Impact of sensory perceptual motor core stability training on sitting control in children with cerebral palsy

Impacto do treinamento de estabilidade do núcleo motor perceptual sensorial no controle ao sentar-se em crianças com paralisia cerebral

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Abstract

Introduction: The ability to sit independently is essential for children, serving as a foundation for reaching and for daily activities. For children with cerebral palsy, especially bilateral spastic cerebral palsy (BSCP), this skill is often unattainable because of impaired neuromuscular control. **Objective:** We aimed to report the protocol for a randomized controlled trial of the novel Sensory Perceptual-Motor Core Stability Exercise Program (SPMCSEP) in improving sitting control in children with BSCP. **Methods:** This is a double-blinded, randomized, controlled trial. Seventy-two children with cerebral palsy (Gross Motor Function Classification Scale – ER III - IV) aged between 3 and 7 years will be recruited and randomly allocated to SPMCSEP and conventional therapy groups. Independent sitting will be evaluated at baseline, 6 weeks, and 8 weeks for all children using the Trunk Control Measurement Scale. **Conclusion:** This study explains the background, hypotheses, rationale, and methodology of the SPMCSEP protocol for children with BSCP, and will adhere to Consolidated Standards of Reporting Trials and Standard Protocol Items Recommendations for Interventional Trials guidelines for reporting. The proposed SPMCSEP represents a novel approach for addressing impaired sitting control in children with BSCP.

Keywords: Cerebral palsy. Sitting. Posture. Core stability. Psychomotor performance.

Resumo

Introdução: *A capacidade de sentar-se de forma independente é essencial para as crianças, servindo como base para alcançar e para atividades diárias. Para crianças com paralisia cerebral, especialmente paralisia cerebral espástica bilateral (BSCP), essa habilidade é frequentemente inatingível devido ao controle neuromuscular prejudicado.* ***Objetivo:*** *Relatar o protocolo para um ensaio clínico randomizado controlado do novo Programa de Exercícios de Estabilidade do Núcleo Sensorial Perceptual-Motor (SPMCSEP) para melhorar o controle postural sentado em crianças com BSCP.* ***Métodos:*** *Trata-se de um ensaio clínico duplo-cego, randomizado e controlado. Setenta e duas crianças com paralisia cerebral (Escala de Classificação da Função Motora Grossa – ER III - IV), com idade entre 3 e 7 anos, serão recrutadas e alocadas aleatoriamente em SPMCSEP e grupos de terapia convencional. A posição sentada independente será avaliada no início do estudo, 6 semanas e 8 semanas para todas as crianças usando a Escala de Medição do Controle do Tronco.* ***Conclusão:*** *Este estudo explica o contexto, hipóteses, fundamentos e metodologia do protocolo SPMCSEP para crianças com BSCP, e irá aderir às diretrizes do* Consolidated Standards of Reporting Trials e Standard Protocol Items Recommendations for Interventional Trials *para relatórios. O SPMCSEP proposto representa uma nova abordagem para lidar com o controle postural sentado prejudicado em crianças com BSCP.*

Palavras-chave: *Paralisia cerebral. Sentar. Postura. Estabilidade do core. Desempenho psicomotor.*

Introduction

Cerebral palsy (CP) denotes a group of enduring impairments affecting the development of mobility and posture.[1] Evidence indicates a global prevalence of CP between 1.5 and 4 per 1000 live births; however, in India, the reported prevalence is greater, varying between 2.08 to 3.88 per 1000 live births, with bilateral spastic CP (BSCP) identified as the most prominent form.[2,3]

CP is generally diagnosed by assessing the motor abilities and postural abnormalities that appear in early childhood and persist throughout an individuals lifetime.[4] The capacity to sit upright is a basic prerequisite for participating in daily activities, and it is the first kind of upright posture acquired throughout an individual's normal developmental period.[4,5] Children with BSCP, Gross Motor Function Classification Scale – Extended Revised (GMFCS-ER) III–IV,[4-6] have poor independent sitting control because of postural, proprioceptive, somatosensory, perceptual motor dysfunctions, weak trunk muscles, altered neural control, and insufficient trunk core stability.[7-11] This reduces the child's total activity, such as playing, feeding, and toileting, which affects other developmental milestones, and increases caregiver overload.[10,11] Although conventional therapies are beneficial, there is growing interest in innovative strategies for addressing the complexities of BSCP.[12,13]

The Sensory Perceptual Motor Core Stability Exercise Program (SPMCSEP) is developed to address the complex interactions between sensory, perceptual, and motor challenges in individuals with BSCP, with the goal of improving independent sitting. Although sensory, perceptual-motor interventions and core stabilisation training have been explored separately to address the movement and postural control dysfunction in BSCP,[13-17] the effectiveness of a comprehensive approach that integrates these components remains understudied in BSCP.[18]

This intervention is planned to combine activities that focus on sensory processing, perceptual skills, and core muscle strengthening. By combining sensory stimulation, perceptual training, and core strengthening exercises, the SPMCSEP intends to enhance trunk stability, balance, and coordination, which are critical for achieving independent sitting. We established this comprehensive approach based on the understanding that optimal motor development requires the harmonious integration of multiple sensory systems and motor functions, as established in various motor control and learning theories.[19,20]

Theoretical perspective

Postural control is the ability to maintain body alignment and body's position upright in space to attain stability and orientation. Sensory information from the visual, vestibular, and sensorimotor systems must be integrated with motor output in order to accomplish the objectives of stability and orientation.[20-24]

According to motor program theory, neural group selection theory, and systems control theory, postural control is a complex interplay between 7 elements: motor synergies, neural representations, adaptive pro-processesing anticipatory techniques, sensory tactics, individual sensory systems, and musculoskeletal components.[7,14,15,19-24]

Initial brain damage leads to impairments in postural networks, tone, aberrant timing, lower amplitude of muscle recruitment, decreased isometric force output, affecting motor networks which cause postural control dysfunction.[1,2,9,14,15] Deficits in visual, tactile, proprioceptive, and vestibular systems all have an impact on perceptual and sensory networks. Children with BSCP may struggle to maintain sitting balance due to these deficits, which can occur individually or together.[9,10,14,15,25]

Children with GMFCS-ER Level III-IV CP have vulnerable trunk control,[5,6,26] which makes it difficult for them to fine-tune their basic direction-specific adjustments to environmental conditions and adapt their postural muscular activity. These adjustments are based on previous experience and sensory data from the somatosensory, visual, and vestibular systems.[9,10,14-16,20-26] Lack of learning these adjustments contributes further to postural instability in sitting.

Postural stability in sitting is the ability to manage the body's center of mass within a stable foundation, which requires enough core muscle strength, power, and stamina. Developing appropriate core strength of muscles, power, and stamina is critical for maintaining spinal stability, which is necessary for avoiding falls, controlling desired movements, and producing useful movement. The ability of the body's core to sustain its posture and movement is known as core stability.[9,10,15,21,22] Children with BSCP have a reduced capacity for force production, which leads to weaker core muscle strength, a diminished awareness of their body's position, and difficulties in evenly distributing their body weight during weight transfer and static positions,[5,6,9,14,15,18,19] making harder for the muscles responsible for stabilizing the trunk, pelvis, and hips to coordinate.[15,21-26] This results in a decline of child's functional abilities and a lower level of gross motor skills like independent sitting control.[5,6] Thus, postural control, which encompasses trunk control, is essential for achieving independent sitting.[9,10,14,15,19,21] A strong and stable trunk provides the foundation for maintaining balance and executing controlled movements.[9,10,15] By targeting trunk control, through the use of core stabilization exercises integrating with sensory and perceptual feedback techniques, the SPMCSEP aims to improve overall postural control and, therefore, enhance independent sitting control in children with BSCP.

Scope of the study

BSCP is a condition that places a huge challenge on patients, their families, and the public healthcare system. While providing care for a young child is a typical aspect of being a parent, when a child experiences functional limitations and possibly long-term dependence, this role assumes a completely different significance.[4,5,10] A child's ability to sit independently is essential to their development because it promotes socialization, engagement in everyday activities, development of motor skills, and to participate in activities that are appropriate for their age.[4,5,17] This study aims to investigate the impact of a SPMCSEP on independent sitting control in children with BSCP, with the hypothesis that the SPMCSEP intervention will lead to significant improvements in sitting control among children diagnosed with BSCP. The research will focus on children with BSCP, classified as GMFCS-ER levels III and IV.

The findings of this study have significant clinical implications for the rehabilitation of children with BSCP. The SPMCSEP, with its emphasis on sensory, perceptual, and motor training, offers a promising approach to enhance posture control and independent sitting in this population. This intervention can be integrated into comprehensive rehabilitation programs by addressing the underlying impairments that contribute to sitting difficulties, such as weak trunk muscles, poor postural control, and sensory processing deficits, in helping the children achieve greater independence and participation in daily activities.

Methods

This is a prospective, parallel group, double-blind, randomized clinical experiment having two arms that are allocated evenly. This prospective community study will be undertaken in Puducherry, India. The population of focus consists of children with BSCP diagnosed in the community. The study is prospectively filed with the Clinical Trial Registry of India (CTRI/2022/10/046279).

Participants and recruitment

We intend to recruit 72 children with BSCP between the ages 3 to 7 years old who have been identified in the community and from Puducherry's special schools and are registered at the District Intervention Centre, National Health Mission, Government of Puducherry. To be included in the study, all children must have adequate intellectual capacity to complete the exercise tasks and meet the inclusion requirements, as well as have parental approval.

Inclusion criteria: Children with BSCP aged 3 to 7 years with the ability to follow verbal instructions without cognitive impairment and classified by GMFCS-ER levels III and IV. Exclusion criteria: Visual, hearing impairments, skeletal impairements and cardiac abnormalities or any impairments that would hinder the implementation of the study intervention; history of orthopedic procedures or Botox injections within the previous four months; other forms of CP and spastic hemiplegic type of CP.

Sample size

The sample size is calculated using the formula for comparing two independent means. The planned study sample size was estimated using a power computation utilizing an existing study by Elanchezhian and SwarnaKumari,[27] which used a minimum expected clinical significant variation in the Trunk Control Measurement Scale (TCMS) score between both groups of 10 with a standard deviation (SD) of 15 at a five percent margin of significance and a power estimate of 80%, and accounting for a 10% dropout rate. The formula yielded an estimated sample size of 72 (36 in each group).

Randomization and allocation

Demographic information of the recruited children with BSCP and their mothers will be obtained and after obtaining informed consent, participants will then be randomly allocated to the SPMCSEP group or the conventional therapy group. Block randomization adopting a computer-generated sequence blinded from the primary investigator and allocator will be done before the study by an independent research staff to ensure equal distribution of participants in each group. Allocation to SPMCSEP group or conventional therapy group will be recorded on paper, folded, and placed in opaque sealed envelopes by an impartial staff member not connected with the study. Participants will then be assigned to their respective intervention groups by opening sealed envelopes containing their assignments.

Therapists assessing outcomes and parents of cerebral palsied children will be blinded to group allocation. If a child cannot undergo the intervention for more than four weeks because of an unrelated adverse event, unmasking will be done and will be recorded and reported. Participant retention will be promoted through consistent contact, counselling to parents, addressing their queries, and by coordinating assessment and intervention sessions as per their needs and convenience.

Data management

The principal investigator will preserve password protected information of the patient's specific identification, block and group allocation documentation. Printed copies relating to evaluation, consent form, results, and any other documents pertaining to the study shall be identified and physically stored in a locked storage. Demographic information regarding participant's age, gender, height, weight, gestational age of mothers will be collected by interviewing the mother and from the case records. The assessment of sitting control will be done quantitatively by evaluation through the TCMS. The outcome measure will be assessed for baseline characteristics and at the end of 6 weeks to prevent attrition bias and to improve the design strength, and at 8 weeks of the intervention.

Intervention

The intervention will be as per Standard Protocol Items Recommendations for Interventional Trials (SPIRIT) guidelines (Table 1).[28,29] Participants in the SPMCSEP group will get both SPMCSEP and conventional therapy. Conventional group participants will receive conventional therapy in the existing treatment setting, which includes range of mobility exercise, strengthening exercises, gentle stretching, functional exercise, along with coordination exercises.

SPMCSEP (Appendix 1) is a series of specialized and customised facilitating exercises guided on the principle of various motor learning theories,[19,20] targeting the core muscles of the trunk and performed on an exercise ball, bolster, or other textured surface and manipulating the treatment surface with appropriate rest intervals in between. The program aims to foster the development of perceptual-motor skills.[21-24,30-32]

The program is designed to improve the interaction of the child with their surroundings by providing tasks, props, cues and through background manipulation.[30-32] To target the core muscles, the child will receive task oriented trunk activities training in the sagittal and trans-verse plane while sitting and lying.[21,22] By ensuring optimal pelvic alignment for weight transfers at the hips and trunk elongation, child will be prepared to cope with the demands of various functional tasks.[31,32] Through subtle cues or facilitation, the child will be further challenged for transverse plane task-oriented activities through tactile, vestibular, proprioceptive, and visual-spatial orientation. They will be guided to focus on specific proprioceptive, tactile, and pressure information to accomplish the task and avoid dependent on the therapist's full physical assistance.[16–25,30-33]

Table 1 - Study timetable based on the SPIRIT diagram[29]

Time periods	Enrolment	Allocation	Post allocation			Close-out
Timepoint	$-t_0$	0	Baseline	6 weeks	8 weeks	t_x
Enrolment						
Eligibility screen	X					
Informed consent	X					
Demographics	X					
GMFCS-ER Classification	X					
Allocation		X				
Interventions						
SPMCSEP			←———	———	———→	
Conventional Therapy			←———	———	———→	
Assessments						
TCMS			X	X	X	

Note: SPIRIT = Standard Protocol Items: Recommendations for Interventional Trials; GMFCS-ER = Gross Motor Function Classification Scale – Extended Revised; SPMCSEP = Sensory Perceptual-Motor Core Stability Exercise Program; TCMS = Trunk control measurement scale.

Therapeutic tools and equipment employed for SPMCSEP

Sensory equipment

- Weighted blankets: To provide deep pressure input and improve body awareness.
- Sensory brushes: For tactile stimulation and sensory integration.
- Therapeutic exercise balls.
- Peanut balls.
- Bolsters.
- Foam mat.

Motor and core stability equipment

- Balance boards: To challenge balance and coordination.
- Small equipment: Cones, markers, and bean bags for dynamic activities and games.
- Small balls.

Perceptual equipment

- Mirrors: To enhance body awareness and visual. feedback.
- Soft toys.

Intervention components

Each SPMCSEP session begins with conventional therapy comprising of range of motion exercise, strength training, and passive stretching to prepare the muscles and joints.

- Core stability exercises: supine and prone weight shifts, rolling, pelvic bridging, and trunk rotations.
- Perceptual skills exercises: Peg board activities, puzzles, obstacle crossing, and mirror play.
- Sensory integration: Tactile stimulation, vestibular input through swings, and proprioceptive input through weighted blankets.
- Visual tracking activities.
- Bilateral motor coordination activities.

- Tactile stimulation and therapist handling guidance through subtle cues, light facilitation, and environmental manipulation to promote independent movement initiation.
- Each exercise will be performed with appropriate rest intervals to prevent fatigue.
- Progression: The intensity, duration, and complexity of exercises will be gradually increased based on the child's progress and tolerance.
- Feedback: The therapist will provide verbal and tactile feedback to guide the child's movements and promote learning.

Each one-hour SPMCSEP session will begin with a 10-minute conventional therapy comprising of range of motion exercise, strength training, and passive stretching, followed by a structured progression of core stability, perceptual skills, and sensory integration activities, each component lasting approximately 15 minutes, with exercises performed in sets of 8-10 repetitions, gradually increasing in complexity and intensity based on the child's demonstrated motor learning, ensuring active engagement and promoting independent skill acquisition.

The exercise sequence and progression will be adjusted based on the child's performance and feedback, ensuring that the intervention remains challenging yet achievable throughout the eight-week period, maximizing skill acquisition and functional improvement. The major goal of the intervention is to assist the child in using external and internal forces to solve tasks and select their independent movement plan by initiating action on their own, using their core muscles. Each exercise session will be for one hour, three times per week for successive 8 weeks. The conventional therapy given to the conventional group as per their treatment setting is also for one hour, three times per week for successive 8 weeks.

Outcome measure

The two components of the TCMS scale are dynamic sitting balance and static sitting balance. Dynamic reaching and selective movement control are the two subscales that make up the second component. The subscales have three, seven, and five items each, while the overall scale has fifteen items.

An ordinal scale is used to score each item. A higher score indicates greater performance on the TCMS, which has a total score ranging from 0 to 58. TCMS has a minimal detectable change (4.8 points), intraclass correlation coefficient for intra-rater reliability = 0.985, inter-rater reliability = 0.997, and internal consistency ($\alpha = 0.945$).[34]

Statistical methods

The statistical analysis will be performed on an intention-to-treat method using Statistical Package for the Social Sciences and presented in accordance with CONSORT (Consolidated Standards of Reporting Trials) statement (Figure 1).[35]

Descriptive statistics (frequencies, means, SD and 95% confidence interval) will be utilzed to analyze the sample at the baseline, sixth, and eighth weeks. If data are skewed, medians and interquartile ranges will be reported. The Kolmogorov-Smirnov test will be utilized for determining variable homogeneity, and related parametric or non-parametric statistical tests will be employed for inter-group and intra-group analyses of TCMS measures at baseline, 6th week, and 8th week, depending on the normality test. Missing data arising from incomplete observations and dropouts will be addressed at the analysis stage as per protocol analysis.

Ethical considerations

The current study will follow the principles outlined in the Declaration of Helsinki as well as the Indian Council for Medical Research's Regulating Norms and Guidelines for Human Subject Research. The study obtained permission from the institution's ethical committee (ECR/677/Inst/PY/2014/RR-17).

Participating parents/legal guardians will receive a detailed explanation of the study process, after which written informed consent will be collected. Parents who voluntarily participate in the study may withdraw their child at any time, but their data will be utilized in the ultimate evaluation. If they decide to withdraw, steps will be taken to assist the child in finding therapy options that match their preferences. The reasons for their withdrawal will be recorded and any modifications to the study protocol will be communicated to the ethics committee.

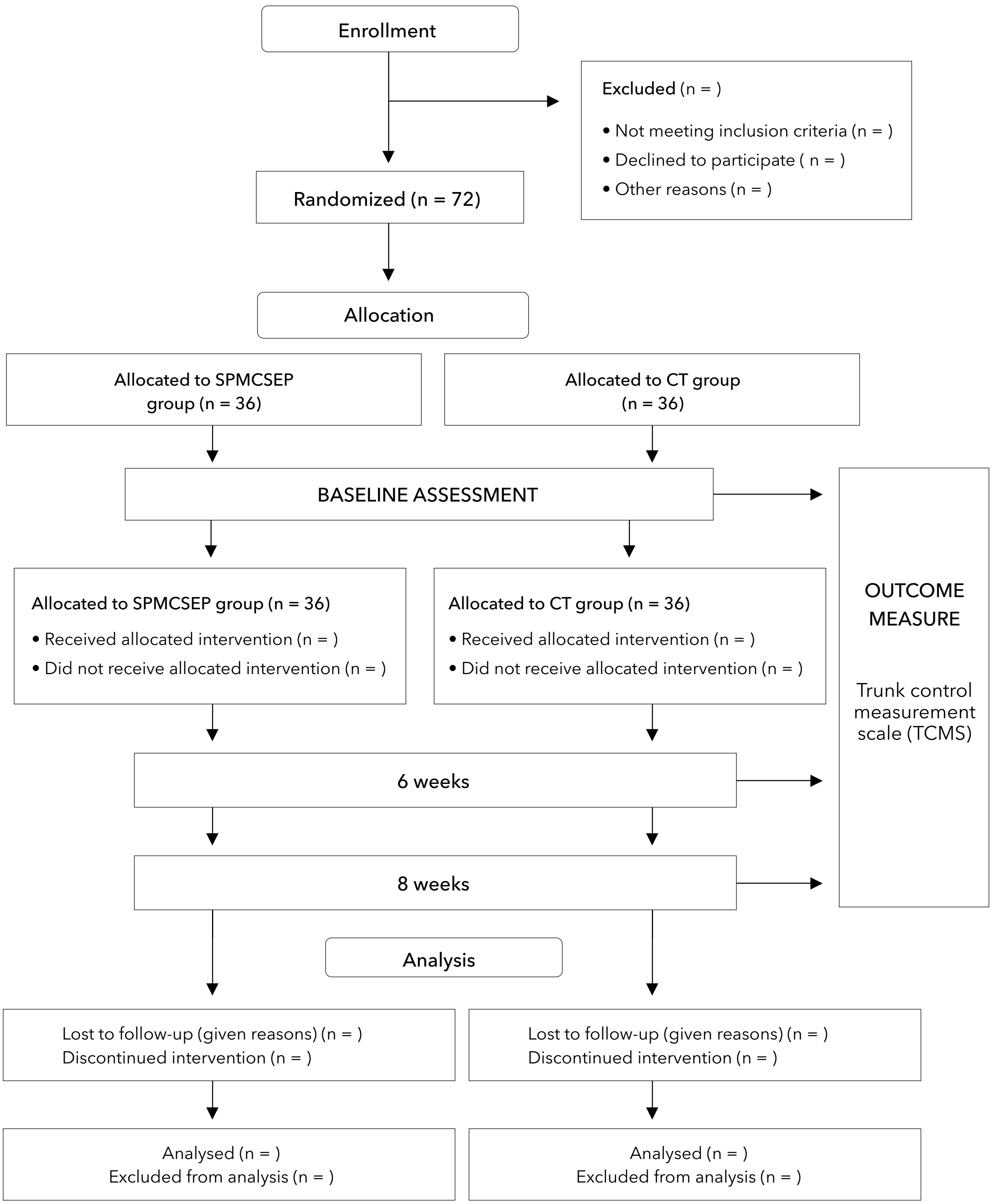

Figure 1 - Study flow chart according to Consolidated Standards of Reporting Trials (CONSORT) – Guidelines for reporting of trial.[35]

Note: SPMCSEP = Sensory Perceptual-Motor Core Stability Exercise Program; CT = conventional therapy.

Discussion

This protocol paper describes the background and study design for a randomized controlled trial to determine the effectiveness of an SPMCSEP for children with BSCP. This program had not before been investigated in this demographic population. The dissemination of the results, if found to be effective, would assist children with BSCP and complement their ongoing therapy through the International Classification of functioning, Disability and Health (ICF) introduced concept of participation.

The SPMCSEP represents a novel approach to addressing core stability and sitting control in children with BSCP. This intervention integrates sensory and perceptual elements with motor activities, targeting specific core muscles essential for postural control and functional movement, promoting an individually customised exercise program designed for BSCP to improve their sitting skill control.[21-24,30-32] Targeting the particular skill of sitting, through home program intervention and sensory-perceptual-motor intervention can both lead to notable improvements in sitting behavior and make it easier for motor development to proceed.[4,6,10,36]

Addressing the ability of sitting at a time when a child demonstrates preparedness for learning at that level and offering additional perceptual-motor training for a short-term intervention may produce excellent motor training adaptive control during sitting.[21-24,30-40] This dedication of resources and time could encourage appropriate motor acquisition and adaptive control in sitting while also relieving stresses from the environment for both the child and their parents.

Conclusion

Infants progress from early head and trunk control to independent sitting by integrating sensory inputs and building core strength and stability over time. Sensory-perceptual-motor, child-centered intervention offers additional versatility and adaptability of the skill, which could translate towards ease of continued motor development. Understanding the typical developmental trajectory of sitting control provides an essential context for assessing deviations and impairments in children with CP.

We anticipate that these adjustments will influence each child's developmental trajectory, improving functional ability, activity, and involvement in the short, mid, and long term, as well as decreasing environmental stressors for both the child and their parents. By investigating the impact of sensory perceptual motor core stability training on sitting abilities, we seek to contribute valuable insights to the field of pediatric physiotherapy and enhance the care and support available to individuals affected by CP in India and beyond.

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Authors' contributions

RS was involved in the writing of the article. RS and MN contributed to the conceptualisation of the topic, methodology of the study, developed and designed the intervention program, read and approved the final version of the manuscript.

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Appendix 1 - Sample SPMCSEP protocol

Component	Mode of activation	Sample exercise activities
Sensory integration Activities that stimulate the senses, including proprioception, vestibular input, and visual-motor integration activities	Sensory integration: This targets the somatosensory system, enhancing tactile discrimination and proprioceptive awareness. Different textures provide varied sensory input, crucial for sensory integration, which is often impaired in children with CP.	Children will be positioned on surfaces with varying textures (e.g., carpet, foam, bumpy mats, soft blankets) making the child hold different textured objects (e.g., rough blocks, smooth balls, soft fabrics).
	Weighted blankets provide deep pressure stimulation, enhancing proprioceptive input and body awareness. Deep pressure can have a calming effect, reducing hypertonicity and improving focus.	Children will be encouraged to sit on stable and unstable surfaces (e.g., therapy balls, mats) while wrapped in weighted blankets.
	Vestibular stimulation: Swinging provides vestibular input, which is essential for balance and spatial orientation. Dynamic trunk control: Maintaining balance on a moving surface challenges dynamic trunk control and postural adjustments. Motor planning: Reaching for objects while swinging improves motor planning and coordination.	Children will be engaged in various activities while seated or prone lying in a suspended swing (e.g., gentle swinging, reaching for objects, maintaining balance). The speed and direction of the swing will be varied as a progression.
	Dynamic stability: Therapy balls challenge dynamic stability and core muscle activation. Weight shifting: Activities promote weight shifting and trunk control, essential for sitting balance. **Core strengthening:** The unstable surface requires increased core muscle activation, improving strength and stability.	Children will be encouraged to sit, lie in prone and supine, or perform exercises on therapy balls of varying sizes. Activities include weight shifting, rolling, and maintaining upright posture in sitting.
	Visual feedback: Mirror play provides visual feedback, enhancing body awareness and motor learning. Motor control: Observing their movements helps children refine motor control and improve posture. **Spatial awareness:** Mirror play improves spatial awareness and understanding of body position in space.	Children will be engaged in activities in a swing while observing themselves in a mirror. They will be encouraged to perform movements, reach for objects, and maintain posture while observing their reflection.
Visual tracking activities Bilateral motor co-ordination and motor planning mirror activities	Visual-motor integration: This activity enhances visual tracking skills, which are crucial for coordinating eye movements with motor actions.	Children will be encouraged to follow moving objects with their eyes, such as a brightly coloured ball, a laser pointer, or a toy moving across a table.
	Oculomotor control: It improves oculomotor control, which is essential for maintaining stable gaze and focusing on moving objects.	The speed and direction of the movement will be varied as progression and the child's ability.
	Attention and focus: Visual tracking requires sustained attention and focus, which can be beneficial for children with attention deficits.	The activity will be performed in different planes (horizontal, vertical, diagonal).
	Bilateral coordination: This activity improves the coordination of both sides of the body, which is often impaired in children with CP. **Motor planning:** It enhances motor planning skills, which are essential for sequencing movements and executing complex motor tasks. Visual feedback: The mirror provides visual feedback, which helps children refine their movements and improve motor control.	Children will be encouraged to perform bilateral motor coordination tasks while observing their movements in a mirror. Examples include clapping hands, or performing symmetrical arm movements in sitting and lying based on their ability. Motor planning will be incorporated by asking children to perform sequences of movements or create patterns.

Note: SPMCSEP = Sensory Perceptual-Motor Core Stability Exercise Program; CP = cerebral palsy.

Component	Mode of activation	Sample exercise activities
Visual tracking activities Bilateral motor co-ordination and motor planning mirror activities	**Body awareness:** This activity enhances body awareness and proprioceptive input, which are crucial for understanding body position and movement. **Visual-proprioceptive integration:** The mirror provides visual feedback, which helps children integrate visual and proprioceptive information.	Children will be encouraged to look in a mirror and will be asked to touch different body parts as the therapists demonstrate on their body The therapist may also progress by encouraging them to perform specific movements with different body parts while looking in the mirror.
	Visual attention: This activity enhances visual attention and focus in a low-stimulus environment. **Visual tracking:** It improves visual tracking skills and the ability to follow moving objects in a challenging setting. **Sensory integration:** The darkened room reduces visual distractions, allowing children to focus on the visual stimuli and enhance sensory processing.	Children will be encouraged to follow the movements of illuminated toys or light sources in a darkened room. The speed, direction, and pattern of the light movements are varied based on their ability.
Tactile stimulation and facilitation Facilitating sensory information and improving postural control through therapist handling and touch	**This involves** the therapist using specific handling techniques and touch to provide sensory input and facilitate postural control. This can include gentle touch, deep pressure, and movement facilitation. The therapist adjusts their handling based on the child's needs and responses.	Play activities will be used to incorporate tactile stimulation and therapist handling in a fun and engaging way. Examples include playing with textured toys, using play dough, or engaging in sensory play. The therapist adjusts the play activities to target specific sensory and motor goals.
	Neuromuscular facilitation: Therapist handling can facilitate neuromuscular responses and improve motor control.	E.g.: When a child could prop sit but struggled to free both hands for play due to poor sitting control, the therapist will provide steady, light touch at the shoulders or trunk.
	Proprioceptive input: Touch and movement provide proprioceptive input, which is essential for postural control. **Sensory integration:** Therapist handling integrates tactile and proprioceptive input, which can improve sensory processing. **Facilitated movement**: The light touch provided sensory input and facilitated trunk control, enabling the child to explore new movement strategies.	This is aimed to encourage the child to explore strategies for lifting the upper trunk over the pelvis or shifting pressure, allowing one hand to be free for reaching. Elevated targeted tasks will be used to promote spinal extension and dynamic stabilization in sagittal and transverse planes. Reaching in various directions while propping with one hand or arm will also be encouraged.
	Weight shifting and balance: Encouraging weight shifting and pressure redistribution improved balance and trunk stability. **Functional reaching:** Promoting reaching while propping with one hand enhanced functional reaching skills and upper limb control. **Trunk extension and stabilization:** The elevated targeted tasks promoted trunk extension and dynamic stabilization, which are crucial for sitting control.	
Perceptual skills Program includes exercises that target these skills, enhancing the child's ability to interpret sensory information, focusing on developing spatial awareness, body schema, and motor planning	**Motor planning and sequencing:** Serial activities require planning and sequencing of movements, improving motor planning skills.	Children will be engaged in serial activities like peg board tasks, constructional tasks, puzzles, and block designs.
	Visual-motor integration: These activities integrate visual perception with motor actions, enhancing visual-motor coordination. **Cognitive skills:** Problem-solving and spatial reasoning are involved, improving cognitive skills alongside motor skills. **Postural control integration:** Performing these tasks on unstable surfaces challenges postural control and integrates it with fine motor skills.	These activities will be performed while seated on different surfaces (e.g., stable chairs, therapy balls, foam mats) to challenge postural control. The complexity of the tasks will be gradually increased based on the child's progress.

Component	Mode of activation	Sample exercise activities
Perceptual skills Program includes exercises that target these skills, enhancing the child's ability to interpret sensory information, focusing on developing spatial awareness, body schema, and motor planning	**Motor planning and problem solving:** Navigating obstacles requires motor planning, problem-solving, and adaptation of movement strategies. **Spatial awareness and body schema:** Creeping through obstacles enhances spatial awareness and body schema. **Gross motor coordination:** This activity improves gross motor coordination and dynamic stability.	Children will be encouraged to navigate obstacles in a creeping position. The child will be allowed and motivated to initiate and problem-solve their movements, with minimal therapist intervention. The obstacles will be varied in height, width, and texture, providing diverse sensory and motor challenges based on the child's ability.
	Child-initiated learning: Encouraging child-initiated movements promotes active learning and problem-solving. **Anticipatory postural control:** This activity targets anticipatory postural adjustments, which are crucial for maintaining balance and preventing falls. **Problem-solving and adaptation:** Children learn to solve motor problems and adapt their movements to different task demands. **Base of support modification:** They learn to modify their base of support to maintain stability and control their center of mass. **Independent learning:** Minimal therapist intervention promotes independent learning and development.	The child will be encouraged and cued or lightly facilitated and guided to solve problem by giving different tasks in sitting and allowing the child to learn how to modify his or her base of support under their center of mass for anticipatory postural adjustments. E.g., children are presented with various tasks while sitting, requiring them to modify their base of support and make anticipatory postural adjustments. The therapist provides minimal cues or light facilitation, encouraging the child to problem-solve and develop independent strategies. Tasks can include reaching for objects at different distances, shifting weight, or maintaining balance on unstable surfaces.
Core stability This component focuses on strengthening and stabilizing the core muscles, which are essential for trunk control and sitting balance. Task-oriented trunk activities are incorporated in both sagittal and transverse planes, in sitting and lying positions. The goal is to improve core muscle activation, endurance, and coordination, leading to enhanced postural control. Trunk Control Foundation: Strong core muscles provide a stable base for trunk movements and postural adjustments.	**Functional activities:** Task-oriented activities mimic real-life movements, promoting functional carryover. **Plane-specific training:** Training in both sagittal and transverse planes ensures comprehensive core muscle activation. **Postural stability:** Enhanced core stability improves postural stability and reduces the risk of falls. **Trunk rotation:** Rolling promotes trunk rotation, which is essential for functional movements. **Weight shifting:** Weight shifting improves balance and coordination. **Foundation movement:** Supine and prone are foundational positions for motor development.	Children will be positioned in supine (lying on their back) and prone (lying on their stomach) positions. They will be encouraged to perform small weight shifts by moving their limbs or torso. They will also be guided / facilitated to roll over to each side, promoting trunk rotation and core muscle activation.
	Increased challenge: The inclined wedge provides a greater challenge to core muscles and postural control. **Gravity resistance:** Working against gravity enhances core muscle activation. **Dynamic stability:** These activities improve dynamic stability and trunk control.	Children will be positioned on an inclined wedge in supine and prone positions. They will be encouraged to perform weight shifts to the sides and roll towards the side of the incline. The incline increases the challenge to core stability and postural control.
	Core and upper limb integration: This activity integrates core muscle activation with upper limb movements. **Lateral stability:** Lateral weight shifts improve lateral stability and trunk control. **Dynamic reaching:** Reaching in prone position enhances dynamic reaching skills.	Children will be positioned in prone with their arms reaching forward. They will be encouraged to perform lateral weight shifts, moving their weight from one side to the other. This activity challenges core stability and upper limb coordination.
	Core strengthening: Pelvic bridging and twists strengthen core muscles, particularly the gluteal and abdominal muscles. **Dynamic stability**: Progressing to arm elevation and ball throws enhances dynamic stability and core control. **Functional progression:** This progression mimics functional movements, promoting carryover to daily activities. **Increased challenge:** The progressive nature of the activity allows for gradual increases in difficulty.	Children will be encouraged to perform pelvic bridging exercises, lifting their pelvis off the mat. They will be progressed to pelvic twists, rotating their pelvis while maintaining a bridge depending on their ability. The exercises will be progressed futher by elevating the arms and then incorporating ball throws, increasing the challenge to core stability.