Research Article

Impact of Universal Exercise Unit On Upper Limb Performance in Children With Hemiplegic Cerebral Palsy: a randomized control study

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Abstract

Background: Spastic hemiplegic cerebral palsy (CP) mainly affects one side of the body, particularly the upper extremity and distal muscles, demonstrating limited hand function. There was a positive correlation between strength in the upper extremities and hands and the capacity to use one or both unimanual and bimanual capabilities. The purpose of this study was to assess the effects of a Universal Exercise Unit strengthening program upon children suffering from spastic hemiplegia's upper extremity strength results.

Methods: Forty children (male and female) with hemiplegia CP and ages 5 to 9 participated in this randomized controlled trial research. The children were chosen from the Outpatient Clinic of the Faculty of Physical Therapy at Cairo University for a 3-month period. Based on their scores on the Gross Motor Function Classification System as well as the Manual Ability Classification System, subjects were categorized as either Level I or II. The subjects were distributed into two equivalent groups (n = 20). Group (A) had traditional physiotherapy, while group (B) were given strengthening exercises according to the Universal Exercise Unit along with traditional physiotherapy. The Quality of Upper Extremity Skill Test was used to evaluate the function of the upper limbs both before and after the intervention.
Results: Statistical analysis of the post-treatment mean values showed that Group B demonstrated significantly greater improvement (52.50 ± 3.07) compared to Group A (46.15 ± 2.06).
The mean difference between groups was 6.35.(p = 0.001)
Conclusion: The integration of strengthening exercises using the Universal Exercise Unit into conventional physical therapy significantly enhances upper limb strength in children with hemiplegia CP. These findings support the incorporation of Universal Exercise Unit-based interventions in pediatric neurorehabilitation programs targeting upper limb function.
Keywords: hemiplegia cerebral palsy, muscle strength, Universal Exercise Unit, radomized control trail

1. Introduction

Cerebral palsy (CP) refers to a neuro-developmental disorder resulting from non-progressive brain abnormalities. CP affects 1.5 to 4 out of every 1000 births worldwide. It is the primary cause of children's motor impairments and is often accompanied by cognitive and sensory deficiencies. With 44% of cases [1,2]. Hemiplegia, a sub-type, is characterized by unilateral motor deficits, with the upper extremity being more affected greater than the lower extremity [3]. Children with hemiplegia often have significant differences in the clinical appearance of the upper extremity regarding muscle tone and strength, range of motion (ROM), somatosensory perception, along with motor skills like dexterity, the ability to produce unimanual as well as bimanual performance [4].

Numerous significant kinematic differences have been demonstrated between children with spastic hemiplegia and typically developing cases in ROM and joint positioning during reaching tasks. Several of these alterations are attributed to muscle spasticity or contraction, with elbow flexion, forearm pronation and wrist flexion accompanied by ulnar deviation [5].

Strengthening therapies are acknowledged for their capacity to enhance muscular performance, improve bodily structure and function, and promote functional independence [6]. In recent years, the Universal Exercise Unit (UEU) has emerged as a promising instrument in pediatric neurorehabilitation. The UEU offers a mechanism of pulleys, suspension belts, and elastic cords intended to facilitate or impede movement by partially alleviating the body's weight against gravity. This configuration enables therapists to promote focused training of underdeveloped muscles while ensuring optimal motor control [7, 8]. The UEU's adjustable design facilitates progressive resistance training, customized to the functional capacity of each child [9].

The One-repetition maximum (1-RM) technique, which refers to the heaviest weight an individual can lift in one complete repetition, is commonly utilized to measure maximal strength capacity. In this context, 1-RM testing of the upper limb, illustrated by vertical chest press, is employed to evaluate performance, utilizing standardized positions to maintain consistency between trials [10].

Studies evaluating the efficacy of therapies in clinical and research settings measure upper limb mobility and activity restriction using the Quality of Upper Extremity Skill Test (QUEST). [11]. There were 34 tasks in the QUEST exam, covering four areas: dissociated movement, grasping, weight bearing, as well as protective extension [12].

Despite increasing interest in functional strengthening for children with hemiplegia, there is a deficiency of research investigating the particular impacts of UEU-based therapies on upper limb strength using standardized assessment procedures such as QUEST. Current research has predominantly concentrated on balance or lower limb functionality, resulting in a deficiency of evidence about specific upper limb results.

The major aim of this study was to examine the impact of a structured UEU-based strengthening program on upper limb muscle movement, particularly in children having hemiplegia CP. It was hypothesized that adding UEU training to standard physiotherapy would result in significantly improvements in upper limb performance, as measured by QUEST, compared with physiotherapy alone.

This work provides a significant children neurorehabilitation literature by presenting the effectiveness of UEU in improving upper limb performance. The results are anticipated to assist health care providers in developing more effective, evidence-based therapies for children with unilateral CP.

2. Randomization and sample size calculation

The purpose of this RCT was to examine the impact of structured UEU strengthening program upon the strength of the muscles in upper extremity of children having hemiplegia CP. The participants were randomly selected using a computer-generated random number sequence. Assignments were concealed by employing opaque envelopes. The intervention period was executed over a 12-week duration, with assessments performed before and following the treatment phase. The G*POWER statistical program (version 3.1.9.2) was used to calculate the sample size, and it was determined that a minimum of twenty children per group was necessary for this study. The parameters used for the calculations were α=0.05, power = 95%, as well as effect size = 1.17.

2.1. Participants

Forty children, from both genders, aged 5 to 9 years, diagnosed with spastic hemiplegic CP, were located from the Outpatient Clinic of the Faculty of Physical Therapy, Cairo University and the duration of therapy sessions 3 times per week for 3 successive months. Participants were included if they demonstrated motor abilities categorized as Level I or II on the Gross Motor Function Classification System (GMFCS) and Level II on the Manual Ability Classification System (MACS). Children were excluded from the trial if they had any visual or auditory impairments, if they had orthopaedic surgery on the upper extremities in the last six months, or if they had heart conditions that contraindicated to exercise.

After eligibility screening and informed consent procedures, subjects were randomized into two equivalent groups (n = 20 per group). Group A underwent a selected physiotherapy program, whereas Group B participated in a tailored strengthening regimen utilizing the UEU augmented with the selected physical therapy program.

Both groups participated in therapy sessions three times weekly for a duration of three successive months

(**Figure 1**)

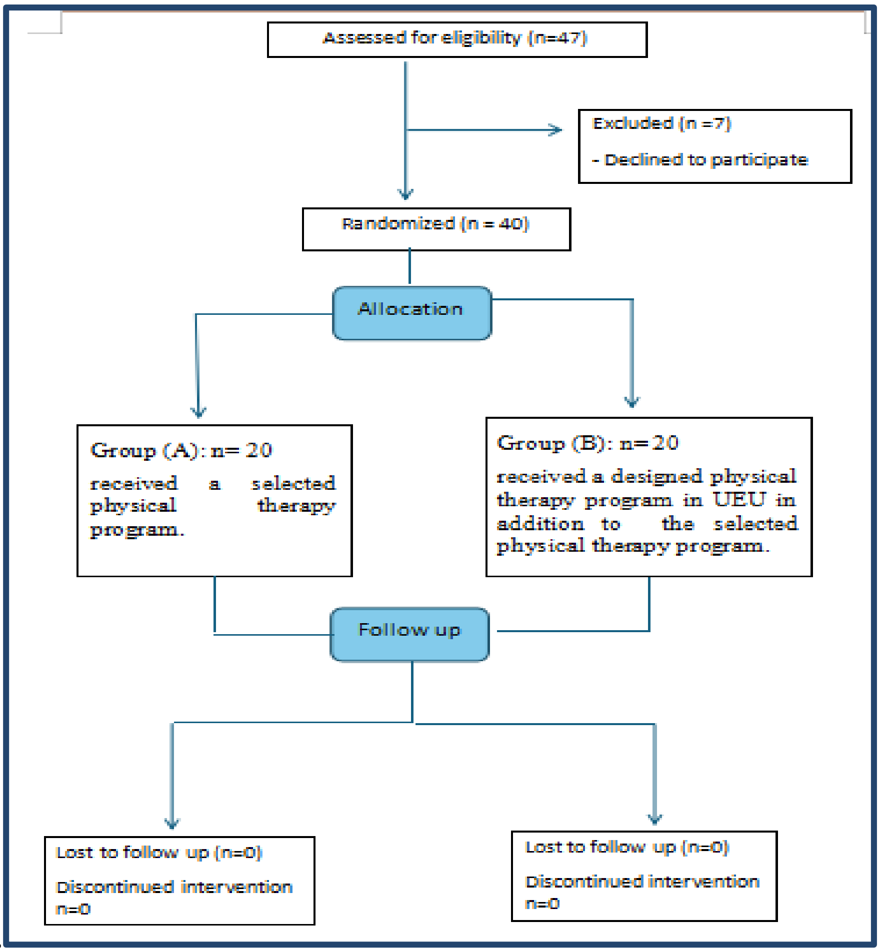

Figure 1. Study Flowchart.

2.2. Instrumentation

The movements of upper limb were evaluated using QUEST as primary outcome measure. The QUEST is considered as a tool widely recognized for evaluation of upper extremity performance. Evaluations were performed at baseline and following the treatment to assess alterations in upper limb performance subsequent to the respective treatment regimes.

The therapy regimen employed the UEU, a modular rehabilitation apparatus made of metal frames, with elastic cords, belts, pulleys, and adjustable resistance weights. This device was utilized to provide focused, incremental resistance training while reducing the effects of gravity and compensatory motions.

2.3. Procedures

All participants were evaluated utilizing the QUEST pre-treatment and immediately following the 12-week treatment period from October 2023 to September 2024. The evaluation methodology required each child to be seated on the torso. Each child was asked to dress in a light t-shirt so the arm would be easily seen. And each child was seated in a chair, the table height was above waist level. The movement had been facilitated through verbal encouragement and demonstration. For a minimum of two seconds, each child was told to maintain the posture [11].

2.4. Intervention

The standard physical therapy regimen provided to both groups comprised a series of upper limb stretching exercises aimed at the elbow flexors, wrist flexors, and forearm pronators, alongside functional strengthening activities including push-ups, wall pushes, hand walking, reaching for toys from kneeling and throwing a large ball.

Participants in Group B received the UEU-based strengthening program alongside the standard regimen. Each UEU session lasted roughly 30 minutes and was conducted with the child positioned supine on a plinth. The torso and the non-exercised upper limb were fastened with belts and elastic cords to ensure stability and inhibit compensatory movements. Exercises were formulated to enhance the musculature of the shoulder and elbow, emphasizing functional movement patterns. These comprised: (1) shoulder diagonal abduction with elbow extension (Diagonal Pattern I), (2) Shoulder diagonal adduction with elbow flexion (Diagonal Pattern II), (3) shoulder horizontal abduction with prolonged elbow extension, (4) shoulder horizontal adduction, and (5) isolated shoulder flexion against resistance.

The resistance weight used was estimated at 60% of 1-RM to ensure safety for children of all ages when performed appropriately.

2.5. Ethical Considerations

The research was registered with Clinical Trials.gov and approved by the Research Ethics Committee of the Faculty of Physical Therapy at Cairo University (No.P.T.REC/012/004849). No.: NCT07233031 and adhered to the guidelines provided in the Declaration of Helsinki. In accordance with the Declaration of Helsinki, all procedures including human subjects were conducted. Prior to enrolment, all participants' legal guardians were contacted to get their informed permission after being thoroughly informed about the process.

2.6. Data Analysis

Data obtained from the QUEST were securely saved and analysed utilizing IBM SPSS Statistics software (v26.0). All of the variables were subject to descriptive statistical calculations, and the results were expressed as means and standard deviations. Dependent t-tests were utilized for within-group comparisons of pre- and post-treatment outcomes, whilst independent t-tests were employed to assess between-group differences. A significance level of $p < 0.05$ was utilized for all statistical analyses. Effect sizes were computed to evaluate the extent of change resulting from the intervention.

3. Results

No statistically significant differences were detected among the two groups in baseline characteristics, involving age, gender distribution, and GMFCS scores. The mean age of children in Group A was 6.75 ± 0.97 years, and in Group B was 6.60 ± 1.09 years, revealing no significant difference (**p = 0.65) (Table 1**).

Table 1. Comparison of the ages between Group A and Group B

Age (years)	Group A	Group B	MD	t-value	p-value	Sig.
Mean ± SD	6.75 ± 0.97	6.60 ± 1.09	0.15	0.46	0.65	NS
Maximum	8	8				
Minimum	5	5				

The difference in sex distribution between groups was not statistically significant (**p= 0.75) (Table 2**); group A consisted of 12 girls (60%) and 8 boys (40%), while Group B included 11 girls (55%) and 9 boys (45%).

Table 2. Comparison of sex distribution between Group A and Group B

Sex	Group A (n = 20)	Group B (n = 20)	χ^2	p-value	Sig.
Girls	12 (60%)	11 (55%)	0.10	0.75	NS
Boys	8 (40%)	9 (45%)			

The median GMFCS score (IQR) was identical in both groups at 1 (2–1), indicating no significant difference between groups (**p = 0.75) (Table 3**).

Table 3. Comparison of GMFCs scores between Group A and Group B

Measure	Group A	Group B	U-value	p-value	Sig.
GMFCs	1 (2–1)	1 (2–1)	190	0.75	NS

Significant improvements were observed in QUEST after 12 weeks of therapy (**Table 4, fig2**).

Table 4: Comparison between pre and post treatment mean values of QUEST of group A.

	QUEST $\overline{X} \pm$ SD	MD	% of change	t-value	p-value	Sig
Pretreatment	**42.45 ± 2.58**	**3.7**	**8.72**	**10.39**	**0.001**	**S**
Post treatment	**46.15 ± 2.06**					

x̄: Mean	**SD: Standard deviation**	**MD: Mean difference**
t value: Paired t value	**p value: Probability value**	**S: Significant**

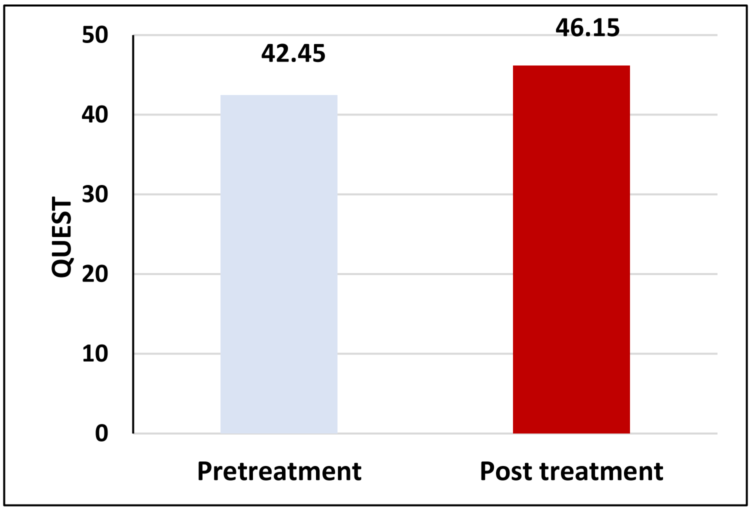

Fig2: Pre and post treatment mean values of QUEST of group A.

Children in Group B demonstrated significantly greater improvements QUEST following intervention. **(Table 5, fig3)**

Table 5. Comparison between pre and post treatment mean values of QUEST of group B.

	QUEST	MD	% of change	t-value	p-value	Sig
	$\bar{X} \pm$ SD					
Pretreatment	41.65 ± 2.53	10.85	26.05	16.49	0.001	**S**
Post treatment	52.50 ± 3.07					
$\bar{X}$: Mean	**SD: Standard deviation**	**MD: Mean difference**				
t value: Paired t value	**p value: Probability value**	**S: Significant**				

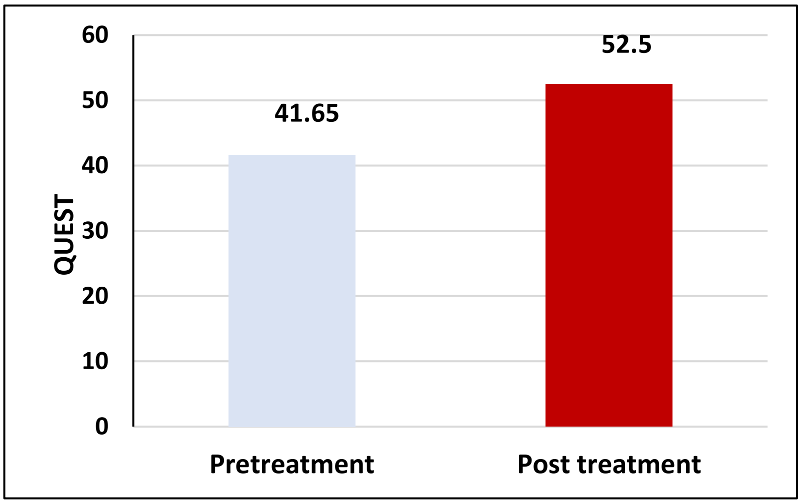

Fig3: Pre and post treatment mean values of QUEST of group B.

4. Discussion

The principal aim of this study was to assess the influence of a tailored strengthening regimen utilizing the UEU on upper extremity function, in children diagnosed with hemiplegia CP. The results indicated a statistically improvement in upper limb function post-intervention, with more substantial improvements noted in group B compared with the group A. Significantly, no significant changes were recorded between the groups at baseline, hence reinforcing the internal validity of the findings.

The UEU operates on biomechanical and neurophysiological principles that are particularly suited to pediatric neurorehabilitation [13]. By suspending limbs and modulating gravitational load, the UEU enables graded resistance training while minimizing compensatory movement patterns, a critical advantage in children with spastic hemiplegia who often rely on synergistic or overflow movements due to impaired selective motor control [14]. This aligns with the principles of motor learning theory, which emphasizes task-specific, repetitive, and feedback-rich practice to drive neuroplastic adaptation [15]. The UEU's capability to deliver adjustable resistance alongside kinematic constraints facilitates the provision of an optimal "just-right challenge," a core principle of pediatric rehabilitation that balances difficulty with success to optimize engagement and motor acquisition [16]. Herein, post-treatment analyses revealed statistically significant enhancements in QUEST in both groups ($p < 0.001$). Children in Group B demonstrated a much higher percentage of improvement 26.05%, reflecting the efficacy of the UEU-based intervention.

Recent neuro-imaging studies suggest that resistance training in children with CP can result in increased corticospinal tract integrity and improved inter-hemispheric inhibition, thereby reducing maladaptive plasticity and promoting more efficient motor unit recruitment [17, 18]. The UEU's structured environment likely amplifies these effects by enabling high-repetition, high-fidelity movement execution, a key driver of use-dependent plasticity. The current findings are consistent with a growing body of evidence confirming the efficacy of UEU and similar suspension-based systems in pediatric CP populations. For instance, UEU-based training has been reported to enhance shoulder girdle strength and functional reach in children having diplegic CP [8]. As reaching is a fundamental motor skill essential for upper limb functional independence; It requires complex multi-joint coordination of the upper extremities and serves as a foundation for the development of manipulative skills [19].

The QUEST test utilized in evaluating the efficacy of UEU-based exercise and the traditional physical therapy approaches on quality of upper extremity function in children with spastic hemiplegic CP [20]. Previous studies have shown that school-aged children with CP face mobility problems as a result of their bodies growing, which is consistent with the chosen age group of 5-9 years. Physical therapy can assist ensure that children develop in a manner that is advantageous to their motor function [21]. Moreover, QUEST was the chosen method for measuring upper extremity function. The specific protocol was adopted from the study by Mohamed, which validated its use for QUEST in evaluating quality of upper extremity function in children [20].

Our results regarding quality of upper limb performance came in line with, Russo et al. [22] who indicated that a 15% increase in upper limb strength correlates with measurable improvements in self-care domains (e.g., dressing, feeding) in children with hemiplegia. Physical exercise is recognized as a crucial instrument for enhancing the quality of life for children and adolescents with CP. Verschuren et.al., demonstrated that physical exercise regimens lower levels of sedentary behaviour while simultaneously enhancing cardiovascular health and muscle strength [23]. Extrapolating from this, the gains observed in the UEU group may translate into meaningful functional improvements, as reflected in enhanced independence in activities of daily living (ADL) following the intervention. Previous evidence indicates that children with CP demonstrate reduced performance in daily living activities when upper limb muscle strength is compromised. Moreover, improvements in motor control and strength achieved within structured therapeutic settings appear to generalize to more complex functional tasks in everyday life, as supported by caregiver-reported observations of spontaneous improvements in daily activities [24].

The UEU's proprioceptive-rich environment which increase synaptic pruning and myelination in motor pathways through elastic resistance, joint loading, and kinesthetic input; This is consistent with models that demonstrate that resistance training with children during school age improves motor map reconstruction [25]. Furthermore, stimulating proprioceptive and somatosensory systems via guided resistance training can facilitate neuromotor reorganization and enhance movement patterns in children with central motor abnormalities [26]. The UEU may enhance motor learning through repeated, executed movement by providing structured support and customizable resistance.

This study indicates that integrating UEU-based exercises into pediatric physiotherapy regimens can significantly enhance upper limb strength in children with hemiplegia. Enhanced upper limb strength is strongly correlated with an improved capacity to execute ADL including dressing, feeding, and writing, skills essential for school involvement and social interaction [27]. Considering that muscle weakness significantly contributes to functional limits in unilateral CP, therapies targeting this deficiency can substantially enhance quality of life and diminish caregiver reliance.

5. Limitations

Although the results are promising, various restrictions might be recognized. First, functional outcomes beyond QUEST, such as manual dexterity or quality of life performance, were not evaluated in this study. Ultimately, the study was confined to children with spastic hemiplegia, and the findings might not generalizable to other types of CP.

6. Recommendations

Additional research is necessary to investigate the impact of UEU training on functional activities and the execution of ADL in children with CP. This study concentrated on muscle strength, although the application of these improvements to daily functionality is a significant subject for further research. Moreover, subsequent research should evaluate the efficacy of UEU therapies across other subtypes of CP and a wider spectrum of age demographics to improve generalizability. Investigating these variables may elucidate if the advantages noted in children with spastic hemiplegia are applicable to others with alternative clinical manifestations. These findings may enhance comprehension of the effects of tailored therapies on motor control and cortical reconfiguration in pediatric populations with motor deficits.

7. Implications to physiotherapy practice

This study's results have important implications for clinical practice, advocating for the integration of UEU-based strengthening into standard pediatric neurorehabilitation protocols for children with spastic hemiplegic CP classified as GMFCS Levels I–II. Given the substantial and statistically significant gains in QUEST particularly the26.05% improvement clinicians should consider UEU as a potent adjunct to conventional therapy, ensuring interventions are delivered at sufficient intensity (three times weekly) and duration (minimum 12 weeks) with resistance weight used was estimated at 60% of 1-RM. To maximize functional carryover, UEU training should be strategically paired with task-specific functional practice, Occupational therapists should be involved in goal-setting and outcome measurement. The high compliance and absence of adverse events further support UEU's feasibility and acceptability in clinical settings, making it a viable, child-friendly modality that can enhance not only muscular performance but also potential independence in daily activities, thereby reducing caregiver burden and improving quality of life, though future studies should directly quantify these functional and psychosocial outcomes to solidify its value-based care proposition.

8. Conclusion

The results of this study endorse the UEU as an efficacious treatment intervention for enhancing upper limb strength in children with hemiplegia CP. When utilized in conjunction with traditional physical treatment, the UEU provides substantial advantages in addressing muscle weakness, a critical deficit linked to functional limits in this demographic.

9. Declarations

Ethics Approval and Consent to Participate

This study got approval by the Research Ethics Committee of the Faculty of Physical Therapy, Cairo University (Approval N0: P.T.REC/012/004849) and registered in the Clinical Trials.gov. Identifier: NCT07233031. Adherence to the ethical principles outlined in the Declaration of Helsinki was maintained during all standards including human participants. Before enrolling any children in the research, their parents or legal guardians were asked to provide written informed permission.

Consent for Publication

Not applicable.

Funding

The study did not receive particular grants from any public, private, or non-profit funding source.

Availability of Data and Materials

The datasets generated and analyzed during the current study are available from the corresponding Author on reasonable request.

Competing Interests

The authors declare that they have no competing interests.

Authors' Contributions

Samaa Hussein Rajab, Naglaa Ahmed Zaky: Conceptualization, Methodology, Investigation, and Manuscript Writing.
Samaa Hussein Rajab, Gehan Hassan El Meniawy: Data Collection, Analysis, and Interpretation.
Naglaa Ahmed Zaky, Gehan Hassan El Meniawy: Supervision, Critical Revision, and Manuscript Final Approval.
All authors read and approved the final manuscript.

Acknowledgments

The authors would like to thank the participating children and their families, as well as the staff at the Faculty of Physical Therapy, Cairo University, for their assistance and support during the study. We sincerely appreciate Edigenomix Scientific Co., Ltd. (https://www.edigenomix-scientific.com/) for their expert editing and proofreading, which greatly improved the clarity and quality of our manuscript. Their meticulous attention to detail and support in refining the document for publication are gratefully acknowledged.

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