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# THE EFFECT OF PELVIC CONTROL EXERCISES ON STANDING POSTURE IN CHILDREN WITH SPASTIC DIPLEGIC CEREBRAL PALSY: A PILOT RANDOMIZED CONTROLLED TRIAL

**ORIGINAL ARTICLE**

## ABSTRACT

**Purpose:** Pelvic instability is a common finding in children with spastic diplegic cerebral palsy (CP). Mobility and day-to-day functioning are impeded by improper muscle activation and inadequate regulation of movement around the pelvis. The study's objective was to investigate the effects of pelvic control exercises on posture of children with spastic diplegic CP.

**Methods:** 24 spastic diplegic children with CP who participated in this single-blind trial were divided into two groups at random by simple random sampling. Group A (n = 12) received conventional intervention and pelvic control exercises, while Group B (n = 12) received only conventional intervention. For a period of eight weeks, the intervention was carried out three days a week. Postural angles like thoracic inclination (TI), trunk angle (TA), pelvic tilt (PT), lumbar angle (LA), lumbar curve (LC), horizontal alignment of anterior superior iliac spine (HAASIS), horizontal alignment of posterior superior iliac spine (HAP) were evaluated as outcome measure before and after the intervention is finished. While the independent t test was used to examine differences between the two groups, the paired-t test was employed to examine differences within the group.

**Results:** When outcome measures from both groups were compared prior to treatment, no significant differences were observed. The values of postural angles in study group A showed a significant improvement after the treatment with conventional physiotherapy and pelvic control exercises in comparison with conventional treatment alone. Angles of TA (p=0.030) and LC (p=0.007) increased while those of TI (p=0.027), PT (p<0.001), LA (p=0.005), HAASIS (p=0.054), and HAP (p=0.017) decreased in group A resulting in better trunk and pelvic alignment.

**Conclusion:** The results indicated that pelvic control training could be beneficial in improving posture of children with spastic diplegic CP.

**Keywords:** Cerebral Palsy, Diplegia, Pelvis, Posture, Spasticity

# SPASTİK DİPLEJİK SEREBRAL PALSİLİ ÇOCUKLARDA PELVİK KONTROL EGZERSİZLERİNİN AYAKTA DURMA ÜZERİNE ETKİSİ: PİLOT RANDOMİZE KONTROLLÜ ÇALIŞMA

**ARAŞTIRMA MAKALESİ**

## ÖZ

**Amaç:** Pelvik instabilite, spastik diplejik serebral palsili (SP) çocuklarda sık görülen bir bulgudur. Hareketlilik ve günlük işlevsellik, uygunsuz kas aktivasyonu ve pelvis çevresindeki hareketin yetersiz düzenlenmesi nedeniyle engellenir. Çalışmanın amacı spastik diplejik SP'li çocuklarda pelvik kontrol egzersizlerinin postür üzerine etkilerini araştırmaktı.

**Yöntem:** Bu tek-kör çalışmaya katılan SP'li 24 spastik diplejik çocuk, basit rastgele örnekleme yoluyla rastgele iki gruba ayrıldı. Grup A'ya (n=12) geleneksel müdahale ve pelvik kontrol egzersizleri yapılırken, Grup B'ye (n=12) yalnızca geleneksel müdahale uygulandı. Sekiz hafta boyunca müdahale haftada üç gün gerçekleştirildi. Torasik eğim (TI), gövde açısı (TA), pelvik eğim (PT), lomber açı (LA), lomber eğri (LC), anterior superior iliak omurganın yatay hizalaması (HAASIS), posterior superior iliak yatay hizalaması gibi postüral açılar omurga (HAP), müdahalenin bitiminden önce ve sonra sonuç ölçüsü olarak değerlendirildi. İki grup arasındaki farklılıkları incelemek için bağımsız t testi, grup içi farklılıkları incelemek için eşleştirilmiş t testi kullanıldı.

**Sonuçlar:** Her iki grubun sonuç ölçümleri tedavi öncesinde karşılaştırıldığında anlamlı bir fark gözlenmedi. A çalışma grubundaki postüral açı değerleri, konvansiyonel fizyoterapi ve pelvik kontrol egzersizleri ile yapılan tedavi sonrasında, tek başına konvansiyonel tedaviye kıyasla anlamlı bir iyileşme gösterdi. TA (p=0,030) ve LC (p=0,007) açıları artarken, TI (p=0,027), PT (p<0,001), LA (p=0,005), HAASIS (p=0,054) ve HAP (p=0,017) grup A'da düşüş gösterdi ve bu da daha iyi gövde ve pelvik hizalanma sağladı.

**Tartışma:** Sonuçlar, spastik diplejik SP'li çocuklarda pelvik kontrol eğitiminin postürün iyileştirilmesinde faydalı olabileceğini gösterdi.

**Anahtar Kelimeler:** Serebral Palsi, Dipleji, Pelvis, Duruş, Spastisite

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## INTRODUCTION

Cerebral palsy (CP), the most prevalent reason for physical impairment in children, can affect the child's health in a variety of ways. Primary neuromuscular deficiencies, including reduced selective motor control, muscle weakness, and spasticity, are among the motor signs of CP, while secondary musculoskeletal issues include bony malformations and contractures (1). The most common form of CP is spastic diplegia, which affects 80% of preterm infants and accounts for approximately 44% of the overall incidence of CP (2). The trunk is noticeably weaker and the extremities are highly spastic in children with spastic diplegia. In comparison to their lower extremities, they demonstrate milder motor impairment in their upper extremities (3). The primary functional issue is poor posture and movement. Appropriate alignment of each body component and spinal segment with the trunk and neighbouring part is necessary for an upright posture (4). Children with CP typically have an abnormal alignment of the spine in comparison to children who are developing normally (5).

The pelvic girdle connects the upper and lower quadrants of the musculoskeletal system anatomically and transmits forces between them, affecting and being influenced by these segments (6). A deficiency in the motor process, manifested as spasticity or weakness in the muscles around the pelvis, results in an aberrant pelvic position (7). As hip movements are limited in children with spastic CP, pathologic motion of the pelvis occurs either with excessive motion or asymmetric motion (8). Some children with CP have spastic hamstring muscles, which cause the pelvis to tilt backward (posteriorly), preventing anterior tilt. On the other hand, some children may exhibit greater hip flexor spasticity, pushing the pelvis into an anterior tilt and preventing posterior tilt (9). These irregularities in the spine lead to changes in postural angles, such as LA, TA, and PT, because of an imbalance between the postural and muscular forces operating on the growing axial skeleton.

Currently, the examination and treatment of the upper and lower extremities are the main topics of research in children with CP (10). Contrarily, there is little research on pelvic control in children with CP. Only one study has mentioned pelvic stabilisation program in spastic CP (11) while other studies have been done in stroke population (12). In contrast to limb muscles, the abdominal muscles require a stable origin to function well. Depending on which section of the trunk is being moved, this origin can be the pelvis, thorax, or central aponeurosis. The mobility over stability task that is necessary for all functional movements is counterrotation between the upper and lower trunks (13). Control of the muscles around the pelvis should be one of the main areas of concentration for enhancing motor performance because it is hypothesised that providing a more stable base of support would enable more regulated and directed movement. The purpose of this study is to examine the impact of pelvic control exercises on standing posture in children with diplegic CP.

## METHODS

### Study Design

Between August 2023 and December 2023, a pilot pretest-posttest, parallel-group, single blinded, randomised controlled experiment was undertaken. The SGT Medical College Hospital and Research Institute and Khushboo Welfare Society, both in Gurugram, Haryana, conducted this study. The university's ethics committee (SGT University, Departmental Ethical Committee, Faculty of Physiotherapy) gave the study approval (SGTU/FPHY/2022/438, dated 12.10.22), and it was registered with the Clinical Trials Registry of India (ICMR-NIMS) as CTRI/2023/08/055957 and was carried out in compliance with the 1964 Helsinki Declaration. The CONSORT standard for reporting randomised controlled trials has been followed in the reporting of this study (14). All participants and their parents received information about the study's goals and methods, and they all signed informed written consent forms. Their permission for publishing their photographs without disclosing their identity was seeked.

### Participants Recruitment, Sample size and Allocation

Children with Spastic Diplegic CP who had been referred by a paediatric neurologist to the Depart-

ment of Physical Therapy's outpatient clinic at SGT University and Khushboo Welfare Society were examined to see which ones could possibly be included in this study. Spastic diplegic children of both genders who met the following criteria were eligible to participate: age groups ranging from 5 to 12 years; motor function at level I or II on the Gross Motor Function Classification System (GMFCS); and spasticity of 1, 1+ or 2 on the Modified Ashworth Scale as assessed by hip adductors, internal rotators, quadriceps, and calf muscles.

Children who had received an injection of botulinum neurotoxins, had lower limb casting within six months, had undergone previous musculoskeletal surgery, had any variation in limb length, any musculoskeletal deformity, participation in any other rehabilitation program, or had attention deficit disorder were excluded.

According to Steven A. Julious's study, we took a sample of 24, as he suggested that pilot studies should examine a minimum of 12 people per group by simple random sampling method (15). The children were asked to select one index card from a box containing 24 cards—12 for each group—to reveal their group membership, and they were then split into two equal groups (A and B) at random in a 1:1 allocation ratio by a person who was not aware of the programs for therapy. Subjects, families, and research personnel were all blinded to treatment allocation. The study physiotherapist was the only person who was not blinded.

## Outcome measure

### Posture Evaluation

The photographic method was used to assess posture (16). Landmarks were placed on the ground to guarantee that each subject was positioned in front of the camera in the same manner. Digital Nikon DSLR 7100 cameras were used. The cameras were set up 200 cm away from the line indicating the subject's location using three tripods (one in front, one in the back, and one on the subject's right side). A spirit level was used to level it on the stand so that it was perpendicular to the floor. The child's eyes were level with the centre of the Nikon 20 mm wide-angle lens when the tripod's height was adjusted. Anterior superior iliac spine (ASIS), posterior superior iliac spine (PSIS), greater trochanter and spinous process of C7, T12, L3, S2 were all marked on the subject's right side of the body before photographs were taken. Two of these

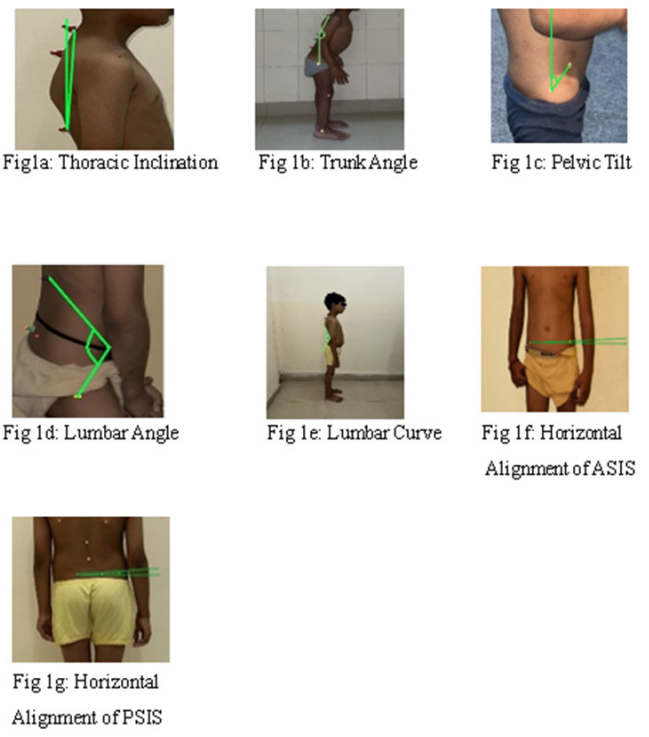


**Figure 1.** Postural Angles

seven points were bilateral. After the markers were positioned, the participant was instructed to stand in front of the front camera at the assigned spot, face forward, and adopt a comfortable habitual standing stance. The researchers captured three shots of every participant with their feet planted on the ground: a frontal, a back, and a right-side image (17).

For the photogrammetry, the following angles were calculated (Figure 1).

1. Thoracic Inclination (TI)

The line connecting C7 to T12 establishes the angle with respect to the vertical.

2. Trunk angle (TA)

The line between T12 and C7 and the line drawn from T12 to the greater trochanter form this angle.

3. Pelvic tilt (PT)

It is the line drawn from greater trochanter to ASIS with regard to vertical.

4. Lumbar angle (LA)

A line that is drawn through the greater trochanter and ASIS, as well as through T12 and ASIS, produces the lumbar angle.

5. Lumbar curve (LC)

The lumbar curve is formed by a line drawn from T12 and L3 and a line drawn from L3 and S2 (18).

6. Horizontal alignment of ASIS (HAASIS)

It is the angle between the two ASIS and a horizontal line.

7. Horizontal alignment of PSIS (HAP)

It is the angle between the two PSIS and a horizontal line (19).

Each participant's photographs, which included several angles, was put into the video analysis programme Kinovea 0.9.5 (kinovea open source project) (20). The software's cross marker, line, and angle tools were used to examine postural angles. To make the points in the image easier to see, the bone landmarks were highlighted using the cross-marker tool and a bright contrast colour.

While there is scarcity of information regarding values of postural angles, one study had evaluated postural angles in children with spastic diplegia and children with typical development. As a reference to this previous study, it may be concluded that there is remarkable deviation in the postural angles in diplegic CP children as compared to healthy controls (17).

**Intervention**

Both the study group (A) and control group (B) received conventional exercises for 30 minutes per session, three times per week for eight weeks, while the study group also received pelvic control exercises for 15 minutes per session, three times per week for eight weeks, after the conventional exercises. Pelvic control exercises were done after 2 min of rest period of conventional exercises and on the same days as were conventional exercises. Both groups performed two sets of each exercise with a two minutes interval between sets. An exercise diary was kept to document information regarding the overall number of sessions, the causes of any absenteeism, the incidence of any unfavourable event, and the number of repetitions and therapy adherence delivered fully as planned.

**Conventional Exercises**

1. Stretching of psoas muscle, hamstrings and gastrocnemius

2. Strengthening of muscle abdominis obliquus, latissimus dorsi and glutei

3. Movement transitions like standing up from a chair

4. Weight shifting and loading of the lower extremities like kicking a ball, reaching in different directions, and picking up objects that are put outside the stability limit (beyond arm's length).

5. Walking exercises such as sideways, backwards, forwards, and obstacle course walking;

6. Moving up and down stairs and ramps

7. Walking through an obstacle course (21)

**Pelvic Control Exercises (Appendix-A)**

This treatment program was divided into four phases: Initial, Improvement, Advance, and Maintenance. Each phase was of 2 weeks duration (13).

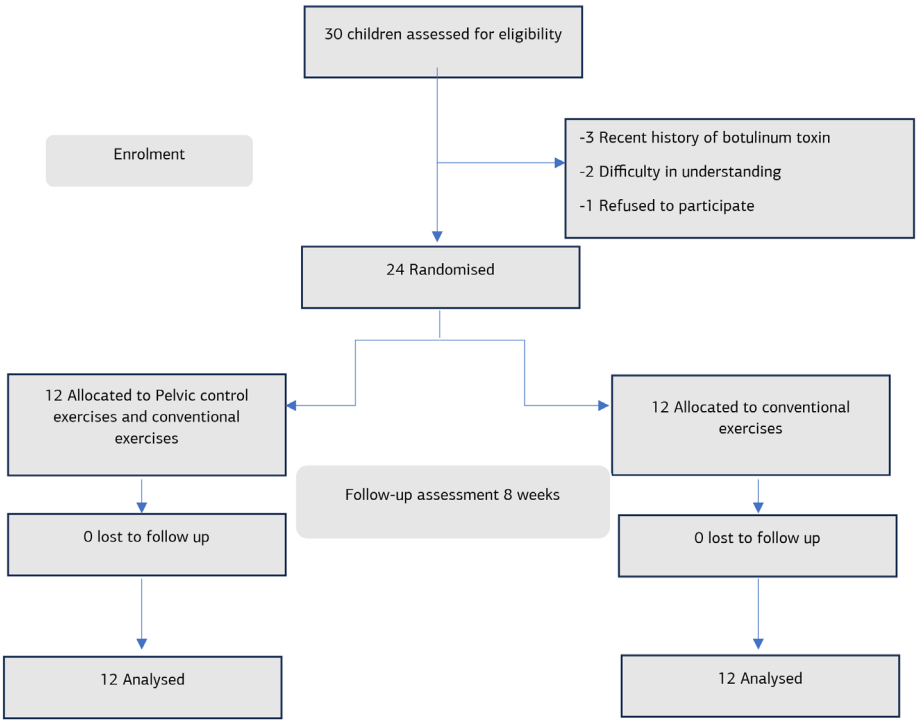


**Figure 2.** Flow chart of the participants

Initial Phase (Antero-posterior movements of pelvis has been introduced in this phase)

1. Sidelying: Pelvic mobilisation

2. Prone kneeling: Cat-camel exercise

3. Sitting: Weight shifting on swiss ball

4. Lying: Bridging

5. Half kneeling: Diagonal pattern

6. Standing: Posterior tilting exercises while kicking football in front, taking step forward on a low height box. Pelvic stabilisation while maintaining hip-knee in 90-90 position and pelvic facilitation during stance phase.

Improvement phase (Sideways movements of pelvis has been introduced in this phase)

1. Sidelying: Pelvic mobilisation

2. Prone kneeling: Quadruped rocking and selective lateral movement of pelvis

3. Lying: Bridging with hold

4. Half kneeling: Diagonal pattern with heavy object

5. Standing: Lateral tilting of pelvis while kicking football sideways, anterior tilting of pelvis while taking step backwards on a low height box. Pelvic stabilisation while maintaining hip-knee in 90-90 position while carrying an object and pelvic facilitation during swing phase.

Advance phase (Rotatory movements of pelvis has been introduced in this phase)

1. Sidelying: Pelvic mobilisation

2. Sitting: Isolated flexion-extension of pelvis

3. Kneel standing: Weight shifts

4. Lying: Bridging with adductor squeeze

5. Half kneeling: Diagonal pattern with catch and throw ball

6. Standing: Forward rotation of pelvis while kicking football in front, lateral tilting of pelvis while taking step sideways on a low height box. Pelvic stabilisation while maintaining hip-knee in 90-90 position with reach-outs and pelvic facilitation during stance and swing phase on irregular surface.

Maintenance phase (Movements of pelvis in all planes have been introduced in this phase)

**Table 1.** Baseline Characteristics of the Children with Spastic diplegic CP in the Study

| Characteristics | Group A(n=12) Mean± SD | Group B (n=12) Mean ± SD | t value | *p* value |
|---|---|---|---|---|
| Gender[€] | M=9, F=3 | M=8, F=4 | 0.202 | 0.653 |
| Age (years) | 6.92 ± 3.17 | 7.42 ± 2.90 | -0.40 | 0.691 |
| Height (m) | 1.17 ± 0.21 | 1.19 ± 0.22 | -0.23 | 0.818 |
| Weight (kg) | 26.77 ± 10.11 | 29.17 ± 11.83 | -0.53 | 0.599 |
| BMI (kg/m$^2$) | 19.68 ± 4.29 | 19.74 ± 1.88 | -0.04 | 0.961 |

M: male; F= female; BMI= body metabolic index; SD: Standard Deviation; [€]: Chi-square test

1. Sidelying: Pelvic mobilisation

2. Lying: Rotate upper body away from lower body

3. Sitting: Isolated flexion-extension of pelvis

4. Lying: Bridging with one leg straight

5. Standing: Pelvic tilting with knees bent, weight shifts, pelvic facilitation while kicking football in all directions, pelvic facilitation while taking step in all directions on different height of boxes, pelvic stabilisation while maintaining hip-knee in 90-90 position with reach-outs in different directions and pelvic facilitation during sit to stand (22).

### Statistical Analysis

IBM SPSS version 26.0 (SPSS Inc., Chicago, IL, USA) was the program used for data analysis. The Shapiro-Wilk test was used to assess the data distribution. An independent t test was used to compare demographic data between groups at baseline. An independent sample t test was used to assess the postural angles between the groups following the completion of pelvic control training and conventional training. The paired t-test was used for the analysis within the group. For the current study, p values < 0.05 were considered statistically significant.

## RESULTS

Data of participants which completed the study (n = 24) was analyzed (Figure 2).

Baseline characters in Table 1 did not show any significant group differences. Thus, baseline characters were consistent.

Table 2 compares the t-value and p-value of the postural angles for Group A and B before and after the intervention. To examine within-group differ-

**Table 2.** Comparison of Postural Angles within Group A and B

| Variables | Group | Baseline | 8th week | *t* value | Effect size[CI] | *p* value |
|---|---|---|---|---|---|---|
| | | Mean ± SD | Mean ± SD | | | |
| TI | Group A | 17.02 ± 4.27 | 10.39 ± 3.20 | 11.27 | 1.73 [1.06, 2.40] | <0.001* |
| | Group B | 15.51 ± 4.22 | 14.20 ± 4.52 | 3.455 | 0.29 [-0.27, 0.86] | 0.005* |
| TA | Group A | 151.95 ± 7.23 | 166.96 ± 9.15 | -6.65 | 1.79 [1.11, 2.47] | <0.001* |
| | Group B | 152.96 ± 5.10 | 158.99 ± 7.64 | -4.302 | 0.91 [0.32, 1.51] | 0.001* |
| PT | Group A | 34.42 ± 8.41 | 22.91 ± 7.53 | 8.37 | 1.42 [0.78, 2.06] | <0.001* |
| | Group B | 38.23 ± 4.28 | 35.70 ± 4.34 | 9.726 | 0.58 [-0.00, 1.16] | <0.001* |
| LC | Group A | 163.91 ± 8.77 | 177.13 ± 9.53 | -12.85 | 1.39 [0.75, 2.02] | <0.001* |
| | Group B | 163.36 ± 8.70 | 165.63 ± 8.54 | -13.718 | 0.26 [-0.31, 0.83] | <0.001* |
| LA | Group A | 113.35 ± 12.02 | 102.12 ± 8.27 | 7.14 | 1.05 [0.44, 1.65] | <0.001* |
| | Group B | 115.58 ± 8.83 | 112.53 ± 8.72 | 10.013 | 0.34 [-0.23, 0.91] | <0.001* |
| HAASIS | Group A | 4.61 ± 3.58 | 2.35 ± 2.08 | 4.78 | 0.76 [0.17, 1.35] | 0.001* |
| | Group B | 5.13 ± 2.31 | 4.21 ± 2.38 | 9.256 | 0.39 [-0.18, 0.97] | <0.001* |
| HAP | Group A | 5.39 ± 3.23 | 1.71 ± 1.40 | 6 | 1.45 [0.81, 2.10] | <0.001* |
| | Group B | 3.94 ± 0.99 | 2.99 ± 0.97 | 12.976 | 0.95 [0.35, 1.55] | <0.001* |

TI: Thoracic inclination; TA: Trunk angle; PT: Pelvic tilt; LA: Lumbar angle; LC: Lumbar curve; HAASIS: Horizontal alignment of anterior superior illiac spine; HAP: Horizontal alignment of pelvis; CI: Confidence Interval; *: significant difference

**Table 3.** Comparison of Postural Angles between the Groups

| Variables | Time Frame | Group A | Group B | t value | Effect size [CI] | *p* value |
|---|---|---|---|---|---|---|
| | | Mean± SD | | | | |
| TI | Baseline | 17.02 ± 4.27 | 15.51 ± 4.22 | 0.865 | 0.35 [-0.22, 0.92] | 0.396 |
| | 8th week | 10.39 ± 3.20 | 14.20 ± 4.52 | -2.378 | 0.96 [0.36, 1.56] | **0.027*** |
| TA | Baseline | 151.95 ± 7.23 | 152.96 ± 5.10 | -0.396 | 0.16 [-0.41, 0.73] | 0.696 |
| | 8th week | 166.96 ± 9.15 | 158.99 ± 7.64 | 2.316 | 0.93 [0.33, 1.53] | **0.030*** |
| PT | Baseline | 34.42 ± 8.41 | 38.23 ± 4.28 | -1.398 | 0.56 [-0.02, 1.14] | 0.176 |
| | 8th week | 22.91 ± 7.53 | 35.70 ± 4.34 | -5.1 | 2.05 [1.34, 2.76] | **<0.001**** |
| LC | Baseline | 163.91 ± 8.77 | 163.36 ± 8.70 | 0.154 | 0.06 [-0.50, 0.63] | 0.879 |
| | 8th week | 177.13 ± 9.53 | 165.63 ± 8.54 | 3.112 | 1.25 [0.63, 1.87] | **0.005*** |
| LA | Baseline | 113.35 ±12.02 | 115.58 ± 8.83 | -0.516 | 0.21 [-0.36, 0.78] | 0.611 |
| | 8th week | 102.12 ± 8.27 | 112.53 ± 8.72 | -3 | 1.20 [0.59, 1.82] | **0.007*** |
| HAASIS | Baseline | 4.61 ± 3.58 | 5.13 ± 2.31 | -0.42 | 0.17 [-0.40, 0.74] | 0.679 |
| | 8th week | 2.35 ± 2.08 | 4.21 ± 2.38 | -2.035 | 0.82 [0.23, 1.41] | 0.054 |
| HAP | Baseline | 5.39 ± 3.23 | 3.94 ± 0.99 | 1.482 | 0.60 [0.02, 1.18] | 0.152 |
| | 8th week | 1.71 ± 1.40 | 2.99 ± 0.97 | -2.592 | 1.05 [0.44, 1.65] | **0.017*** |

TI: Thoracic inclination; TA: Trunk angle; PT: Pelvic tilt; LA: Lumbar angle; LC: Lumbar curve; HAASIS: Horizontal alignment of anterior superior illiac spine; HAP: Horizontal alignment of pelvis; CI: Confidence Interval; *: significant difference

ences at baseline (before intervention) and week 8 (after intervention), a paired t-test was used. After receiving conventional physical therapy along with pelvic control exercises, the results demonstrated improvement in all postural angles in group A [TA (p<0.001); LC (p<0.001); TI (p<0.001); PT (p<0.001); LA (p<0.001); HAASIS (p=0.001); and HAP (p<0.001)]. Similarly, all postural angles revealed statistically significant difference in-group B after conventional training [TA (p=0.001); LC (p<0.001); TI (p=0.005); PT (p<0.001); LA (p<0.001); HAASIS (p<0.001); and HAP (p<0.001)].

The analysis for the difference between two independent groups was conducted using a summary independent t-test on the postural angles of the TI, TA, PT, LC, LA, HAASIS, and HAP. The results showed both groups had significantly improved postural angles (p <0.05). There were no discernible variations between the groups' pre-treatment outcomes. However, a comparison of the two groups' findings after the treatment protocol was completed revealed significant improvements in favour of group A [TA (p=0.030); LC (p=0.007); TI (p=0.027); PT (p<0.001); LA (p=0.005); HAASIS (p=0.054); and HAP (p=0.017)] (Table 3).

## DISCUSSION

This study examined how posture in children with CP was affected by pelvic control exercises. We discovered that pelvic control exercises significantly changed the postural angles. One of the most restricting conditions in the CP population is postural dysfunction. It limits abilities, which lowers participation in daily activities (23). Postural angles can be used to quantify this postural impairment. Exercises for pelvic control showed advantages in higher performance as indicated by postural angles. The pelvis, which is a part of the lower trunk, offers dynamic postural stability during anterior and lateral weight transfers, according to biomechanics. To perform lateral flexion and rotation of the trunk movements, a person need more dynamic stability of the lower trunk and pelvis (12).

Pre-treatment measurements of the postural angles from the two groups showed no significant changes and aberrant readings for these variables. According to Cook and Wollacot, this may be linked to neuromuscular abnormalities that obstruct the growth of appropriate postural control (24). We noticed changes in the angles of the TI, PT, LA, HAASIS, and HAP compared to children who are growing normally (7).

When standing, ambulant CP patients frequently have an anterior imbalance. Erroneous pelvic orientation and hip flexion contractures may also be connected to and contribute to the development of sagittal abnormalities because of anomalous pressures acting on the lumbar spine and pelvis that result in a relationship between TI and PT. Weak hip-extensors, abductors, and abdominal muscles may result in decreased hip extension and PT changes, which may in turn influence the link between LA and PT. Additionally, Suh SW et al. looked at the sagittal spinal alignment on radiographs of children with CP and found important connections between the sagittal spinopelvic properties (25).

The study group (A) that received pelvic control exercises saw a substantial improvement in postural angles after treatment. Angles of TA and LC increased while those of TI, PT, LA, HAASIS, and HAP decreased. We credit the pelvic control exercises, which encompassed pelvic motions in sagittal, coronal, and transverse planes, for this progress. In addition to helping a child establish a posture that promotes postural alignment, range of motion is crucial since pelvic movement is involved in numerous movement patterns, such as walking, sequencing actions, and balance. Decrease in anterior tilting of pelvis by pelvic control exercises like kicking football in front, taking step forward on a low height box improved the pelvic alignment which further increased the TA and LC. These exercises not only improved range of motion but also proximal dynamic pelvic stability, which may have improved intra-limb coordinated synergistic motions involving the hip, knee, and ankle joints. Additionally, it's possible that the selective contraction of the lower trunk and proximal hip muscles reduced the excessive co-contraction and stiffness of the involved lower limb muscles, potentially overcoming the stereotypical movement patterns (12) resulting in decrease of postural angles like PT, LA, HAASIS, HAP. The pelvic position impacts the alignment of the thoracic and cervical spines, which in turn affects the posture of the head and limbs and thus, decreasing TI. Therefore, additional postural angles can be adjusted by regulating the pelvis. Said et al.'s findings, which indicated that pelvic stability training can assist children with spastic CP improve their balance, validated the study group's notable increase in every measuring variable (26). This improvement was further supported by Sharma V et al.'s conclusion that proprioceptive neuromuscular facilitation (PNF), a type of pelvic training exercise, aids in enhancing pelvic control, which is crucial for preserving trunk control, gait, and balance (27).

Improvement has also been seen in the control group (B) where angles of TA and LC have increased while those of TI, PT, LA, HAASIS, and HAP have decreased in a similar pattern as seen in study group. These changes may have been brought about by the therapeutic exercise program's emphasis on a set of activities that help maintain a normal, upright posture. This is in line with the findings of Campbell et al., who found that the conservative methods of treatment for children with CP are centred on helping them meet sequential developmental goals and promoting normal movement patterns so they may learn useful activities (28). A general programme that emphasises postural alignment and movement quality includes particular targets for sitting, standing, and walking.

The two groups' post-treatment results showed a considerable improvement in favour of the study group (A) that had been given pelvic control exercises. This was supported by the findings of Dubey et al., 2018 who came to the conclusion that difficulty moving around and going about everyday activities is caused by improper muscle activation and inadequate movement control around the pelvis. They created an exercise regimen based on neurophysiological and biomechanical components of pelvic stability and discovered that pelvic stability training is advantageous in enhancing the control of the trunk and lower extremities movement, the strength of the hip muscles, the speed of gait, and daily activities in stroke patients (29). Additionally, Kim & Seo, 2015 claimed that the modified trunk-hip strengthening exercise was superior to the conventional exercise for improving trunk-hip activation and reducing anterior pelvic tilt motion when standing in children with spastic diplegia (30). These results align with those of Martín-Valero et al., 2018 who investigated the benefits of hippotherapy in children with spastic diplegic cerebral palsy and concluded that the three-dimensional reciprocal movement of the walking horse produced a rider's normalised pelvic movement, which was

similar to the pelvic movement of people without disabilities when they walk (31).

Following eight weeks of pelvic control training, an improvement in postural angles may be connected to improved motor control in the lower extremities and stronger hip muscles. The proximal dynamic pelvic stability is crucial to meet daily functional needs including transfers, walking on an even floor, and climbing stairs because the pelvis is the lower extremity's functional kinematics during standing and during mobility.

### Limitations

Firstly, future studies are necessary to examine long-term impacts because a long-term follow-up assessment was not conducted. Second, muscle tone of children had been decreased after intervention but spasticity had not been included as outcome measure. Third, sophisticated techniques for assessing postural angles, such as 3-d motion analysis, were not applied. The fact that the study did not assess the strength of the pelvic muscles presents another potential flaw. Future research may show the real effects of pelvic control training using isokinetic strength testing or EMG analysis.

### Conclusion

The results of this study indicate that incorporating pelvic control exercises into a conventional exercise regimen appears to be a popular way to help children with spastic CP improve their posture. For children with spastic diplegic CP, doctors and rehabilitation specialists may choose to incorporate selective pelvic control training into their multimodal treatment plan.

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## APPENDIX

### Pelvic Control Exercises for children with Spastic Diplegic Cerebral Palsy

Total duration: 8 weeks (thrice a week, each session: 30 minutes)

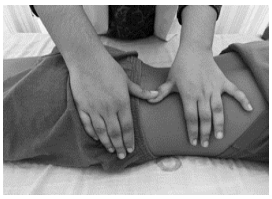
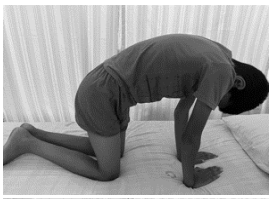
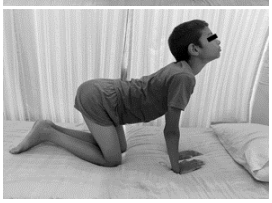
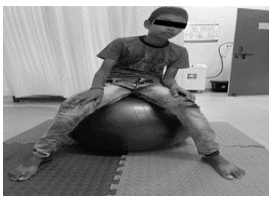
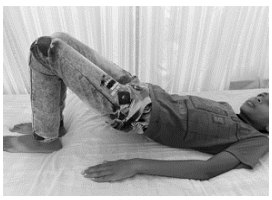
Total sessions: 24

Total phases: 4

Each phase is of 2 weeks duration

### INITIAL PHASE (2 weeks)

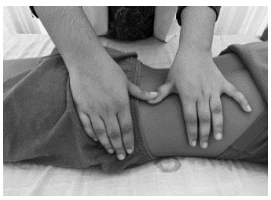
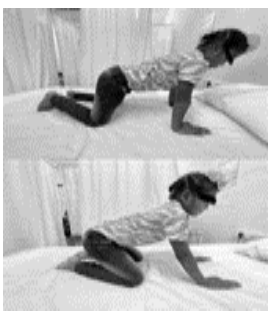
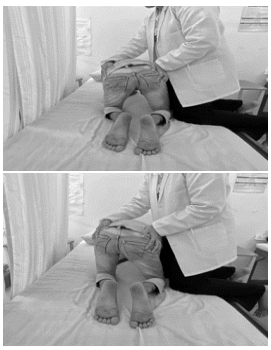
| **1. Pelvic Mobilisation** | |
|---|---|
| **Posterior rotation of the innominate** | **5RepsX2sets** |
| Patient is in side-lying position with the bottom leg extended (to maintain a more neutral lumbar spine) and the top leg flexed. Starting posture for the therapist involves supporting the patient's bent leg while standing in front of their hips. One hand is put on the posterior surface of the ischial tuberosity, while the heel of the other is positioned over the anterior iliac spine. Using both arms at once, push the anterior iliac spine posteriorly and superiorly while pulling the ischial tuberosity down and forward to do the innominate's posterior rotation. |  |
| **Anterior rotation of the innominate** | **5RepsX2sets** |
| Patient is in side-lying with the top leg slightly extended and the bottom leg flexed to 90 degrees (to make the lumbar spine more neutral). Starting posture for the therapist is to stand behind the patient and place one hand on the iliac crest and ASIS of the top leg while placing the heel of the other hand beneath the PSIS and buttocks of the same leg. Application of forces: Using both arms at once, push the PSIS superiorly and posteriorly while pulling the ASIS and iliac crest's anterolateral border forward and down to do the anterior rotation of the innominate. |  |
| **Central oscillatory P/A movement over the sacrum** | **5RepsX2sets** |
| Patient lied in prone position, therapist by standing on the side with the heel of hand perform grade 3 P/A oscillations at S1 (base), S3 (middle), S5 (apex). |  |
| **Unilateral oscillatory P/A movement over the base of the sacrum** | **5RepsX2sets** |
| Patient lied in prone position, therapist by standing on the side with the heel of hand perform grade 3 P/A oscillations at S1 level on each side. |  |
| **P/A movements to the PSIS** | **5RepsX2sets** |
| Patient lied in prone position, therapist by standing on the side with the heel of hand perform Grade 3 P/A oscillations on each PSIS. |  |

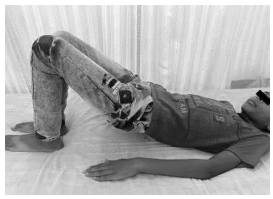
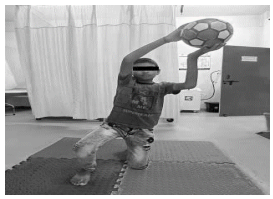
| **Lateral movement of the PSIS** | **5RepsX2sets** |
|---|---|
| Patient lied in prone position, therapist by standing on the side with the both thumbs perform Grade 3 lateral oscillatory translation<br>on PSIS. |  |
| **2. Cat-camel exercise** | **5RepsX2sets** |
| Place the patient in quadruped position. Ask the patient to slump his shoulders down towards the floor, arch his spine like a camel, tuck his tailbone in, and produce a cat-like curve with his spine. |  <br>  |
| **3. Weight shifting on swiss ball** | **5RepsX2sets** |
| Place the patient on the swiss ball in a supported sitting position. Gently rock the ball from side to side and forward to back while supporting their trunk or hips. |  |
| **4. Bridging** | **5RepsX2sets** |
| Place the patient in supine position and ask him to bend his knees and raise his pelvis. |  |
| **5. Diagonal patterns in half kneeling** | **5 left to right X2sets**<br>**5 right to left X2sets** |
| Patient is in half kneeling position and do chopping patterns |  |
| **6. Posterior tilting exercises while kicking football in front** | **5RepsX2sets** |
| The patient stands with his weight on his left leg and moves or kicks a football with his right foot. The only thing he does is kick the ball hard enough to maintain control of the right leg and stop it from pushing into the full extension pattern, whether it's towards a wall or someone else. The therapist facilitates the movement by tilting pelvis posteriorly. |  |

| **7. Posterior tilting exercises while taking step forward on a low height box** | **5RepsX2sets** |
|---|---|
| The patient while standing, steps forward and places his one foot on the small step. He carefully places it on the stair without hurrying or slamming it while the therapist standing beside the patient tilt the patient's pelvis posteriorly. |  |
| **8. Pelvic stabilisation while maintaining hip-knee in 90-90 position** | **5RepsX2sets** |
| The patient is in standing position. While supporting the patient's body with one arm, the therapist stands behind the patient and lifts his foot up while flexing his knee. With the aid of her hands, she supports his lower leg between her knees while allowing his thigh to fall towards the opposite knee while maintaining a level pelvis. She carefully lowers the foot to the floor once she senses that the injured leg is no longer pressing down into extension or pulling up with hip flexion. The patient tries to let his toes rest lightly on the ground behind him rather than forcing his foot downward. |  <br>  |
| **9. Pelvic facilitation during stance phase** | **5RepsX2sets** |
| The patient is in standing position. The therapist places her hands on each side of the patient's pelvis to tilt the pelvis up at the front by placing her thumbs or the ball of her palm over the gluteal muscles to encourage hip extension and prevent knee hyperextension. |  |

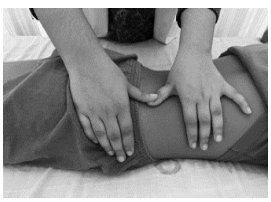
## IMPROVEMENT PHASE (2 WEEKS)

| **1. Pelvic Mobilisation** | |
|---|---|
| **Posterior rotation of the innominate** | **5RepsX2sets** |
| The patient is in side-lying position with the bottom leg extended (to maintain a more neutral lumbar spine) and the top leg flexed. Starting posture for the therapist involves supporting the patient's bent leg while standing in front of their hips. One hand is put on the posterior surface of the ischial tuberosity, while the heel of the other is positioned over the anterior iliac spine. Using both arms at once, push the anterior iliac spine posteriorly and superiorly while pulling the ischial tuberosity down and forward to do the innominate's posterior rotation. |  |
| **Anterior rotation of the innominate** | **5RepsX2sets** |
| Starting posture for the patient is side-lying with the top leg slightly extended and the bottom leg flexed to 90 degrees (to make the lumbar spine more neutral). Starting posture for the therapist is to stand behind the patient and place one hand on the iliac crest and ASIS of the top leg while placing the heel of the other hand beneath the PSIS and buttocks of the same leg. Application of forces: Using both arms at once, push the PSIS superiorly and posteriorly while pulling the ASIS and iliac crest's anterolateral border forward and down to do the anterior rotation of the innominate. |  |

| **Central oscillatory P/A movement over the sacrum** | **5RepsX2sets** |
|---|---|
| Patient lied in prone position, therapist by standing on the side with the heel of hand perform grade 3 P/A oscillations at S1 (base), S3 (middle), S5 (apex). |  |
| **Unilateral oscillatory P/A movement over the base of the sacrum** | **5RepsX2sets** |
| Patient lied in prone position, therapist by standing on the side with the heel of hand perform grade 3 P/A oscillations at S1 level on each side. |  |
| **P/A movements can also be applied to the PSIS** | **5RepsX2sets** |
| Patient lied in prone position, therapist by standing on the side with the heel of hand perform grade 3 P/A oscillations on each PSIS. |  |
| **Lateral movement of the PSIS** | **5RepsX2sets** |
| Patient lied in prone position, therapist by standing on the side with the both thumbs perform Grade 3 lateral oscillatory translation<br>on PSIS. |  |
| **2. Quadruped Rocking** | **5RepsX2sets** |
| The patient is in quadruped position. Ask the patient to place his hands directly under his shoulders, and his knees should be directly under his hips. Rock backward as far as he can without arching his lower back. |  |
| **3. Selective lateral movement of pelvis** | **5RepsX2sets** |
| Patient is in quadruped position and his weight is evenly distributed between the hands and knees. The patient is asked to tilt his pelvis up while the therapist places her hands on either side of it, shortening that side of his trunk. She then facilitates the other side of his pelvis by switching the direction of her hands' motion. |  |

| | |
|---|---|
| **4. Bridging with hold** | **5RepsX2sets** |
| Same as in bridging along with maintenance of position for 5 seconds |  |
| **5. Diagonal pattern with heavy object** | **5 left to right X2sets**<br>**5 right to left X2sets** |
| Patient is in half kneeling position and do chopping patterns while carrying heavy object in hands |  |
| **6. Lateral tilting of pelvis while kicking football sideways** | **5RepsX2sets** |
| The patient is in standing position and moves or kicks a football sideways with his right foot while standing with his weight over the left leg. The only thing he does is kick the ball hard enough to maintain control of the right leg and stop it from pushing into the full extension pattern, whether it's towards a wall or someone else. The therapist facilitates the movement by tilting pelvis laterally. |  |
| **7. Anterior tilting of pelvis while taking step backwards on a low height box** | **5RepsX2sets** |
| While standing, the patient steps backward and places his one foot on the small step. He carefully places it on the stair without hurrying or slamming it while the therapist standing beside the patient tilt the patient's pelvis anteriorly. |  |
| **8. Pelvic stabilisation while maintaining hip-knee in 90-90 position while carrying an object** | **5RepsX2sets** |
| The patient stands with object in his hands. While supporting patient's body with one arm, the therapist stands behind the patient and lifts his foot up while flexing his knee. With the aid of her hands, she supports his lower leg between her knees while allowing his thigh to fall towards the opposite knee while maintaining a level pelvis. She carefully lowers the foot to the floor once she senses that the injured leg is no longer pressing down into extension or pulling up with hip flexion. The patient tries to let his toes rest lightly on the ground behind him rather than forcing his foot downward. |  |
| **9. Pelvic facilitation during swing phase** | **5RepsX2sets** |
| The patient is in standing position and releases his hip and knee while allowing his heel to slide inward or in outward hip rotation in order to get ready to swing. The therapist applies pressure to the pelvis forward and downward along the femur's line as the hip and knee bend. She assists the pelvis rotate forward as the leg swings forward by preventing the patient from hitching up the side of it. |  |

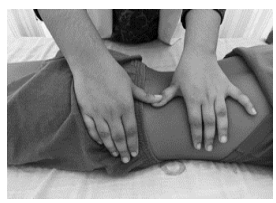
## ADVANCE PHASE (2 WEEKS)

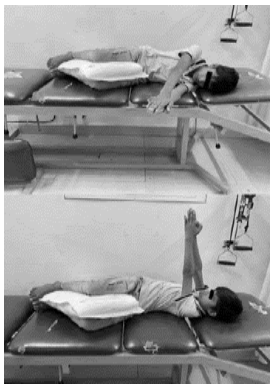
| **1. Pelvic Mobilisation** | |
|---|---|
| **Posterior rotation of the innominate** | **5RepsX2sets** |
| The patient is in side-lying position with the bottom leg extended (to maintain a more neutral lumbar spine) and the top leg flexed. Starting posture for the therapist involves supporting the patient's bent leg while standing in front of their hips. One hand is put on the posterior surface of the ischial tuberosity, while the heel of the other is positioned over the anterior iliac spine. Using both arms at once, push the anterior iliac spine posteriorly and superiorly while pulling the ischial tuberosity down and forward to do the innominate's posterior rotation. |  |
| **Anterior rotation of the innominate** | **5RepsX2sets** |
| The patient is in side-lying position with the top leg slightly extended and the bottom leg flexed to 90 degrees (to make the lumbar spine more neutral). Starting posture for the therapist is to stand behind the patient and place one hand on the iliac crest and ASIS of the top leg while placing the heel of the other hand beneath the PSIS and buttocks of the same leg. Application of forces: Using both arms at once, push the PSIS superiorly and posteriorly while pulling the ASIS and iliac crest's anterolateral border forward and down to do the anterior rotation of the innominate. |  |
| **Central oscillatory P/A movement over the sacrum** | **5RepsX2sets** |
| Patient lied in prone position, therapist by standing on the side with the heel of hand perform grade 3 P/A oscillations at S1 (base), S3 (middle), S5 (apex). |  |
| **Unilateral oscillatory P/A movement over the base of the sacrum** | **5RepsX2sets** |
| Patient lied in prone position, therapist by standing on the side with the heel of hand perform grade 3 P/A oscillations at S1 level on each side. |  |
| **P/A movements can also be applied to the PSIS** | **5RepsX2sets** |
| Patient lied in prone position, therapist by standing on the side with the heel of hand perform grade 3 P/A oscillations on each PSIS. |  |
| **Lateral movement of the PSIS** | **5RepsX2sets** |
| Patient lied in prone position, therapist by standing on the side with the both thumbs perform grade 3 lateral oscillatory translation<br>on PSIS. |  |

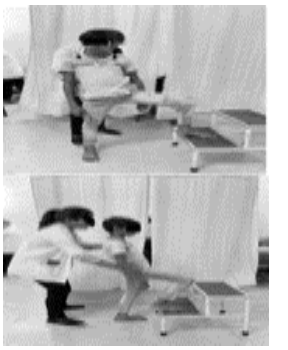
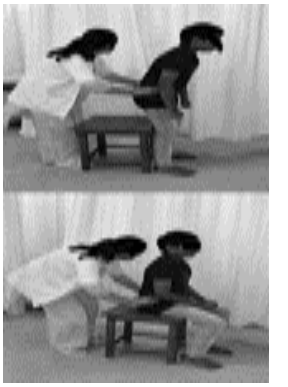
| **2. Isolated flexion-extension of pelvis in sitting** | **5RepsX2sets** |
|---|---|
| The patient is in short sitting position and the therapist places one hand on the patient's lumbar spine while standing or sitting in front of him. She pulls his trunk forward until his hips are sufficiently flexed and it is vertically over his pelvis. |  |
| **3. Weight shifts in kneel standing** | **5RepsX2sets** |
| The patient is in kneel standing position and shifts his weight from one leg to the other in turns. The therapist aids the pelvis' lateral mobility with her hands. |  |
| **4. Bridging with adductor squeeze** | **5RepsX2sets** |
| Same as in bridging. Along with that, squeeze the thighs. |  |
| **5. Diagonal pattern Half kneeling with catch and throw ball** | **5 left to right X2sets**<br>**5 right to left X2sets** |
| In half kneeling position, patient does diagonal chopping patterns while catching and throwing ball |  |
| **6. Forward rotation of pelvis while kicking football crossing midline** | **5RepsX2sets** |
| The patient is standing and moves or kicks a football with his right foot towards left foot while standing with his weight over the left leg. The only thing he does is kick the ball hard enough to maintain control of the right leg and stop it from pushing into the full extension pattern, whether it's towards a wall or someone else. The therapist facilitates the movement by forward rotating the pelvis. |  |

| **7. Lateral tilting of pelvis while taking step sideways on a low height box** | **5RepsX2sets** |
|---|---|
| The patient is standing and steps sideways and places his one foot on the small step. He carefully places it on the stair without hurrying or slamming it while the therapist standing beside the patient tilt the patient's pelvis laterally. |  |
| **8. Pelvic stabilisation while maintaining hip-knee in 90-90 position with reach-outs** | **5RepsX2sets** |
| The patient is standing while doing reach outs in front. While supporting patient's body with one arm, the therapist stands behind the patient and lifts his foot up while flexing his knee. With the aid of her hands, she supports his lower leg between her knees while allowing his thigh to fall towards the opposite knee while maintaining a level pelvis. She carefully lowers the foot to the floor once she senses that the injured leg is no longer pressing down into extension or pulling up with hip flexion. The patient tries to let his toes rest lightly on the ground behind him rather than forcing his foot downward. |  <br>  |
| **9. Pelvic facilitation during stance phase on irregular surface** | **5RepsX2sets** |
| Patient is standing on an irregular surface. The therapist positions her hands on each side of the pelvis for the patient who still needs help extending his hip in order to prevent knee hyperextension. She tilts the pelvis up at the front by placing her thumbs or the ball of her palm over the gluteal muscles to encourage hip extension. |  |
| **10. Pelvic facilitation during swing phase on irregular surface** | **5RepsX2sets** |
| Patient is standing on an irregular surface. The patient releases his hip and knee while allowing his heel to slide inward or in outward hip rotation in order to get ready to swing. The therapist applies pressure to the pelvis forward and downward along the femur's line as the hip and knee bend. She assists the pelvis rotate forward as the leg swings forward by preventing the patient from hitching up the side of it. |  |

## MAINTENANCE PHASE (2 WEEKS)

| **1. Pelvic Mobilisation** | |
|---|---|
| **Posterior rotation of the innominate** | **5RepsX2sets** |
| The patient is in side-lying position with the bottom leg extended (to maintain a more neutral lumbar spine) and the top leg flexed. Starting posture for the therapist involves supporting the patient's bent leg while standing in front of their hips. One hand is put on the posterior surface of the ischial tuberosity, while the heel of the other is positioned over the anterior iliac spine. Using both arms at once, push the anterior iliac spine posteriorly and superiorly while pulling the ischial tuberosity down and forward to do the innominate's posterior rotation. |  |
| **Anterior rotation of the innominate** | **5RepsX2sets** |
| The patient is in side-lying position with the top leg slightly extended and the bottom leg flexed to 90 degrees (to make the lumbar spine more neutral). Starting posture for the therapist is to stand behind the patient and place one hand on the iliac crest and ASIS of the top leg while placing the heel of the other hand beneath the PSIS and buttocks of the same leg. Application of forces: Using both arms at once, push the PSIS superiorly and posteriorly while pulling the ASIS and iliac crest's anterolateral border forward and down to do the anterior rotation of the innominate. |  |
| **Central oscillatory P/A movement over the sacrum** | **5RepsX2sets** |
| Patient lied in prone position, therapist by standing on the side with the heel of hand perform grade 3 P/A oscillations at S1 (base), S3 (middle), S5 (apex). |  |
| **Unilateral oscillatory P/A movement over the base of the sacrum** | **5RepsX2sets** |
| Patient lied in prone position, therapist by standing on the side with the heel of hand perform grade 3 P/A oscillations at S1 level on each side. |  |
| **P/A movements can also be applied to the PSIS** | **5RepsX2sets** |
| Patient lied in prone position, therapist by standing on the side with the heel of hand perform grade 3 P/A oscillations on each PSIS. |  |
| **Lateral movement of the PSIS** | **5RepsX2sets** |
| Patient lied in prone position, therapist by standing on the side with the both thumbs perform grade 3 lateral oscillatory translation on PSIS. |  |

| **2. Pelvic tilting with knees bent** | **5RepsX2sets** |
|---|---|
| The patient is flexing both knees while standing with his feet apart. While keeping his upper body, shoulders, and head stationary, he rhythmically tilts his pelvis anteriorly and posteriorly. The therapist helps him through the exercise with her hands and several verbal cues until he succeeds. He bends his lumbar spine and she places her hand under his buttocks, tightening the gluteal group as if he were tucking in his tail. His lower abdominal muscles are helped to contract by her other hand. She gives him the impression that his lower abdominals are stretching and his buttocks are being raised at the rear when he is extending his lumbar spine |   |
| **3. Weight shifts in standing** | **5RepsX2sets** |
| The patient while standing rotates his body as if he were skiing, shifting his weight from one side to the other while standing up straight with his hips and knees slightly bent. His relaxed arms are at his sides. With her hands on either side of his pelvis, the therapist helps him move by maintaining his supporting hip forward while also facilitating his body's rotation. |  |
| **4. Bridging with one leg straight** | **5RepsX2sets** |
| Same as in bridging. Along with that, patient keep his one leg straight. |  |
| **5. Rotate upper body away from lower body** | **5RepsX2sets** |
| Ask the patient to twist their upper body and pelvis in the opposite directions while holding a block between their legs. |  |

| **6. Pelvic facilitation while kicking football in all directions** | **5RepsX2sets** |
|---|---|
| The patient uses his foot to kick a football in various directions with enough force to maintain control of his leg and keep it from pushing into the full extension pattern, whether it is up against a wall or towards another person. The therapist facilitates the pelvic movement. |  |
| **7. Pelvic facilitation while taking step in all directions on different height of boxes** | **5RepsX2sets** |
| The patient carefully places his foot on different height steps placed in different directions without hurrying or slamming the foot while the therapist standing beside the patient facilitate the pelvis accordingly. |  |
| **8. Pelvic stabilisation while maintaining hip-knee in 90-90 position with reach-outs in different directions** | **5RepsX2sets** |
| The patient is in standing position.<br>While supporting patient's body with one arm, the therapist stands behind the patient and lifts his foot up while flexing his knee. With the aid of her hands, she supports his lower leg between her knees while allowing his thigh to fall towards the opposite knee while maintaining a level pelvis. She carefully lowers the foot to the floor once she senses that the injured leg is no longer pressing down into extension or pulling up with hip flexion. The patient tries to let his toes rest lightly on the ground behind him rather than forcing his foot downward. While maintaining this position, patient do reach outs in different directions. |  |
| **9. Pelvic facilitation during sit to stand.** | **5RepsX2sets** |
| The therapist facilitates the pelvis from posterior to anterior while patient do sit to stand. |  |