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Bashar Banwan Hasan
College of physical Education and Sport Sciences, Wasit University, Iraq

Azzam Sabah Hameed
College of Engineering, Wasit University, Iraq

Corresponding Author:
Bashar Banwan Hasan
College of physical Education and Sport Sciences, Wasit University, Iraq

Effect of using a special apparatus in rehabilitating and increasing motor abilities of stroke patients

Bashar Banwan Hasan and Azzam Sabah Hameed

Abstract
Background: Stroke can be described as one of the significant factors that lead to disability worldwide. It can affect motor skills for patients impacting their daily activities. Rehabilitation is the most effective tool to reduce motor impairment in stroke patients.
The Objective: This paper aims to study not only standard treatment practices but also rehabilitation techniques targeting motor skills in stroke patients.
Method: The purposive sample technique was followed in selecting patients who had been hit with a stroke within one month. The total number of cases was 8 and those patients were going to Specialized Center for Physiotherapy and Physical Rehabilitation in Wasit Governorate to get their rehabilitation done. The range of the sample age is between 50-65 years old males only.
Results: There is a statistically significant difference for the first strength between the two measurements at 0.01 level of significance and the superiority is recorded for the ex-post measurement. A calculated t-test is 13.17 which is larger than tabular-t at 0.01 level of energy. The enhancement rate reached 33.43%. For the ball pushing power, superiority is also recorded for the ex-post measurement at 0.01 level of significance and calculated t is higher than the tabular one. The enhancement rate is 43.91%. The power of bushing for the injured foot has the same scenario where the calculated t is higher than the tabular one. Superiority is recorded for the ex-post measurement with a high enhancement rate.
Conclusion: The rehabilitation protocol used in this paper approved its effectiveness in areas related to physical efficiency. The effectiveness of this protocol can be seen clearly in the way of walking pretty close to normal walking. Another result of this paper was achieved by improving the strength of muscles responsible for walking. Examples of these muscles are in the Upper limb (i.e. arm muscles) and lower limb (i.e. hip, knee, and ankle).

Keywords: Stroke, rehabilitation program, rehabilitation apparatus, muscle strength, Special apparatus, motor abilities, stroke patients

Introduction
Mankind these days are living in an orbit filled with different types of pressure. Examples would be tensions, emotions, responsibilities and duties that exhaust mental and physical abilities. This would, eventually, leads to getting different kinds of diseases and stroke is an example. Stroke has spread recently leading to a restriction in mobility skills and daily activities. Situation of a stroke patient is like putting him in an open prison where he can see everything and do nothing. In this case, felling of pain, sadness, frustration and isolation can be reached leading the patient to being a disable person.
Stroke is the third cause of death in the whole world. This induce doing a lot of research trying to understand why it is happening, how can we diagnose it, and how can we treat it. Answering those questions may prevent reaching semi or full disability status [1].
Physicians classify two stages of stroke, Ischemic Hemorrhagic. Ischemic forms 80% of stroke cases. It happened due to blocking brain arteries. Hemorrhagic forms the rest. A ruptured blood vessel is the main reason due to a blood leak into the brain tissues [2].
In both types of stroke, remedy can be near impossible. Average age of patients with stroke is 70 years old in male cases versus 75 years old in females [3]. Truelsen T, Piechowski mentioned that a partial heal can reach 85% of stroke patients [4].
In Iraq, number of patients with stroke doubled in only eight years. Diabetes, obesity, high blood pressure, and anxiety are the main reasons of stroke.

The available scientific literature suggests that post stroke rehabilitation intervention is significantly more effective when it is delivered in the early phase of recovery (< 6 months). Evidence supports that better functional outcome is determined by rehabilitation that is initiated promptly [5] and based on intensive, especially multisensory, stimulation [6-7]. This kind of stimulation is associated with increased adaptive plasticity of the brain in the early post stroke stages [8-9].

The use of robotic systems to complement post stroke multidisciplinary programs is a recent approach that looks very promising; robotic devices can provide high-intensity, repetitive, task-specific, interactive treatment of the impaired limb (passive and/or active-assisted exercises) and can objectively and reliably monitor patients' motor progress, measuring changes in movement kinematics and forces [10-11].

This paper aims to design a rehabilitation apparatus and investigate its role in rehabilitating stroke patients. This apparatus is also trying to lower gravity effect related to patient weight. This paper, through its apparatus, trying also to help the patient do the rehabilitation exercises and walk without any help such as wheelchair and crutches. All of these will induce the ability of adaptation and getting back the mental and physical skills.

Literatures related to stroke rehabilitation techniques and videos showing how to perform these techniques were showing that the rehabilitation process was done either with a trainer or an apparatus lacking the role of gravity. Gravity can act as an external effect represented by the body weight. This body weight can make rehabilitation exercises very hard especially for legs. Legs are carrying the body weight so the patient needs either a wheelchair or a subject can rely on when walk. These latter techniques lower the body weight effect on the targeted part of the body (i.e. legs). However, these techniques can make rehabilitation took long time. This is due to the dependence on these techniques that might cause muscular atrophy and the patient might not walk in the near future.

This paper will fill the knowledge gap through designing an apparatus lowering the gravity effect by lowering the body weight of the patient. The basic idea of this apparatus is lifting the patient and lowering his weight in a safe manner. This may allow the patient to walk and put pressure on the targeted leg gradually without using crutches.

Aim of the paper

1. Designing a rehabilitation apparatus for patients with stroke.
2. Studying if the designed apparatus can rehabilitate patients with stroke and bring them back to normal life through
- Enhancing their muscular power.
- Empowering their dynamic and static balance

Hypothesis of the paper

There is a statistical significant differences between ex ante and ex post trials in the ability of stroke patients to walk again when enhancing their muscular power and empowering their dynamic and static balance.

Research Methodology and Field Experiment

Based on the aim and the problem statement of the paper, an experimental procedure is applied here. This was done by using one experimental group utilizing ex ante and ex post measurement to best addressing the studied problem.

Purposive Sample technique was followed in selecting patients who had been hit with stroke within one month. Total number of cases were 8 and those patients were going to Specialized Center for Physiotherapy and Physical Rehabilitation in Wasit Governorate to get their rehabilitation done. Range of the sample age is between 50-65 years old males only.

Table 1: Study sample descriptive statistics

Variables	Descriptive Statistics		
	Average	Standard deviation	Skewness
Age (year)	56	6.401	-0.06
Height (cm)	172.83	5.34	0.10
Weight (kg)	77.83	7.19	0.58
Stroke duration (day)	19.33	5.92	0.02

Sample selection criteria

The following criteria were followed when selecting the study sample

1. Voluntary willingness to participate.
2. They have hemiplegia due to stroke.
3. They have stroke for the first time with no other diseases.
4. Participants have the mental ability to understand all instructions.
5. They were newly hit by stroke and they have never get physical therapy before.

Other observations were eliminated if they have the following

1. Unstable heart beats with blood vessels problems (i.e. high blood pressure and coronary artery disease) or nervous system problems.
2. Joint pain or muscle spasm.
3. Acute neuropsychiatric impairment.

Materials and Methods

In this paper, the following devices and tools were used:

1. The rehabilitation apparatus.
2. Form for each observation (patient) to write down the data.
3. Medical scale to measure weight,
4. Dynamometer to measure muscle strength (kg)
5. Stop watch.

In this paper, some tests were performed such as

1. Walk on parallel wood device back and forth

- Purpose of the test: measure the mobility balance.
- Tools used:
  - Whistle.
  - Stop watch.
  - Piece of wood with 30 cm width, 6 m length, and 10 cm height.
  - Two pieces of wood with 40 cm width, 6 m length, and 90 cm height.
- Performance description:
  - The patient stands on the piece of wood holding with his two hands the two pieces of wood. When he hears the whistle, he is going to walk on the piece of wood back and forth for (5 m) for the same distance.
- Recording:
  - Write down back and forth time for each patient. Micro second time frame is also recorded.

2. Stand on the healthy foot

- Purpose of the test: measure the steady balance.
- Tools used

- Whistle.
- Stop watch.

o Performance description:

- When hearing the whistle, the patient need to stand on the healthy feet as much as he can.

o Recording

- Write down the longest period the patient took from the beginning to stand on the healthy feet until losing balance.

3. Pushing the medical ball (3 kg) with both hands

o Purpose of the test: Measuring muscle power for arms and shoulders.

o Tools used

- Open space.
- Medical balls (2 kg).
- Chair.
- Measurement tape.

o Performance description:

- Patient sit on the chair holding the medical ball with two hands in a position where the ball will be facing the chest under the cheek. The back of the patient should be touching the chair edge.
- In order to prevent the patient from moving forward, a rope is fixed around the patient's chest while moving the ball with two hands.

4. Fist strength test

o Purpose of the test: Measuring fist strength for the targeted hand.

o Tools used

- Dynamometer to measure muscle strength (kg).

o Performance description:

- While sitting, the patient holds the Dynamometer with one hand.
- The patient needs to press as much as he can on the Dynamometer.

o Recording:

- Two attempts given to each patient. Write down the best one.

1- Injured feet strength test

o Purpose of the test: measuring the strength of quadriceps of the injured feet

o Tools used

- Chair aims to enhance muscular strength.

o Performance description:

- Patient sits on the chair and got the appropriate weight. The patient extends leg forward full stretch.

o Recording:

- Two attempts given to each patient. Write down the best one.

Robotic Device

Is a rehabilitative device designed to mitigate the gravity effect by lowering patient weight? This device also allowing patient to move his hands and legs smoothly by using a stationary bike.

The device has two parts. The first one is a metal frame and the other one is a stationary bike.

First part components

1. **Metal frame:** Has a different length and dimensions of iron poles. In the middle of this frame, there is an electric lifting device that lower the weight of the patient by lifting him up. This frame has 12 iron poles in total with total weight reach 50 kg. The frame has upper iron pole with 120 cm as a length fixed firmly with other iron components. Total height is 250 cm with the electric lifting device in the middle.
2. **Electric lifting device:** Electric engine tied to a roller rotate by the electric engine. The roller has an iron wire tied from the other end with another roll to lower the weight effect. This wire can hold up to 100 kg and fixed on the upper part of the device with four screws. This can be adjusted by controlling points and it even can be adjusted to be stopped at certain point. This can lower the weight of the patient through tighten and relaxing the wire.
3. **Belt suit to be wear by the patient:** This was made mainly to lower the weight of the patient. The belt is made from cloth materials put around chest, belly bottom, and thighs. This suit is adjustable to best fit the patient. This suit has an iron stand fix it from the upper part on the electric lifting device.
4. **Control Panel:** Bottoms controlling lowering and raising the patient to lower the weight. There is also a safety switch cut the power when detecting any safety issue.

Second part components

Stationary bike: KNC Chinese bike were modified from mechanical to electric bike. It has a control panel which can be used to adjust gages related to speed, distance, time. Speed can be adjusted from slow to fast. Speed can be adjusted to be consistent with the patient circumstances and various types of exercises. The bike also has two dynamic levers fixing hands of the patient. The bike now will be working to move hands and legs in a consistent movement letting them move freely. This technique can 'reset' the mobility part within the brain that lost his ability sue to the stroke.

Full component of the bike are

1. Metal frame.
2. Electric lifting device.
3. Belt suit.
4. Controlling bottoms.
5. Stationary bike.
6. Armrests.
7. Feet rests.
8. Control Panel.
9. Rotating wheel.
10. Bike Chain.

Research Methodology

To perform research methodology, the following steps has been followed.

The main experiment

o The main experiment was applied on each patient separately. The experiment took 12 week to finish. During the experiment, the 'ceteris paribus' has been applied as follows:

- All the data were collected in the same way.
- Measurement tool were that same all over the sample.
- Measurement tool or the data collection were on the same sequence.

Fig 1: Device shape

The whole rehabilitation program was divided into three stages through the research period which last for three months. Each stage took four weeks with five rehabilitation session. Each session lasts for 60 minutes.

In the first stage, each patient got a preliminary exercises lasts for four weeks at the early stages of stroke. These exercises were performed to enhance blood circulation, joints flexibility, and nervous and muscular system. Second and third stage were focusing on using the apparatus with a supervision of a physical therapist. The therapist lowered the speed of the stationary bike until the patient feel relaxed. After that, the therapist is going to increase the speed gradually until reaching full speed at 9 (km/h).

Ex-ante Measurements

These measurements were applied on study sample. More specifically, 8 patients were subject to these measurements. These measurements were performed in Specialized Center for Physiotherapy and Physical Rehabilitation in Wasit Governorate on 21/12/2021.

Ex-post Measurements

These measurements were performed on study sample on 21/03/2022 following the same sequence followed on ex-ante measurements under the same condition and for each patient separately.

Descriptive statistics used

Average, median, standard deviation, enhancement ratio, and T-Test.

Results and Discussion

Table 2: Averages, standard deviation, calculated t-test, and level of significant between ex-ante and middle measurements on dynamic balance variable

Descriptive statistics	Ex-ante		Middle stage measurement		Difference between averages	T-Test	Enhancement ratio
	A	S	A	S			
Walk on wood parallel device	66.875	3.516	53.88	2.368	12.995	13.26	24.13%
Static balance test	3.25	0.97	13.38	1.11	10.13-	50.65	39.34%

Significant at 0.01

What can be inferred from table 2 is that there are differences between ex-ante and middle measurements at 0.01 level of significance. Middle measurement recorded highest. Calculated t was 13.26 which is higher than tabular t at 0.01 level of significance. Enhancement ratio was 24.13%.

Table 3: Averages, standard deviation, calculated t-test, and level of significant between middle measurement and ex-post measurements on dynamic balance variable

Descriptive statistics	Middle stage measurement		Ex-post		Difference between averages	T-Test	Enhancement ratio
	A	S	A	S			
Walk on wood parallel device	53.88	2.368	40.375	1.317	13.5	13.17	33.43%
Static balance test	13.38	1.11	27.38	1.58	14-	33.3	55.32%

Significant at 0.01

As shown in table 3, a statistical significant differences can be shown between middle and ex-post measurement at 0.01% level of significant with obvious superiority recorded for the ex-post measurement. Tabular t reached 13.26 which is higher than tabular t at 0.01 level. Enhancement rate reached 33.43%.

Table 4: Averages, standard deviation, calculated t-test, and level of significant between ex-post and ex-post measurements on dynamic balance variable

Descriptive statistics	Ex-ante		Ex-post		Difference between averages	T-Test	Enhancement ratio
	A	S	A	S			
Walk on wood parallel device	66.875	3.516	40.375	1.317	26.5	18.66	65.62%
Static balance test	3.25	0.97	27.38	1.58	24.13-	34.47	76.21%

Significant at 0.01

As shown in table 4, there is a significant statistical difference between ex-ante and ex-post. Superiority is recorded for the ex-post measurement. For t-stat, calculated-t (18.66) is higher than tabular-t at 0.01 level of significant. Enhancement rate was 65.62%.

Table 5: Averages, standard deviation, calculated t-test, and level of significant between ex-ante and middle measurements on muscular power variable

Descriptive statistics	Ex-ante		Middle measurement		Difference between averages	T-Test	Enhancement ratio
	A	S	A	S			
Fist strength	1.463	0.245	4.975	0.468	3.51-	17.6-	70.68%
Power of bushing medical ball	1.6	0.235	3.138	0.250	1.54-	13.05-	49%
Power of bushing for injured foot	2.3	0.187	4.85	0.212	2.55-	23.18	52.58%

Significant at 0.01

Moving toward the muscular power variable. Table 5 is measuring statistical differences between ex ante and middle measurement. It is showing that there is a statistical significant differences between the two measurement at 0.01 level of significance and the superiority is recorded for the middle measurement. Calculated T-Test is -17.6 which larger than tabular-t at 0.01 level of significance. Enhancement rate reached 70.68%.

For the ball pushing power, superiority is recorded also for the middle measurement at 0.01 level of significance and calculated t is higher than the tabular one. Enhancement rate is 49%.

Power of bushing for injured foot has the same scenario where calculated t is higher than the tabular one. Superiority is recorded for the middle measurement with high enhancement rate.

Table 6: Averages, standard deviation, calculated t-test, and level of significant between middle measurements and ex-post on muscular power variable

Descriptive statistics	Ex-ante		Ex-post		Difference between averages	T-Test	Enhancement ratio
	A	S	A	S			
Fist strength	4.975	0.468	8.875	0.349	13.5	13.17	33.43%
Power of bushing medical ball	3.138	0.250	5.163	0.239	3.91-	17.77	43.91%
Power of bushing for injured foot	4.85	0.212	9.187	0.262	2.02-	15.53	39.15%

Significant at 0.01

Table 6 is showing that there is a statistical significant differences for Fist strength between the two measurement at 0.01 level of significance and the superiority is recorded for the ex-post measurement. Calculated t-test is 13.17 which larger than tabular-t at 0.01 level of significance. Enhancement rate reached 33.43%.

For the ball pushing power, superiority is recorded also for the ex-post measurement at 0.01 level of significance and calculated t is higher than the tabular one. Enhancement rate is 43.91%.

Power of bushing for injured foot has the same scenario where calculated t is higher than the tabular one. Superiority is recorded for the ex-post measurement with high enhancement rate.

Table 7: Averages, standard deviation, calculated t-test, and level of significant between ex-ante and ex-post on muscular power variable

Descriptive statistics	Ex-ante		Ex-post		Difference between averages	T-Test	Enhancement ratio
	A	S	A	S			
Fist strength	1.463	0.245	8.875	0.349	7.42-	41.22	83.56%
Power of bushing medical ball	1.6	0.235	5.163	0.239	3.56-	10.41	68.99%
Power of bushing for injured foot	2.3	0.187	9.187	0.262	6.89-	54.68	74.97%

Significant at 0.01

Table 7 is showing that there is a statistical significant differences between the two measurement at 0.01 level of significance and the superiority is recorded for the ex-post measurement. Calculated t-test is 41.22 which larger than tabular-t at 0.01 level of significance. Enhancement rate reached 83.56%.

For the ball pushing power, superiority is recorded also for the ex-post measurement at 0.01 level of significance and calculated t is higher than the tabular one. Enhancement rate is 68.99%.

Power of bushing for injured foot has the same scenario where calculated t is higher than the tabular one. Superiority is recorded for the ex-post measurement with high enhancement rate.

Discussing muscular strength results

What can be inferred from Tables 5, 6, and 7, when we compared averages for the three measurement techniques in muscular strength variable, is that there is statistical significant differences between the three measurements for

the middle and ex-post in all muscular power measurements. This means that the designed apparatus has a positive impact. This is due to its role in lowering the gravity effect and the stationary bike. Also the positive impact is due to the rehabilitation technique followed. The designed apparatus increased muscular power and tissues for both arms and legs.

Using this apparatus gave a positive results in terms of enhancing muscular power. This device approved its effectiveness in rehabilitating muscles of the upper, lower body part, and fist strength. This happened due to the increased efficiency of the nervous and muscular system resulted from the trainings given by the apparatus and the training resulted from the static and dynamic balance. Those two are the main components of the rehabilitation program proposed in this paper.

Another factor related to the positive impact of this apparatus is balancing weight during the application of the rehabilitation program. This program is aiming to increase the muscular power. In this program, a gradual increasing in weight is applied making muscles fibers to get bigger. This program is also increasing the blood flow to the muscle which can increase its efficiency. All of these can show the significance of the rehabilitation program to rehabilitate the static muscular strength and muscular atrophy. This is consistent with Hasan's statement that muscle strength exercises can develop the muscle strength of the affected part [12, 13].

Discussing static and dynamic balance results

From tables 2, 3, and 4, a comparison is made between the three averages of static and dynamic balance for the study sample. What is found is that there is a statistically significant differences between the three measurement techniques especially for the middle and ex-post measurement. This is another evidence of the successful application of the apparatus. Specialists support this positive impact due to lowering the body weight and stationary bike with some rehabilitation exercises. This apparatus targeted increasing static and dynamic balance for the lower body parts.

This can be explained that taking exercises utilizing the stationary bike and different balance exercises has a positive impact on increasing balance time in static balance. Also, times of falling lowered significantly. In addition, walking in a correct was obtained in dynamic balance. These exercises play a focal role in enhancing receptors within the joint and regain the balance again. Increased consistency between nervous and muscular system is also obtained again. This is consistent with what Faraj Tawfiq (2007) has reached. Also, both balance types can affect each other. Making progress in one can affect the other and vice versa [14]. This also consistent with what had been found by Tayseer nassr (2003) [15] where providing medical rehabilitation services can help the patient's mobility in getting the balance that they need. This study is also consistent with studies that used robotics in rehabilitating stoke patients such as Reinkensmeyer *et al.* [16], who used robotic treatment in substitution of unassisted movement training of the paretic upper limb in a chronic-phase setting. In this work, a computational model of motor plasticity in chronic stroke patients is presented (based on experimental evidence) that predicts an exponential-like motor recovery driven by practice, regardless of range or speed of the practiced movement, suggesting that robotic and no robotic techniques can result in similar improvement in movement ability after stroke. The same premise is supported by a recent multicenter RCT by Hesse *et al.* [11], who used robotic training of the upper limb with a mechanical arm trainer as an alternative to electrical stimulation of the paretic wrist extensors in sub-acute stroke patients. In this study, no statistically significant difference between groups was found in the primary outcome (FM scale); i.e., the mechanical arm trainer was not superior to the electrical stimulation on the impairment level despite a much higher repetition rate, more DOFs, and a bilateral approach. The authors hypothesized that this unexpected result may have been due to the different limb segment exercised in the two groups.

Conclusions

Based on objectives, results, sample, statistical significance, and discussion of results, this paper can conclude the following

1. Significant enhancement is obtained on the way of walking very close to the normal before the stroke.
2. Rehabilitation program approved its effectiveness in increasing muscular power especially on hip, knee, and ankle joints.
3. Rehabilitation program increased muscular power of arm muscles that operate wrist joint.
4. Starting early in the rehabilitation program after a physician consultation is very important before reaching muscular atrophy and joint stiffness.
5. Paying more attention to rehabilitation after the physical therapy. Lacking to do so can can lower the body efficiency of hemiplegia resulted from stroke.
6. Doing more studies on rehabilitation focusing on the psychological and social side. This is very important in returning the patient to his normal life before stroke.
7. Using the rehabilitation apparatus in this paper in all rehabilitation centers due to its role in speed recovery of stroke patients and getting back to normal life very soon.

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