Re-assessing the Design Needs of Trans-Radial Amputees in Product Design Innovation

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ABSTRACT

The previous study on design for disabled people has indicates that product development for trans-radial amputees should integrate designer's reflection in identifying significant variables such as the real needs of their users, functionality, ergonomic aspect, and aesthetic. Hence, this paper intends to re-assess the design needs of trans-radial amputees through an observation study with 15 trans-radial amputees (right side). The observation aims to understand the difficulties that occurred in the daily activities of amputees, in their home situation without the help of prosthesis. The result of the study suggests the amputees' main struggle in their daily activities; preparing meals and eating independently. Therefore, a few design criteria have been proposed, and the prototype design was successfully developed as a proposal for potential future development and production. It is hoped the outcome of this research help to surpass the kind of device constrained to help amputees preparing meals and eating independently.

Keywords: *product design, design thinking, design for disabled people*

INTRODUCTION

Trans-radial amputation is not merely a loss of one hand, but it affects a person's daily activity. According to Boyle et al. (2000) 66% of the trans-radial amputation had antagonistically influence amputee's participation in sports, hobby, and housework. The vast majority of them needed to leave their place of employment since they are unable to adapt their working activities. The backbone of treatment for hand amputation has been prosthesis. Different types of prostheses are accessible and range from a non-functional cosmetic prosthetic, to a hook, and to a further developed myoelectric prosthetic. Be that as it may, not every person could manage the cost of it. In the event that they might, they will need a proper prosthetic hand with working prosthetic fingers, which usually cost them a fortune. Moreover, an amputee will not be wearing the prosthetic hand for the entire day due to (dis)comfort factors. In spite of the fact that a prosthetic may provide an assisting hand, it is constrained by the burden of weight, inconvenience, and absence of functional feedback. It is then vital that a good design that can comfortably oblige daily activities, and simultaneously, affordable so that they will have a better life after the amputation.

Matos et al. (2014) for instance, argue that the most recent decade has seen an expanded spotlight on medical devices design for the disabled, explicitly concerning patient safety, and several initiatives have been set up to improve such elements. In any case, Matos et al. (2014) likewise contended that most multidisciplinary groups that are responsible for the product advancement for disabled or amputees neglected to consider and incorporate good design as a basic component. Aside from that, the perception was strengthened by the impression that the vast majority of the products intended for disabled or amputees do not completely respond to the users' real and practical needs. For instance, issues such as aesthetic, formal or symbolic functions, or in outrageous cases, ergonomic and functional ones are commonly not considered as important as mechanical performance, or economic and innovative variables.

Hence, it is gravely significant that the product development for trans-radial amputees ought to incorporate designer's reflection in recognising prominent variables such as the real needs of their users, functionality, ergonomic elements, and aesthetic. Based on the above statements, our research aims to assess the product design criteria for trans-radial amputees to improve single-handed activities. Visual documentations with the amputees were conducted. The research model of the study was based on the framework of Activities of Daily Living (ADLs) and Ergonomics Ergo-system. Subsequently, a design process was initiated based on the data analysis to establish the most suitable and appropriate design preferences for single-handed activities.

Amputation

In general, amputation is defined as a surgical procedure for the removal of part or the whole of a limb (Jain and Robinson 2008). Pecoraro, Reiber, and Burgess (1990), however, defined amputation as a removal of an injured or diseased body part, which might be the after-effect of a horrendous physical issue, or it might be an arranged operation to forestall the spread of the illness such in an infected finger or hand. The reasons for amputation vary between the upper and lower limbs. For example, Jain and Robinson (2008) argue that the essential explanations behind the lower limb amputation because of trauma and vascular-related diseases (with or without diabetes). Meanwhile, the essential explanations behind the upper limb amputation are heredity, conditions during childbirth (inherent), surgical removal for trauma, vascular-related reasons, or cancer. Generally based on age, upper limb amputation in young patients is normally the result of trauma, infection, or is secondary to congenital anomalies. Meanwhile, for more older patients, amputation is almost certain an after-effect of medications or peripheral vascular diseases. The incidence of upper limb amputation is variable in the literature however it is evaluated to be 11.6 in 100,000 adults (Trofe-Clark and Levin 2017).

Upper limb amputation involves removal of all or part of the fingers, hand, forearm, upper arm, or shoulder (see Figure 1). Jain and Robinson (2008) outlined the following eight types of upper limb's amputation: (1) forequarter; (2) shoulder disarticulation; (3) trans-humeral; (4) elbow disarticulation; (5) trans-radial; (6) wrist disarticulation; (7) partial hand; and (8) digit. Based on the study conducted by Jang et al. (2011), trans-radial amputation was the most frequent (48.4%), followed by trans-humeral amputation (19.4%), partial hand and fingers amputation (17.9%), shoulder disarticulation (6.6%), wrist disarticulation (6.6%), and elbow disarticulation (1.1%).

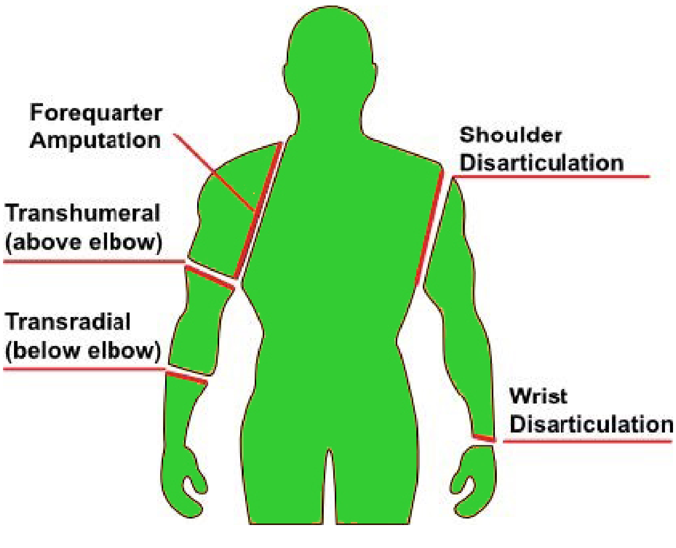

Figure 1 Types of amputation.
Source: Author's illustration.

Contrasted with the lower limb amputation, upper limb deficiency is regularly more functionally disabled because of the fine motor tasks carried out by the hands and arms. Although human beings adapt very well and the contralateral upper limb takes over the greater part of the tasks and in this way becomes the dominant limb, the degree of amputation will, to a great extent, determine the degree of functional disability—i.e., the impact on quality of life and the capacity to carry out tasks of daily living (Jain and Robinson 2008). Expressed differently, upper limb amputation, irrespective of its cause (trauma, disease, or congenital malformation), will unquestionably cause problem(s) that will definitely prompt a specific degree of functional disability.

Issues Related to Prosthetic Arm among Trans-Radial Amputees

According to Jang et al. (2011), among the trans-radial amputees, the cosmetic hand was mostly used (80.2%), followed by functional hand (15%), and hook hand (4.8%). Semasinghe et al. (2019) stress that despite the fact that there had been a stamped improvement in functionality, performance, and appearance of subsequent generations of trans-radial prostheses, the robotic counterparts are still lacking in certain elements to restore or mimic the missing part of the biological limb. This is in agreement with Jang's et al. argument that prosthetic arm for the trans-radial amputee has neglected to recreate delicate/complex movements and the tactile/proprioceptive sensory functions. Despite the fact that the design of prosthetic arm—for example, myoelectric prostheses—has been created and correspondingly utilised with electronic advancements, it remains heavy, fails to imitate accuracy movement functions, and has a sluggish movement speed (Jang et al. 2011). Therefore, amputees experience a huge feeling of dissatisfaction and issues in the rehabilitation process.

Jang et al. (2011) also stress that the most well-known challenges in daily living activities experienced by amputees commonly involve precise and delicate finger movements, for example, preparing meals, shoe-lacing, removing bottle-tops with a bottle opener, and using scissors. According to Semasinghe et al. (2019), most trans-radial prostheses are intended to perform few grasping tasks with limited degrees of freedom (DoFs), where a healthy human hand-wrist has a total of 27 DoFs. Be that as it may, externally powered trans-radial prostheses are regularly limited in operation due to high power consumption, complexity in operation, and/or bulkiness of the device. Consequently, to develop an anthropomorphic prosthetic hand and/or wrist key factors such as, size, shape, weight, number of independently actuated DoFs, level of tactile feedback, and speed of activity, magnitude of grasping force should be deliberately considered at the design stage.

Also, understanding the general significance of various grasping patterns such as power grip such as power grip (35% of ADLs), precision grip (30% of ADLs), lateral grip (20% of ADLs), index point, and other essential gestures is paramount to arrive at a better design with acceptable trade-off. Semasinghe et al. (2019) argue that in the near future, innovative progression may empower the prosthetic developers to derive an ideal artificial arm, but it is essential to have a better comprehension on the performance capabilities and design elements of existing trans-radial prostheses.

Meanwhile, unlike the lower limb amputees, Jang et al. (2011), argue that a generally huge number of upper limb amputees do not fully utilise their prosthetic in light of the fact that they struggled to compensate for the inconveniences in carrying out daily activities by utilisation of their remaining upper limb regardless of the inconvenience issue. This is in agreement with Lee's et al. (2017) argument that numerous amputees do not utilise prosthesis since they are capable of carrying out activities of daily living with the remaining healthy upper limb. In addition, since upper-extremity prosthesis are generally exposed contrasted with lower-extremity prosthesis, patients regard the manipulation, shape, and convenience as important issues when fitting a prosthesis.

The average duration of daily use of prosthetic arm among trans-radial amputees also varies. Based on the study conducted by Jang et al. (2011), 50.76% reported an average daily use of 8–16 hours, 21.97% answered 4–8 hours, and 14.39% utilised their prostheses for less than 4 hours. Nonetheless, 12.88% indicated almost no use at all. In spite of the fact that the number is very low, the amputees without a doubt have a low degree of satisfaction and comfort with the functional use of their prosthetic for daily activities and influence their inspiration to utilise such a product.

Financial Cost of Prosthesis

Specifically in Malaysia, Arifin et al. (2017) indicates that the expense of a prosthesis typically differs somewhere in the range of RM4,000 to RM15,000. It is considerably higher with the incorporation of advanced components or computerised systems such as myoelectric prosthetic which is ranges from USD9,000 to even USD40,000; depending on the method of control and amputation of forearm, these devices require a broad fitting procedures to build up the final device, and frequently incorporates a perplexing system of cables and harnesses (Lee et al. 2017). In addition, the majority of the certified prosthetists and orthotists (CPOs) are based in West Malaysia and can support optimal services only in this region, inexorably ignoring the far larger East Malaysia region. Albeit some of them made respectable attempts to cover the often-disregarded parts in Malaysia, their cost is expanded mainly due to the higher transportation costs.

Therefore, uncertified prosthetic creators are mushrooming in East Malaysia to fill this hole. Nevertheless, the quality of their prosthetic devices is comparatively lower than that of organisations employing CPOs. Moreover, the significant expense of prostheses forces a financial burden on a significant percentage of amputees in Malaysia. Thusly, a considerable lot of them are left with the choice of lower-priced prosthetics that are less effective and ultimately, inhibit their rehabilitation progress.

Furthermore, Arifin et al. (2017) also indicates that there is no proper information about how individuals pay for prosthetic services were gathered. This can go from self-paying patients, assistance from the employer or insurance agency (the Public Services Department for civil servants; the Ministry of Health—under *Tabung Bantuan Perubatan*; the Welfare Department; Social Security Organisation (SOCSO); political fund; company's insurance; religion-related association; non-governmental organisations) and by government offices (Welfare Department, Ministry of Health, Ministry of Higher Education). Besides, government hospitals treat prostheses similarly as other medical implants and these are not covered by the annual hospital budget plan. Therefore, patients need to discover resources to fund their prosthesis. The absence of organised prosthetic service management system prompts repayment issues which increase the waiting period for amputees to be fitted with a prosthesis. These constraints are probably going to stay as significant obstacles to improving the country's prosthetic service unless there are substantial changes in government strategies to accomplish mutual concordance concerning prosthetic services.

One way that could lessen the overall expense of prostheses could be central fabrication and mass production. By redistributing the production process, prosthetists could maximise clinical productivity and consequently provide excellent patient care to amputees. Likewise, privately owned businesses could decrease their operating costs by eliminating the requirement for enormous working regions, specialised machinery and additional technical staff. It has been indicated that mass produced, prefabricated orthotic and prosthetic devices have comparable fit and function to custom-made devices. Private practice and government hospitals could work in partnership to build up a financially savvy model dependent on central fabrication and a mass production approach. However, in certain specific deformity cases, a custom-made device will consistently be required for compelling and fruitful treatment outcomes.

The Framework of Activities of Daily Living (ADLs)

According to Noelker and Browdie (2014), ADLs is a term used in healthcare to refer to people's daily self-care activities. The index of ADLs was originally proposed in the 1950s by Sidney Katz and his group at the Benjamin Rose Hospital in Cleveland, Ohio. Originally, with the goal of restoring patients to as much independent functioning as possible, the team made a thorough study of each patient's activity status pattern using a graded index to record functional independence or dependence in bathing, dressing, toileting and continence, transferring, and feeding/eating. These functional skills are mastered early in life and are relatively more preserved in light of declined cognitive functioning when compared to higher-level tasks. The criteria for independence were clearly explicated; for example, dressing was evaluated as independent if the patient could get all the clothes from the closet or drawer, put them on, and fasten them without supervision, direction, or active assistance. Patients who functioned best could independently bathe, dress, transfer, toilet, control continence, and feed themselves. Throughout the study conducted by Sidney Katz and his team, it has been concluded that the index of ADLs was based on primary biological and psychosocial functions that reflected the adequacy of neurological and locomotor responses.

Initially, the study was conducted due to no scientifically developed guidelines for chronic care nor was there a collection of empirical evidence about the course of chronic illness and effectiveness of specific treatments. The multidisciplinary group of doctors, nurses, social workers, and physical and occupational therapists at the hospital made it their mission to carry out through patient assessments and record every patient's progress. They utilised information on results to figure out what treatments worked for whom and applied this information to improve clinical decision making. Principally, ADLs incorporate the fundamental skills ordinarily expected to oversee fundamental physical needs. The structure for assessment of ADLs ability may incorporate an issue of psychological, cognitive, emotional, or behavioural factors that can meddle with essential capacities and how these obstructions can be defeated to improve independence.

Nowadays, a few instruments and studies utilising the framework of ADLs are currently available to evaluate the functional ability of amputees such as: the Locomotor Capabilities Index (LCI) (Larsson et al. 2009), the Functional Measures for Amputees (FMA) (Callaghan et al. 2002), Brief Activity Measure for Upper Limb Amputees (BAM-ULA) (Resnik, Borgia, and Acluche 2018), motion capture and data processing (Drew et al. 2017), and postal questionnaire survey (Jang et al. 2011). These instruments and studies depend intensely on the amputee to have a realistic self-knowledge in order to evaluate the functional ability of amputees, which makes these instruments and studies are highly subjective. A few scope of daily living activities were included in the instruments and studies such as: washing face, combing hair, putting on and taking off underwear, buttoning shirts, closing zipper of pants, wearing socks, tying of shoelaces, eating with spoon, opening and drinking canned beverages, writing name with a pencil, using scissors, opening doors by turning door knobs, opening and drinking a bottled beverage using a bottle opener, making telephone calls by pressing buttons on a mobile phone, opening envelopes, putting on and taking off prosthesis without the help of another person, mixing of black bean sauce noodles, etc. Based on the studies conducted, although a prosthetic device has greater significance for cosmetic and supplementary purposes than functional purposes but almost all the subjects, who said the task was possible, failed to indicate the extent of difficulty in carrying out the task.

The instruments and studies focus on individual aspects of execution with a prosthesis, though it would be much progressively imperative to concentrate on the important capacity of the amputee during practical execution in their home circumstance without the assistance of prosthesis. A recent search of the literature hardly reveals any instruments that unbiasedly evaluate the genuine useful capacity of amputees (without prosthesis) to perform normal daily activities. Such an instrument, be that as it may, is significant on the grounds that it could give data about the challenges looked by amputee in everyday life. It could therefore help in the choice and remedy of plan models for an alternate classifications of product design (rather than prosthetic arm) that best suit the person's physical capacities and participation aims.

The Design Needs Assessment Model

The design needs assessment model was adapted from the ergonomics ergo-system framework by Bridger (2008). The framework is generally used as a template for the optimisation of the system operation but can also be applied within the context of product design. In this study, the framework is formulated as a design model to aid designer's design thinking from the early stage of empathetically experiencing the case being studied, brainstorming and coming up with the solution for the user's need (based on the insights from the empathising stage), conceptualising, to the modelling and periodically testing the design prototype (see Figure 2). The system is accelerated by the following five sets of ergonomics science elements: (1) physics; (2) psychology; (3) anatomy; (4) physiology; and (4) engineering.

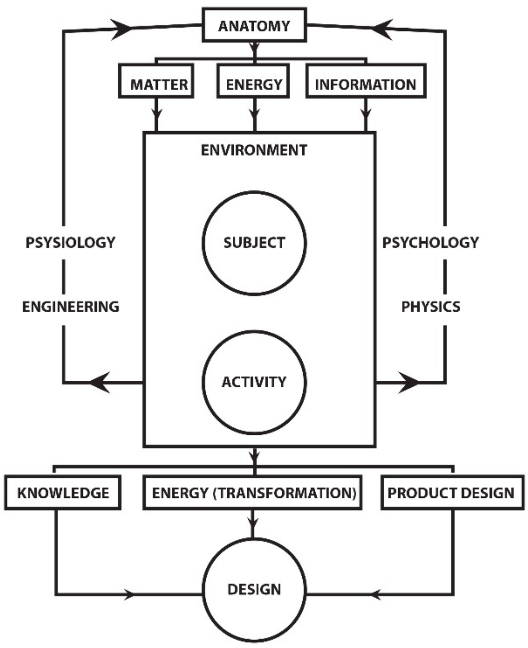

Figure 2 The ergonomics ergo-system framework.
Source: Adopted from Bridger (2008).

The foundation of the system incorporates the synchronisation of the subject in a particular environment. To make sense of the relationship, one must understand the condition or situation (matter) of the subject operating the activities in a particular environment or space. Theoretically, the condition or situation will illuminate the information regarding the subject's reflection on the physics of the environment being experienced, which includes how it affects the subject's psychology and needs. Nevertheless, the articulation of the anatomy aspects and physiological needs will provide the much-needed design information to be further refined. In this research work, the design assessment model is adopted to assess the design needs of trans-radial amputees for product design innovation. The five elements were synchronised and applied to illuminate the system's animation to embody the trans-radial amputee's body movements during daily activities, and subsequently, steering design thinking activity strenuously towards a better understanding of the subject's need.

METHODOLOGY

In light of the past investigation, the significant expense of prostheses imposes a financial burden on a significant percentage of amputees in Malaysia. As a result, a considerable lot of them are left with the decision of lower-priced prosthetics that are less effective and, ultimately, restrain their rehabilitation progress. Moreover, in spite of the fact that the design of prosthetic arm has been created and associatively utilised with electronic innovations such as myoelectric prostheses, and yet it remains heavy, fails to recreate exactness movement functions, and has a sluggish movement speed. As a result, a moderately huge number of upper limb amputees don't utilise their prosthetic on the grounds that they struggled to compensate for the inconveniences in carrying out daily activities. Hence, there were two objectives developed as follows: (1) to determine the type of activities that difficult to achieve by an amputee; and (2) to develop a new product which are affordable, convenience and specifically solve the difficulties that occurred in the daily activities of amputees.

Observational Study

This research work is a qualitative research. Hence, purposive sampling will be used with a certain number of subjects to achieve saturated data. Based on the research that have been done by Guest, Bunce, and Johnson (2006), a total number of 15 respondents is sufficient to achieve the saturated data. Hence, the assessment via observational studies was carried out on 15 trans-radial amputees at Universiti Sains Malaysia in Pulau Pinang. The amputees were involved in incidents (e.g., motor-vehicle/machine accidents) respectively, which required trans-radial amputations (right side).

Adapted based on an amalgamation of the ergonomics contexts Abdullah Sani et al. (2019) the framework divides the assessment procedures and illustrates the strategy in accomplishing the research objective (see Figure 3).

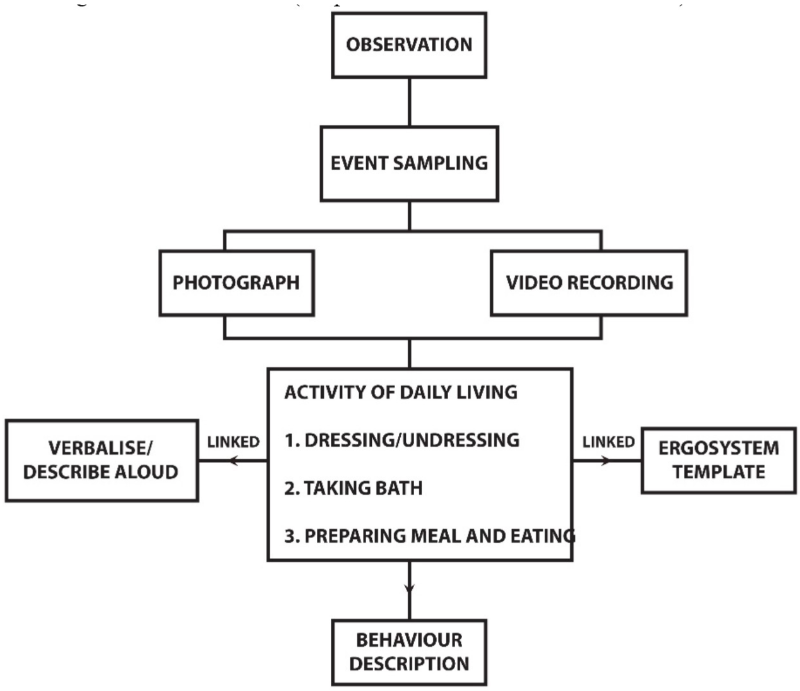

Figure 3 The framework of design needs assessment.
Source: Adopted from Abdullah Sani et al. (2019).

Using the descriptive event sampling, the assessment focused on these daily activities: (1) dressing and undressing; (2) taking a bath; and (3) preparing a meal and eating. The assessment observed how the amputees execute daily activities while simultaneously noted what the amputees verbalised and described aloud while performing the above-mentioned tasks. To score the amputee's level in achieving the daily activities as outlined, the analysis of the observational study has been separated into these five scales: (1) very easy; (2) easy; (3) moderate: (4) difficult; and (5) impossible. The whole session was recorded (both visual and sound) by the researchers to prevent any missing information.

Ethic Clearance

The researchers have acquired the informants' consent after explaining the purpose and method of the study to ensure confidentiality.

DATA ANALYSIS

Based on the observation study, we found that respondents mostly are moderately able to wear clothes on their own, but it took them a longer time to wear a pants. Meanwhile, it was moderate for them to take off their clothes compared to take off their pants which is much easier. Nevertheless, it was difficult for respondents to button up/zipping their clothes/pants, but it was moderate for them to unbutton and unzip. Based on the results, overall rate of respondents' ability to dress and undress is moderate.

Table 1 Observational analysis of the ability to dress and undress.

Observational analysis	Very easy	Easy	Moderate	Difficult	Impossible
Wearing the pants				√	
Wearing the clothes			√		
Take off the pants		√			
Take off the clothes			√		
Button up/zipping the clothes/pants				√	
Unbutton/unzipped clothes/pants			√		
Overall rate of respondents' ability to dress and undress			Moderate		

Furthermore, we found that instead of scooping the water using bucket, the amputees prefer to use shower as it is more effortless. It was difficult for the amputees to apply soap and wash certain body parts, especially on the left side. Nevertheless, it was also difficult for amputees to press out shampoo single-handedly. As an alternative, amputees had to press out the shampoo using their chin or forearm while their left hand holding the shampoo. Based on the results, overall rate of respondents' ability to bath is difficult.

Table 2 Observational analysis of the ability to take a bath.

Observational analysis	Very easy	Easy	Moderate	Difficult	Impossible
Take a bath using shower hose		√			
Take a bath using bucket			√		
Apply the soap and wash a certain body part				√	
Able to press out shampoo single-handedly				√	
Overall rate of respondents' ability to bath			Difficult		

Based on the observation, amputees moderately able to eat using fork and spoon single-handedly. However, most of the amputees had to intentionally throw out about 10% of the meal due to the difficulties in cutting and scooping them single-handedly, unless it was soup- or noodle-based. Moreover, it was impossible for amputees to prepare and cook meals on their own. According to one of the amputees, there was a time when he was profusely hungry, but his wife was not around, and the only option he had was to use his mouth to open a bread packaging. He had to contend with just the plain bread as he could not spread neither butter nor jam. Based on the results, overall rate of respondents' ability to preparing a meal and eating is impossible.

Table 3 The descriptive analysis of the ability to preparing a meal and eating.

Observational analysis	Very easy	Easy	Moderate	Difficult	Impossible
Eats using fork and spoon single-handedly.			√		
Cut and scoop the meal (meat/fish/chicken) single-handedly					√
Prepare and cook their meals single-handedly.					√
Overall rate of respondents' ability to preparing a meal and eating			Impossible		

DISCUSSION

Throughout the study, the authors found that the application of the ergonomics ergo-system as a design needs assessment model is important as it integrates the amputee's actual needs and facilitates the product design development. Per this significance, although studies by Jang et al. (2011) and Arifin et al. (2017) have established that the prosthetic arm design has been developed and recently used in combination with electronic technologies such as myoelectric prostheses, but the high price of prostheses imposes a financial burden on a significant percentage of amputees in Malaysia. Furthermore, a study conducted by Jang et al. (2011) also indicates that the amputees have a low level of satisfaction with the functional use of their prosthetic for daily activities. As a result, they were left poorly motivated and reluctant to make full use of their prostheses. In relation to this current research objective, the results of the assessment have shown a multitude of issues faced by the trans-radial amputees, especially during meal preparation and eating. Based on the analysis of the study, our research team proposes HandC; a smart chopping board, to assist trans-radial amputees during meal preparation and eating. A few design criteria were outlined to improve HandC's design development (see Table 4).

Table 4 HandC design criteria based on design needs assessment of trans-radial amputees.

Design Criteria
Multiple magnetise holder design: help to hold fruits, vegetables, meat, chicken, and fish while chopping them single-handedly. The magnet enables the defender/border to stick onto the tabletop and moveable when needed, e.g., changing the holder selection.
Portable and magnetise food defender/border: help to optimise the chopping food process single-handedly. The magnet enables the defender/border to stick onto the tabletop and moveable when needed, e.g., changing chopping arrangements.
Vacuum suction food defender/border: help to optimise the process of cutting and scooping foods single-handed. The vacuum suction enables the food defender/border to stick onto the plate but can be easily removed when needed, e.g., changing scooping arrangement.
Affordable: using low-cost, nimbler, and safer material such as three-dimensional (3D) printed plastic Acrylonitrile Butadiene Styrene (ABS), silicon and metal sheet for design production
Aesthetic: using pastel colour for the design

The design includes a magnetised holder design that can help to stick onto the tabletop and hold fruits, vegetables, meat, chicken, and fish while chopping them single-handedly. Multiple holder designs are also provided for selection, depending on the types of food. Nevertheless, the design also includes a magnetised food defender/border to stick onto the tabletop but portable enough to change the chopping arrangements. To optimise the single-handed eating process, the design also includes a vacuum suction food defender/border. The vacuum suction enables the food defender/border to stick onto the plate but can be easily removed when needed, such as changing the food scooping or cutting arrangements. Furthermore, we have also suggested that a low-cost, nimbler, and safer material (3D printed ABS plastic, silicon, and metal sheet) to be used for design production. Nevertheless, to make the product visually appropriate and presentable for the kitchen use, the researchers also suggest a pastel colour to be used in the design.

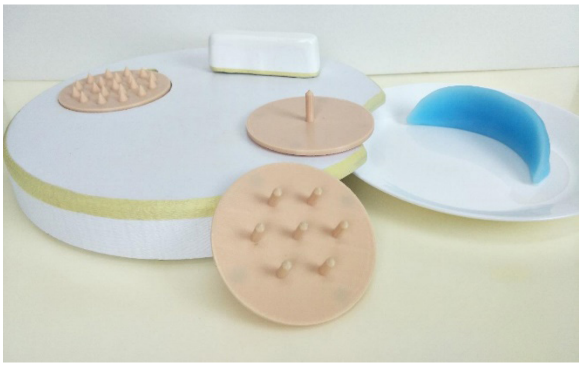

Photo 1 The prototype of HandC design.
Source: Photographed by author.

Photo 2 Holding orange for a single-hand peel using the holder design.
Source: Photographed by author.

Photo 3 Holding a piece of bread for a single-hand butter spreading using the magnetise food defender/border.
Source: Photographed by author.

Photo 4 Single-handedly moving the chopped item onto the plate.
Source: Photographed by author.

Photo 5 Single-hand food scooping using vacuum suction food defender/border.
Source: Photographed by author.

CONCLUSION

With the initial design research data, it shows that the orchestration of the ergonomics ergo-system is essential in assessing the design needs of trans-radial amputees in their daily life activities. The amputees' experience assessment signifies the fundamentals of design to spur the adherence and compliance with the ability to accomplish one of the simplest and basic daily activities—prepare and eat a meal—independently. The prototype has the potential for further development and possibly, to be mass-produced. This can be realised through the application of the recommended elements in the design criteria. It is hoped with this development; the product would benefit the trans-radial amputees. More importantly, with the proposed design and material, we would finally be able to empower low-income trans-radial amputees to lead a meaningful life.

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