The Egyptian Journal of Hospital Medicine (April 2023) Vol. 91, Page 4869-4878

Balance and Quality of Life Variations Post Achilles Tenotomy versus Conventional Physical Therapy

Mai A. Saleh*, Radwa S. Abdul-Rahman, Mamdouh G. Haggag, Khaled A. Mamdouh
Department of Physical Therapy for Pediatrics, Faculty of Physical Therapy, Cairo University, Cairo, Egypt
***Corresponding author:** Mai Abdelatty Saleh, **Mobile:** (+20) 01110499403,
Email: dr.maisaleh22@gmail.com, **ORCID No.:** 0009-0004-2605-707X

ABSTRACT
Background: The lives of children with cerebral palsy were worsened by the development of deformities, which impacted their lifestyle negatively. One of the major concerns was the equinus deformity in hemiparetic children. Different treatment procedures were used to remedy such deformities, including physical therapy training, or surgical correction through different types of Achilles tenotomies.
Objective: To evaluate the effect of conventional physical therapy training versus Achilles tenotomy on balance as well as quality of life in hemiparetic children.
Patients and Methods: Thirty-four hemiparetic children from both sexes, whose ages ranged from 6 to 10 years, were recruited equally into 2 groups. Group A underwent an Achilles tenotomy and received conventional physical therapy training for one month after removing the immobilizing plaster cast, while Group B received continuous physical therapy training over 3 months without any surgical procedures. Evaluation was done at three intervals, using the Humac Balance System and Quality of Life Questionnaire.
Results: The stability scores for Group A showed a significant decline at post-treatment (1) in comparison with pre-treatment. Whereas in Group B there was a significantly higher stability score at post-treatment (1) in comparison with pre-treatment. The overall limit of stability and quality of life measurements showed a decline in their scores post-treatment in Group A, while higher scores post-treatment were seen in Group B.
Conclusion: The findings of the study support the impact of physical therapy, given the emergence of complications after Achilles tenotomy, which affect the balance and quality of a child's life.
Key words: Achilles tenotomy; Balance; Cerebral palsy; Humac balance system; Quality of life.

INTRODUCTION
Cerebral palsy (CP) is mainly a developmental disorder rather than a disease, as it is caused by a non-progressive lesion (a "static lesion") to the immature brain in the uterus at birth or shortly after birth, with a changing clinical picture derived from static pathology [1]. The brain lesion is non-progressive and causes a variety of neuromuscular and musculoskeletal problems, including: contractures, dystonia, spasticity, poor balance, abnormal bone growth, and loss of selective motor control. These movement disorders are not static and tend to progress with growth [2].

Most spastic CP children are in an equines deformity when they start walking. In patients with equinus deformity, passive dorsiflexion is restricted beyond the neutral position. This deformity can be either dynamic (caused by an excessive stretch reflex in the calf muscles) or static (caused by triceps surae contracture). The end result is a clumsy, inefficient gait that is characterized by a tiptoeing or toe-heel pattern [3].

An ankle foot orthosis (AFO) is the most effective treatment for equinus. Typically, we start using a solid AFO, which limits the child's range of motion to neutral plantarflexion while still allowing some dorsiflexion, followed by a transition to an articulated AFO once the child grows [4]. The equinus disrupts the gait cycle by reducing stability during the standing phase and causing insufficient clearance throughout the swing phase [5].

Three main methods are employed throughout this surgery [Achilles tenotomy]: First, triple-cut sliding lengthening; second, the gastrocnemius recession. And the third and most common method is called Z-plasty. A Z-shaped incision is made in the tendon, and once it is stretched to the desired length, the tendon is reattached [6]. Balance control is essential for functional performance, and impaired balance may be caused by reduced muscle strength, decreased range of motion, impaired motor coordination, impaired sensory organization, and abnormal muscle tone [7].

Balance is the body's ability to provide muscles with the adequate force and timing to control body movements, like sitting, standing, walking, running, and specific sports activities [8]. The maintenance of balance and postural control is achieved by a complex integration of three unique sensory systems, the vestibular, visual, as well as somatosensory proprioceptive systems to provide the final motor response to muscle groups for sustaining attention, head and body position, in addition to regulating both static and dynamic balance. The disease or disorder of any of the three systems will negatively affect the balance as the equines deformity affects the gait cycle, leading to stability reduction during the standing phase [9].

Static balance is the ability to maintain a stable posture and preserve it in a counter-gravity position. It is also defined as the ability to keep the center of gravity (COG) vertically within the base of support (BOS) with little or no movement while maintaining certain positions for periods of time [10]. While dynamic balance is defined as the maintenance of an erect body posture during the execution of a task or movement or the ability to keep balance on an unstable surface, both are

Received: 07/12/2022
Accepted: 09/02/2023

important for mastering the performance of daily living activities [11].

Thus, this study was designed to evaluate the effect of conventional physical therapy training versus Achilles tenotomy on balance as well as quality of life in hemiparetic children.

PATIENTS AND METHODS

Study design

An observational study with a cross-sectional design, carried-out from January to August 2021.

Participants

Thirty-four hemiparetic children from both sexes were involved in this study. Sample size calculation was estimated using G power and was done using the comparison of the children's dynamic balance (limit of stability) between hemiplegic children treated with physical therapy and those treated with Achilles tenotomies [12,13].

The patients were recruited from the outpatient clinic of the Faculty of Physical Therapy at Cairo University and were distributed into 2 equal groups:

- **Group (A)** included 17 children (11 girls and 6 boys) whose average ages were 8.41 ±1.38 years (flowchart given in Figure 6). They underwent an Achilles tenotomy and receive conventional physical therapy training for one month after removing the immobilizing plaster cast.
- **Group (B)** included 17 children (11 girls and 6 boys) whose average ages were 8.65 ±1.20 years, and they received continuous physical therapy training for 2 hours per week. Over 3 months of evaluation, they didn’t have any surgical procedures ever.

The subjects have been chosen based on the subsequent criteria:

(1) The spasticity grades were ranging from 1 to 1+ based on the modified Ashworth scale (Appendix A) [14]. (2) They were capable of following simple verbal orders involved in the tests.

(3) All children didn’t have fixed deformities in both lower extremities.

(4) All children were capable of standing without support (those who can stand independently without using an assistive device at levels I or II, according to the Gross Motor Function Classification System (GMFCS)) (Appendix B).

(5) The children underwent the surgical intervention (Achilles tenotomy for group A). Exclusion criteria: (1) Heart or neurological surgeries (2) History of epilepsy (3) Hearing or visual disorders (4) Orthopedic or neurological surgeries (for group B) (5) Injection with botulinum toxin (For group B). All procedures were involved in the evaluation.

METHODS

For evaluation

Balance and quality of life were evaluated before Achilles tenotomy (1st shot), after removing the immobilized plaster cast (2nd shot), and one month after receiving the physical therapy training (3rd shot) for Group (A), while Group (B) was evaluated over three successive months of conventional physical therapy training using the Humac balance system and the cerebral palsy quality of life questionnaire. A familiarity session was mainly essential for the children to confirm their comfort with the study team as well as protocol.

The Humac Balance system (Figure 1)

It was used for evaluation using the center of pressure test (COP) that represents the static balance and the limit of stability (LOS) that represents the dynamic balance. At first, definite parameters were fed to the device. All two groups of children were asked to stand on the platform in the center of the device in a two-legged stance. The display screen was accustomed so they could look straight at it. They were asked to maintain their foot positions to get accurate measurements and try to keep the cursor in the center of the screen. The variables in the COP report (Figures 2 and 3) represented the stability score, path length, and average velocity for each child. This study, assessed the stability score that represents the capability of a child to keep his center of gravity within the base of support. The same instructions were conducted to assess the limit of stability (Figures 4 and 5), but it was a dynamic test [15].

Egyptian quality of life questionnaire for cerebral palsy (Appendix C)

It was utilized for the children with cerebral palsy in the local Egyptian Arabic dialect of Cairo. The Egyptian Quality of Life Questionnaire was designed in order to be understood by all Egyptian primary school students of different educational levels, giving examples for all items to be clarified. Within the Egyptian quality of life questionnaire, these items are grouped to measure three domains of QOL for a child with CP, namely: (1) social domains (24 items); (2) psychological domains (20 items); and (3) physical domains (17 items) [16, 17]. In this study, we measured just two domains, namely, the physical domain (19 items) and the psychological domain (16 items). We used the parent-proxy version (for parents of children aged 4–12 years) [18]. The items’ values in each domain were summed, and the final summation of two domains was divided by the number of items in the two domains (35 items). Then, the final result was graded on a 5-point scale, namely: (5) means mostly satisfied, (4) means mixed, (3) means mostly dissatisfied, (2) means unhappy, and (1) means terrible. Therefore, the highest value indicates the highest satisfactory level [19].

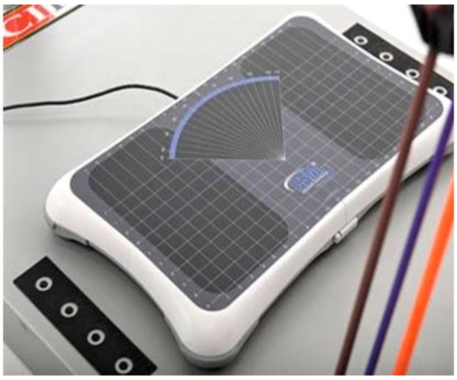

Figure (1): Humac balance system, adopted by (HUMAC® Balance and Tilt System User's Guide, 2013 [15]).

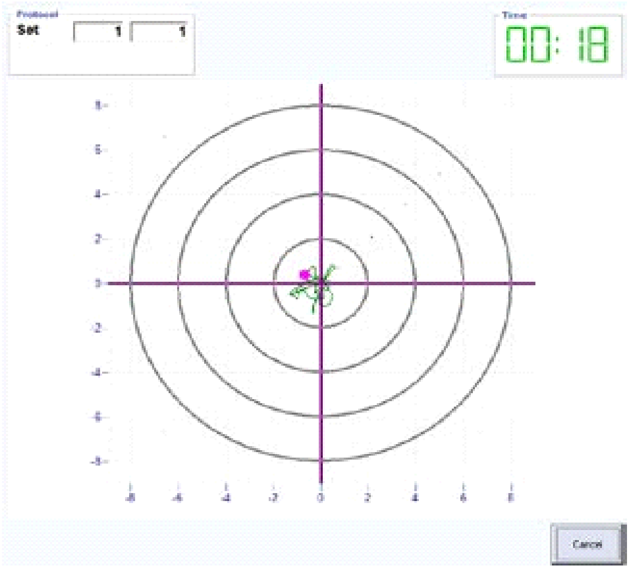

Figure (2): Center of pressure display, adopted by (HUMAC® Balance and Tilt System User's Guide, 2013 [15]).

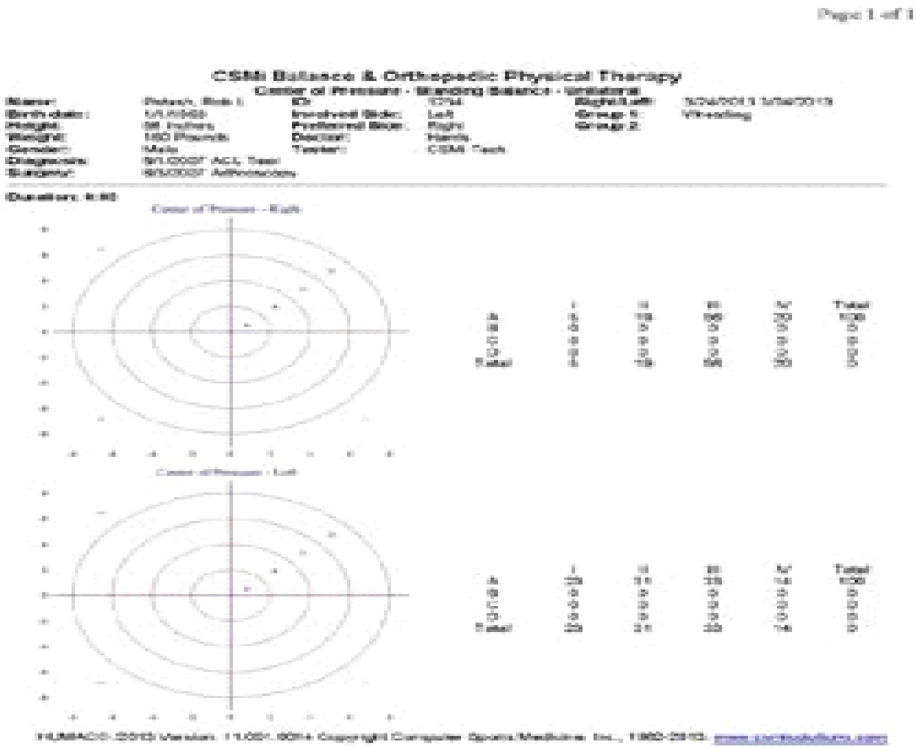

Figure (3): Center of pressure report, adopted by (HUMAC® Balance and Tilt System User's Guide, 2013 [15]).

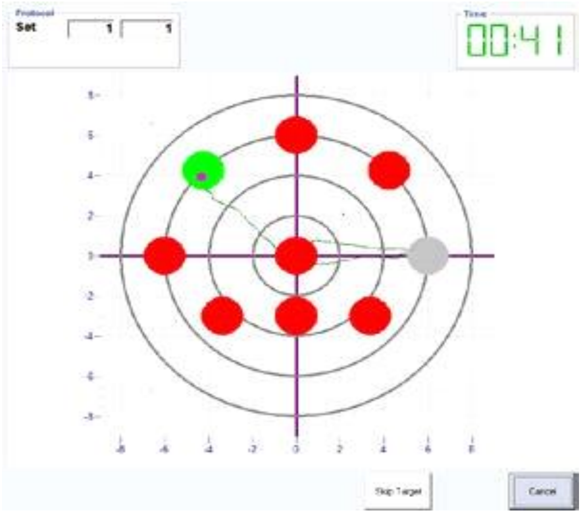

Figure (4): Limit of stability display, adopted by (HUMAC® Balance and Tilt System User's Guide, 2013 [15]).

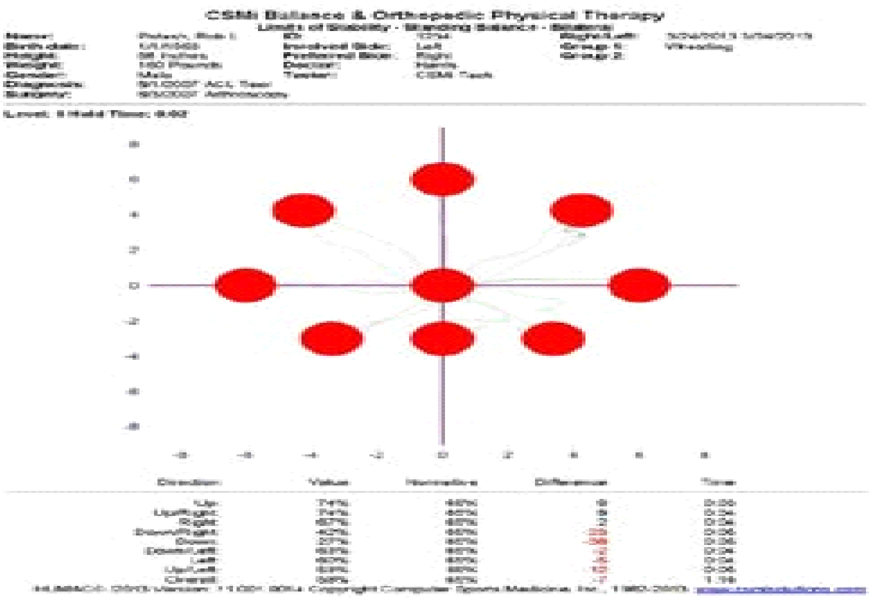

Figure (5): Limit of stability report, adopted by (HUMAC® Balance and Tilt System User's Guide, 2013 [15]).

Ethical approval:

The Ethical Committee for Scientific Research at Cairo University's Faculty of Physical Therapy has approved the study's protocol; No P.T.REC/012/003678. It has also been approved by Cochrane South Africa (Identifier: PACTR202207830913698). Written informed consent was taken from all participants**.** The study was conducted according to the Declaration of Helsinki.

Sample size:

Sample size calculation was done using the comparison of dynamic balance (limits of stability) between hemiplegic children treated with physical therapy training and those treated with Achilles tenotomy. As demonstrated in preceding studies by **Sherafat *et al.* [12] and Bourelle *et al.* [13].**

Statistical analysis

The statistical analysis has been carried-out utilizing the statistical SPSS Package program, version 25 for Windows (SPSS, Inc., Chicago, IL). Quantitative data of age, stability score, front, right, and quality of life were expressed as mean and standard deviation. The qualitative data of sex, spasticity, as well as GMFM were reported as numbers and percentages. The Wilcoxon signed ranks test has been used to compare between pre- and post-treatment (1) and post-treatment (1) versus post-treatment (2) in the surgical as well as non-surgical groups in terms of stability score, front, right, and quality of life variables. The Mann-Whitney U test has been used to compare in the surgical as well as non-surgical groups in terms of age variability. The Chi-square test has been used to compare between the surgical and non-surgical groups in terms of gender, spasticity, and GMFM variables. All analyses were statistically significant and accepted at the level of significance ($P \leq 0.05$).

RESULTS

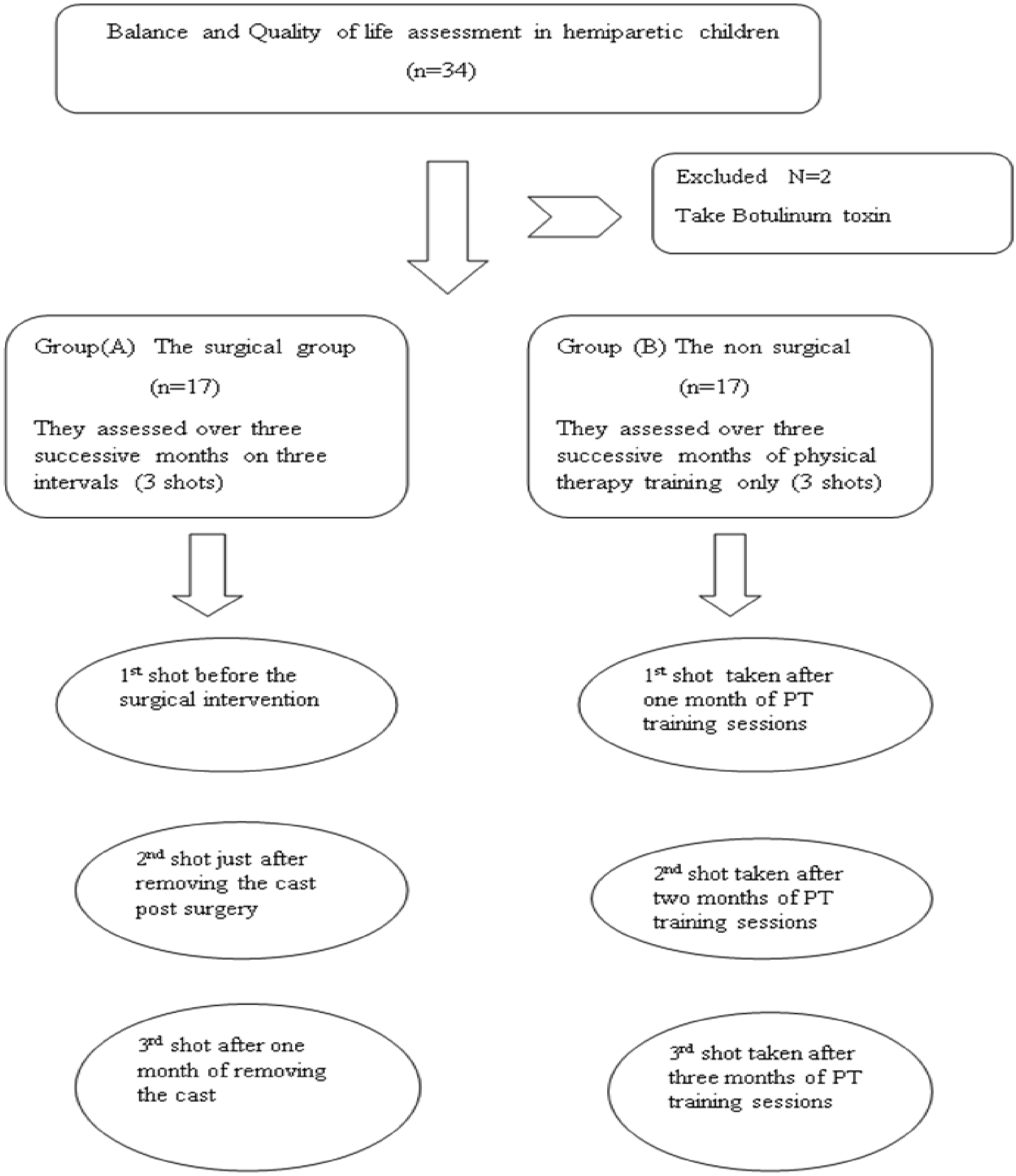

Figure (6): Flow chart showing the study design and the subject inclusion in the study

In the present study, an overall of 34 children diagnosed with hemiparetic cerebral palsy were randomized into two groups (17 children per group). No significant differences in demographic data in terms of age, gender, spasticity, and GMFM were found between the surgical and non-surgical groups (Table 1).

Table (1): Comparison of general characteristics between the surgical and non-surgical groups

Items	Groups		P-value
	Surgical group (n=17)	Non-surgical group (n=17)	
Age (year)	8.41 ±1.38	8.65 ±1.20	0.612
Gender (boys: girls)	6 (35.3%): 11 (64.7%)	6 (35.3%) :11 (64.7%)	1.000
Spasticity (1: 1+)	5 (29.4%): 12 (70.6%)	7 (41.2%) :10 (58.8%)	0.473
GMFM (1: 1+)	5 (29.4%) :12 (70.6%)	7 (41.2%):10 (58.8%)	0.473

Quantitative data (age) are expressed as mean ±standard deviation and compared by Mann-Whitney U test.
Qualitative data (gender, spasticity, and GMFM) are expressed as number (percentage) and compared by chi-square test.

The comparison of the stability score and quality of life for the surgical as well as non-surgical groups is presented in table (2).

Regarding the stability score%, it was significantly decreased in the surgical group and increased in the non-surgical one at post-treatment (1) in comparison with pre-treatment. The change and change percentage of stability score in Group A were found to be higher at post-treatment 1 than Group B, whose children were diagnosed with hemiparetic cerebral palsy without previous surgical intervention. Stability score was significantly higher in the 2 studied groups at post-treatment (2) in comparison with post-treatment (1).

The change and change percentage of the stability score in Group A were found to be higher at post-treatment-2 than those in Group B.

Regarding the front percentages, no significant differences were found between the surgical group and the non-surgical group in pre- and post-treatment (1).

The change and change percentage in front percentage in Group A were very close at post-treatment I to Group B. No substantial differences for the surgical group were found between post-treatment (1) and post-treatment (2) of the front percentage. They were significantly higher for the non-surgical group at post-treatment (2) in comparison with post-treatment (1) of the frontal direction. The change and change percentage in the front percentage in Group B were found to be higher at post-treatment-2 than in Group A.

Regarding the right direction, no significant differences were found between the pre- and post-treatment (1) in the surgical group. They were significantly higher for Group B at post-treatment (1) in comparison with pre-treatment for the right. The change and change percentage in right for Group B were found to be higher at post-treatment-1 than in Group A. No significant differences were found between the surgical group and the non-surgical group between post-treatment (1) and post-treatment (2) of right. The change and change percentage in right for Group B were found to be higher at post-treatment-2 than Group A.

Regarding the overall outcome, significant differences were found in the surgical group. No substantial differences were detected in the non-surgical group at post-treatment (1) in comparison with pre-treatment in overall. The change and change percentage of overall in Group A were found to be higher at post-treatment-1 than Group B. No substantial differences for the surgical group were found between post-treatment (1) and post-treatment (2). They were significantly higher for the non-surgical group at post-treatment (2) in comparison with post-treatment (1). The change and change percentage of overall in Group B were found to be higher at post-treatment-2 than those in Group A.

Regarding the quality of life, significant differences were found in the surgical group and the non-surgical group at post-treatment (1) in comparison with pre-treatment. The change and change percentage of quality of life in Group B were found to be higher at post-treatment-1 than those in Group A. No substantial differences for the surgical group and the non-surgical one were found between post-treatment (1) and post-treatment (2) in quality of life. The change and change percentage of quality of life in Group B were found to be higher at post-treatment-2 than in Group A.

Table (2): Comparisons of stability score (front, right, overall directions) and quality of life variables for the surgical and non-surgical groups

Variables	Items	Pre-treatment vs. Post-treatment (1)		Post-treatment (1) vs. post-treatment (2)	
		Surgical group (n=17)	Non-surgical group (n=17)	Surgical group (n=17)	Non-surgical group (n=17)
Stability score (%)	Pre-treatment	69.53±11.50	58.06 ±19.18		
	Post-treatment (1)	46.59±15.35	70.06 ±13.58	46.59±15.35	70.06±13.58
	Post-treatment (2)			58.47±12.80	78.71 ±9.63
	Change (MD)	22.94	12.00	11.88	8.65
	Change %	32.99%	20.67%	25.50%	12.35%
	P-value	0.0001*	0.0001*	0.009*	0.003*
Front (%)	Pre-treatment	20.59 ±5.50	9.00 ±2.69		
	Post-treatment (1)	11.47 ±2.22	13.00 ±2.93	11.47 ±2.22	13.00 ±2.93
	Post-treatment (2)			10.59 ±4.46	22.88 ±7.09
	Change (MD)	9.12	4.00	0.88	9.88
	Change %	44.29%	44.44%	7.67%	76.00%
	P-value	0.059	0.136	0.589	0.039*
Right (%)	Pre-treatment	25.82 ±5.20	13.06 ±9.59		
	Post-treatment (1)	14.06 ±7.06	21.41 ±3.72	14.06 ±7.06	21.41 ±3.72
	Post-treatment (2)			22.00 ±2.36	36.76 ±3.28
	Change (MD)	11.76	8.35	7.94	15.35
	Change %	45.55%	63.94%	56.47%	71.70%
	P-value	0.058	0.039*	0.187	0.080
Over all (%)	Pre-treatment	23.18 ± 6.58	12.06 ± 6.02		
	Post-treatment (1)	13.41 ± 9.24	14.18 ± 5.24	13.14 ± 9.24	14.18 ± 5.24
	Post-treatment (2)			16.76 ± 7.04	22.35 ± 8.52
	Change (MD)	9.77	2.12	3.35	8.17
	Change %	42.15%	17.58%	24.98 %	57.62%
	P-value	0.009*	0.208*	0.108	0.003*
Quality of life	Pre-treatment	2.82 ±0.80	2.71 ±0.58		
	Post-treatment (1)	2.29 ±0.58	3.29 ±0.58	2.29 ±0.58	3.29 ±0.58
	Post-treatment (2)			2.29 ±0.77	3.41 ±0.50
	Change (MD)	0.53	0.58	0.00	0.12
	Change %	18.79%	21.40%	0.00%	3.65%
	P-value	0.039*	0.012*	1.000	0.157

Data are expressed as mean ± standard deviation (SD)
MD: Mean difference, *: Significant

DISCUSSION

The hemiparetic children may have a delayed development of several motor functions as well as gross motor skills as a result of the motor weakness and decreased stability. Thus, this study was conducted to differentiate between different procedures applied to those children and their effects on balance and quality of life. The pre-treatment mean values of the stability score, right, front, and overall directions of stability limit (dynamic balance), and quality of life revealed a significant decrease in their values, indicating that those children had substantial balance and postural control problems, as supported by **Ramella *et al.*** [20].

The static and dynamic postural control was decreased in children with cerebral palsy because of the following: (1) abnormal muscle tone; (2) deficient equilibrium reactions; (3) imbalance between agonist and antagonist muscles; and (4) loss of muscle control [21]. For the comparison of stability scores for the surgical and non-surgical groups, it was found that the mean difference (MD) of the stability score in Group A (the surgical group) pre and post (1) was = 22.94, which means that there was a significant change in static balance, and for Group B, MD = 12.00.

The statistical analysis has revealed that the stability score at post-treatment (1) was lower compared to pre-treatment in Group A, which indicates that Achilles tenotomy has an inverse effect on static balance for hemiparetic children. These findings agreed with the findings of **Dietz *et al.*** [22], who stated that Achilles tendon lengthening lead to a high rate of over-weakening of the triceps surae, which affects the child's balance and QOL in the long run. Physical therapy, or non-surgical treatment, may be the ideal treatment for ambulatory patients.

While in Group B (the non-surgical group), the stability score increased at post-treatment (1) in comparison with pre-treatment. The statistical analysis has showed that there was a substantially increased stability score at post-treatment (1) in comparison with pre-treatment. The percentage of improvement indicates improved static balance in Group B after receiving physical therapy over three months of investigation. These results resemble those previously published by **Ali *et al.*** [23] and this study concluded that a regular physiotherapy program yielded a significantly better improvement in static balance.

The balance is the capability to preserve the center of gravity within the base of support (BOS). It is also the ability to activate certain muscles at a given amplitude and velocity to control movement and prevent falling down, which means that the affected muscle power may cause balance problems [24]. Thus, this decrease in values for group (A) post-Achilles tenotomy may be caused by muscle weakness and slow recovery. These findings were consistent with **Lieber and Fridén** [25], who stated that the surgical cases required months of recovery post-operation to regain movement and some muscle power.

By the evaluation of front direction for Group A (the surgical group) at pre-treatment and post-treatment (1) (P = 0.059) there was an improvement of 44.29% at post (1). And at post-treatment (2), there was an improvement of 7.67% (P = 0.589). These results are consistent with those published previously by **Lofterod *et al.*** [26], who indicated that 47.5% of their patients still had drop foot during the swing phase following calf lengthening, which affects balance in the forward direction. So, there were an equal percentage of children who improved and who did not improve after surgery, so it means that the children in Group A didn't get the targeted improvement from surgery. While for Group B (the non-surgical group), there was an improvement of 44.44%, at post-treatment (1) (P=0.136) and a much higher improvement percentage in post-treatment (2) 76.00%. (P=0.039). These findings came in accordance with those measured before by **Domagalska *et al.*** [27]. They showed that a 5-weeks balance program had an impact on the velocity as well as area of the center of pressure in the main directions of movement, so there was an improvement in dynamic balance.

Also, in the comparison among Group A and Group B improvement values of right direction; for Group A were 45.55% at post treatment (1) (P=0.058) and 56.47% at post treatment (2) (P=0.187) and these findings are supported with the results of **Klausler *et al.*** [28] who failed to recognize any signs for active ankle dorsiflexion in the swing phase, which affects dynamic balance in the right and side-to-side directions and didn't get the targeted improvement after surgery, and also affects inversely dynamic balance**.** While in another study, **Davids *et al.*** [29] they stated that the existence of active ankle dorsiflexion in the swing phase improved from 79% to 96% of patients following surgery, with 19% of patients improving dynamic balance in the right direction.

In Group B the statistical analysis has revealed that there were substantially (P=0.039) increase in right direction score at post-treatment (1) in comparison with pre-treatment, with an improvement of 63.94% and improvement percentage 71.70% at post treatment (2). These results are supported by **Pavlikova *et al.*** [30] who stated that physiotherapy significantly improved dynamic balance in most directions.

The mean values of the overall limit of stability (LOS) in Group (A) at pre- and post-treatment (1) were 23.18 and 13.41, respectively. The statistical analysis has showed that they were substantially (P=0.009) decreased in overall at post-treatment (1) in comparison with pre-treatment, which indicates that the overall direction of dynamic balance was inversely affected after surgery. **Lieber and Fridén** [25] stated that the surgical cases require months of recovery post-operation to regain movement, so overall dynamic balance didn't improve after removing the cast or even after one month from surgery.

In addition, **Thomason *et al.*** [4], **Cimolin *et al.*** [31]**, Drongelen *et al.*** [32] **and Rutz *et al.*** [33] analyzed the impact of surgery in hemiparetic CP children and reported some decline in muscle power detected on physical examination, which affects negatively the overall dynamic balance. While kinetic data revealed an improvement in the power production of the ankle over time [4].

While in Group (B), the overall dynamic balance improved in Group (B) post-treatment (1) and post-treatment (2), with an improvement percentage of 17.58% at post-treatment (1) and 57.62% at post-treatment (2). Physiotherapy training and rehabilitation need time to show a significant change in the child's dynamic balance, as stated by **Chung *et al.*** [34] "Physical therapy training programs, mainly balance training, improve static and dynamic balance when they are done regularly, as their effects appear over time".

The results mainly support the effect of physical therapy and show the negative effects of Achilles tenotomy due to the slow recovery of some cases that may lead to a recurrence of the deformity. **Chung *et al.*** [34] stated in a previous study that recurrence of equinus deformity following surgery is frequent in patients with cerebral palsy due to slow recovery and muscle weakness, which inversely affect static and dynamic balance, so the period of follow-up must be increased to investigate much more about the surgical effect, while physical therapy had no complications on the children, so Group (B) improved better.

Regarding the quality of life scores, in Group (A) the statistical analysis has revealed that they was a substantial (P=0.039) decline in quality of life at post-treatment (1) in comparison with pre-treatment, with an improvement of 18.79%. These results are confirmed by **Carlsson *et al.*** [16]**,** who demonstrated that the psychological and physical state of children in this group is affected by the long period that it takes them to recover after surgery and muscle weakness, so the quality of their lives decreases. While for the non-surgical group (Group B), the statistical analysis showed that they had a substantially (P=0.012) increased quality of life at post-treatment (1) in comparison with pre-treatment, with an improvement of 21.40%. These results are confirmed by **Mutoh *et al.*** [18]**,** who demonstrated that physical therapy rehabilitation for CP children improved their physical, psychological, self-independence, and self-confidence states, so the child's satisfactory score improved after physical therapy sessions.

Our study revealed the positive effects of physical therapy training on balance and quality of life in hemiparetic children, in contrast to the negative effects of Achilles tenotomy due to further complications.

CONCLUSION

According to the obtained results of this study, it can be concluded that the improvement state in the period of assessment is different in both groups, as in the surgical group the children require months of recovery post-operation to regain movement in order to evaluate the improvement of balance and quality of life. In this study, we found that not all hemiparetic cases that have non-fixed equine deformities and undergo Achilles tenotomy got the required improvement from the surgery.

Moreover, it was found that the balance and quality of life have decreased one month after the surgery. Their values before the Achilles tenotomy procedure were better, and it may be due to the onset of complications from this procedure, such as adhesions, muscle weakness, slow recovery, and rehabilitation. While the physical therapy showed an improvement state in the three assessment months, in most cases. There were increases in the balance and quality of life over the three months of physical therapy training. Other cases showed a fixed state with no improvement

Appendix A. Modified Ashworth scale
Available on the following link:
https://www.ncbi.nlm.nih.gov/books/NBK554572/.
Appendix B. Gross Motor Function Classification System
Available on the following link:
https://cerebralpalsy.org.au/our-research/about-cerebral-palsy/what-is-cerebral-palsy/severity-of-cerebral-palsy/gross-motor-function-classification-system/ .
Appendix C. Egyptian quality of life questionnaire
Available on the following link:
https://doi.org/10.2147/ndt.s59599

Sponsoring financially: Nil.
Competing interests: Nil.

REFERENCES

1. **Khan S, Talat S, Malik M *et al.* (2022):** Risk factors, types and neuroimaging findings in children with cerebral palsy. Med Sci., 38(7): 1738-1742.
2. **Mastroyianni S, Petra M, Nikaina I *et al.* (2020):** Correlation of intellectual ability with gestational age and pattern of brain MRI findings according to SCPE-MRICS in a population-based cohort of patients with cerebral palsy (CP). Dev Med Child Neurol., 62: 4. doi: 10.1111/dmcn.14688.
3. **Leunkeu A, Lelard T, Shephard R *et al.* (2014):** Reproducibility of gait cycle and plantar pressure distribution in children with spastic hemiplegic cerebral palsy. Neuro Rehabilitation, 35(3): 597-606.
4. **Thomason P, Selber P, Graham H (2013):** Single event multilevel surgery in children with bilateral spastic cerebral palsy: A 5-year prospective cohort study. Gait Posture, 37: 23-28.
5. **Saini C, Reb M, Daniel J (2015):** Achilles tendon disorders. The Journal of the American Osteopathic Association, 115: 670–676.
6. **Wilkins R, Bisson L (2012):** Operative versus nonoperative management of acute Achilles tendon ruptures: a quantitative systematic review of randomized controlled trials. Am J Sports Med., 40(9):2154-60.

7. **Chen A, DeAngelis G, Angelaki D (2011):** Convergence of vestibular and visual self-motion signals in an area of the posterior sylvian fissure. J. Neurosci., 31: 11617-11627.
8. **Kilroy E, Crabtree O, Crosby B *et al.* (2016):** The effect of single leg stance on dancer and control group static balance. International Journal of Exercise Science, 9(2): 110-112.
9. **Patel H, Malawade M, Butte-Patil S *et al.* (2017):** Comparison of balance in children with and without hearing impairment. Int J Healthcare Biomed Res., 5: 19-27.
10. **Sherrington C, Canning C, Dean C *et al.* (2008):** Weight bearing exercise for better balance (WEBB)-A challenging, safe, evidence-based physiotherapy program for older people. Pp. 1-34. https://www.webb.org.au/attachments/File/WEBB_draft_19.pdf
11. **Keller M, Rottger K, Taube W (2014):** Ice skating promotes postural control in children. Scandinavian Journal of Medicine & Science in Sports, 24(6): 456-461.
12. **Sherafat S, Salavati M, Ebrahimi Takamjani I *et al.* (2013):** Intrasession: intersession reliability of postural control in participants with and without nonspecific low back pain using the Biodex Balance System. J Manipulative Physiol Ther., 36(2):111-8.
13. **Bourelle S, Berge B, Gautheron V *et al.* (2010):** Computerized static posturographic assessment after treatment of equinus deformity in children with cerebral palsy. J Pediatr Orthop B., 19(3):211-20.
14. **Bandy W, Sanders B (2008):** Therapeutic exercise for physical therapist assistants. 2nd ed., Philadelphia: Lippincott, Williams & Wilkins, pp. 223- 232. https://cmc.marmot.org/Record/.b27688586
15. **HUMAC® Balance System (2013):** HUMAC® Balance and Tilt System User's Guide. Pp. 1-99. https://manualzz.com/doc/6606244/humac%C2%AE-balance-system
16. **Carlsson M, Olsson I, Ilagberg G *et al.* (2008):** Behaviour in children with cerebral palsy with and without epilepsy. Dev Med Child Neurol., 50: 784-90.
17. **Abbass M, Shoukry K, Abd-El Hameed K (2014):** Standardization of Egyptian Quality of Lifer Questionnaire for the children with cerebral palsy. Journal of Medical Science and Clinical Research, 2(9): 2380-2387.
18. **Mutoh T, Kurosaki H, Shimomura H *et al.* (2019):** Development and exploration of a Japanese version of the cerebral palsy quality of life for children questionnaire for primary caregivers: a pilot study. J Phys Ther Sci., 31(9):724–728.
19. **Braccialli L, Braccialli A, Silva M *et al.* (2018):** Validation of the Brazilian version of the CP QOL-child for primary care givers proxy. Physiother Res Rep., 1(3): 1-5.
20. **Ramella M, Fronte F, Converti R (2014):** Postural disorders in conservatory students: The Diesis project. Med Probl Perform., 14: 19–22.
21. **Kazon S, Grecco L, Pasini H *et al.* (2012):** Static balance and function in children with cerebral palsy submitted to neuromuscular block and neuromuscular electrical stimulation: study protocol for prospective, randomized, controlled trial. BMC Pediatr., 12: 53. doi: 10.1186/1471-2431-12-53.
22. **Dietz F, Albright J, Dolan L (2006):** Medium-term follow-up of Achilles tendon lengthening in the treatment of ankle equinus in cerebral palsy. Iowa Orthop J., 26:27-32.8.
23. **Ali M, Awad A, Elassal M (2019):** The effect of two therapeutic interventions on balance in children with spastic cerebral palsy: A comparative study. J Taibah Univ Med Sc., 14(4): 350-356.
24. **Smalley A, White S, Burkard R (2018):** The effect of augmented somatosensory feedback on standing postural sway. Gait and Posture, 60:76-80.
25. **Lieber R, Fridén J (2019):** Muscle contracture and passive mechanics in cerebral palsy. Journal of Applied Physiology, 126: 1492-1501.
26. **Lofterod B, Fosdahl M, Terjesen T (2009):** Can persistent drop foot after calf muscle lengthening be predicted preoperatively? J Foot Ankle Surg., 48: 631–636.
27. **Domagalska M, Szopa A, Lembert D (2011):** A descriptive analysis of abnormal postural patterns in children with hemiplegic cerebral palsy. Medical Science Monitor, 17(2): 110-16.
28. **Klausler M, Speth B, Brunner R *et al.* (2017):** Long-term follow-up after tibialis anterior tendon shortening in combination with Achilles tendon lengthening in spastic equinus in cerebral palsy. Gait Posture, 58: 457–462.
29. **Davids J, Rogozinski B, Hardin J *et al.* (2011):** Ankle dorsiflexor function after plantar flexor surgery in children with cerebral palsy. J Bone Jt Surg Am., 93: 1381–1387.
30. **Pavlikova M, Cattaneo D, Jonsdottir J *et al.* (2020):** The impact of balance specific physiotherapy, intensity of therapy and disability on static and dynamic balance in people with multiple sclerosis: A multi-center prospective study. Mult Scler Relat Disord., 40: 101974. doi: 10.1016/j.msard.2020.101974.
31. **Cimolin V, Galli M, Virmercati S *et al.* (2011):** Use of the gait deviation index for the assessment of gastrocnemius fascia lengthening in children with cerebral palsy. Research in Developmental Disabilities, 32: 377–381.
32. **Drongelen S, Dreher T, Heitzmann D *et al.* (2013):** Gait patterns in twins with cerebral palsy: Similarities and development over time after multilevel surgery. Research in Developmental Disabilities, 34: 1595–1601.
33. **Rutz E, Baker R, Tirosh O *et al.* (2011):** Tibialis anterior tendon shortening in combination with Achilles tendon lengthening in spastic equinus in cerebral palsy. Gait & Posture, 33: 152–157.
34. **Chung C, Sung K, Lee K *et al.* (2015):** Recurrence of equinus foot deformity after tendo-achilles lengthening in patients with cerebral palsy. J Pediatr Orthop., 35(4): 419-25.