Relationship Between Isokinetic Strength Training and Gross Motor Function in Children with Spastic Diplegic Cerebral Palsy

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Abstract

Background: Spastic diaplegia is amongst the most widely recognized clinical subtypes of cerebral palsy due to a number of deficits; including spasticity, muscle weakness, poor muscle control, impaired balance. poor balance control is one of the most contributing factors for poor gait.

Aims: To correlate the isokinetic strength training and Gross motor functions in children with spastic diplegic cerebral palsy.

Materials and Methods: A single prospective clinical, randomized control trial with a correlational design. Thirty-two children with spastic diplegic cerebral palsy were selected from both sexes, their age range was 6 to 12 years old, they were randomly assigned into two equal groups: control group (A): received traditional physiotherapy program only. Study group(B): received Isokinetic strength training program of the upper and lower limbs in addition to the traditional physiotherapy program. Evaluation was done before and after 12 weeks of treatment using: gross motor function measure (GMFCS); to assess gross motor function, pediatric balance scale, to assess balance, and kinovea software, to assess gait.

Results: There was a positive correlation between isokinetic strength training and guess motor function in children with spastic diplegic cerebral palsy (r= 0.698 and p<0.05).

Conclusions: isokinetic muscle strength training of the upper and lower limbs is related to gross motor functions in children with spastic diplegic cerebral palsy demonstrating that the higher muscle strength, the higher the improvement in functional abilities as in standing and walking.

Key words: Cerebral palsy, Gross motor function, Isokinetic strength training

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Resumen

Antecedentes: La diplejía espástica es uno de los subtipos clínicos más reconocidos de parálisis cerebral, caracterizado por diversos déficits como la espasticidad, debilidad muscular, control muscular deficiente y equilibrio alterado. El mal control del equilibrio es uno de los factores que más contribuyen a un patrón de marcha deficiente.

Objetivos: Correlacionar el entrenamiento de fuerza isocinética con las funciones motoras gruesas en niños con parálisis cerebral espástica tipo diplejía.

Materiales y Métodos: Ensayo clínico prospectivo, aleatorizado y controlado, con un diseño correlacional. Se seleccionaron treinta y dos niños con parálisis cerebral espástica tipo diplejía, de ambos sexos y con edades entre 6 y 12 años. Fueron asignados aleatoriamente en dos grupos iguales: Grupo control (A), que recibió únicamente un programa tradicional de fisioterapia; y Grupo de estudio (B), que recibió entrenamiento de fuerza isocinética para las extremidades superiores e inferiores además del programa tradicional. La evaluación se realizó antes y después de 12 semanas de tratamiento mediante la medida de función motora gruesa (GMFCS), la escala de equilibrio pediátrica y el software Kinovea para analizar la marcha.

Resultados: Se encontró una correlación positiva entre el entrenamiento de fuerza isocinética y la función motora gruesa en niños con parálisis cerebral espástica tipo diplejía (r = 0.698 y p < 0.05).

Conclusiones: El entrenamiento de fuerza muscular isocinética de las extremidades superiores e inferiores se relaciona con mejoras en las funciones motoras gruesas en niños con parálisis cerebral espástica tipo diplejía, demostrando que a mayor fuerza muscular, mayor es la mejora en habilidades funcionales como estar de pie y caminar.

Palabras clave: parálisis cerebral, función motora gruesa, entrenamiento de fuerza isocinética

Resumo

Contexto: A diplegia espástica é um dos subtipos clínicos mais reconhecidos da paralisia cerebral, caracterizada por diversos déficits, incluindo espasticidade, fraqueza muscular, controle motor deficiente e equilíbrio comprometido. O controle precário do equilíbrio é um dos fatores que mais contribuem para uma marcha inadequada.

Objetivos: Correlacionar o treinamento de força isocinética com as funções motoras grossas em crianças com paralisia cerebral espástica tipo diplegia.

Materiais e Métodos: Ensaio clínico prospectivo, randomizado e controlado, com desenho correlacional. Trinta e duas crianças com paralisia cerebral espástica tipo diplegia, de ambos os sexos, com idades entre 6 e 12 anos, foram selecionadas. Foram distribuídas aleatoriamente em dois grupos iguais: Grupo controle (A), que recebeu apenas um programa tradicional de fisioterapia; e Grupo de estudo (B), que recebeu um programa de treinamento de força isocinética para os membros superiores e inferiores, além do programa tradicional. A avaliação foi realizada antes e após 12 semanas de tratamento utilizando: Medida de Função Motora Grossa (GMFCS), Escala de Equilíbrio Pediátrico e o software Kinovea para análise da marcha.

Resultados: Foi encontrada uma correlação positiva entre o treinamento de força isocinética e a função motora grossa em crianças com paralisia cerebral espástica tipo diplegia (r = 0,698 e p < 0,05).

Conclusões: O treinamento de força muscular isocinética dos membros superiores e inferiores está relacionado com melhorias nas funções motoras grossas em crianças com paralisia cerebral espástica tipo diplegia, demonstrando que quanto maior a força muscular, maior a melhoria nas habilidades funcionais como ficar em pé e andar.

Palavras-chave: paralisia cerebral, função motora grossa, treinamento de força isocinética

Introduction

Cerebral palsy (CP) is a neurological condition that primarily affects an individual's motor functions and physical coordination. It is characterized by impairments in movement, posture and muscle control. Cerebral palsy is caused by abnormalities or injuries, to the developing brain which can occur before, during or shortly after birth [1]. Cerebral palsy patients present with impairments in body function such as spasticity, low muscle strength and selective motor control. These impairments may limit the performance of activities and participation in daily life [2]. Spastic diplegia is the most prevalent type of cerebral palsy characterized by a greater impairment of the lower limbs. Compared to the upper limbs. In this form of CP, the motor difficulties and muscle tone abnormalities are more pronounced in the legs and hips often resulting in challenges with mobility, gait and body coordination, while the upper extremities may also be affected to some degree, the primary focus of intervention and management for individuals with spastic diplegia is typically on improving upper and lower body functions and independence [3]. Until recently, strength training in children with cerebral palsy was considered to be inappropriate because it could lead to increased spasticity on abnormal movement patterns. However, the results of recent studies

suggest that progressive strength training can lead to increased strength and improved function [4]. A recent review has shown that low muscle strength and not spasticity cause the greatest limitations in motor function in children with CP [5]. Patients with cerebral palsy present different affectations such as decreased muscle strength, gait deviations, impaired proprioception, and spasticity. Isokinetic strengthening programs combined with intensive rehabilitation may improve muscle strength and therefore gait efficiency [6].

The isokinetic dynamometer is widely used to assess and improve muscle function for both rehabilitation and training purposes. It has been used for strength testing and training in clinical settings. It is also safe to use with children because there is minimal risk of muscle and Joint injuries [7]. The unique features of isokinetic dynamometry are optimal loading of the muscles in dynamic conditions and constant preselected velocity of movement. These features provide safety in the rehabilitation of patients with muscular and ligamentous injuries [8,9].

Material and methods

Design and setting

A randomized controlled trial was carried out at the outpatient physical Therapy clinics, faculty of physical Therapy, Kafr Elsheikh University, Egypt with an ethical code stated in Helsinki Declaration 1975. It was conducted between July 2024 and March 2025. Our study had registration Number. KFSIRB 200-490.

Procedures

Ethical considerations

The procedure had ethically approved by ethical committee board approval of the faculty of physical Therapy, Kafr Elsheikh University before performing the study.

A consent form was obtained from all parents of participated children. All parents received a brief explanation of the examination and treatment of procedures before signing an informed permission form. In addition to reading the study myself, I've also had it read and explained to me, when I've had the possibility to inquire about it. I've always gotten good response. I voluntarily agree to have my child participate in this study.

Sample size calculation

Calculation done by G power (Version 3.1.9.2. Germany) was used to compute the sample size prior to using these values and our assumption (alpha = 0.05, power = 0.8 and effect size = 0.75). As a result, the total estimated sample size for children with spastic diplegic cerebral palsy was 32.

Subjects

Thirty-two spastic diplegic cerebral palsy children were selected from the outpatient clinic of faculty of physical Therapy, Kafr Elsheikh university. They were referred from pediatric neurologists as having spastic diplegia. After screening, the selected children were from both genders, their age ranged from six to twelve years (mean value of control group 8.3 ±1.8 and mean value of study group 8.37 ± 2.1). Spasticity grades varied from 1 to 1+ as assessed by the modified Ashwarth Scale (MAS), they were able to follow verbal instructions and Gross motor function classification system (GMFCS) Level I (N=10), Level II (N= 16) and level III (N=6). children who had any visual or auditory problems, fixed deformities in the upper or lower limbs that interfere with motor functions, history of any surgical interference in upper or lower limbs for less than one year and uncooperative children were excluded (Figure 1).

Randomization

Forty spastic diplegic cerebral palsy children were evaluated for eligibility;

Six children excluded because they failed to fulfill the inclusion criteria, and two parents refused to participate in this study. As a result, 32 children with spastic diplegic cerebral palsy were included in this study figure (1). They were assigned randomly into two equal-sized groups using random allocation software to reduce selection bias (Saghaei, 2004). The control group(A) received a designed physical therapy program, and the study group (B) received the same designed physical

Therapy program as group (A) in addition to Isokinetic resistance training of the upper and lower limbs.

Outcomes

At the baseline evaluation and three months following the intervention, all children were evaluated for the following outcomes:

Primary outcome: The gross motor functional measures (GMFM).

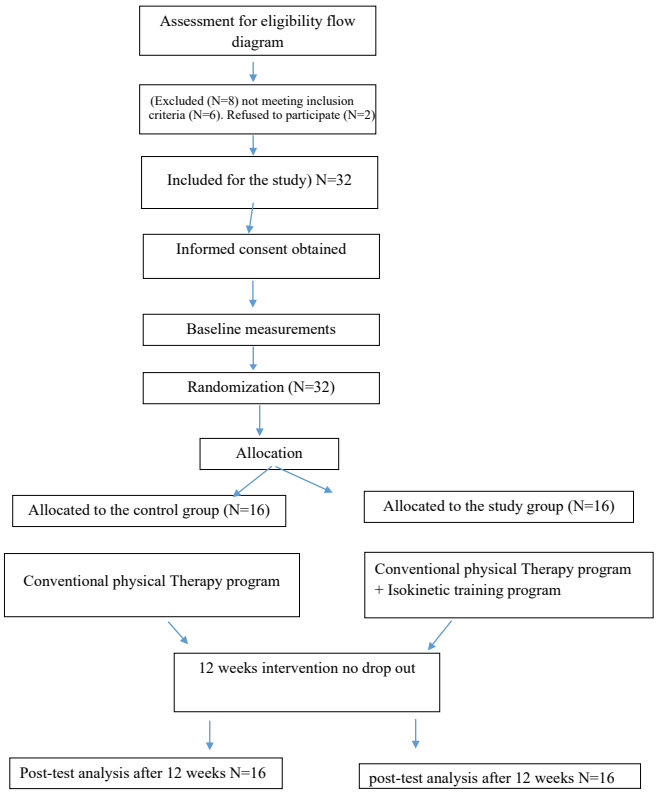

Figure 1: flow chart of the study procedure.

Gross Motor Function Measure 88 (GMFM-88)

The GMFM is used by a variety of rehabilitation specialists for clinical and research purposes to measure change over time and the effectiveness of interventions to effect change. [9,10]

The standardized measures provide objective information in an easy-to-understand format. As stated earlier, the GMFM has become the standard tool for measuring change in gross motor function over time for children with CP. Given its unique purpose, its wide use, and the amount of research that has been conducted using this outcome measure, examining the usefulness as related to intervention is important to measure change over time for children with CP. the Gross Motor Function Measure (GMFM) and its subsequent revisions, has become the most common functional outcome measure used by rehabilitation specialists to measure gross motor functioning in children with CP and other neurologically based conditions, such as down syndrome and traumatic brain injury. (11]

This tool showed high validity at 0.91 when applied, the GMFM-88 was reported to be a useful method for measuring gross motor function in children with CP because of its high reliability, with inter-rater reliability of 0.77, test-retest reliability of 0.88, and intra-rater reliability of 0.68. [12]

Secondary outcomes

Functional balance skills using pediatric balance scale (PBS)

The PBS is a standardized tool for testing balance. this tool developed by modifying the Berg Balance Scale to test the functional balance of the school-age population with mild-to-moderate motor impairment. The tool has been confirmed to be reliable in terms of both intra-rater reliability (intraclass correlation coefficient (ICC) = 0.99) and inter-rater reliability (ICC = 0.99). The items can be measured within 15 min and do not require the use of specialized equipment. PBS consists of 14 items that are scored from 0 points to 4 points with a maximum score of 56 points. The scale examines many of the functional activities such as sitting, standing, transfers and stepping. [13]

Evaluation of gait using Kinovea Software

Kinovea is a free 2D motion analysis software for computers that can be used to measure kinematic parameters. This software allows to analyze video without markers although its reliability may improve with the use of passive markers. Kinovea has been used by various authors to analyze running or vertical jumping in athletes. [14]

Intervention

The control group (A)

Children in this group underwent a designed physical therapy program for 60 minutes, three sessions per week for three consecutive months. This physical therapy program was based mainly on the neuro developmental technique and directed toward improvement of normal patterns of postural control (antigravity mechanism, stability mechanism, counterpoising, righting, equilibrium and protective reactions). These adaptable motor patterns were used as abasis for the development of skilled Functions. They also received stretching exercises in order to present the length and elastic recoil of all soft tissues that could become tight and strengthening exercises to help children become more functional.

The study group (B)

Children in this group received the same designed physical therapy program given to the control group(A) in addition to Isokinetic resistance training of the upper and lower limbs in concentric mode at the angular velocity of 180 degrees (second applied three times per week for 12 weeks making a total of 36 training sessions. Each session included three sets of eight maximal repetitions.

Statistical analysis

Data were fed to the computer and analyzed using SPSS software package version 20.0. tested for normality using Kolmogorov-smir Nov test, shapiro-wilk test and D'Agstino test was conducted. parametric tests were applied, if it reveals normal data distribution. In case of abnormally distributed data non-parametric tests were used. Comparison between two independent populations was done using independent t-test as well as Paired t- test is used to analyze two paired data for Normally distributed data, comparison between two independent populations were done using Mann whitney test for abnormally distributed data.

Significance of the obtained results was judged at the 5% level confidence interval 95% value ≤ 0.05 was considered significant. To verify the correlation of isokinetic strength training and gross motor function in children with spastic diplegic cerebral palsy, spearman correlation test was used.

Results

The collected data from this study represent the statistical analysis of general characteristics of both control & study groups (Table 1).

Comparing the pre and post treatment of gross motor function measure (GMFM%), pediatric balance scale and gait parameters revealed that there was significant difference between the control and study groups in the median of gross motor function and mean of pediatric balance scale and gait parameters (Table 2-6).

Discussion

The present study was conducted to study the effect of Isokinetic strength training on gross motor function in children with spastic diplegic cerebral palsy. Among all types of cerebral palsy (CP), Spastic diplegia is the most prevalent form in individuals with Spastic diplegia, the lower limbs are Significantly more affected than the upper limbs. This condition primarily impacts the muscles of the legs and upper limbs leading to greater difficulties with movement and function in the lower body compared to the upper body [3].

The changes observed in the motor abilities with cp are believed to be linked to a combination of secondary musculoskeletal issues, muscle weakness and the experience of pain. The underlying neurological impairments associated with cerebral palsy can lead to the development of abnormalities in the musculoskeletal system, which in turn contribute to further limitations in movement and physical function.

Additionally, muscle weakness and the sensation of pain experienced by these children can exacerbate the challenges they face in performing physical activities and developing optimal motor skills. [9]

Because of impairments such as weakness, spasticity and incoordination many people with cp have difficulty with activities such as walking independently, negotiating steps and running or navigating safely over uneven terrain. Improving one's ability to walk or to perform other functional activities are often the primary therapeutic goals for people with CP [15].

A recent view has shown that low muscle strength and not spasticity causes the greatest limitations in motor function in children with CP ([5], and this has shifted the focus from spasticity management towards strength training for these children. To be successful, strength training must be individualized, and should involve a progressive increase in intensity, thereby stimulating strength gains that are greater than those associated with normal growth and development [16].

while strength training was once discouraged for cerebral palsy patients due to a link with increased spasticity, new research shows that it can help patients become more mobile and stronger. Strength training can help cerebral palsy

Table 1. General characteristics of both control and study groups.

Variables	Control group(N=16)	Study group (N=16)	T-value	P-value	Significance
Sex (M: F)	9.7	8.8	1.8	0.712	NS
Age (Years)	8.3 ± 1.8	8.5 ± 2.1	1.2	0.246	NS
Height (cm)	128.2 ± 6.67	127.3 ± 6.24	0.216	0.831	NS
Weight (Kg)	35.2 ± 7.13	34.8 ± 5.24	1.925	0.07	NS

Table 2. Comparison between pre and post treatments of gross motor function measure (GMFM%).

Variables	Pretreatment	Post treatment	P- value
GMFM % a Control group (A)	54.6	60.67	0.04 *
Study group (B)	55.53	76.12	0.02*

a wilcoxon signed- ranks test, *significant at P<0.05

Table 3. Comparison between pre and post treatment of pediatric balance scale and gait parameters in both groups.

variables	Pretreatment	Post treatment	T-value	P-value	Significance
Pediatric balance scale control group (A)	26.15 ± 2.7	29.4 ± 3.29	10.854	0.02	S
Study group (B)	26.47 ± 2.9	35.2 ± 3.47	9.099	0.001	S
Initial contact for knee flexion control group (A)	17.4 ± 3.2	12.6 ± 2.8	2.4	0.01	S
Study group (B)	17.6 ± 2.6	6.3 ± 2.4	28.549	0.001	S
loading for knee flexion control group (A)	28.9 ± 4.6	23.3 ± 4.4	34.293	0.01	S
Study group (B)	29.3 ± 4.2	18.4 ± 2.84	18.028	0.001	S
Midstance for knee flexion control group (A)	20.1 ± 2.9	16.2 ± 2.8	5.522	0.01	S
Study group (B)	19.1 ± 2.7	7.6 ± 1.96	15.999	0.0004	S
Terminal stance for knee flexion control group (A)	12 ± 2.58	7.1 ± 2.6	27.297	0.01	S
study group (B)	11.8 ± 2.66	2.3 ± 1.7	20.954	0.001	S

Table 4. Comparison between both control and study group post treatment as regard gross motor function (GMFM%).

Variable	Control group	Study group	P- value	significance
Gross motor function measure (GMFM %)	60.67	76.12	0.0423	S

A Mann Whitney test

Table 5. Comparison between control and study groups post treatment as regards pediatric balance scale and gait parameters**.**

Variable	Pretreatment	Post treatment	t- value	P-value	Significance
Pre swing for knee flexion control group (A)	43 ± 5.94	37.3 ± 5.85	26.706	0.01	S
Study group (B)	42.7 ± 4.88	32.8 ± 3.19	13.714	0.001	S
Initial swing for control group (A)	78.2 ± 3.58	71.3 ± 4.83	7.465	0.01	S
Study group (B)	78.5 ± 3.1	64 ± 3.46	18.301	0.001	S
Mid swing for knee flexion control group (A)	45.2 ± 3.52	39.5 ± 3.63	26.706	0.01	S
Study group (B)	45.5 ± 3.78	32.7 ± 2.06	20.949	0.001	S
Terminal swing for knee flexion control group (A)	15.8 ± 3.68	10 ± 3.62	43.5	0.01	S
Study group (B)	15.7 ± 3.22	3.8 ± 1.74	40.249	0.001	S

Variables	Control group (A)	Study group (B)	t- value	P- value	Significance
Pediatric balance scale	29.4 ± 3.29	35.2 ± 3.47	2.285	0.035	S
Initial contact for knee flexion	12.6 ± 2.8	6.3 ± 2.4	5.232	0.001	HS
Loading response for knee flexion	23.3 ± 4.4	18.4 ± 2.84	2.925	0.001	S
Terminal stance for knee flexion	7.1 ± 2.6	2.3 ± 1.7	4.882	0.0001	HS
Pre swing for knee flexion	37.3 ± 5.85	32.8 ± 3.19	2.135	0.0475	S
Initial swing for knee flexion	71.3 ± 4.83	64 ± 3.46	3.883	0.001	S
Mid swing for knee flexion	39.5 ± 3.63	32.7 ± 2.06	5.155	0.0001	HS
Terminal swing for knee flexion	10 ± 3.62	3.8 ± 1.74	4.317	0.0004	HS

Table 6. Correlations between isokinetic strength training and gross motor function in children with diplegic cerebral palsy (N=16) (spearman's correlation).

Variables	Correlation with gross motor function Mean ± SD	r	P- value	Significance
Peak torque of hip flexion at 60 / sec (Nm)	18.63 ± 2.33	0.512	0.004917	S
Peak torque of hip abductions at 60 % / sec (Nm)	14.64 ± 1.69	0.741	0.049019	S
Peak torque of knee extensors at 60 / sec (Nm)	23.96 ± 2.76	0.815	0.001	S
Peak torque of knee flexors at 60 / sec (Nm)	19.94 ± 2.25	0.711	0.001	S
Peak torque of shoulder flexors at 60 / sec (Nm)	22.95 ± 2.89	0.816	0.001	S
Peak torque of shoulder abductors at 60 / sec (Nm)	20.61 ± 2.81	0.595	0.0038	S

patients by improving muscle strength, flexibility, balance and posture. Strength training is also linked with improved walking ability and increased activity levels in cerebral palsy patients. This can be especially beneficial for cerebral palsy patients that struggle to move freely and complete daily activities [17]

The present study was conducted on thirty-two children with diplegic cerebral palsy ranging in age from 6 to 12 years from both sexes. They were classified randomly into two groups of equal number. Control group (A) and study group (B). Group (A) received the designed physical therapy program only while group (B) received Isokinetic training program of the upper and lower limbs in addition to the designed physical therapy program. This is in line with the findings of Banka and yalcin, 2010, who demonstrated that about 50% of CP were affected by either diplegia or hemiplegia and the Spastic type accounts for approximately 80% of all CP cases [18]

The age ranged from 6 to 12 years for the children in this study aligns with the findings of Jha et al; 2021 who indicated that children within that age group can successfully follow verbal instructions [19].

Comparing the pre-treatment values of gross motor function measure (GMFM%), pediatric balance scale and gait parameters for both control and study groups revealed no significant differences, this indicated that these children experienced notable difficulties in their overall motor development, balance and walking abilities prior to the commencement of the treatment.

This finding is consistent with the findings of Alsaif and Alsenany,2015 who reported that motor control issues and muscle strength impairments are the leading causes of motor behaviour disorders in children with spastic cerebral palsy [20].

As cerebral palsy (CP) cannot be cured, various interventions aim to reduce impairments and enhance the ability of individuals to perform daily activities independently so incorporating strength training in cerebral palsy physical therapy sessions can be an effective way to improve general motor skills and functional independence. The present study comes in agreement with Elder et al, who demonstrated that children with CP muscle strength nearly half the strength ability of their typically developed peers [20]. A reduced muscle function found in children with spastic diplegic cerebral palsy had different disadvantages, firstly it could diminish movement and hence disrupt postural reactions efficiency, secondly it can cause changes in musculoskeletal alignment and joint biomechanics which lead to decrease the child's ability to exhibit appropriate protective reactions, decrease range of motion and base of support so limits mobility of these children.

This comes in agreement with literature reviews which showed that the limited capacity to develop force is a great limitation to move than the resistance to passive stretch (spasticity) [4,5] The weakness of the hip abductors and extensor muscles as well as knee extensors lead to reduced hip and knee Joint movement in the sagittal plane restricting the patient's gait. [22]

A statistically significant improvement in gross motor performance, pediatric balance scale and gait parameters in study group (B) which received isokinetic strength training program in addition to the designed physical therapy program.

The results of the present study came in agreement with the results of Eagleton et al and Blundell et al. who reported that the increase in muscle strength resulted in improvement in gait pattern with less crouch, faster speed and improved gross motor ability (standing, sit-to-stand walking, running, Jumping activities [23,24].

This study in accordance with the interpretation of Andres et al; who emphasized that a strength training program has positive functional and activity effects on muscle strength, balance, gait speed and gross motor function without increasing spasticity for children and adolescents with Cerebral palsy in gross motor function classification system level I, II and III with adequate dosage and specific principles are utilized. [25]

The results of this study come in agreement with the findings of Schelte's et al; who concluded that functional progressive resisted exercises training will strengthen the lower limbs and will accordingly lead to functional improvements in gross motor function and walking ability in children with CP. [4]

The results of this study agree with the findings of Guérin et al who stated that isokinetic strengthening programs combined with intensive rehabilitation may improve muscle strength and therefore gait efficiency. [6]

Literature review examined Children with spastic diplegic cerebral palsy demonstrated that strength values ranging from 16% to 71% of the same age children depending on the muscle tested. The gluteus maximus and soleus muscles, showed the greatest strength deficits. [26] when comparing the post-treatment variables of all assessed between the two groups, the isokinetic strength training group exhibited a statistically significant improvement, these results are consistent with those of Abaldel Blanco and Taboada- Iglesias who shown that well programmed strength exercises can improve muscular strength, power, neuromuscular function, mobility, physical functionality and the performance of activities of daily living. It can also prevent falls, increase psychosocial well-being and preserve functional independence. [27]

Conclusion

From the results obtained of this study, it may be concluded that adding Isokinetic strength training to the designed physical therapy program can be an effective modality for improving child level of activity and participation and improving strength and gross motor function in children with spastic diplegic cerebral palsy and this study recommends this procedure in conducting Pediatric rehabilitation protocols.

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Disclosure

The authors declare that there is no financial conflict of interest with regard to the content addressed.

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