JOINTS
JOURNAL ORTHOPAEDI AND TRAUMATOLOGY SURABAYA

JOINTS (Journal Orthopaedi and Traumatology Surabaya)
October 2025; 14(2): 84-91, DOI: 10.20473/joints.v14i2.2025.84-91
Received: 04 July 2025 / Revised: 10 September 2025
Accepted: 10 September 2025 / Published: 30 October 2025

Original Article

Anticipatory Balance in Athletes Cerebral Palsy After 6-Month Intervention of Proprioceptive Neuromuscular Facilitation Stretching Techniques

Nieko Caesar Agung Martino[1], Imam Subadi[1], Rwahita Satyawati[1,2], Diah Indriani[3]

[1]Department of Physical Medicine and Rehabilitation, Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia
[2]Department of Physical Medicine and Rehabilitation, Dr. Soetomo General Academic Hospital, Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia
[3]Department of Epidemiology, Population Biostatistics, and Health Promotion, Faculty of Public Health, Universitas Airlangga, Surabaya, Indonesia

Correspondence should be addressed to Rwahita Satyawati, Department of Physical Medicine and Rehabilitation, Dr. Soetomo General Academic Hospital, Faculty of Medicine, Airlangga University, Mayjend Prof. Dr. Moestopo No. 6-8, Gubeng, Surabaya 60286, Indonesia. e-mail: satyawatir@yahoo.com

ABSTRACT

Background: The effect of Proprioceptive Neuromuscular Facilitation (PNF) stretching, in addition to standard stretching, improves anticipatory balance in athletes with Cerebral Palsy (CP). We aimed to analyze the effects of PNF stretching to standard training over 4 weeks on anticipatory balance in Cerebral Palsy athletes at 6-month post-intervention evaluation.
Methods: The subjects of this study are 24 athletes with Cerebral Palsy at the Indonesian National Paralympic Committee (NPC) training facility. Subjects divided into the treatment group (n = 12) received standard stretching exercises along with PNF stretching, and the control group (n = 12) performed only standard stretching exercises. Both groups received intervention 3 times per week for 4 weeks and evaluation 6 months post-intervention. Y balance tests (YBT) were measured in three directions: anterior (A), posterolateral (PL), and posteromedial (PM), pre- and post-intervention.
Results: There was significant improvement of YBT in the treatment group after 4 weeks of intervention. For the right and left limbs, marked increases were observed in all directions ($p < 0.05$). No significant improvements in YBT were observed at 6 months post-intervention in all directions ($p > 0.05$).
Conclusions: Significant improvements in the Y Balance Test were observed after 4 weeks, but no differences between the two groups at the 6-month evaluation. These findings suggest that while short-term gains in dynamic stability are achievable with PNF, sustained benefits require ongoing reinforcement to maintain neuromuscular adaptations over time.

Keywords: Anticipatory balance; Athletes; Cerebral palsy; Health risk; Proprioceptive neuromuscular facilitation; Stretching

INTRODUCTION

Participation in sports and exercise among individuals with Cerebral Palsy has been rapidly expanding, both in rehabilitation and professional sports, as evidenced by the growth of the Paralympic Games.[1] Cerebral Palsy athletes are at a higher risk of developing overuse syndrome, muscle strain, chronic knee pain, patellofemoral issues, and chondromalacia.[1] During training and competition, Cerebral Palsy athletes are constantly challenged by dynamic movements such as walking, running, and jumping.[2] Dynamic balance assessments provide more specific insights for para-athletes compared to static balance evaluations. Research over the past two decades has prioritized the study of successful standing postures and active movement strategies in stable positions. Balance control systems have also been developed based on diverse principles, including linear motion regulation, angular movement

control, predictive modeling, and virtual stabilization mechanisms.[3] Multiple methodologies exist for studying anticipatory balance. Research-developed strategies include rapid movement transitions and dynamic environmental interactions, which optimize the center-of-mass reference trajectory (CMRT) through task-specific movements, such as forward-fall responses to provoke balance-stabilizing reflexes.[3] The Star Excursion Balance Test (SEBT) has gained recognition as a tool for assessing lower extremity injury risk. However, its practicality is limited by the time required to perform all eight directional reach tasks. To address this, the Y Balance Test (YBT) was designed to streamline assessment by focusing on three primary SEBT directions: anterior (A), posteromedial (PM), and posterolateral (PL).[4]

Numerous athletes integrate stretching into their pre-exercise regimens as a fundamental component of warm-up protocols. Stretching serves multiple objectives, such as mitigating injury risks, alleviating muscle discomfort, and optimizing physical performance. It is characterized as a structured exercise regimen aimed at maximizing joint range of motion (ROM) to its anatomically achievable limits. Widely utilized techniques encompass Proprioceptive Neuromuscular Facilitation (PNF), static stretching, and isometric stretching. PNF integrates static holds with isometric contractions, enabling enhanced muscle elongation by augmenting neuromuscular signalling via controlled muscle activation. This method involves voluntary contractions (5–10 seconds) followed by targeted relaxation phases (5–10 seconds) to facilitate progressive flexibility gains.[5]

A case study involving a 19-year-old individual with spastic diplegic cerebral palsy demonstrated that the benefits of a 4-week PNF stretching regimen persisted for 4 months post-intervention when supplemented with home-based exercises.[6] Furthermore, a comparative analysis revealed that combining PNF stretching with conventional therapy yielded superior long-term enhancements in balance and gait parameters compared to standard interventions alone, with these improvements remaining evident 6 months after therapy discontinuation.

MATERIAL AND METHODS

Study Design

The study is a single-arm study with a pretest–posttest design to evaluate outcomes over a defined follow-up period. It was carried out at the Indonesian National Paralympic Committee (NPC) training center, Surakarta, Indonesia, in February 2024.

Ethical Clearance

Ethical approval for this study was granted by the Health Research Ethics Committee of Prof. Dr. R. Soeharso Orthopedics Hospital, Surakarta, Indonesia, under clearance number: IR.03.01/D.XXV.3/3997/2023.

Participant Criteria

The participants were athletes with Cerebral Palsy (CP) who met the following inclusion criteria: 1) classified as CP 5, CP 6, CP 7, or CP 8 according to the Cerebral Palsy–International Sports and Recreation Association (CP-ISRA); 2) male or female aged 18–40 years; 3) possessing normal cognitive function; 4) willing to participate in the study and provide informed consent; and 5) approved by the team physician. The exclusion criteria were as follows: 1) musculoskeletal injuries within the last month; 2) currently engaged in a high-intensity training program at a frequency of 2–3 times per week during the past month; 3) pregnancy; and 4) complaints of lower limb pain with a Wong-Baker Faces Scale (WBFS) score exceeding 4. The dropout criteria included the following: 1) the subject voluntarily withdraws from the study for any reason; 2) the subject fails to complete the training protocol as required, misses more than two consecutive sessions, or exceeds 20% total absences (a maximum of three missed training sessions); 3)

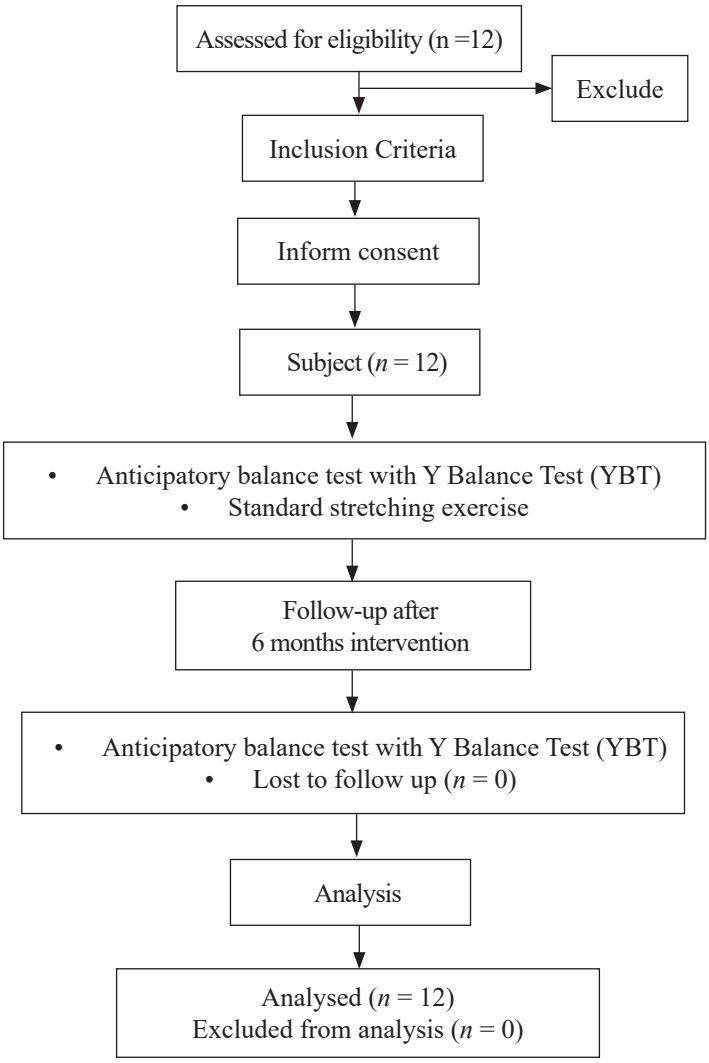

Figure 1. Flowchart of the study

the subject develops an illness that prevents continuation in the study; 4) the subject passes away; and 5) the subject is found to have cardiovascular, pulmonary, or musculoskeletal disorders, as indicated by symptoms such as pain, swelling, redness, warmth, numbness, fractures, sprains, strains, weakness, loss of hand coordination, or difficulty in movement, rendering them ineligible to continue participation.

Procedure

The subjects of the study were 12 athletes with Cerebral Palsy. Subjects were prescribed standard stretching exercises with stretching using the PNF technique. Proprioceptive Neuromuscular Facilitation stretching exercises targeting the quadriceps and hamstrings of each leg. The routine includes passive hamstring stretching, hamstring contraction, and quadriceps contraction, each held for 30 seconds. This sequence should be repeated for 4-5 sets, with a 20-30 second rest between sets. The exercise should be conducted three times per week for a duration of 4 weeks. The flowchart of the study design is summarized in Figure 1. Evaluation of anticipatory balance uses the Y Balance Test, performed 6 months after the intervention period to evaluate the long-term retention of neuromuscular adaptations.

Data Collection and Statistical Analysis

The data obtained were analyzed using IBM SPSS Statistics for macOS, Version 27.0 (IBM Corp., Armonk, NY, USA). The change in scores was calculated using a paired sample test with the Wilcoxon Sign Rank Test. The effect size was

calculated (Cohen's D) and statistical significance defined as $p < 0.05$. Subject should wear comfortable clothing that allows free leg movement, with training conducted at their optimal time, preferably after adequate rest and meals, avoiding strenuous physical activity beforehand. PNF exercises are performed at the Indonesia NPC Training Center or other designated facilities, with wheelchairs, safety boxes, and emergency kits available. Before and during the session, patient assessments include recording complaints, Borg Scale ratings, pulse, blood pressure, and oxygen saturation. The session begins with 30 seconds of passive hamstring stretching, followed by a 15-second hamstring contraction within the joint's limited range, then 15 seconds of quadriceps contraction at 20–30% of maximum effort. This sequence is repeated for 4–5 sets, with 20–30 seconds of rest between sets, performed three times per week for four weeks.

Training volume is increased progressively by extending duration and contraction intensity according to the patient's condition. If fatigue or complaints arise, the session is paused for rest and resumed when the patient is ready. Training is temporarily stopped if the patient experiences symptoms such as chest pain, dizziness, or fatigue; muscle or joint pain with a WBS > 4; shortness of breath with a respiratory rate > 24/min; diastolic blood pressure ≥ 110 mmHg, resting systolic ≥ 180 mmHg, or exercise systolic > 200 mmHg; resting heart rate > 120 bpm; or fever > 37.5°C. Pulse, blood pressure, and oxygen saturation are rechecked after each session. Patients must be accompanied by at least one trained healthcare professional, such as a rehabilitation medicine resident or physiotherapist, throughout the training.

These exercises are performed regularly and in a structured schedule, tailored to each athlete with Cerebral Palsy based on the specific requirements of their respective sports disciplines. Contraindications for doing exercise are: 1) joint movement may be restricted by a bony block or an incomplete bone healing process in the case of a recent fracture; 2) acute inflammation or signs of infection, such as heat and swelling, or impaired soft tissue healing in the affected area, should be taken into consideration; 3) sharp in acute pain during joint movement or muscle stretching, as well as the presence of hematoma or other signs of tissue trauma, indicate the need for caution; 4) hypermobile joints also require special attention; 5) additionally, soft tissue shortening may serve a functional purpose by providing necessary joint stability in cases of structural or neuromuscular deficits; 6) in some situations, soft tissue shortening allows patients with paralysis or severe muscle weakness to perform specific functional activities that would otherwise be impossible.

RESULTS

The study included 12 subjects that met the inclusion criteria. General characteristics of the study subjects in both groups are shown in Table 1.

Table 2 showed significant improvements in Y Balance Test reach distances following a 4-week PNF stretching intervention. For the right limb, marked increases were observed in the all directions anterior ($p < 0.001$), posterolateral ($p < 0.001$), and posteromedial ($p < 0.001$). Similarly, the left limb exhibited significant gains in the all

Table 1. Characteristics of the research subjects

Variable	*n* = 12 Mean ± SD
Age (years)	26.08 ± 4.62
Body Height (cm)	168.33 ± 7.17
Body Weight (kg)	61.22 ± 9.50
Body Mass Index (kg/m^2)	21.43 ± 1.85
Classificatin CP ISRA	
6-7	7 (58,3%)
7	1 (8,3%)
7-8	4 (33,3%)
CP Type	
Hemi Dextra	7 (58,3%)
Hemi Sinistra	4 (33,3%)
Athetoid	1 (8,3%)
Double Hemi	0 (0%)
Mono	0 (0%)
Spastic Diplegic	0 (0%)

Table 2. Result after 4 weeks intervention

No	Variable	Pre (cm)	Post (cm)	p^a	Effect Size
1	Anterior dextra	73.33 ± 15.95	91.33 ± 15.19	0.000	1.60
2	Anterior sinistra	81.16 ± 18.92	96.66 ± 15.60	0.001	1.26
3	Posteromedial dextra	65.83 ± 11.53	87.08 ± 18.55	0.000	1.58
4	Posteromedial sinistra	71.41 ± 14.60	89.41 ± 20.01	0.002	1.19
5	Posterolateral dextra	77 ± 11.09	101.58 ± 16.99	0.000	1.56
6	Posterolateral sinistra	79.33 ± 15.46	103 ± 17.97	0.000	1.92

a) Paired t-test *) Significant if $p < 0.05$

Table 3. Result after 6 months intervention

No	Variable	Post 4 weeks (cm)	Evaluation 6 Months after Intervention (cm)	p^a	Effect Size
1	Anterior dextra	73.33 ± 15.95	91.33 ± 15.19	0.000	1.60
2	Anterior sinistra	81.16 ± 18.92	96.66 ± 15.60	0.001	1.26
3	Posteromedial dextra	65.83 ± 11.53	87.08 ± 18.55	0.000	1.58
4	Posteromedial sinistra	71.41 ± 14.60	89.41 ± 20.01	0.002	1.19
5	Posterolateral dextra	77 ± 11.09	101.58 ± 16.99	0.000	1.56
6	Posterolateral sinistra	79.33 ± 15.46	103 ± 17.97	0.000	1.92

a) *Paired t-test* *) Significant if $p < 0.05$

directions anterior ($p < 0.001$), posterolateral ($p < 0.001$), and posteromedial ($p < 0.002$). Large effect sizes (Cohen's D > 0.8) were identified across all directions: anterior (right: D = 1.60; left: D = 1.26), posteromedial (right: D = 1.58; left: D = 1.19), and posterolateral (right: D = 1.56; left: D = 1.19), underscoring the intervention's substantial clinical impact on dynamic balance.

Table 3 showed no significant difference after 6 months post-intervention evaluation of the YBT following PNF stretching revealed no statistically significant improvements in reach distances from the standing position. For the right limb, non-significant changes were observed in all directions anterior ($p = 0.082$), posteromedial ($p = 0.318$), and posterolateral ($p = 0.851$). Similarly, the left limb showed no significant gains in all directions anterior ($p = 0.870$), posteromedial ($p = 0.120$), or posterolateral ($p = 0.613$). Effect sizes were categorized as follows: Medium effect ($0.5 \leq d < 0.8$): Right limb anterior (d = 0.55), right limb posteromedial (d = 0.30), left limb posteromedial (d = 0.48), and left limb posterolateral (d = 0.15). Small effect ($0.2 \leq d < 0.5$): Left limb anterior (d = 0.04) and right limb posterolateral (d = 0.05). These results suggest that the PNF intervention's impact on anticipatory balance diminished over time, with only modest residual effects observed at 6 months.

DISCUSSION

To the authors' knowledge, this is the first study in Indonesia to use the YBT to assess anticipatory balance in athletes with Cerebral Palsy. The cohort included 12 athletes (aged 18–40 years) who met predefined inclusion criteria and underwent a 4-week intervention comprising standard stretching protocols integrated with Proprioceptive Neuromuscular Facilitation techniques, administered three times weekly. A six-month post-intervention follow-up period was implemented to evaluate the sustainability of neuromuscular adaptations and long-term retention of balance improvements.

Research was conducted at the NPC Indonesia Training Center in Surakarta City February 2024. Due to the limited number of subjects, gender homogenization was not feasible, so a total sampling method was applied. Average age was 26.08 ± 4.62 years, respectively, indicating that most participants were within the productive age range, which supports their ability to perform muscle-strengthening exercises with minimal injury risk and good awareness. Mean Body

Mass Index (BMI) was 21.43 ± 1.85 categorized as normoweight according to the Asia-Pacific criteria.

Study utilized the YBT to assess anticipatory balance, a functional evaluation tool derived from the Star Excursion Balance Test through simplification. Y Balance Test serves as a comprehensive measure of physical capabilities, including muscular strength, flexibility, neuromuscular coordination, postural stability, and joint range of motion.[7] The Y Balance Test requires participants to maintain a single-leg stance while maximally reaching with the contralateral limb in three distinct directions: anterior, posterolateral, and posteromedial. During the assessment, participants are instructed to keep their hands on their hips, stand on the central platform, and ensure the non-weight-bearing limb remains elevated without floor contact. The test is performed over three trials for each leg, with the average reach distance across all directions calculated and normalized to limb length to derive a composite score.[8]

The findings of this 4-week intervention align with existing literature on PNF stretching. Proprioceptive Neuromuscular Facilitation techniques induce cyclical mechanical tension and controlled contractions, which generate microtrauma within muscle myofibers. This microtrauma triggers the release of proinflammatory mediators, including TNFα, TGFβ, and IL6, thereby activating satellite cells. Elevated satellite cell activity enhances the production of growth factors such as HGF and IGF, which stimulate myoblast proliferation and differentiation, facilitating muscle regeneration and repair. Concurrently, this process downregulates myostatin expression while upregulating TGFβ, promoting enhanced myogenic differentiation and the formation of stronger myofibers. These adaptations improve muscle extensibility and viscoelastic properties. Furthermore, reduced myostatin levels mitigate sarcomeric titin degradation—a critical benefit in individuals with Cerebral Palsy, who often exhibit elevated myostatin levels that compromise muscle strength and function.[9]

This study aimed to evaluate the efficacy of Proprioceptive Neuromuscular Facilitation with Contract-Relax (PNF-CR) and Static Stretching (SS) in enhancing hamstring flexibility, assessed via range of motion, controlled active range testing (CART), and electromyographic (EMG) activity of the biceps femoris muscle during maximal voluntary isometric contraction (MVIC). Results demonstrated that both PNF-CR and SS improved knee joint ROM immediately post-intervention and after a four-week regimen. However, PNF-CR uniquely increased biceps femoris MVIC activity only following the four-week program. Notably, PNF-CR exhibited immediate improvements in hamstring flexibility, with further gains after sustained training, whereas SS solely enhanced flexibility over time without influencing EMG metrics. Although both interventions achieved statistically significant long-term flexibility improvements, SS demonstrated a comparatively greater absolute effect than PNF-CR.[10]

The 6-month post-intervention evaluation of anticipatory balance using the Y Balance Test revealed no statistically significant increases in reach distances from the standing position in the anterior, posterolateral, or posteromedial directions. According to these results, Proprioceptive Neuromuscular Facilitation stretching is not a long-term effective way to improve flexibility or lessen muscle spasticity in people with cerebral palsy when it is used alone without further strategies or an extension of the intervention period. This emphasizes the need for longer-term or combined treatment strategies to maintain neuromuscular adaptations and functional improvements.[10] An 8-week Proprioceptive Neuromuscular Facilitation stretching regimen demonstrates efficacy in augmenting hamstring muscle strength and neuromuscular activation among team-sport athletes. These findings suggest practical implications for optimizing PNF stretching frequency to achieve acute strength gains. However, extending the intervention beyond 8 weeks did not yield statistically

significant long-term enhancements in muscular performance or neuromuscular adaptation. This highlights the need for structured, time-bound PNF protocols to maximize short-term benefits in athletic training programs.[11] This study did not individually report variations in the physiological status of athletes with Cerebral Palsy. However, it provides initial evidence suggesting that Cerebral Palsy athletes performance characteristics may be influenced by sport-specific stretching training programs tailored to their respective disciplines.[12] Study of six elite Paralympic sprinters with Cerebral Palsy demonstrated that these athletes exhibited a 6% slower performance in the 40-meter sprint test and an 18% lower vertical jump height compared to able-bodied athletes matched for baseline performance metrics. These findings highlight potential neuromuscular and biomechanical disparities in Cerebral Palsy athletes during explosive motor tasks.[1]

CONCLUSION

The study findings indicate a statistically significant increase in Y Balance Test reach distances among Cerebral Palsy athletes following a 4-week intervention integrating Proprioceptive Neuromuscular Facilitation stretching into standard training protocols, compared to pre-intervention baseline measurements. However, no statistically significant differences in anticipatory balance outcomes were observed between the intervention group (PNF-supplemented training) and the control group (standard training alone) at the 6-month post-intervention evaluation. These results suggest that while short-term neuromuscular adaptations occur with PNF, sustained improvements in dynamic stability require ongoing or periodic reinforcement of the intervention.

ACKNOWLEDGMENTS

The authors would like to thank the National Paralympic Committee Indonesia for their valuable contribution to data recording.

FUNDING

The authors did not receive financial support for the manuscript and or for publication.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

ETHICAL APPROVAL

Ethical clearance for this study was granted under number IR.03.01/ D.XXV.3/ 3997/ 2023 by the Health Research Ethics Committee of Prof. Dr. R. Soeharso Orthopedics Hospital in Surakarta, Indonesia.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are not publicly available due to patient confidentiality. However, data may be made available upon reasonable request directed to N.C.

REFERENCES

1. Runciman P and Derman, W. The athlete with cerebral palsy: Challenges for the team physician. Aspetar Sport Med J. 2018;7:142–7.
2. Hrysomallis C, McLaughlin P, Goodman C. Balance and injury in elite Australian footballers. Int J Sports Med. 2007;28(10):844–7.
3. Rabbani AH, van de Panne M, Kry PG. Anticipatory balance control. In: Motion in Games. MIG '14: Proceedings of the 7th International Conference on Motion in Games; 2014 Nov 9-11; Newcastle upon Tyne, UK. p. 71–6.
4. Nelson S, Wilson CS, Becker J. Kinematic and kinetic predictors of Y-balance test performance. Int J Sports Phys Ther. 2021;16(2):371.
5. Gasibat Q, Simbak NB, Aziz A. Stretching exercises to prevent work-related musculoskeletal disorders: A review article. Am J Sports Sci Med. 2017;5(2):27–37.
6. Krishna KR, Thakur A, Priya PR, HS S, Srivastav S, Prabhu S. Effect of PNF in improving lower extremity function in adolescent with spastic

diplegic cerebral palsy-A case report. Indian J Public Health Res Dev. 2020;11(7):406–8.
7. Gonell AC, Romero JAP, Soler LM. Relationship between the Y balance test scores and soft tissue injury incidence in a soccer team. Int J Sports Phys Ther. 2015;10(7):955-66.
8. Neves LF, de Souza CQ, Stoffel M, Picasso CLM. The Y balance test–how and why to do it. Int Phys Med Rehab J. 2017;2(4):99–100.
9. Yildiz M and Mehmet Ç. Acute Effect of Proprioceptive Neuromuscular Facilitation-Based Warm-Up on Isokinetic Strength, Endurance and Balance. 2024.
10. Zaidi S, Ahamad A, Fatima A, Ahmad I, Malhotra D, Al Muslem WH, et al. Abdulaziz S, Nuhmani S. Immediate and Long-Term Effectiveness of Proprioceptive Neuromuscular Facilitation and Static Stretching on Joint Range of Motion, Flexibility, and Electromyographic Activity of Knee Muscles in Older Adults. J Clin Med. 2023;12(7):2610.
11. Latouf BKA, Halouani J, Khalil M, Chtourou, H. Effect of 8-Weeks PNF Stretching on Muscle Strength and Neuromuscular Activity of the Hamstring Muscles. Int J Sport Stud Health. 2023;6(1):37–42.
12. Fleeton JRM, Sanders RH, Fornusek C. Strength training to improve performance in athletes with cerebral palsy: A systematic review of current evidence. J Strength Cond Res. 2020;34(6):1774-89.