DESIGN AND DEVELOPMENT OF A CORE STRENGTHENING EXERCISE AND REHABILITATION MACHINE FOR ELDERLY

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Received: March 06, 2020; Revised: May 23, 2020; Accepted: June 04, 2020

Abstract

For elderly people, being healthy is factor that allows them to live their daily lives normally. Reinforcing the strength of core muscles is extremely important. However, there are several limitations of currently available exercise machines. Firstly, the currently exercise machines are not suitable for improving elderly people's core muscles due to posting certain threats to elderly people. Secondly, exercise machines are not easily accessible and quite expensive. Therefore, the researchers design and develop the exercise machine specifically for improving elderly people' core muscles. The machine is equipped with the weight-assisted system that assists the user's body weight during the exercise with the 6-adjustable levels of assistance, from 2.5-15 kg. The weight-assisted system allows elderly people to exercise much easier and for a longer period of time and reduces potential injury and the force of impact. The designed machine has the initial angle of movement at 110 to 140 degrees. The researchers use correlation coefficients to analyze validity and reliability of the machine's weight-assisted system in order to make sure that the weight-assisted system will assist users with the required weight and that the assistance will be reliable and consistent during individual use. The results reveal that the machine's validity is P = 0.000 (r = 0.998) and the reliability is P = 0.000 (r = 1.000) which present the statistical significance. Therefore, this machine is considered a suitable option for elder people to use in their exercise or physical therapy to improve the strength of their core muscles.

Keywords: Core Strengthening, Exercise Machine, Rehabilitation Machine, Partial Weight-Assisted Mechanism, Elderly

Introduction

Elderly people are very important in Thai society, whether in terms of social activities, economy, culture, etc. Elderly people play vital role in Thailand and as the country sees the rising number of elderly people every year, preparation for becoming an Aged Society becomes a thing that everyone emphasizes, in order to continuously drive the country's economy and society efficiently. For

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elderly people, having good health is another factor that allows them to live their daily lives normally. Having good health also reduces the risk of falling, the cost of health care and the cost of treatment for chronic illnesses (Laukkanen *et al*., 1995; Moreland *et al*., 2004) Therefore, the researchers focus on the subject of improving elderly people's health and preventing any illness. The movement of core muscles to stabilize the body works closely with the body's movement in various planes (Hibbs *et al*., 2008). If elderly people have strong core muscles, they will be able to perform various daily routines and activities easily, for example, to reach up and grab something without falling, to walk quickly without the need to use walking aids, etc (Cavani *et al*., 2002; Latham *et al*., 2003). As we age, our physical performance deteriorates, as well as our bodily functions. The most prominently found problem in elderly people is the weak abdominal muscle, which greatly affects their daily lives, for example, causing them to fall. Weak abdominal muscles are the result of the shrinking size of muscular fibers from the muscle atrophy where, as a result, elderly people suffer diminishing physical strength of their muscles (William *et al*., 2015; Bertoli *et al*., 2017). Moreover, as a result of the reduced stability of the body, elderly people are prone to fall. Falling is the main reason of broken bones in elderly people, as well as many complications, even mortality. Fall-related injuries, such as broken bones, will deprive elderly people's independence to live their lives, put them into the hospital, or even lead to their death (Roe *et al*., 2009).

(a)

(b)

Figure 1. (a) and (b) depicting the machine's movements for exercising and therapy to improve the strength of elderly people's core muscles

Most importantly, the Trunk-stabilizing Muscle Weakness was used as an index for determining the risk of injury to muscles and joints (Hibbs *et al*., 2008). Therefore, having strong core muscles is highly important for elderly people to live their lives

However, most of the exercise machines made for building of core muscles are resistance-based machines (Kasee, 2004; Ellis, 2014; Jelenko, 2019; Lalaoua, 2019) individuals with weak muscles may not be able to use these machines to exercise efficiently. Moreover, using these machines in such a condition presents them the risk of injury and further harms. Also, exercise machines are quite large and hard to use. Users will require the assistance of several medical personnel to use the machine. These machines are also hardly accessible to Thai people, as they are expensive and mostly imported. Therefore, the researchers intend to develop a Core Strengthening Exercise and Rehabilitation Machine for Elderly that can be used for exercising and physical therapy, with the aim to improve the core muscles' strength of elderly people, for them to train and restore their core muscles and to improve the core muscles' strength.

Design and Development

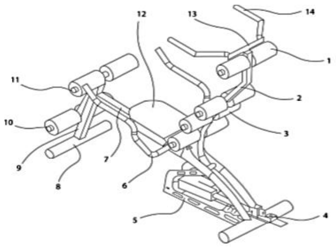
The researchers design the Core Strengthening Exercise and Rehabilitation Machine for Elderly with the weight-assisted system and designs the movement angle of the machine to match the requirement of elderly people, with the aim to improve the strength of elderly people' core muscles. The machine movements involve the transition from sitting to the reclined position, as depicted in Figure 1.

This form of movements allows the strengthening of several muscle groups, namely, Rectus Abdominis, External Oblique, Internal Oblique, and Transversus Abdominis. The researchers design the machine to be equipped with the remote controlled, adjustable weight-assisted system that helps stabilize users' body. The machine is also equipped with hand rails for further stabilization so elderly people or individuals with weak muscles will be able to exercise much easier, for a longer period of time, and in a safe manner. Once these people do enough exercise or physical therapy and restore the strength of their core muscles, they may adjust the assisted weight and use the increased strength of their core muscle to exercise further. Besides supporting user's body while he exercises and trains his core muscles, the machine also supports user's body while he's resting. Thus, the machine will always secure and protect the back and head of elderly people or individuals with weak core muscles. This Core Strengthening Exercise and

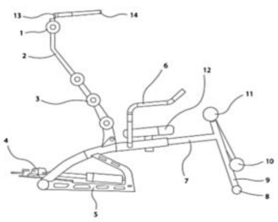
Rehabilitation Machine have got Thailand Pending Patent Number 2003000039. The components of the exercise machine for improving the strength of elderly people' core muscles are shown in Figure 2.

The weight-assisted mechanism consists of linear actuators and elastic bands, as depicted in Figure 3. This machine will be able to support the user with an adjustable level of assistance by adjusting the linear actuator that, in turn, stretches the elastic band. The more stretch the elastic band, the more weight will be supported. The linear actuator's action is controlled by a remote that can adjust the weight to 6 levels. The machine was designed the assisted weight at the range of 2.5-15 kg, approximately. The first level provides the assisted weight of 2.5 kg and the assisted weight increases at approximately 2.5 kg per level, approximately. The linear actuator operates using AC power (Load 500 N (push), 500 N (pull), actuator range is 200 ml, speed is 20 ml per sec). The elastic band has an external diameter of 10 ml and is 200 ml in length, with the extension rate (k) of 2.5 N/mm. During the operation, the machine will be able to calculate and adjust the assisted weight as per the user's body weight appropriately.

The reasons for safety and comfort while using especially among the elderly, therefore, the researchers design the initial movement angle of the machine at 110 degrees and the ultimate movement angle at 140 degrees as show in Figure 4. because the optimal sitting position was with a trunk-thigh angle of 135-140 degree. This position was shown to cause the least 'strain' on the lumbar spine (Bashir *et al*., 2006). So if users suddenly lose their strength or fall backward, the machine will only swing to the 140th-degree angle at the most, and thus prevents any potential harm to users. However, if users are able to move agilely, the machine's movement angle can be adjusted to 150 degrees. Anyway, for elderly people to exercise or to perform physical therapy, using the machine, they should



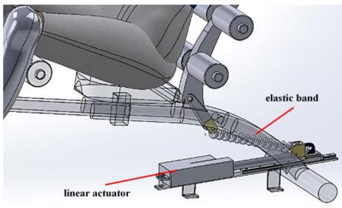
(a)



(b)

Figure 2. The components of the exercise machine are, including, head rest (1), back structure (2), back rest (3), elastic band holder (4), the weight-assisted mechanism (5), hand rests (6), adjustable leg-length structure (7), machine base (8), machine leg structure (9), the foot retainer (10), knee rest (11), bench (12), head rest structure (13), hand rails (14)

(a)



(b)

Figure 3. (a)-(b) show linear actuators and elastic bands

(a)

(b)

Figure 4. The initial movement angle of 110 degrees (a) and the ultimate movement angle of 140 degrees (b) of the exercise machine (calculate by Kinovea program)

start from the narrower movement angle. The angle can be later increased, in order to prevent potential injury to elderly people.

Since this research studies and designs the novel exercise machine, specifically made for elderly people, the researchers, therefore, simulates the weight-assisted mechanism to operate in the actual condition, whereas the machine's structure will have to repeatedly support the weight and brace the impact force. For this research, the researchers use SolidWorks version 2018 to simulate the actual forces that occurred during the operation of the machine, in order to make sure that all components will not be compromised during the operation. The resulting factor of safety (FoS) is 4, therefore, the simulation warrants that the machine is strong and will not be compromised or cause harm or injury to users.

(a)

(b)

Figure 5. Testing procedure for measuring the weight-assisted level, using the hanging scale

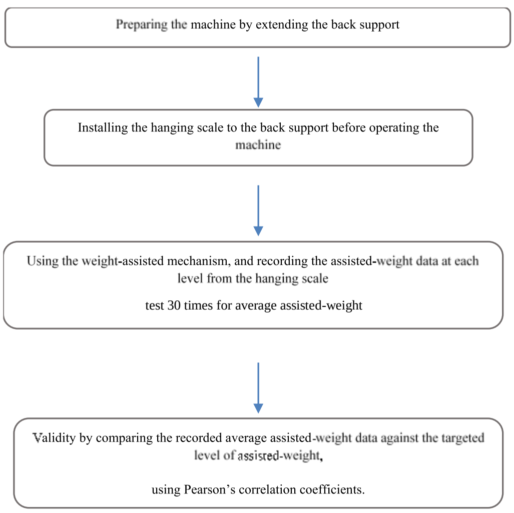


Figure 6. Validation Testing Procedures

Materials and Methods

The researchers test the validity of the weight-assisted mechanism of the machine designed for elderly people to use for exercising or performing physical therapy and improve their core muscles' strength. Validity is one of the important apparatuses in testing innovative research. Because the researchers required the machine to be safe, effective and has standard of use. Therefore, this research measured the validity between the desired assisted-weight and the real assisted-weight of the machine. It is a Convergent Validity study design. The testing procedure is depicted in Figure 5. The test starts from preparing the machine by extending the back support, installing the hanging scale to the back support before operating the machine, using the weight-assisted mechanism, and recording the assisted-weight data at each level from the hanging scale, test 30 times as show in Figure 6. The researchers then analyze the machine's validity by comparing the recorded average assisted-weight data against the targeted level of assisted-weight using Pearson's correlation coefficients.

The researchers also test the reliability of the weight-assisted mechanism of the machine designed for elderly people to use for exercising or performing physical therapy and improve their core muscles' strength. The testing procedure, as depicted in Figure 5, starts from preparing the machine by extending the back support, installing the hanging scale to the back support before operating the machine, using the weight-assisted mechanism, and recording the assisted-weight data at each level from the hanging scale, test for 2 sets; 30 times for each set (test-retest) as show in Figure 7. The researchersthen analyze the machine's reliability by comparing the measured assisted-weight in 2 times (test-retest), using Pearson's correlation coefficients. The test-retest study design is the tool's reliability by testing the machine twice to check how consistent the results of both measurements are. And then took the scores from both tests to calculate the correlation coefficient by using Pearson's correlation. This relationship indicates the certainty of use, which will be the confidence value of the tool. The sample size (n = 30) of each test calculated by G*power program; the effect size d = 0.57 (Juan *et al*., 2014), significance

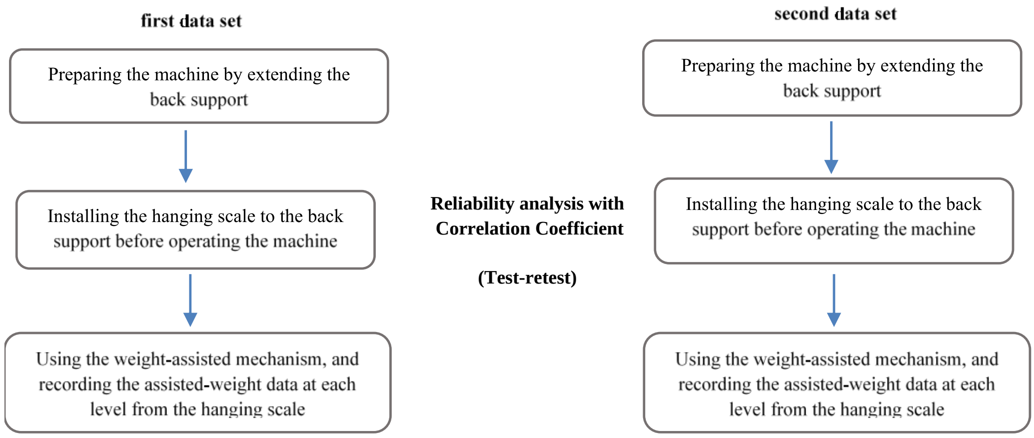


Figure 7. Reliability Testing (Test-retest) procedures

set at an alpha level of P<0.05, power (1- β) = 0.95. The obtained data were validity and reliability analyzed in each level compared with the standard level using Pearson's correlation coefficient (set at an alpha level of P = 0.01 level; 2-tailed).

Results and Discussion

The Validity of the Weight-Assisted Mechanism of the Exercise Machine

The characteristic of Core Strengthening Exercise and Rehabilitation Machine for Elderly were shown in Table 1 which depicts the comparison of the measured assisted-weight of 6 levels, starting from level 1, where the researchers designed the assisted-weight at 2.5 kg. It revealed that the average assisted-weight is 2.7±0.06 kg. For Level 2, designed the assisted-weight at 5 kg, It revealed that the average assisted-weight is 5.4±0.08 kg. For Level 3, designed the assisted-weight at 7.5 kg, It revealed that the average assisted-weight is 8±0.20 kg. For Level 4, designed the assisted-weight at 10 kg, It revealed that the average assisted-weight is 10.4±0.07 kg. For Level 5, designed the assisted-weight at 12.5 kg, It revealed that the average assisted-weight is 12.8±0.09 kg. And for Level 6, designed the assisted-weight at 15 kg, It revealed that the average assisted-weight is 14.6±0.21 kg. The statistical validity of the weight-assisted mechanism of the exercise machine were shown in Table 2. The researchers analyze the result, validity of the weight-assisted mechanism of the exercise machine, comparing the desired assisted-weight and the measured assisted-weight, using the hanging scale to compare the desired assisted-weight against the measured - average assisted weight. The results reveal the validity of the assisted-weight mechanism with the statistical significance of P = 0.000, that is, the machine presents a high level of validity, at r = 0.998.

The results also reveal that the exercise machine designed for exercising and physical therapy to improve the strength of elderly people' core muscles provides the assisted-weight at the levels that are close to the desired level of assisted-weight which are not different more than 0.5 kg with small Standard Deviation, that is, at the range between 2.7 to 14.6 kg (the desired assisted-weight range between 2.5 to 15 kg). Though the assisted-weight doesn't precisely match the desired assisted-weight, statistically speaking, they are significantly close. Therefore, the machine can be used safely. However, the underlying reason for the deviation of the assisted-weight stems from the limitations of the elastic bands used in the research, whereas the researchers use generally and commercially

Table 1. The desired and average assisted-weight level (n = 30)

Level of assisted-weight	The desired assisted-weight (kg)	The average assisted-weight (kg+SD)
Level 1	2.5	2.7+0.06
Level 2	5.0	5.4+0.08
Level 3	7.5	8.0+0.20
Level 4	10.0	10.4+0.07
Level 5	12.5	12.8+0.09
Level 6	15.0	14.6+0.21

Table 2. The statistical validity of the weight-assisted mechanism of the exercise machine

Assisted-weight	r value	P value
desired assisted-weight compared to measured assisted weight	0.998**	0.000

** Correlation is significant at the 0.01 level (2-tailed).

available elastic bands, as they are inexpensive and easily accessible. The researchers, at the moment, is developing and ordering the custom elastic bands that will provide the precise level of assisted-weight.

The Reliability of the Weight-Assisted Mechanism of the Exercise Machine

The level of assisted-weight from the first and second sets of measurement were shown in Table 3 which depicts the assisted-weight at each level, namely, from Level 1 to Level 6, and the assisted-weight taken data from 2 sets of measurements; the result is expressed in kg and standard deviation, as follows. At Level 1, the first measurement yields the result of 2.7±0.06 kg and the second measurement yields the result of 2.7±0.07 kg. At Level 2, the first measurement yields the result of 5.4±0.08 kg and the second measurement yields the result of 5.4±0.09 kg. At Level 3, the first measurement yields the result of 8.0±0.20 kg and the second measurement yields the result of 8.0±0.22 kg. At Level 4, the first measurement yields the result of 10.4±0.07 kg and the second measurement yields the result of 10.4±0.22 kg. At Level 5, the first measurement yields the result of 12.8±0.09 kg and the second measurement yields the result of 12.8±0.10 kg. At Level 6, the first measurement yields the result of 14.6±0.21 kg and the second measurement yields the result of 14.6±0.19 kg. The statistical reliability of the weight-assisted mechanism of the exercise machine were shown in Table 4. the researchers conduct statistical analysis, the reliability of the weight-assisted mechanism of the exercise machine, between the actually measured assisted-weight from the first and the second sets of measurement which is exactly the same value with small Standard Deviation and comparing the measured data between both measurements. The results reveal, from both measurements, the reliability of the weight-assisted mechanism performance, with the statistical significance of P = 0.000, that is, the machine presents the high level of reliability, at r = 1.000.

Therefore, the results reveal that this exercise machine can be used for exercising and physical therapy to improve the strength of elderly people' core muscles, whereas the machine's weight-assisted mechanism performs with a high level of reliability which warrants that the machine produce the same assisted-weight in each level which can be used safely. However, the limitation of the elastic band is when it used repeatedly for years or used beyond its yield point, the elastic band has become loose its elasticity (Marco *et al*., 2016).

The researchers also found other research papers on the machines used for exercising and physical therapy. These papers (Burnfield *et al*., 2002;. Veneman *et al*., 2007; Hornby *et al*., 2008; Kwakkel *et al*., 2008; Banala *et al*., 2009; Matjacic *et al*., 2016; Mao *et al*., 2018) confirm that exercise machines or physical therapy machines that are equipped with the weight-assisted mechanism will be able to support the user's weight and allow elderly people or patients to exercise or conduct physical therapy easier and for a longer period of time and a larger set of repetition. Such machines are also safer for elderly people, allow patients to move fluidly on their own, without the feeling of becoming a burden to their caretakers. Such machines allow elderly people and patients to significantly restore and improve various aspects of their physical performance, such as their muscular strength, their range of movement, balance, etc. This is a medical machine that can be used as a machine for exercising and performing physical therapy aimed to improve users' core muscles, as well as the abdominal muscles and lower-back muscles.

Table 3. The assisted-weight with standard deviation from the first and the second sets of the measurement in each level (n = 30)

Level of assisted-weight	The assisted-weight from the first measurement (kg+SD)	The assisted-weight from the second measurement (kg+SD)
Level 1	2.7±0.06	2.7±0.07
Level 2	5.4±0.08	5.4±0.09
Level 3	8.0±0.02	8.0±0.22
Level 4	10.4±0.07	10.4±0.22
Level 5	12.8±0.09	12.8±0.10
Level 6	14.6±0.21	14.6±0.19

Table 4. The statistical reliability of the weight-assisted mechanism of the exercise machine

The reliability of the assisted-weight	r value	P value
Test and retest (the first measurement compared to the second measurement)	1.000**	0.000

** Correlation is significant at the 0.01 level (2-tailed).

Conclusions

The researchers design and develop a core strengthening machine for exercising and performing physical therapy, with the aim to improve the strength of elderly people' core muscles or patients such as patients of stroke, Parkinson's Disease, Myasthenia Gravis, etc. The validity and reliability of the machine's weight-assisted mechanism prove that this machine can be used safely. The machine's impact buffering mechanism allows elderly people to exercise and perform physical therapy much easier, allows them to improve the strength of their core muscles, which, in turn, allow their arms and legs to operate much efficiently better. Strong core muscles help with the balance and, thus, reduce the risk of falling down in elderly people; ultimately reduces the cost of health care and chronic health issues. Having strong core muscles allows elderly people to live their daily lives much easier (Hibbs *et al*., 2008). In the future, the researchers will subject this study to the Ethics Committee for Research Involving Human Subject, in order to test the machine with elderly people and patients. The researchers wish that this machine can be used by elderly people or patients, so they may exercise or perform physical therapy and improve the strength of their core muscles. Having strong core muscles will ultimately improve their health in general. In this sense, physical therapists and sports scientists may consider this innovation for exercising and performing physical therapy, to improve the strength of elderly people' core muscles.

Acknowledgement

The researchers acknowledge financial support from from Faculty of Allied Health Sciences, Thammasat University and Thammasat University Research Unit in Health, Physical Performance, Movement and Quality of Life for Longevity Society, Thammasat University. The financial sponsors played no role in the design, execution, analysis and interpretation of data or in writing the research for publication.

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