Tricycle Applications for Physical Therapy Sufferers

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Abstract. Bicycles are one of the sports equipment as well as a mode of transportation that is environmentally friendly, when using a bicycle, all members of the body perform movements. In this study, a tricycle with a delta concept was made, that is 2 wheels behind and 1 wheel in front. This bike is designed to help stroke sufferers perform physical rehabilitation independently by pedaling a bicycle. To find out the benefits of bicycles to help cure strokes, especially the legs of the patient, a stroke test were carried out for 1 month (30 days) by 4 stroke patients, who were the respondents in this research. Each respondent pedaled the bike once every 3 days, so the amount of therapy became 9 times a month for each respondent. During pedaling respondents vital sign was recorded, the value of heart recovery rate (HRR) and amount of energy consumption were calculated. To find out the usefulness of bicycle therapy for stroke patients, 4 stroke sufferers were also selected who were doing stroke rehabilitation as respondents in this research, but did not pedal a bicycle. Furthermore, all respondents, whether bicycle therapy or not, performed a fitness test using the six minute walking test (6-MWT) test method. The method is used to determine the maximum oxygen volume capacity (VO2 max) of a person who walks on a certain path for 6 minutes. From the test, it can be seen that the distance taken by the respondent after walking for 6 minutes. The distance traveled is converted in the form of VO2 Max capacity. The test results shows that respondent therapy using a bicycle has a significant increase in body fitness, compared to respondent therapy without using a bicycle.

1. Introduction

Stroke makes the sufferer experience interference in the body's coordination system. One method of healing stroke is to use therapy that aims to restore the body's coordination function. Various tools were created by experts to help stroke patients perform physical therapy to speed up healing or recovery of patients from stroke. Besides the conventional treatments in the physical rehabilitation section of the hospital, equipment that's widely used to help treat stroke patients is a static bicycle, Leg and Arm / Upper Body Trainer, and a treadmill. Static bicycle therapy equipment is a common therapeutic tool in hospitals and health and sports equipment stores. Static bicycles can be used for rehabilitation of patients who are sick with calcification, knee pain, stroke, or post-accident that are recommended by doctors to train their legs, knees or joints.

Leg and Arm / Upper Body Trainer is a special rehabilitation tool developed by the MOTOmed company, as shown in figure 1. This device functions like a static bicycle, which is there is a stroke for the feet. The difference is in this tool, the patient does not need to move seats from a wheelchair or ordinary chair that has wider surface area and is comfortable than a small static bicycle seat. In
addition there are also strokes for hands and monitors that can indicate feedback from the rehabilitation being performed.

Figure 1. Leg and Arm / Upper Body Trainer along with examples of its use [MOTOmed]

The new study found that a structured and progressive walking exercise program using a treadmill, was effective in helping patients to build strength and balance after one year suffer from stroke. The study also found that 52 percent of stroke patients who participated, in physical therapy programs that included in treadmill walking exercises and home programs that focused on progressive strength and balance exercises experienced an improvement in walking ability. This trial was held by Locomotor Experience Applied Post-stroke (LEAPS) and led by physical therapist Pamela W. Duncan, and involved 408 participants who had a stroke. Researchers initially hypothesized that physical therapy with the help of a treadmill and coupled with a walking program, were more effective than exercises just performed at home. But after one year, both methods proved to have the same effectiveness that is able to increase walking speed, balance, and quality of life, "said Duncan of Duke University School of Medicine in Durham, North Carolina". Examples of the use of treadmills for stroke therapy can be seen in Figure 2.

Figure 2. Treadmill

According to Duncan, research conducted for six months concluded that both forms of physical therapy programs, both treadmills and physical exercises at home are more effective and superior, when compared to the usual standard care provided.

The above equipment can only be used in a fixed place, can not help stroke patients to move places independently, such as going to the park, seeing the environment or to the market. Therefore, since 2013 at the Product Design and Development Laboratory, the Mechanical Engineering Department of
ITS, three-wheeled bicycles have been designed and developed as a physical therapy aid for stroke sufferers by several designers [1] [2] [6]. Three-wheeled bicycles developed are intended to help stroke patients carry out physical therapy as well as psychological therapy, where patients not only live inside the house, but also can see and enjoy the environment, and can even go pedaling to public places, such as parks, markets and other places [5]. The entire bicycle design is based on the tadpole concept, which is a tricycle, where 2 wheels are installed in the front and 1 wheel is mounted behind. In principle, the bicycle is very helpful for stroke sufferers to do therapy by pedaling. But the design still has problems in setting the right and left turn movements by the patient. This is because, the 2 front wheels are quite heavy to be bent, on the other hand stroke sufferers often do not have the strength to move things by hand. To overcome this problem, since 2016 a delta concept tricycle was developed, that is a tricycle with 1 wheel in front and 2 wheels behind [3] [4]. The prototype of a bicycle therapy design with the delta concept as shown in figure 3. To find out the benefits of bicycles as a stroke rehabilitation aid, stroke patients were tested with stroke requirements in accordance with the standard and procedure for stroke patients.

2. Research Method
The method used in this study is an experiment using a bicycle. Respondents in this study were stroke patients who were undergoing therapy at the Haji Surabaya General Hospital Medical Rehabilitation Installation. Respondents were divided into two groups, namely: therapy groups using tricycles (post stroke bikes) and therapy groups without using bicycles. Respondents underwent a physical fitness examination using the 6-MWT method at the beginning of therapy and one month after therapy. Therapy using a bicycle after a stroke is done dynamically through a predetermined path. Before the implementation of therapy, vital sign respondents were taken, and continued with warming up for 5 minutes. During the respondent’s performs therapy, the speed of the bicycle was maintained in the range of 4-6 Km/hour, this was done to avoid the excessive workload on the respondent's body and avoid the occurrence of accidents when respondent’s perform the therapy, considering that this was the first therapy to use a bicycle dynamically for patients post stroke. Vital sign measurements include measurement of heart rate, blood pressure and respiratory intensity (Respiration). The measuring instrument used to measure vital sign is a cyclometer, tens meter, stop watch. During the paddle test, respondent’s pedaled two sessions with a duration of each session for 10 minutes. At the end of each session a vital sign was taken and the respondent was asked to rest for 3 minutes. Experimental results are displayed in the graph of the heart rate, blood pressure and respiratory intensity (Respiration). Besides that, there is also a graph of the development of the heart recovery rate (HRR), the VO2 Max chart, and the graph of the energy consumption of the respondent during pedaling. At the end of the research, the fitness of each respondent will be evaluated, both respondent therapy with bicycle and respondent who do therapy manually without pedaling a bicycle. From these results it can be seen the usefulness of tricycle as a physical therapy aid for stroke patients.

3. Experimental Trials

3.1. Testing Procedures
In this study, the type of stroke therapy that will be given to post-stroke respondents is dynamic paddle therapy. Therefore, to ensure the safety of respondents and ensure each respondent gets identical treatment, it is necessary to have testing procedures. Before paddling therapy using a post stroke bikes is started, measurement of the vital sign respondent is done first, then the measurement results are recorded in the data sheet. Then the respondent warms up for 5 minutes, after warms up the respondent will performs the first stage of paddle therapy for 10 minutes. After 10 minutes, the respondent is rested for 2 minutes and the vital sign is recorded. Then the respondent entered the second stage paddle therapy for ten minutes. After 10 minutes the respondent is rested for 2 minutes and the vital sign is recorded. The stages of therapy were repeated 9 times. The 6-MWT measurement was done before the first therapy, after the ninth.
Respondents in this research were post stroke patients who had passed the critical period and bed rest. This means that post-stroke patients who are respondents are post-stroke patients with a stable vital sign, so that it will allow them to perform maximum paddle therapy and the risk of having another stroke is small. Respondents who participated in this research amounted to 8 respondents, the 8 respondents will be divided into two groups, namely the paddle therapy group (A, B, C, and D) and the non-paddle therapy group (E, F, G, and H). Respondent data in this study can be seen in table 1.

| Name     | Age (Yrs) | Weight (Kg) | Type of Stroke | Group               |
|----------|-----------|-------------|----------------|---------------------|
| Winarno  | 62        | 68          | Stroke Infark  | Paddle therapy group|
| Suyono   | 55        | 58          | Stroke Infark  |                     |
| Lexi     | 72        | 65          | Stroke Infark  |                     |
| Ahyar    | 45        | 62          | Stroke Infark  | Paddle therapy group|
| Soekardi | 66        | 58          | Stroke Infark  | Non Paddle therapy group |
| Gunawan  | 52        | 58          | Stroke Infark  |                     |
| Suyono   | 64        | 69          | Stroke Infark  |                     |
| Puamin   | 58        | 57          | Stroke Infark  |                     |

3.2. Results Of Vital Sign Measurement and Fitness
From the research that have been carried out, there are vital sign charts which include: heart rate, blood pressure, and respiratory intensity, as well as graphs of heart recovery rate (HRR) development, VO2 max chart, and consumption graph of respondent energy paddle.

3.2.1. Heart Rate.
During therapy by pedaling a bicycle, the heart rate of paddle therapy group was measured. Measurement results are displayed in the graph and can be seen in Figure 5.

![Figure 3. Development of heart rate (Heart rate) of respondents A, B, C and D](image-url)

From graph in the figure 3, it can be seen that the heart rate of each respondent that is the respondents A, B, C and D are stable, during the four respondents doing therapy using post stroke bikes. The respondent's heart rate is said to be stable if there is no extreme change that exceeds the safe limit, namely (50-80)% of the maximum heart rate of each respondent.
3.2.2. Blood Pressure
Respondent's blood pressure was measured during a paddle therapy with tensimeter. The results of blood pressure measurement from paddle therapy group can be seen in Figure 4.

![Figure 4](image1.png)

**Figure 4.** Development of blood pressure (TD) of respondents A, B, C and D

From graph in Figure 4, it can be seen that the blood pressure of each respondents, respondents A, B, C and D who were doing bicycle therapy after stroke is stable. The respondent's blood pressure is said to be stable if there is no extreme change that exceeds the safe limit. However, for respondent A requires special attention because blood pressure tends to decrease, a decrease in blood pressure can be caused by disruption of nerve function that regulates blood pressure, but it can also be caused by dehydration and drug use. Besides respondent A, respondent B also needs special attention, this is because the respondent's blood pressure is close to the upper limit of the blood pressure that is permitted. Stable blood pressure will reduce the risk of the respondent having a stroke again when the respondent undergoes therapy using a bicycle after a stroke.

3.2.3. Respiratory Intensity
The respiratory intensity in question is the amount of inhalation and exhalation during a certain period. The results of the measurement of respiration intensity for 2 x 10 minutes pedaling is poured in graphical form. The following is a graph of respiratory intensity of respondents A, B, C and D during therapy using a post stroke bicycle, can be seen in Figure 5.

![Figure 5](image2.png)

**Figure 5.** Development of respiration intensity of respondents A, B, C and D

From the graph above, it can be seen that the respiratory intensity of each respondent, namely respondents A, B, C and D is stable during post stroke bicycle therapy. Respondent's respiration intensity is said to be stable if there is no extreme change that exceeds the safe limit. However, for
respondents A and B need to get special attention, this is because the respondent's A and B respiration intensity exceeds the allowed upper limit of 20 inhalation exhalations per minute.

3.2.4. Heart Recovery Rate (HRR)
In this sub-chapter will be discussed about the heart recovery rate (HRR) of respondents A, B, C and D during post stroke bicycle therapy. Heart recovery rate is obtained from the results of a reduction in heart rate just after physical activity with a heart rate at 2 minutes after a person has done physical activity. Using the formula of equation (1), the HRR of each respondent can be known, as follows:

\[ HRR = HR_{just\ after\ exercise} - HR_{2\ minute\ after\ exercise} \]  

(1)

After the respondent's heart rate was measured, then the HRR value of each respondent was calculated and presented in graphical form as shown in figure 6 below.

![Figure 6. Development of heart recovery rate of respondents A, B, C and D](image-url)

From the graph above, it can be seen that the heart recovery rate of each respondent, namely respondents A, B, C and D, began to develop better, this was indicated by an increase in heart recovery rate of each respondent. Heart recovery rate from respondents A, B, C and D is far from the normal number of 22-52 beats per 2 minutes. Heart recovery rate values that are still far below these standards indicate that the heart condition of respondents A, B, C and D is in a bad condition. An increase in the heart recovery rate of respondents means that the heart rate of respondents A, B, C and D increases with the burden of the activities carried out, but the heart of respondents A, B, C and D takes longer than normal people to return to heart rate normal (resting pulse). On the heart recovery rate chart shown in Figure 8, it is known that the increase is very extreme, which is 2 beats per 2 minutes. This extreme increase occurs due to the calculation method used, where the pulse rate calculation method used is calculating the pulse at the first 15 seconds then multiplied by 4 to get pulses per minute of the respondent's pulse. From these results obtained the pulse of the respondent for session 1 therapy and session 2 therapy, then searched for the average pulse rate from both sessions. With this measurement method, the accuracy obtained is at least 2 beats per 2 minutes.

3.2.5. \( VO_2 \) Maximum
\( VO_2 \) Max measurement, aims to get the amount of \( O_2 \) that can be processed by the respondent’s body during carrying out paddling therapy using a post stroke bicycle. \( VO_2 \) Max as long as the patient performs therapy using a post stroke bicycle is obtained from an equation which is a function of the maximum heart rate (HR Max) and the resting heart rate of the respondent (HR Rest) listed in equation (2).
\[ VO_2 \text{ Max} = 15.3 \times \frac{HR_{\text{Max}}}{HR_{\text{Rest}}} \]  

Where:

- \( HR_{\text{Max}} \) = Heart rate just after therapy
- \( HR_{\text{Rest}} \) = Heart rate at 2 minutes after therapy (recovery heart rate).

Figure 7. Development of VO2 Maximum capacity of respondents A, B, C and D

From the graph above, it can be seen that the VO2 Max capacity of each respondent is respondents A, B, C and D. For respondents A and C experienced an increase in VO2 Max, while respondents B and D experienced a decrease in VO2 Max capacity. Respondent A experienced an increase of 10.28% of VO2 Max capacity compared when the respondent A performed the first time post stroke bicycle therapy. Respondent B experienced a decrease of 6.93% from VO2 Max capacity at the first time post stroke bicycle therapy. The decrease in VO2 Max capacity from respondent B was influenced by the heart rate of respondents who tended to be high in the last few therapies without following the increase in HRR of respondent B. Respondent C experienced an increase of 4.88% of VO2 Max capacity compared when the respondent C performed the first time post stroke bicycle therapy. The decrease in VO2 Max capacity from respondent D was influenced by the heart rate of respondent D did not experience a big change as long as respondent D underwent post stroke bicycle. This is because the height of the bicycle is not in accordance with the respondent D body posture which causes respondents feels uncomfortable and afraid to fall when use post stroke bicycle which causes the respondents' heart rate to increase.

3.2.6. Energy Consumption

Paddle energy is the amount of energy used by respondents to carry out paddling therapy activities using post stroke bicycle. The value of the energy released by the respondent was obtained by using the quadratic regression equation of the respondent's heart rate listed in equation 3. From the quadratic regression equation can be known the amount of energy released by the respondent during therapy and when the respondent rested. The results of the calculation of the respondent's energy calculation can be seen in Figure 8.

\[ KE = Et - Ei \]  

Where:

- \( KE \) = Energy consumption for certain activities (Kcal / minute)
- \( Et \) = Expenditures of energy at a certain work time (Kcal / minute)
- \( Ei \) = Energy expenditure at rest (Kcal / minute)
Figure 8. Development of energy consumption of respondents A, B, C and D

From the graph of energy consumption of each respondent in Figure 8, it can be seen that the energy consumption of each respondent A, B, C and D are as follows: Energy consumption of respondent A experienced an increase of 34.04% compared when the respondent A performed the first time post stroke bicycle therapy. Energy consumption of respondent B experienced an increase of 67.05% compared when the respondent B performed the first time post stroke bicycle therapy. Energy consumption of respondent C experienced an increase of 42.27% compared when the respondent C performed the first time post stroke bicycle therapy. Energy consumption of respondent D experienced an increase of 56.82% compared when the respondent D performed the first time post stroke bicycle therapy. On the graph of energy consumption of respondents A, B, C and D there is a drastic increase. Keep in mind the amount of energy consumption needed to perform activities is a function of heart rate. So that the rhythm of the heart rate of the respondent is very influential on the graph of energy consumption.

4. Usefulness Analysis of Post Stroke Bicycle

To determine the usefulness of post stroke bicycle in helping to recover the health of stroke patients. Then the VO\(_2\) Max analysis from the two groups that became respondents in this research was carried out. The measurement of VO\(_2\) Max in both groups used the 6 minute walking test method. So that the measurement results of VO\(_2\) Max from both groups can be compared both descriptively. This method is used because, being able to interpret respondent VO\(_2\) Max well, besides this method also does not cause fatigue effect on the respondent and can be done independently and does not require a lot of money. From the results of testing the 6 minute walking test on both groups of respondents, the data obtained increased VO\(_2\)Max of each group as in table 2 as follows.

From the table it can be seen that, there was a difference in the increase in VO\(_2\) Max capacity in both therapy groups. Therapy groups that use post stroke bicycle have an average increase in VO\(_2\) Max capacity of 1,892 mL / (Kg.min). While the group of therapy without using post stroke bicycle has an average increase in VO\(_2\) Max capacity of 1,282 mL / (Kg.min). This means that with the help of post stroke bicycle for 30 days, the VO\(_2\) Max capacity of the post stroke bicycle therapy group is 47.58% greater than the therapy group without using post stroke bicycle.
Table 2. Enhancing Body Fitness for Each Group

| Respondents          | VO₂ Max Capacity (Using 6 MWT Method) (mL/(Kg.minute)) | 1st Evaluation | 2nd Evaluation | ∆ VO₂ Max | Mean of oxygen volumen (∆ VO₂ Max) each group |
|----------------------|--------------------------------------------------------|----------------|----------------|-----------|-----------------------------------------------|
| Paddle therapy group | A                                                      | 28,95          | 31,16          | 2,216     |                                                |
|                      | B                                                      | 31,68          | 33,32          | 1,646     |                                                |
|                      | C                                                      | 26,93          | 28,69          | 1,761     |                                                |
|                      | D                                                      | 32,90          | 34,84          | 1,945     |                                                |
| Non – Paddle therapy group | E                                              | 29,71          | 31,10          | 1,393     |                                                |
|                      | F                                                      | 31,45          | 32,57          | 1,122     |                                                |
|                      | G                                                      | 33,25          | 34,51          | 1,260     |                                                |
|                      | H                                                      | 27,98          | 29,33          | 1,352     |                                                |

5. Conclusion
From the usefulness analysis that has been done, it was found that the body fitness of the respondent of paddling therapy using post stroke bicycle experienced an increase of 47.58% more than the respondents of therapy without using post stroke bicycle. So it can be concluded that the tricycle is very helpful for the patient to perform physical therapy, and in a certain time can recover patient health, at least in 1 month the patients more be able to move their legs.

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