Underwater Treadmill for Exercise and Injury Prevention for the Elderly

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Abstract: This research is to develop an underwater treadmill for ageing people who have osteoarthritis problems or the elderly who need physical therapy or exercise by designing the structure of the treadmill to be strong, portable and safe to use. As Thai society in the present is becoming an aging society, most of the elderly have symptoms of osteoarthritis. This underwater treadmill device is essential to reduce knee injuries while exercising. It is also effective to use for walking or running as regular treadmill. In addition, the COVID-19 pandemic made life difficult for the elderly to do regular exercise in normal fitness place or a public sport complex due to the need to observe the social distancing and vigilant COVID-19 prevention. In this experiment, a total of 7 subjects were used with subjects running on a treadmill (on land) and on an underwater treadmill (in water) developed for walking or running in water. Seven parameters are collected for both (land and water) running to compare the performance of both treadmills and their feelings after using an underwater treadmill with 7 parameters: 1) VO2 2) VO2 /kg 3) Heart rate 4) %Heart rate 5) Respiratory Exchange Ratio (RER) 6) Total Energy Expenditure (Total EE) 7) Rating of Perceived Exertion (RPE). The results showed that the underwater treadmill had higher exercise energy efficiency than the land-based electric treadmill while running with the same speed. Moreover, the underwater treadmill can reduce impact on the knees with the help the water resistance and uplift during the exercise.

*Keyword***:** Underwater treadmill, osteoarthritis, elderly people, exercise

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1. Introduction

Osteoarthritis of Knee is a condition in which the knee joint deteriorates as a result of articular cartilage, which is constantly corroded over time, or subchondral bone thickening, as well as synovial fluid that helps to lubricate the joints. [1] From statistics in 2017, it was found that there are more than 6 million cases of the disease and it is likely to increase every year. [4] The most degenerative joint is knee arthritis. Most people think that osteoarthritis occurs in the elderly because it deteriorates the body with age, but the fact that the disease can also occur in adolescents and working ages. The knee joint is classified as the largest joint in the body, acting to help hold about 3-4 times the weight of the body. If you are overweight or perform high impact activities, it will result in a greater burden on the knee joint. This is one of the leading causes of osteoarthritis. People with extreme osteoarthritis, if not treated or treated properly, will cause pain. Deformed knee joints, irregular walking. [5] Activities during inconvenient days can be suffered both physically and mentally. This water treadmill, also known as Underwater Treadmill, is another option of a new workout. [6] Underwater Treadmill is burning four times as much calories as it does. It can also treat sports injuries as well as help with physiotherapy for patients. As a result, leading fitness facilities and hospitals in Thailand have incorporated it into Tara Therapy physiotherapy to strengthen health and rejuvenate the body from illness.

Figure 1. High-cost commercial underwater treadmill.

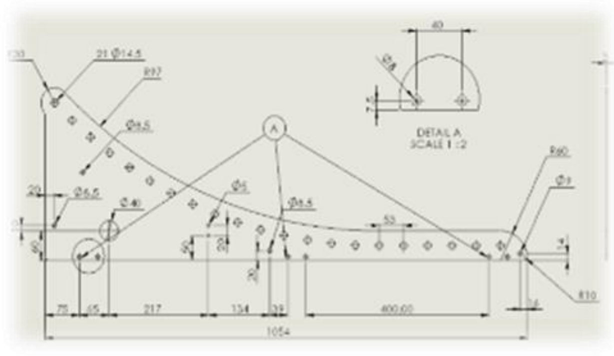
Figure 1 is a high-cost commercial underwater treadmill which is one of the two main types of underwater Treadmills: glass cabinets and the other for use in the pool. As the elderly in many countries may not be able to afford the high-cost glass cabinet type of the underwater treadmill, a non-electric underwater treadmill as a device for underwater exercise to reduce the risk of knee joint damage for the elderly was developed for the purpose and the treadmill was tested to evaluate the effectiveness comparing to normal electrical treadmill. The device was designed to be lightweight, easy to carry, to be used in the pool without harm to people around or the environment.

2. Design Structure of Treadmill

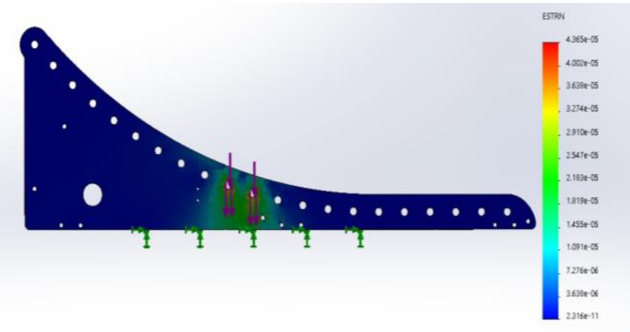
2.1 Structure Design

The overall structural design of the underwater treadmill was designed with SolidWorks (SolidWorks) program.

Studies and research have shown that curved treadmill users have less injuries from osteoarthritis than flat treadmills, so this underwater treadmill was designed to be curve in shape that can reduce knee pain better than the flat model. From human anthropology, the human pace has a length of approximately 35-50 centimeters, which from the survey of the length of the treadmill showed that 32 treadmill machines had the average width of 46 cm and the length of 128 cm. The curved treadmill was larger than the typical slope treadmill. From this finding, the developing treadmill machine was designed to have a width of 47 centimeters and a length of 160 centimeters as shown in Figure 2. As for the length, it must be calculated to calculate the height from the slope. and find the appropriate length (net length).



(a)



(b)

Figure 2. (a) The drawing of treadmill design and (b) Finite Element Analysis of simulation of loading damage to treadmill structural

2.2 Calculation of Loading Damage

Calculation of damage that may occur to an underwater treadmill using the Solid work program is divided into 2 main sections. There are 2 parts which are the treadmill structure and pipe section:

1) Calculate the damage of the treadmill structural part.

The load is set to 1000 Newtons at the connection point with 2 pipes in all 3 locations, namely the front, middle and rear areas, to simulate stepping and to support the weight while resting (this is a calculation of an underwater treadmill for use on land to obtain the force acting in the direction at the maximum load)

2) Calculation of the damage of the pipe section as shown in Figure 3.

The load is set to 1000 N at the pipe's contact surface. To simulate stepping and weight support (this is an underwater treadmill calculation for land use in order to get the maximum strength to carry the load)

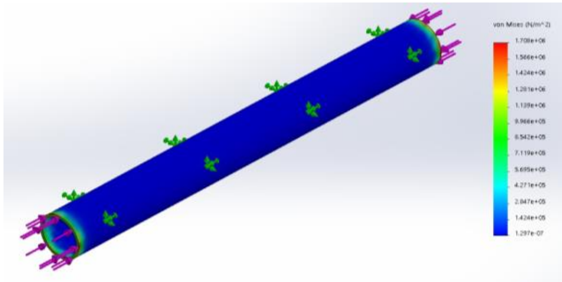


Figure 3. Calculation of the damage of the pipe section

Having designed and assembled the structure of the underwater treadmill, the assembled treadmill was designed to strengthen the frame on both sides and the front axle. Additionally, it is reinforced with wheels. To make it easier to transport. For the handle area, it is firmly assembled with the pivot point and the nut attachment. The completely assembled treadmill can be tested and evaluated to find out the efficiency when it is actually used in water comparing to the ordinary land treadmill.

a

b

Figure 4. The Fully Assembled Treadmill

3. METHODS to compare the efficiency between a conventional and a curved underwater treadmill

This experiment was set to compare the performance between a conventional treadmill and a curved underwater treadmill. The experiment was determined to consist of 7 participants. In the experiment, a gas analyzer (PNOE, California, United States) was used to display results through an application on mobile phone or a tablet. The PNOE was used to find the values of interest between using a general land treadmill and a curved underwater treadmill. The values which were of interest are VO2 (Oxygen consumption), HR (Heart Rate), RER (Respiratory Exchange Ratio), Total EE (Total Energy Expenditure) and RPE (Rating of Perceived Exertion), which are values used to analyze the differences between conventional treadmills and curved underwater treadmills.

A total of 7 healthy subjects were recruited with the subjects running on a treadmill (on land) and on an underwater treadmill (in water) developed for walking or running in water. As mentioned, seven parameters are collected for both (land and water) running to compare the performance of both treadmills and their feelings after using an underwater treadmill with 7 parameters: 1) VO2 2) VO2 /kg 3) Heart rate 4) %Heart rate 5) Respiratory Exchange Ratio (RER) 6) Total Energy Expenditure (Total EE) และ 7) Rating of Perceived Exertion (RPE).

Seven volunteers of healthy university student subjects with informed consent were recruited to perform running on conventional treadmills and curved underwater treadmills.

No.	Weight(kg)	Height (cm)	Gender
1	58	180	male
2	81	170	male
3	63	174	male
4	60	174	male
5	52	165	female
6	45	153	female
7	80	165	male

Figure 5. The details of the subjects.

As this trial was done during the COVID-19 pandemic, healthy volunteers were used to avoid any risks to the elderly. The details of the subjects are in Figure 5.

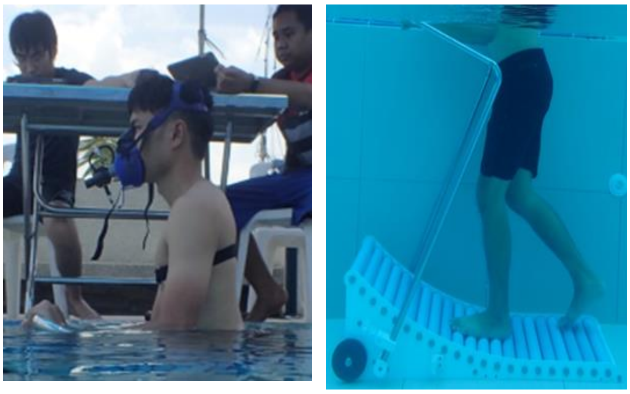
3.1 General Treadmill Experiment

A conventional treadmill (h/p/cosmos, Munich, Germany) was used in comparison with an underwater treadmill. This comparison was done because the conventional treadmill is an exercise option that many exercisers focus on and prefer to use in the normal exercise. Therefore, it is compared with an underwater treadmill in order to see the difference and show the suitability of the actual use. Initially, each subject wore a mask to the gas analyzer and a chest heart rate monitor. By setting the treadmill speed randomly ordering all the speeds used from 4 values: 2.8 km/h , 3.28 km/h , 3.78 km/h and 2.8 km/h, it takes 5 minutes to walk at each speed. alternate with rest In the land treadmill experiment, an average pedometer was installed per minute (Step/min) of each subject. To use the average number of steps per minute obtained in an underwater treadmill experiment. After walking on a normal treadmill at a random speed, the values that interest us are recorded in the data for analysis to determine the difference. The setup of gas analyzer on the subject is shows in Figure 6 below.

Figure 6. The subject wearing the Gas Analyzer

3.2 Curved Underwater Treadmill Experiment

Since the curved treadmill is a non-electric treadmill, it is not possible to set a constant speed to an underwater treadmill like a conventional treadmill. Therefore, the average steps per minute data at various speeds of general treadmill experiments were determined as individual cadences at each speed. which uses a metronome to create a cadence of steps on a curved underwater treadmill The experiment uses a gas analyzer in the experiment with the characteristics of the experiment, like all conventional treadmill trials. Each subject wears a mask, gas analyzer and wears a chest heart rate monitor to be tested in a pool at a depth of 1.2 m. Provides a cadence for walking through a metronome that corresponds to four speed values: 2.8 km/h, 3.28 km/h, 3.78 km/h and 2.8 km/h. It takes 5 minutes to walk at each speed, alternating with a rest. After the experiment was completed, the obtained values were recorded and recorded. The comparative data was obtained between a conventional treadmill and an underwater treadmill.



(a) A subject in water (b) Underwater view of subject

Figure 7. underwater treadmill experiment

4. Results and Discussion

The test measured the performance of an underwater treadmill compared to a land treadmill with seven evaluation values:

1) VO2 (Oxygen consumption) indicates the efficiency of aerobic metabolism in milliliters per minute (ml/min).

2) VO2/kg Each exercise, how much oxygen does 1 kg of our body use in this process in 1 minute ml per 1 kg of body weight per minute (ml/min /kg)

3) HR (Heart Rate) is the heart rate. Our heart's pulse BPM is an abbreviation for beats per minute, or BPM, which stands for Beats Per Minute.

4) %HR is our heart rate. to indicate that the level of fatigue It also helps to determine the intensity of the exercise as well. The heart rate zone is divided into 5 zones as shown in Figure 8.

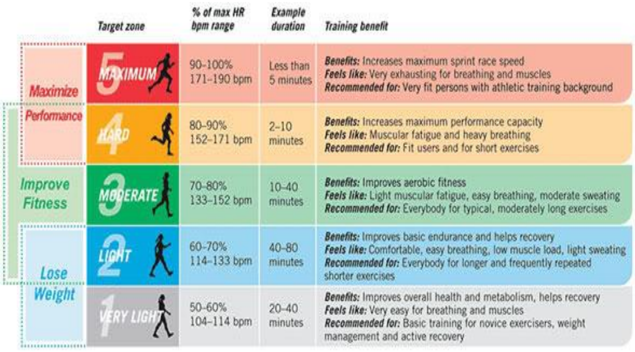


Figure 8. The Heart rate zone

4.1 The results of the VO2 test on land and underwater treadmills

VO_2 of land treadmill	2.8 km/hr	3.3 km/hr	3.8 km/hr	2.8 km/hr
subject 1	387	384.7	488.9	416.2
2	644.4	776	876.9	643.6
3	597.2	607	691.6	533.9
4	576.1	652.2	700.2	585.9
5	335	403.1	424.9	383.3
6	279.1	356.2	362.3	299.4
7	699.9	733.4	750.4	679.3
mean	502.67	558.94	613.6	505.94
SD	165.73	175.27	189.71	142.56

VO_2 of underwater	2.8 km/hr	3.3 km/hr	3.8 km/hr	2.8 km/hr
subject 1	478.3	525.1	660.7	493.5
2	1096	1043.7	1674.8	851.8
3	1082.4	1044	1182.3	859.1
4	623.7	827.5	1078.2	795.7
5	774	801.6	1048.6	777.3
6	458.3	517.3	613.9	484
7	896.4	830.5	912.4	803.6
mean	772.73	798.53	1024.41	723.57
SD	265.66	214.51	357.02	163.11

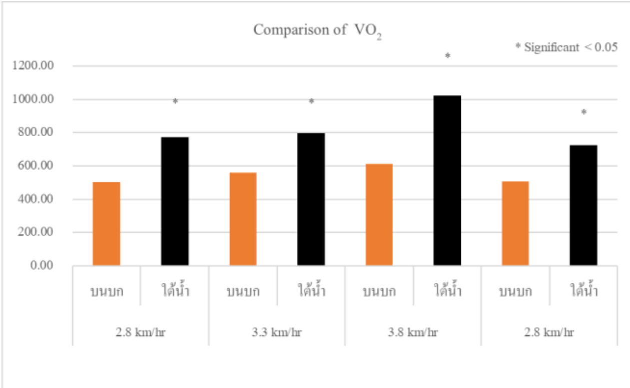
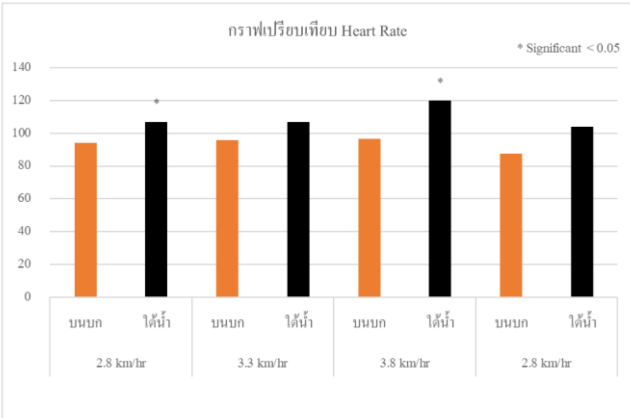


Figure 9. Results of VO2 of Land and Underwater Treadmill

4.2 The results of the Heart Rate on land and underwater treadmills



Paired t-test 2 tails	HR at 2.8 km/hr land vs underwater	HR at 3.3 km/hr land vs underwater	HR at 3.8 km/hr land vs underwater	HR at 2.8 km/hr land vs underwater
P-value	0.022	0.127	0.001	0.156

Figure 10. Statistics of Paired t-test, 2-Tailed of HR

A summary of results to compare the efficacy and parameters obtained from the land and underwater treadmill can be shown in Figure 11.

Earth	km/hr	VO_2 (ml/min)	VO_2 (ml/min/kg)	HR(bpm)	%HR	RER	Total EE	RPE
A	2.8	597.2	9.5	87	43.94	0.81	13.6	8
B	3.3	607	9.6	88	44.44	0.74	13.9	9
C	3.8	691.6	11	87	43.94	0.78	16	9
D	2.8	533.9	8.5	88	44.44	0.76	12.2	9

Water	km/hr	VO_2 (ml/min)	VO_2 (ml/min/kg)	HR (bpm)	%HR	RER	Total EE	RPE
A	2.8	1082.4	17.2	108	54.55	0.83	24.9	8
B	3.3	1044	16.6	106	53.54	0.79	24.1	8
C	3.8	1182.3	18.8	112	56.57	0.83	27.3	9
D	2.8	859.1	13.6	100	50.51	0.83	19.8	7

Figure 11. Summary of comparison of all parameters

The results showed that the underwater treadmill had higher exercise energy efficiency than the land-based electric treadmill while running with the same speed. Moreover, the underwater treadmill can reduce impact on the knees with the help the water resistance and uplift during the exercise. The satisfaction assessment results indicated that subjects were satisfied with 91.4% of the structure's strength and design, 82.9% of usability, 88.6% of its cost-effectiveness, and overall practicality and injury reduction performance of the knee 91.4%. Due to the COVID-19 pandemic, the developed prototype could not be tested by the elderly as it was too risky under the COVID-19. Therefore, the prototype was tested by the seven healthy adult subjects. Furthermore, the elderly care specialist assessed and evaluated the prototype as moderately safe usage results were obtained. The average level of satisfaction from the elderly care specialist is 70% as there is a concern about the need to prevent the elderly fall. The findings from this study are promising for the future development of exercising devices for ageing people who have osteoarthritis problems or the elderly who need physical therapy or regular exercise without the risk of knee or joint injury.

5. Conclusion

This research was conducted to develop an underwater treadmill for ageing people who have osteoarthritis problems or the elderly who need physical therapy or exercise by designing the structure of the treadmill to be strong, portable and safe to use. The findings show that the results are in the same direction as expected. For protocols used in general treadmill walking groups. The speed used cannot cause the recognition of a person. The underwater treadmill is more effective than a normal treadmill. In terms of weight, fatigue energy and reducing the negative effects on the knee joint resulting from the support of water and walking in the form of the natural gait of the human body, it is suitable for people with osteoarthritis. Elderly or overweight. In this way, it is also effective to use for walking or running as regular treadmill. In addition, as the COVID-19 pandemic made life difficult for the elderly to do regular exercise in normal fitness place or a public sport complex due to the need to observe the social distancing and vigilant COVID-19 prevention. The intensity of walking on an underwater treadmill was found to be higher and significantly different from that of a general treadmill which can help the exercise and injury prevention of the elderly.

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The authors have no conflicts of interest to declare that are relevant to the content of this article.