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Development of Ergonomics Checklist on Stroke Therapy Aids (Wearable Elbow Exoskeleton)

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ABSTRACT. This study aims at building a checklist used on each stage of wearable Elbow Exoskeletons development. The Wearable Elbow Exoskeleton is one of the hand stroke therapy aids which was developed by Diponegoro University. Te product is still in the form of a prototype so that some tests must be carried out before the product is tested on respondents. Test during this far is still focus on functionality test. This study provides a general checklist for ergonomics testing of stroke therapy aid products. Method of checklist is developed based on exploration study and literature review for producing appropriate test related to product characteristics. There are three iteration on development product and each version repair the previous version. The implementation of checklist shows that on third iteration, product is in accordance with objective of development and reach the targeted level of respondents' satisfaction.

Keywords: Checklist, Ergonomics, Stroke, Therapy, Wearable Elbow Skeleton

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1. INTRODUCTION

Stroke is still the main cause of disability in Indonesia. Based on data from the Ministry of Health [1] , the prevalence of stroke in urban areas is 0.82% and 0.57% in rural areas. The prevalence of stroke in Jakarta is 1.46% among individuals aged 15 years and over. Stroke is also the leading cause of death in urban areas (15.9%) and the second leading cause of death in rural areas (11.5%) in Indonesia. In the age range of 45-54 years, the main cause of death due to stroke is 28.8% in urban areas and 17.4% in rural areas.

The burden that must be borne by stroke sufferers is long-term physical disability. In addition, from the side of the patient's family, the treatment for stroke therapy is quite complicated and difficult to take because a stroke suddenly affects the patient's quality of life. The uncertainty of healing also creates a burden, both mentally and financially. Rehabilitation is one way to recover stroke sufferers. One of the ways to do rehabilitation is through regular physical therapy performed by professionals. However, because the therapy is carried out by stroke therapists, exercise is limited due to time, so it is necessary to have an alternative form of rehabilitation that is safe but in accordance with the rehabilitation standards for stroke patients. Condition The pandemic also spawns worries that contact physique therapist and patient by direct could increase the potency transmission of the COVID-19 virus.

Some of the previously described limitations and support from technological advances have made it possible to manufacture a stroke therapy device for the limbs called a Wearable Elbow Exoskeleton therapy aids. The exoskeleton is one of the first-hand stroke therapy aids in Indonesia that can be set automatically. This therapy aids can be set up automatically so that it gives the therapist an advantage, such as that therapy can be carried out simultaneously using only one therapist. In addition, with the current condition that is being hit by the corona virus outbreak, this product can be used for stroke patients who are affected by Covid because the therapist does not have long-term contact with the patient so the risk of transmission is reducing. Elbow Exoskeletons also have the advantage of being relatively cheap. This can be seen from the Elbow exoskeleton product benchmark, for example Myopro. The price of stroke therapy aids from Myopro products ranges from $20,000 - $50,000 or when converted to Indonesian currency Rp. 300,000,000, - to Rp. 750,000,000, - while the wearable elbow exoskeleton is estimated to have a selling price of IDR 60,000,000. With a cheaper price compared to its closest competitors, it is expected that this product can be a new alternative for hospitals or the patients. This product has been tested for ergonomics and reusability to see the response from patients and therapists regarding the use of the device [2]. Several other studies related stroke therapy aids with various approach has conducted as based on tele-rehabilitation with consumer technology [3], robots for stroke therapy [4], design of robot-assisted neurorehabilitation strategies [5], manufacture of bilateral therapeutic hand devices [6], design therapy web -based [7], even in form of care continuum or empowerment program [8-9]. A number of local and

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international stroke therapy aids developed by a number of researchers, as well [10-11].

In the process of development, this product through a number of iterations. Every stages of iteration just accompanied with testing to proves the function of this product. A number of shape testing designed and tested for simplify the testing process on every iteration. Study related testing on development product of health equipment specifically explained in study of Susanto et al., [12-15].

Based on background behind and formulation problem, the objective of this study can be formulated. This study is aiming at building a general checklist of tests that can used in general on each step of iteration development product. This study evaluates the result of checklist implementation on a case studies of development a prototype of wearable elbow exoskeleton.

2. MATERIALS AND METHODS

Steps taken on this study is compile background behind and formulation problem as well as objective research. This study aims at testing appropriateness of Wearable Elbow Exoskeleton before it is used for stroke patients. In order to fulfil various criteria in product testing, an ergonomics checklist is established. Checklist development is performed through observation direct product prototype and in-depth interview with the respondents including expert stroke therapy and technician development product. Method applied ergonomics in this study refers to [13] which explains that ergonomics study can done through approach Follow-up. This method is performed by subjective or objective evaluation. The approach examples of subjective evaluation are convenience/comfort questionnaire, part body aches, shoulder and elbow pain, fatigue, head pain and others. Objective approach provides an evaluation through rejected product parameters, absenteeism or sick events, numbers accident and others

2.1 Wearable Elbow Exoskeleton

Wearable Elbow Exoskeleton consisting of skeleton mechanics that can worn on human arm both up and bottom part. The mechanism of product is set by a microcontroller. On this product, there are number of buttons containing different order such as on and off button, angle setting, mode setting, and repetition movement setting. When the user pushes the available buttons on, command will be accepted by microcontroller and then it will be continued to the actuator. Moving actuator produces movement on wearable elbow exoskeleton.

There are three types of movements:

1. Manual

Firstly, we set the limit of the starting angle and the end angle, then we set the speed of the tool by pressing the button to the right or left. After that, we just move the equipment by pressing the button up or down. For this movement, all movements are carried out by the equipment while the patient hand is in passive state.

2. Automatic

This mode is almost similar with manual mode. We still have to set the limits of the starting and ending angles, then we set the speed. After that, we set the movement frequency of this equipment. When we have everything set, press the on button, the equipment will run itself.

3. Passive

For this movement, we only have to set the initial and final angle limits because the equipment only functions as a training load for the patient. The patients theirselves must try to move the device up or down. The equipment will only display the ROM performed by the patient.

2.2 Ergonomic Checklist

At the stage of compiling the ergonomic checklist, an analysis of the wearable elbow exoskeleton was carried out. Currently the wearable elbow exoskeleton is still in the form of a prototype and can still be repaired several times. Composition of ergonomics checklist is adapted from the Ergonomic Hazard Assessment principles. The checklist was than adapted to the conditions at the first observation. In this study, before the equipment was used by the patient, initial testing by the stroke therapist was required. This should be performed because the product is an early prototype and has not paid attention to stroke therapy steps in general.

After tested by a stroke therapist, the next step is checking the readiness of the equipment with the ergonomics checklist. This checklist will result an evaluation whether the equipment is ready to be tested on patients.

3. RESULT AND DISCUSSION

Ergonomics checklist obtained from collected information when stroke therapy aids were tested on therapists. In this study, the product changes three times until it was finally declared feasible. At first, this product was demonstrated by the researcher. In the first demonstration process, it was observed what needs to be improved before the tool is ready to be tested on patients. From the demonstration observation process, the ergonomics hazard assessment checklist form are adjusted because the ergonomics potential hazard assessment checklist form observes the work area as a whole, while in this study the observations were limited only during the therapy process. From the results of the adjustment of the ergonomics hazard assessment checklist form, ergonomics checklist is obtained. The adapted checklist is shown in Table 1.

The first observation using ergonomics checklist is initially demonstrated by the designer. There were some explanations about installation and features that have been available. In the next step, a stroke therapist will try the product to find out improvements still needed according to the standard of stroke therapy. This first observation also involved expert (medical doctor) to provide additional input and observations. There were assessments about the suitability between ergonomic standards and the prototype. The results of this first observation find many descriptions that have not been fulfilled so that the product needs to be improved. An additional note regarding the product related

with requirement of adjustment the angle at the start of therapy should be in the 0^o position when the arm is straight. Besides, the loading program needs to be added because it is a part of the ongointg stages of stroke therapy. Figure 1 shows the first version of stroke therapy aids.

Table 1.
Ergonomic Checklist

No	Description	Yes	No	Information
1.	Accidents that may be related to ergonomics			
2.	Any comments/complaints related to ergonomics			
3.	Item design can cause restriction of one's movement			
4.	The design of the item can lead to awkward and uncomfortable positions			
5.	Observation shows that there is a problem in sitting condition			
6.	Education or socialization related to the therapeutic process			
7.	There are therapeutic activities that put a person in an awkward position			
8.	There are activities that require the user to move awkwardly or uncomfortable			
9.	There is severe physical injury (lifting and lowering)			
10.	There is a problem in the loading therapy process			
11.	The user performs the same continuous movement			
12.	Equipment vibrates during use (unstable)			
13.	There are complaints related to fatigue after doing the therapy process			
14.	There are complaints related to the stages of the therapy process			
15.	The tool is too noisy when operating			

Fig. 1 Stroke Therapy Aid Version 1

In the second observation, wearable elbow exoskeleton still tested in technical respondents. The second version provides some improvements from the first version. The stroke therapist tried the product to find out the improvements still needed according to the standard stroke therapy. This second observation also involved expert doctors to provide additional input and observations. In Figure 2, version 2 of the stroke therapy aid is shown. It can be seen from the picture that there are several changes, namely the placement of device on the table, the presence of elbow and palm supports, the utility of electricity not only batteries like the first version, and addition of a loading feature.

The results of this second observation show that the product is having a significant change and revision. However, there are still some aspects that have not been improved related to the repetition speed which is still too slow. It also found a new problem arises in the gear that slips easily when several experiments are carried out so the simulation of the loading process cannot run optimally.

Fig. 2 Stroke Therapy Aid Version 2

Figure 3 shows the third version of the stroke therapy aids. Visually, this third version does not have a drastic change compared to the second version. The results of this third observation found minor corrections, but the product is declared ready to be tested directly on patients. In terms of medical and therapeutic stages, the product suits with the requirement because it can withstand the load and has a fit repetition speed. The delay between repetitions is also enaough, so the product is declared worthy to be tested. By concise, result studies for three version of the product could seen on Table 2 and Figure 4.

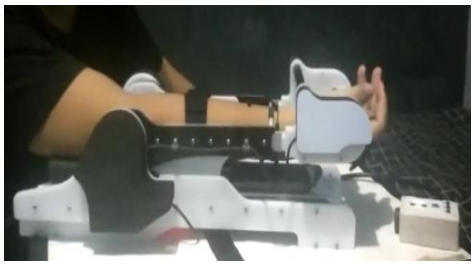

Fig. 3 Stroke Therapy Aid Version 3

Table 2
Ergonomics checklist results for wearable elbow skeleton

Nr.	Description	Version 1			Version 2			Version 3		
		Yes	No	Information	Yes	No	Information	Yes	No	
1.	Accidents that may be related to ergonomics	□		Hands still hanging no backrest		□	Already have armrests		□	The width of the hand is wide
2.	Any comments/complaints related to ergonomics	□		The width of the hand is still not wide	□		The width of the hand is still not wide	□		The therapy process is carried out while sitting so the movement is limited
3.	Item design can cause restriction of one's movement	□			□		The therapy process is carried out while sitting so the movement is limited		□	The position when using the item is in a good sitting position
4.	The design of the item can lead to awkward and uncomfortable positions	□				□	The position when using the item is in a good sitting position		□	The sitting position is good and upright
5.	Observation shows that there is a problem in sitting condition		□	Research has not reached the sitting position because it still lacks features		□	The sitting position is good and upright	□		The order of therapy is appropriate
6.	Education or socialization related to the therapeutic process		□	There is no order related to the therapeutic process	□		The order of therapy is appropriate		□	
7.	There are therapeutic activities that put a person in an awkward position	□				□			□	Because the therapy process is still in place, there are no awkward movements
8.	There are activities that require the user to move awkwardly or uncomfortable		□	Because the therapy process is still in place, there are no awkward movements		□	Because the therapy process is still in place, there are no awkward movements	□		
9.	There is heavy physical work (lifting and lowering)		□	Not available yet but needed for loading program	□				□	The loading process has been running smoothly and

							the gear does not slip
10.	There is a problem in the loading therapy process	□	There is no program so there are no problems	□	Gear skid in the middle of loading process	□	Same continuous movement 10x with 3 variations
11.	The user performs the same continuous movement	□	continuous movement 10x with 3 variations	□	continuous movement 10x with 3 variations	□	Equipment no longer stutters
12.	Equipment vibrates during use (unstable)	□	Not vibrating but unstable and still stuttering	□	Does not vibrate but falters especially when loading	□	The therapy simulation process has been running smoothly
13.	There are complaints related to fatigue after doing the therapy process	□	The therapy simulation process has not run fully	□	The therapy simulation process has not run fully because there is a slipping gear problem	□	
14.	There are complaints related to the stages of the therapy process	□	Still a lack of features and tools that are still lagging	□	Still lacking the loading feature	□	The sound of the gear is already smooth
15.	The tool is too noisy when operating	□		□	Gear sound is too rough		

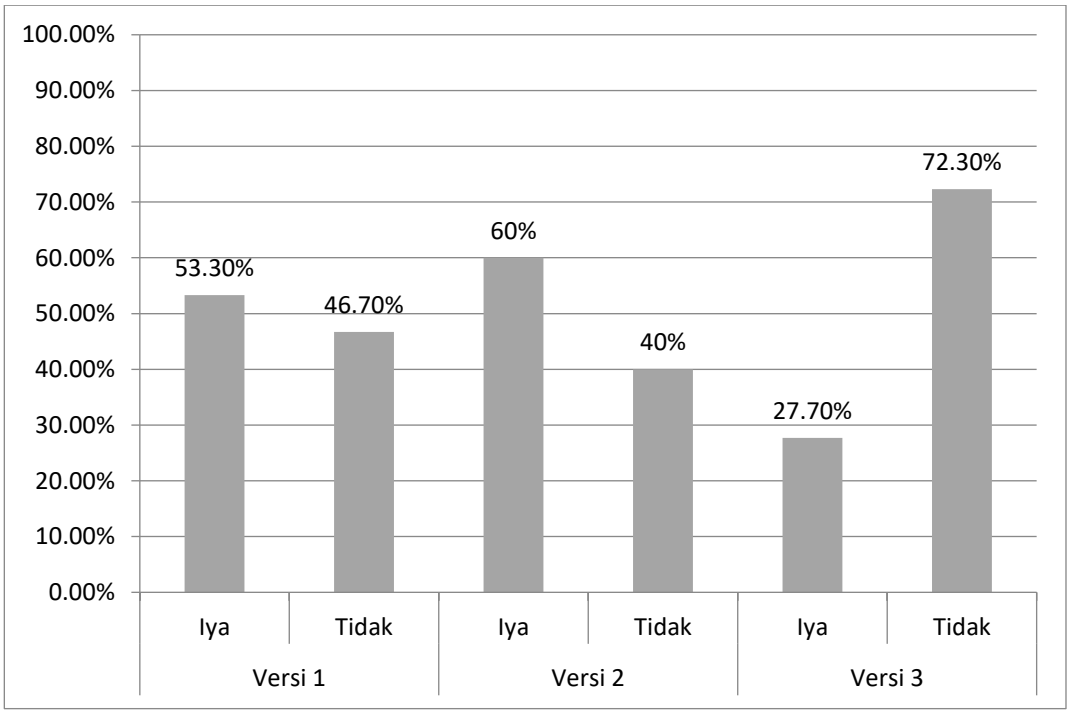

Fig. 4 Elbow Exoskeleton Comparison Chart

From the three versions, it can be seen clearly that each version has significant changes. In addition, although each version need to be evaluated and required some changes, the *Wearable Elbow Exoskeleton* remains to the portability and easy to user principles.

The first prototype still focuses on the ease of the tool to be carried, assembled, and removed. However, the assessment based on the ergonomics side still has many shortcomings. The prominents limitations include the hands still hanging and there is no backrest. When the first version of the prototype was operated, the user was in standing position. This position was considered inappropriate especially for elderly because the therapy process took quite a long time. In addition, because the designer does not have a medical background, so the during stroke therapy do not considered and required additional. The width of the hand is not suitable and needs to be considered to anticipate users who have a fairly wide hand. From the medical side, there are also several inputs, namely the repetition speed is too slow, there is no additional load feature on the therapy aids, the starting angle is not fit and there is no display to show the number of repetitions have been done. As overall, assessment using ergonomics checklist shows the product reach 53.3% of incompatibility with the checklist standards and categorized as not feasible to be tested towards patients.

On second version of the prototype, ergonomic assessment shows a larger potency of danger (60%). This is due to a significant change in product design which is prioritizing the fulfillment of medical aspects, namely the suitability of therapeutic steps. The problem that is quite serious in this version is related to the noise of the gear, Since the second version has added a loading feature, the different gear was used. In addition, the problem that arises because of the loading feature is the gear that slips easily. During the therapy simulation process, the product experienced several slipping and staggering gear shifts until in the end the loading feature could not be used because the gear skidded and had to be stopped in the middle of the loading process simulation. There were some recommendation related to ergonomics and safety term. From the medical side, there are also some inputs, they are increasing the repetition and loading speed.

The hazard risk assessment in ergonomics in third version has reached 27.7%. The problem that has not been fulfilled is the loading process. This cannot be eliminated because the loading process is an initial and obligatory step in stroke therapy using the wearable elbow skeleton. The control strategis is conducted by performing supervision during the loading to avoid the risk of injury. Overall, the results achieved have met expected results from the technical and medical aspects. This is indicating that the stroke therapy aids are ready to be used for stroke patients w

The checklist become simpler if it compared with the previous checklist that technically and specifically developed for hand therapy aids [2]. With more context general, the checklist is easier to be used and adapted for testing other products such as therapy aids for finger and shoulders.

4. CONCLUSION AND FURTHER RESEARCH

Based on the research the ergonomic checklist on the Wearable Elbow Skeleton as stroke therapy aid has been successfully used as one of the supporting parameters to proves the readiness of the product before it tested to stroke patient respondents.

Some opportunities and further studies from medical and ergonomics sides are adding features or variations, improving the smooth of resistance during straightening phase and increasing flexibility of product size.

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