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Effectiveness of a Rehabilitation Program in Improving Achilles Tendon Response and Treating its Shortening in Cerebral Palsy Patients

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Abstract

The research explores the effectiveness of a rehabilitation program in treating Achilles tendon shortening in children with cerebral palsy. It addresses the need for tailored rehabilitation exercises to improve the neural response and physical capabilities of affected individuals, focusing on enhancing muscle strength, balance, and functional abilities. The study employed an experimental method, targeting a sample of seven children aged 8-12 years, selected from a sports medicine unit. Participants underwent a six-month rehabilitation program divided into three phases, each involving progressive exercises designed to strengthen the ankle joint and improve balance. Data collection tools included dynamometers, balance measurement devices, and detailed observation. Results highlighted significant improvements in muscle strength and balance, demonstrating a positive impact on the affected limb's functionality. Specifically, dorsiflexion and plantarflexion resistance improved by 9.64% and 7.50%, respectively, while balance showed a marked increase of 51.11%. These outcomes were attributed to the program's gradual intensity progression and its focus on muscle and ligament reinforcement. The research concludes that a scientifically designed rehabilitation program can restore near-normal functionality in cerebral palsy patients' affected limbs. Recommendations emphasize the importance of individualized programs, attention to unaffected limbs, and integrating preventive measures to enhance overall physical strength and biomechanics. Future studies should explore broader applications of such programs in rehabilitative care.

Keywords: *Cerebral Palsy Rehabilitation, Achilles tendon, Treating the Shortening*

Introduction

Disability impacts both the individual and society. Society must positively interact with disability by fostering the development of individuals with disabilities in all aspects—physical, skill-based, psychological, social, and intellectual. The progress of any society is measured by the services it provides to individuals with disabilities without discrimination, enabling them to contribute across various fields. It is an educational axiom that every child has the right to education, regardless of whether they are abled or disabled. Providing opportunities for

individuals with physical disabilities to lead a natural life and integrate into society is crucial. (Mishari, 2018)

Rehabilitation responsibility lies with the sports specialist, who is tasked with designing, implementing, and supervising rehabilitation programs for injured athletes. Additionally, the specialist should work on minimizing the risk of sports injuries among players. (Abdel Gawad, 2013)

Rehabilitation exercises are classified based on their nature into first, Passive Exercises: Movement of the injured part is assisted by a rehabilitation specialist or therapeutic devices, with no physical or muscular effort from the patient. Second, Assisted Exercises: The patient moves the injured part with the help of another person to support muscle contraction and flexibility. Third, Active Exercises: Performed independently by the patient, aiming to develop muscular strength, flexibility, and range of motion based on the pain level.

Resistance Exercises are performed using various forms of resistance such as weights, sandbags, a fixed wall, the patient's body, or therapist resistance. These exercises aim to enhance muscular strength and restore range of motion. (Al-Shatori, 2016)

Cerebral palsy is a developmental disability or a motor neurological disorder. It refers to motor developmental disorders, contributing to muscle weakness, spasticity, and poor coordination. These issues may lead to complications such as contractures (shortening of muscle tissues due to severe spasticity), bone growth prevention, joint deformities, and dislocations. Common deformities include hip dislocation, spinal curvature (scoliosis), and others. (Al-Safadi, 2020)

Cerebral Palsy is a group of disorders affecting movement, muscle tone, or posture, resulting from brain damage before its development is complete, often before birth. Signs and symptoms appear during infancy or preschool years. (Janmey, et al, 2007)

Rehabilitation Exercise Program refers to retraining the patient to achieve the highest possible functional level in the shortest time, using methods suitable for the type and severity of the injury. (Al-Sharfi, 2023)

Achilles Tendon which Also known as the calcaneal tendon, located at the back of the leg, connecting the gastrocnemius and soleus muscles to the calcaneus bone.(Al-Baalbaki, 2018)

The impact of a (motor-functional) rehabilitation program on the central body muscles of children with cerebral palsy. He confirmed that the proposed program had a positive effect on strengthening the central muscles of children, which was reflected in an improvement in their motor abilities as well as in their range of motion indicators. (Hefni, 2020)

Emphasize the importance of designing a rehabilitation program to enhance the functional efficiency of children with hemiplegia, whether in mild or moderate cases. He stated that the proposed rehabilitation program contributed to improving muscle tone, reducing spasm, increasing muscle strength, and enhancing the range of motion. The program also positively influenced balance development and improved joint angles in the affected limbs through continuous movement and strength exercises, indicating the absence of joint stiffness. (Abdel Wahab, 2021)

The effectiveness of a motor rehabilitation program on certain physical variables and motor functions in children with hemiplegic cerebral palsy from category VII. He explained that the program had a positive impact on physical variables such as (strength, speed, power, coordination, balance, agility, endurance, and flexibility), with a percentage change ranging from 11.15% to 250%. Additionally, the program contributed to improving motor function, with a percentage change ranging from 59.74% to 126.49% in the study sample. (Al-Nahhas, 2021)

Through his work and observation at the sports medicine unit in Shebin Al-Kom, the researcher noticed a patient with cerebral palsy, sparking an interest in delving into related studies. Cerebral palsy is a broad term encompassing results of brain damage during development, causing varying degrees of motor, sensory, intellectual, and systemic disorders. These brain defects may occur during pregnancy, childbirth, or up to the age of five.

Cerebral palsy is the primary cause of childhood disabilities, with an incidence rate of approximately 1 in 400 live births. Its complications include muscle contractures causing bone bending, joint deformities, partial or complete dislocation, early aging, malnutrition due to swallowing or eating problems, and psychological issues such as depression and social isolation. Other complications include heart and lung issues, osteoarthritis, and bone density loss.

Given this, the researcher aimed to alleviate some suffering by proposing a rehabilitation exercise program to improve the neural response of the Achilles tendon and address its shortening in patients with cerebral palsy (C/P).

The research aims to design a rehabilitation exercise program targeting the neural response and shortening of the Achilles tendon in cerebral palsy patients to investigate its effects on improving foot muscle strength and enhancing the balance.

Study Hypotheses

1. There are statistically significant differences between the pre-test and post-test means in the muscle strength variable affecting the ankle joint among the study sample.
2. There are statistically significant differences between the pre-test and post-test means in the balance variable for both feet among the study sample.

Materials and Method

The authors used the experimental method, employing a pre-test, post-test, and follow-up test design with a single group.

Participants

The research population was selected from individuals with cerebral palsy who regularly visited the sports medicine unit in Menoufia, located in Shebin El-Kom, Menoufia Governorate. It included ten male individuals with cerebral palsy.

The research sample was purposively and randomly selected from individuals with cerebral palsy attending the sports medicine unit in Menoufia, Shebin El-Kom. Two participants over the age of 18 were excluded, leaving seven participants aged between 8 and 12 years. Two participants were allocated for the pilot study, while the remaining five constituted the main research sample, as shown in Table (1).

Table 1. Description of the participants with Cerebral Palsy

No.	Age	Height (cm)	Weight (kg)	Affected Foot		
				Right	left	Both
1	8	125	29	✓	-	-
2	12	131	30	-	✓	-
3	9	129	28	✓	-	-
4	10	128	27	✓	-	-
5	12	130	31	✓	-	-
6	11	132	30	-	✓	-
7	9	126	29	✓	-	-

Criteria of Choosing the Participants:

The authors selected the participants individually based on the following criteria:

1. Participants must not be enrolled in any other therapeutic program during the study.
2. Participants must be individuals with cerebral palsy aged between 8 and 12 years.
3. Participation must be voluntary and with the knowledge and consent of the participant and their guardian.
4. Commitment to completing the program until its conclusion.
5. Participants must not have any other diseases or health problems that could influence the research outcomes.
6. Homogeneity among participants concerning weight, height, and age must be maintained

Table 2. Distribution of the group of participants (n = 8)

Variable	Unit	Arithmetic Mean	Median	Standard Deviation	Skewness Coefficient
Age	Years	10.143	10.000	1.574	0.272
Height	cm	128.714	129.000	2.563	-0.334
Weight	kg	29.143	29.000	1.345	0.319

It is evident from the above table that the skewness coefficient ranged between (-0.334 to 0.319), which is within the range of (±3), indicating the homogeneity of the sample.

Table 3. Descriptive statistics of the participants that thier Ankle Joint Affected by Cerebral Palsy (n = 7)

Muscular Strength Variable	Unit	Arithmetic Mean	Median	Standard Deviation	Skewness Coefficient
(Dorsiflexion) Resistance Pull Test for Ankle	kg	0.957	0.960	0.021	-0.407
(Plantarflexion) Resistance Push Test for Ankle	kg	0.853	0.850	0.011	0.782

It is evident from the above table that the skewness coefficient ranged between (0.04 to 0.54), which is within the range of (+3), indicating the homogeneity of the sample

Table 3. Descriptive statistics of Overall Balance Variables for participants with Cerebral Palsy (n = 7)

Balance Variable	Unit	Arithmetic Mean	Median	Standard Deviation	Skewness Coefficient
Both Feet Together	Score	8.571	9.000	0.976	-1.318

It is evident from the above table that the skewness coefficient (0.25) is within the range of (+3), indicating the homogeneity of the sample.

Data collection

1. Expert questionnaire.
2. Data recording form for the injured individuals.
3. The proposed rehabilitation program in its final version after consulting the experts.

Pilot studies

The researcher conducted a pilot study from 10/12/2022 to 31/12/2022 for a duration of 21 days on a sample consisting of two injured individuals from the same research population and exploratory sample. The purpose was to ensure the suitability of the devices, tools used,

and the appropriateness of the proposed rehabilitation program for the sample under study. The authors ensured the homogeneity of the participants (pilot– experimental) by calculating skewness coefficients in the morphological shape variables.

Proposed Training Program

The rehabilitation program under study was implemented over a period of six months for each injured individual. The program was applied individually for each participant, starting with the first session for the first individual on Sunday, 1/1/2023, and ending with the last session for the final participant on Monday, 2/10/2023. The researcher conducted the practical implementation of the study over a duration of 24 weeks, divided into three phases. During this time, all objectives of the motor rehabilitation program were achieved, and the researcher adhered to the pre-established timeline of the rehabilitation program.

Objectives of the Motor Rehabilitation Program

The motor rehabilitation program aims to:

1. Reduce knee pain.
2. Restore and improve the muscle strength of the muscles working on the knee.
3. Regain the range of motion and reach the normal rate.
4. Gradually return to functional activities and engage in sports activities.

Principles of the Program

1. Strengthen the muscles working on the ankle joint for individuals with cerebral palsy.
2. Restore the range of motion for the ankle joint for individuals with cerebral palsy.
3. Eliminate and relieve pain for individuals with cerebral palsy.
4. Regain the overall balance level for individuals with cerebral palsy.

Proposed Rehbilitation Program

The researcher, after reviewing references and prior studies on rehabilitation program design and consulting with experts, designed the proposed rehabilitation program for individuals with cerebral palsy, specifying the program's objectives.

Based on the researcher's review of references, scientific studies, rehabilitation programs developed by physical rehabilitation centers, information from Egyptian universities, the Academy of Scientific Research, and the internet, as well as local and international studies focusing on rehabilitation programs for similar cases, where the studies emphasized the importance of physical and motor rehabilitation, therapeutic massage, and aquatic therapy for rehabilitating cerebral palsy injuries. Moreover, a survey of expert opinions was conducted to select the most suitable exercises for the program.

The rehabilitation method consists of therapeutic exercises for individuals with cerebral palsy. The workload is tailored for everyone, adhering to the principle of individual differences and the severity of cerebral palsy.

The program's total duration is six months (24 weeks) divided into three phases:

1. Phase 1: 6 weeks
2. Phase 2: 6 weeks
3. Phase 3: 12 weeks

The number of rehabilitation sessions is three per week, with one session per day, except Fridays (rest day). The duration of each session ranges from 45 to 55 minutes, depending on the phase. Exercises progress from simple to complex based on the participant's capabilities.

The main study

The proposed rehabilitation program was implemented at the Sports Medicine Unit in Shebin El-Kom, Menoufia Governorate from 1/1/2023 to 2/10/2023 for all participants. Due to differences in the rehabilitation start dates for each participant, the timing of pre-tests, program implementation, and post-tests varied, the program followd the next key considerations:

1. Pre, follow-up, and post-tests were conducted uniformly for all participants.
2. Measurements followed a systematic sequence.
3. The same tools were used for all participants.
4. Photos of participants during program implementation were documented.

Tools and Devices (measurements & program)

1. Restameter device for measuring height and weight (Appendix 6).
2. Dynamometer device for measuring muscle strength (Appendix 9).
3. Balance measurement device (Appendix 10).
4. Application Devices and Tools Used in the Program:
5. Fully equipped gym.
6. Stationary bike (ergometer) for endurance development.
7. Multi-purpose device (leg press unit) to strengthen muscle groups working on the ankle joint.
8. Multi-level step block for training on stepping up and down.
9. Rubber resistance bands (2 kg and 3 kg).
10. Cones.
11. Various balance tools with different shapes and levels of difficulty (Balance).
12. Stopwatch for time regulation during the program implementation and measurements.
13. Electric treadmill.
14. Measuring tape for circumference measurements.
15. Sandbag weights (2 kg).
16. Sand court.

Statistical Analysis

The authors used The researcher used SPSS V24 to process data, employing the following statistical methods:

- Arithmetic Mean
- Standard Deviation
- Coefficient of Skewness
- One-way analysis of variance (ANOVA)
- Tukey's Honest Significant Difference (HSD) test for least significant differences
- Percentages.

Results and Discussion

It is clear from Table (6) that there are statistically significant differences at the 0.05 significance level between the measurements of the muscle strength variables acting on the ankle joint, which is illustrated in the graphical representation.

Table 6. Mean and Standard Deviation of Muscle Strength Measurements Acting on the Ankle Joint (n=5)

The variables of muscle strength acting on the ankle joint		Mean	St.Dv.	Error Coeff.	95% Confidence Interval for the Mean		Min Value	Max Value
					Lower Bound	Upper Bound		
Resistance Pull Test (Dorsiflexion) for the Ankle	Pre-test (kg)	0.538	0.018	0.008	0.516	0.560	0.520	0.560
	Follow-up test 1(kg)	0.748	0.008	0.004	0.738	0.758	0.740	0.760
	Follow-up test 2(kg)	0.958	0.019	0.009	0.934	0.982	0.930	0.980
	Post-test (kg)	1.624	0.185	0.083	1.394	1.854	1.450	1.940
	Total (kg)	0.967	0.427	0.095	0.767	1.167	0.52	1.940
Resistance Pull Test (Plantar Flexion) for the Ankle	Pre-test (kg)	0.472	0.022	0.010	0.445	0.499	0.440	0.490
	Follow-up test 1(kg)	0.550	0.027	0.012	0.516	0.584	0.510	0.580
	Follow-up test 2(kg)	0.854	0.011	0.005	0.840	0.868	0.840	0.870
	Post-test (kg)	1.312	0.097	0.043	1.192	1.432	1.240	1.470
	Total (kg)	0.797	0.342	0.076	0.637	0.957	0.440	1.470

Table 7. Analysis of Variance (ANOVA) Between tests of Muscle Strength Variables Acting on the Ankle Joint (n=5)

Muscle strength variables	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Sum of Squares	F Value	Significance
Dorsiflexion Resistance	Follow-up test 1	3.319	3	1.106	126.101	0.000
	Follow-up test 2	0.140	16	0.009		
	Total	3.459	19			
Plantar Flexion Resistance	Follow-up test 1	2.176	3	0.725	270.590	0.000
	Follow-up test 2	0.043	16	0.003		
	Total	2.218	19			

* The F critical value at (0.05) with 4 degrees of freedom =1.89

Figure 1. Muscle strength acting on the ankle joint (Dorsiflexion resistance)

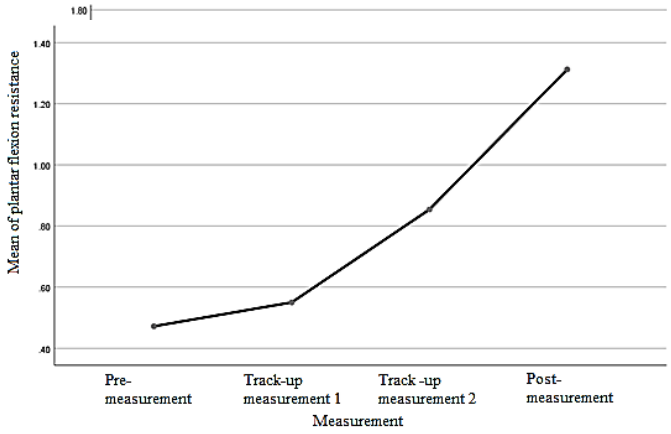

Figure 2. Muscle strength acting on the ankle joint (Plantarflexion resistance)

The arithmetic mean of the sum of squares was used to display the groups in homogeneous subgroups with an alpha coefficient, and the harmonic mean was applied for sample size at a significance level of 0.05.

Table (9) shows the arithmetic mean, standard deviation, and skewness coefficient in the measurements (Follow-up test 1- Follow-up test 2 -post-test).

Table 8. Mean differences in using Tukey HSD test for muscle strength acting on the ankle joint

Variables	Measurement	Mean Difference	Error Margin	P value	95% Confidence Interval for the Mean	
					Lower Bound	Lower Bound
Dorsiflexion Resistance	Follow-up 1	0.210	0.059	0.013	0.379	0.040
	Follow-up 2	0.420	0.059	0.000	0.589	0.250
	Post-test	1.086	0.059	0.000	1.255	0.916
Plantar Flexion Resistance	Follow-up 1	0.0780	0.033	0.121	0.171	0.016
	Follow-up 2	0.382	0.033	0.000	0.475	0.288
	Post-test	0.840	0.033	0.000	0.934	0.7463

Table 9. Significance of percentage improvement in the muscle strength variable acting on the ankle joint (n=5)

Muscle Strength Variables	Measurements	Percentage Improvement			
		Pre-Test	Follow-up Test 1	Follow-up Test 2	Post-Test
Dorsiflexion Resistance	**Pre-Test**	4.821%	1.879%	3.753%	9.645%
	Post-Test 1 Improvement Percentage		6.700%	1.874%	7.766%
	Post-Test 2 Improvement Percentage			8.574%	5.892%
	Post-Test Final Improvement Percentage				14.466%
Plantar Flexion Resistance	**Pre-Test**	4.200%	0.792%	3.398%	7.550%
	Post-Test 1 Improvement Percentage		4.992%	2.606%	6.758%
	Post-Test 2 Improvement Percentage			7.598%	4.125%
	Post-Test Final Improvement Percentage				11.750%

It is evident from Table (9) and the graphical results in Figures (3) and (4) that the overall improvement in the variable of muscle strength working on the ankle joint increases. Additionally, there is variation in the improvement percentages between the means of the research measurements: the pre-test, follow-up test 1, follow-up test 2, and post-test. The post-test measurement shows the greatest improvement, indicating an increase in the muscle strength working on the ankle joint after each stage of the motor rehabilitation process.

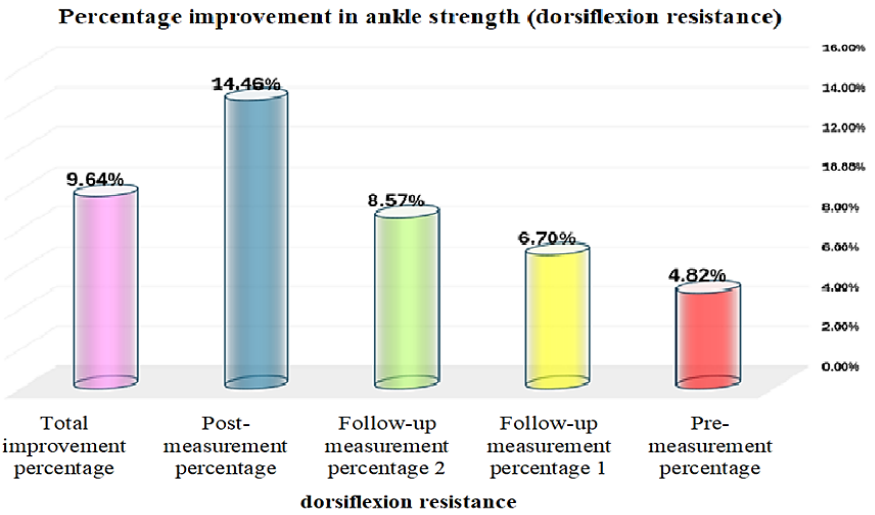

Figure 3. Percentage of improvement in muscle strength working on the ankle joint (Dorsiflexion resistance)

The results in tables (6)(7)(8)(9) and figures (1)(2)(3)(4) indicate that the percentage of improvement in the variable of muscle strength working on the ankle joint during dorsiflexion resistance is equal to (9.64%), while the improvement in the variable of muscle strength working on the ankle joint during plantar flexion resistance is equal to (7.50%), which indicates the existence of statistically significant differences between the four measurements (pre-test - follow-up 1 - follow-up 2 - post-test) of the participants in favor of the post-test.

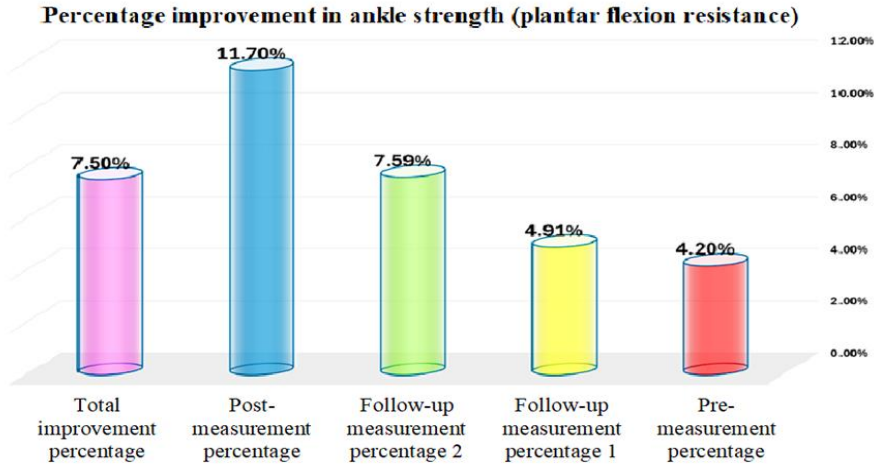

Figure 4. Percentage of improvement in muscle strength

As it is clear from the previous table and figures of the Tukey HSD test, the significance of the differences between the four measurements (pre-test - follow-up 1 - follow-up 2 - post-test) all indicated that this improvement is in favor of the post-test in the variable of muscle strength working on the ankle joint. The researcher attributes this improvement between the four measurements (pre-test - follow-up 1 - follow-up 2 - post-test) in the variable of muscle strength working on the ankle joint to the fact that rehabilitation exercises were practiced

regularly, which were gradually increased in terms of volume and intensity during the three stages of the rehabilitation program, which contained exercises that suit cerebral palsy patients in terms of muscle strength, as it is weak in the first stage, and with the gradual increase in exercises and increasing intensities and repetitions, muscle strength increased in the second stage, and after increasing the loads and resistances in the third stage, this improvement occurred, as indicated by the previous tables and figures. Wakwak, M. Sharif, M. (2021) (10) state that practicing muscle strength exercises regularly, in a variety of ways, and gradually in terms of volume and intensity helps to gain and grow strength, which helps to prevent injuries, as strong muscles enable the athlete to move quickly, while avoiding collision and injury, and increases joint stability. The researcher attributes this improvement in muscle strength and its variables to rehabilitation exercises for people with cerebral palsy, due to their positive role in developing muscle strength, as these exercises help to rebuild and form muscle tissues, ligaments, and tendons, as confirmed by the study of: Hefny, A. (2020) (2), Abdel Wahab, M. (2021) (11), El Nahhas, M. (2021) (12), as their research indicates the role played by kinetic chain exercises in developing muscle strength. Rehabilitation exercises for cerebral palsy patients improve muscle strength and help achieve the desired result, which is strengthening the muscles of the affected limb, in addition to trying to return normal functions to their normal state again. Therefore, using the rehabilitation program that includes specialized exercises for cerebral palsy patients led to strengthening the muscles of the affected limb for the experimental group on which the research was conducted. This showed noticeable progress in the dimensional measurements in the variable of muscle strength working on the ankle joint in favor of the dimensional measurement over the pre- and follow-up1, 2 and follow-up. This is consistent with what El-Sharafi, I. (2023) (6) indicated, that the relative improvement that occurs after the end of each stage in the variable of muscle strength is due to the content of the rehabilitation program, which includes a set of gradual exercises that suit each stage and achieve its goal, which leads to the development of muscle strength. Muscle strength is one of the most important physical and motor abilities that affect the level of human performance in daily activities. Muscle strength is considered one of the most important basic elements that distinguish life requirements and is the basis for an individual's ability to meet daily life requirements without feeling tired. Practicing muscle strength training for cerebral palsy patients on a regular, varied and gradual basis in terms of volume and intensity helps to acquire and grow muscle strength and helps prevent injuries. Thus, the first hypothesis has been achieved.

It is evident from Table (11) that there are statistically significant differences at the 0.05 significance level between the measurements of the balance variable, which is also demonstrated by the bar chart. The F-critical value at a significance level of 0.05 with 7 degrees of freedom is 1.89.

Table 10. Arithmetic means and standard deviation of balance tests (n=5)

Variables		Mean	St.Dv.	Error Coefficient	95% Confidence Interval for the Mean		Min Value	Max Value
					Minimum	Maximum		
Balance	Pre-test (Sec.)	3.4	1.140	0.510	1.984	4.816	2	5
	Follow-up 1 (Sec.)	7	0.707	0.316	6.122	7.878	6	8
	Follow-up 2 (Sec.)	8.6	1.140	0.510	7.184	10.016	7	10
	Post-test (Sec.)	12.6	0.894	0.400	11.489	13.711	12	14
	Total (Sec.)	7.9	3.508	0.784	6.258	9.542	2	14

Table 11. Analysis of variance (ANOVA) between the measurements of the balance variable (n=5)

Variables	Source of Variance	Sum of Squares	Degrees of Freedom	Mean Sum of Squares	F Value	Significance
Balance	Follow-up test 1	218.2	3	72.733	74.598	0.000
	Follow-up test 2	15.6	16	0.975		
	Total	233.8	19			

The harmonic meaning is used for sample size at a significance level of 0.05, and the arithmetic mean of the sum of squares is employed to present the groups in homogeneous subgroups with an alpha factor.

It is clear from Table (12) that there are statistically significant differences at the 0.05 level between the pre-test, follow-up 1, follow-up 2, and post-test measurements, in favor of the post-test measurement, in the balance variable.

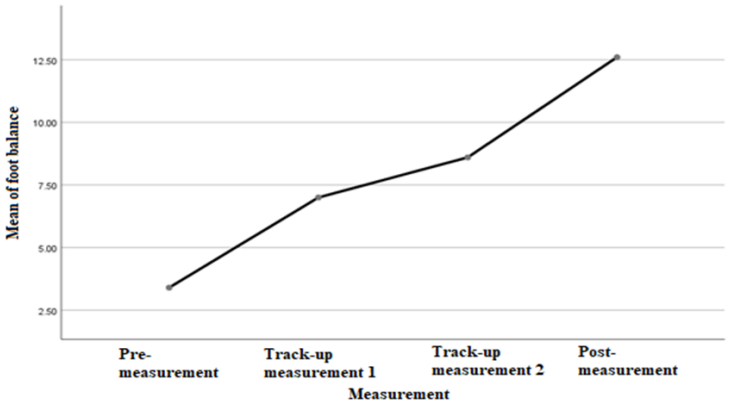

Figure 5. A Graph Representing the Balance Variable

Table 12. Mean Differences Using Tukey HSD Test in the Balance Variable

Variable	test	Mean Differen ce	Error Margin	P-value	95% Confidence Interval for the Mean	
					Lower Bound	Lower Bound
Balance	Follow-up 1	3.6	0.625	0	5.3867	1.8133
	Follow-up 2	5.2	0.625	0	6.9867	3.4133
	Post-test	9.2	0.625	0	10.9867	7.4133

It is evident from Table (13) and the graphical results in Figure (6) that the overall improvement percentage in the variable of pain severity increases. Additionally, there is variation in the improvement percentages between the average measurements of the study: pre-test, follow-up 1, follow-up 2, and post-test, favoring the post-test measurement. This indicates a reduction in pain severity after each phase of the physical rehabilitation program.

Table 13. The significance of the percentage improvement in the balance variable

Variables	Measurements	Percentage Improvement			
		Pre-Test	Follow-up 1	Follow-up 2	Pre-Test
Balance	Pre-Test	22.666%	24.001%	30.667%	57.334%
	Post-Test 1 Improvement Percentage		46.667%	6.666%	33.333%
	Post-Test 2 Improvement Percentage			53.333%	26.667%
	Post-Test Final Improvement Percentage				80.000%

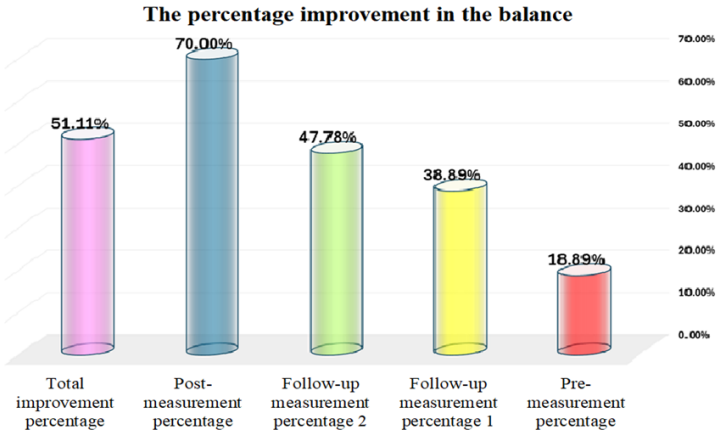

Figure 6. Percentages of improvement in the balance variable

The results presented in tables (10), (11), (12), (13) and figures (5), (6) show that the percentage in the balance of the affected foot is 51.11%. This indicates statistically significant differences between the four measurements (pre-test, follow-up 1, follow-up 2, and post-test) for the research sample, favoring the post-test measurement.

Additionally, as indicated by the Tukey HSD test, the statistical significance of the differences between the four measurements pointed to improvement in favor of the post-test measurement in balance.

The researcher attributes this improvement in the balance measurement to the success and progress achieved through the proposed rehabilitation program. Initially, the balance percentage was weak, as shown in the pre-test measurements (18.89%), while at the end of the third phase, it reached its highest level at 51.11%.

During the implementation of the program, balance-specific rehabilitation exercises were regularly practiced, with a gradual increase in intensity and volume across the three phases of the rehabilitation program, which included balance exercises. In the first phase, balance was very weak. As the exercises progressed and the strength of muscles and ligaments surrounding the ankle increased, especially the Achilles tendon, the balance percentage significantly improved in the second phase. After increasing the loads and resistance in the third phase, this improvement continued as shown in the tables and figures above.

The researcher views balance as a crucial factor in performing movements for individuals with cerebral palsy, who often experience great difficulty in performing activities. The importance of balance in executing basic motor skills is evident, particularly in movements that may require sudden changes, during which the individual may lose balance. Restoring balance quickly is essential to continue moving. Furthermore, daily activities demand specific types of balance, depending on the individual's health condition, which was considered when designing the proposed rehabilitation program. The program included exercises to help individuals with cerebral palsy maintain body posture, both in static and dynamic conditions, to achieve the required motor tasks throughout the day.

This aligns with Ibrahim, I. (2020) who indicated that the relative improvement observed at the end of each stage in balance results from the content of the rehabilitation program, which consists of a range of progressive exercises that suit each stage and help achieve the goal of improving balance in individuals with cerebral palsy. Balance exercises enhance sensory feedback and improve its efficiency.

This also matches the findings of studies by Hafni, A. (2020), Abdel Wahab, M. (2021), and Al-Nahhas, M. (2021), which emphasize that the rehabilitation program and the speed of its application lead to improved overall body balance in individuals with cerebral palsy. Rana

Amer (2023) also noted that balance exercises help individuals control their bodies and improve neuromuscular coordination and balance during different movements and postures.

It is also consistent with the findings of Mahmoud, A. and Kazem, M. (2023), who indicated that balance exercises could start in the second phase, with sensory feedback being restored through exercises such as balance on a wobble board. The mechanoreceptors in muscles, tendons, and ligaments around the joint are activated by the stimuli affecting the joint.

Thus, Hypothesis ‘’ There are statistically significant differences between the meaning of the pre-test and post-test measurements for the study sample in the balance of both feet’’ is confirmed.

Conclusion

Considering the study's objectives, questions, the scope of the study, and the nature of the sample, and based on the results and data collected, as well as the statistical treatments used, the researcher reached the following conclusions:

1. The proposed rehabilitation program led to improvements in the muscular strength variables acting on the ankle joint in individuals with cerebral palsy, as observed in the dorsiflexion and plantarflexion resistance tests, bringing the values closer to normal.
2. The proposed rehabilitation program led to improvements in the balance level in individuals with cerebral palsy, bringing it closer to the unaffected limb.
3. The proposed rehabilitation program had a positive impact on the functional and mechanical performance of the affected foot due to cerebral palsy, returning it to near-normal functionality for walking.

Recommendations

Based on the study's results and the conclusions drawn, the researcher recommends the following:

1. Utilizing the study's procedures and the proposed program to design and implement other programs based on scientific principles.
2. Focusing on specialized rehabilitation exercises for individuals with cerebral palsy during various rehabilitation stages due to their significant impact on improving the biomechanical properties under study.
3. Considering individual differences when rehabilitating cases of cerebral palsy and similar injuries.
4. Ensuring the unaffected limb is not neglected during the implementation of the proposed rehabilitation program.
5. Increasing focus on injury prevention and improving overall body strength.

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