspects of ergonomics and body health principles to provide comfortable walking. |
|           | 16. Agrees that prosthetic ankle technology that matches aspects of ergonomics and body health principles to provide comfortable walking. |
| 4. Social-cultural | 17. Agrees the application of prosthetic ankle technology is acceptable in the foot disability community. |
|           | 18. Agrees from the application of prosthetic ankle technology can increase confidence for users. |
|           | 19. Agrees the application of prosthetic ankle technology does not change habits for users. |
|           | 20. Agrees the application of prosthetic ankle technology there is no conflict with values or norms in society. |
| 5. Saved Energy | 21. Agrees the application of prosthetic ankle technology does not use external motors such as motors, hydraulics, pneumatic to replace the leg moving muscles. |
|           | 22. Agrees the application of prosthetic ankle technology does not use a control system that uses energy or the nervous system in the leg muscles. |
| 6. Environment | 23. Agrees the application of prosthetic ankle technology using materials that can be recycled. |
|           | 24. Agrees the application of prosthetic ankle technology in the production process does not cause pollution or waste to the environment. |
| 7. Trendy | 25. Agrees the application of this prosthetic ankle technology can continue to be upgraded in accordance with the times. |
|           | 26. Agrees the application of prosthetic ankle technology is always adopting technology on an ongoing basis. |