Impact of Comprehensive Rehabilitation Therapy on Trunk Controlling Ability of Children with Cerebral Palsy

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ABSTRACT

Objective: *This study aims to investigate the impact of comprehensive treatment on the trunk controlling ability (TCA) of children with cerebral palsy (CPC).*
Methods: *Twenty children with spastic cerebral palsy had truncal stability parameters in the sitting posture and the symmetry parameters of left-right-forward-backward centre of pressure evaluated by the stationary stability assessment module of the PK 254 P balance training instrument. After a six-month trunk control training with physical therapy technology and balancing instrument, the above indicators were re-evaluated, and the evaluations before and after the treatment were analysed to assess the therapeutic effect.*
Results: *The difference in the truncal stability parameters before and after the treatment was statistically significant ($p < 0.05$); the difference in the symmetry parameters of forward-backward centre of pressure was significant ($p < 0.05$).*
Conclusions: *The balancing instrument training, combined with physical therapy technology training, could effectively improve the TCA of CPC, and the balancing instrument could also provide the objective and quantitative efficacy assessment toward the TCA of CPC.*

Keywords: Cerebral palsy, efficacy, trunk controlling ability

Impacto de la Terapia de Rehabilitación Integral en la Capacidad de los Niños con Parálisis Cerebral para Controlar el Tronco

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RESUMEN

Objetivo: *Este estudio persigue investigar el impacto del tratamiento integral en la capacidad de control del tronco (CCT) de los niños con parálisis cerebral (NPC).*
Métodos: *A veinte niños con parálisis cerebral espástica se les evaluaron los parámetros de estabilidad de tronco en la postura de sentado y los parámetros de simetría del centro de presión izquierda-derecha-adelante-atrás por el módulo de evaluación de estabilidad estacionaria del instrumento de entrenamiento de equilibrio PK 254 P. Luego de seis meses de entrenamiento de control del tronco con tecnología de terapia física e instrumento de equilibrio, se re-evaluaron los indicadores anteriores, y se analizaron las evaluaciones realizadas antes y después del tratamiento para evaluar el efecto terapéutico.*
Resultados: *La diferencia en los parámetros de estabilidad troncal antes y después del tratamiento fue estadísticamente significativa ($p < 0.05$); la diferencia en los parámetros de simetría del centro de presión hacia adelante y hacia atrás fue significativa ($p < 0.05$).*
Conclusiones: *El entrenamiento con el instrumento de equilibrio, combinado con el entrenamiento de la tecnología de la terapia física, podría mejorar efectivamente la CCT de los NPC, y el instrumento de equilibrio también podría proveer una evaluación objetiva y cuantitativa de la eficacia de CCT de NPC.*

Palabras claves: Parálisis cerebral, eficacia, capacidad de control del tronco

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INTRODUCTION

Cerebral palsy refers to the developmental disorders of movement and posture, which are caused by non-progressive injuries during fetal or infant brain development, and thus leading to limited activity (1). Children with cerebral palsy (CPC) would exhibit postural reflex disorder, movement development abnormality, muscle dystonia, muscle and skeletal development abnormality and sensory system disorder due to the brain damage or developmental defects, therefore they could not stably control the trunk (2). Trunk posture control is an important part of sports skills, and is closely related to the activities of daily living (3). Currently, it is widely accepted that unstable posture control would lead to restriction of upper limb activities and self-movement (4), and the importance of truncal stability control is also reflected in maintaining and controlling the upright posture when walking (5). The poor control of trunk muscles would need the other muscles to maintain the compensatory upright posture, such as the respiratory muscles, which would directly affect the original functions of the respiratory muscles (6). The balance function feedback training instrument could digitize the balance disorders in eyes-open and eyes-closed situations through a computer software system, then provide the objective and quantitative evaluation results, and based on the assessment results, provide the corresponding training programmes. The Tecnobody balancing instrument introduced into our hospital has been widely used, domestically and abroad, in assessing and training the patients with central nervous system damage, with good reliability (7, 8), which is a prerequisite in clinical assessment and treatment (9). The instrument was previously used in the trunk control function assessment of CPC, and it was concluded that the truncal stability control functions of CPC in eyes-open and eyes-closed situations were not the same as in normal aged-matched children, and the forward-backward directional stability in the sitting posture was asymmetric (10). Therefore, the trunk control training of CPC in the sitting posture is still one of the main purposes of cerebral palsy rehabilitation. This study sought to observe the roles of the Tecnobody balancing instrument in improving the TCA of CPC and the efficacy assessment in CPC.

SUBJECTS AND METHODS

Twenty CPC, who were admitted as outpatients and inpatients in the Department of Rehabilitation, the 2nd Affiliated Hospital of Anhui Medical University from February 2011 to August 2012, were selected, including 13 males and 17 females, with the average age of 58.55 ± 30.80 months old. This study was conducted in accordance with the Declaration of Helsinki and with approval from the Ethics Committee of the Second Affiliated Hospital of Anhui Medical University. Written informed consent was obtained from all participants.

Inclusion criteria: children who met the definition, classification and diagnostic criteria of cerebral palsy, which was discussed and adopted in the Chinese 2nd Session of the National Children's Rehabilitation, the 9th Chinese Pediatric Cerebral Palsy Rehabilitation Conference in Changsha, 2006; the cerebral palsy was spastic; aged from 3 to 12 years old; according to the Bobath balancing assessment, the sitting-posture balance (SPB) function was above grade 2; the vital signs were stable; the parents of CPC signed the informed consent form.

Exclusion criteria: children with diseases with poor truncal stability control caused by non-cerebral palsy, such as vestibular cerebellar lesions, progressive muscular dystrophy, polio, severe malnutrition, myasthenia gravis; associated with severe organic diseases in the heart, liver, kidney and other vital organs; associated with concurrent mental retardation, mental illness or severe epilepsy, which made it difficult to cooperate; associated with severe perceptual disorders such as vision and hearing *etc*.

Test instrument

The PK 254 P balancing feedback training instrument (Tecnobody, Italy) was used to test the trunk control abilities of the subjects before and after the treatment. The basic composition of the balance testing and training system is to use the sensor network to measure the multi-angle motions and the applied loads on a complex oblique plate. When the patient performed the mutual movement on the oblique plate, the plate obtained data on the electrical pulse based on and transferred from every single motion, and the data were directly imported to a computer. The true trajectories of the movements and loads of the pressure centre were displayed on the computer screen (8). During the test, the four locking devices of PK 254 system were fixed within the balance board; at the same time, the four resistance valves were adjusted to the largest resistance position (position 10) to move the system from the dynamic status into the static status. The static stability assessment module of the prokin software was used to assess the SPB of CPC before and after the treatment. During the training, different resistance and training programmes were selected in accordance with the SPB abilities of CPC to perform the SPB training under the dynamic module.

Tecnobody balancing instrument training

According to the assessment results of the SPB of CPC, the position and resistance of the piston were adjusted, and the balance plate was set as a plate pointing to a certain direction; the corresponding training programmes were then selected, or the therapist could set the training programmes according to their own assessments of the CPC. At the initial stage of the training, the CPC could hold the handles with their hands for the truncal stability control training, and the training programmes should be from easy to difficult, from the simple linear trajectory controlling training to the mixed trajectory training. With the improvements of the SPB ability, the armrests could be gradually removed, and during the whole training process, the therapist should be around the children to ensure their safety. If the SPB of CPC was above grade 2, the multiaxial host evaluation module should be used to assess and train, and the results would be sent as feedback to us as the 8-quadrant annular diagram on the computer screen, with each quadrant representing the sitting-posture body activities in certain space. The circle graph was divided equally by four straight lines into eight regions, which were marked as s1–s8 clockwise. Each area was separated by a straight line, and the straight lines which separated the regions were defined as A1–A8, among which A1−A5 indicated the directions of forward-backward movements of the trunk, while A3−A7 indicated the direction of left-right movements of the trunk. During the multiaxial evaluation, the system would provide the ideal trace route and trace scope; after the patient completed the evaluation following the ideal trajectory, according to the distribution of trajectory described by the patient, the system would automatically generate a tracking error toward each quadrant, which would prompt the quadrant that had the most serious problems, and provide the corresponding easy to difficult rehabilitation training programmes. The therapist might choose the personalized targeted rehabilitation according to the system indications. During the training with the balancing instrument, the amount and hardness of training could be set according to the situation each time. The training programmes could be constantly adjusted according to the characteristics of the patient's functional defects to ensure that the patient would be in the critical state of imbalance and balance in each training, so that the current balancing ability of the child could be maximally stimulated, and the balance ability of the child could not only be strengthened, but also transitioned to a more advanced equilibrium state simultaneously. The balance training with the balancing instrument was 20 minutes each time, once a day, six days a week, and four weeks was set as a course.

The therapist and the CPC themselves should find the posture asymmetry and the gravity centre deviation through the screen assessment results or the image information during the training, and perform the sitting-posture adjustment of the gravity centre deviation and postural symmetry. This process would not only train the TCA of CPC, but the process itself would form a proprioceptive stimulation to the CPC. This process of adjusting the gravity centre and posture according to the visual targets required the trunk muscles and bones to be well coordinated. And the lack of the coordinated movements of trunk muscles and bones was also one of the motor dysfunction reasons, therefore, the balancing feedback training could improve the exercise coordination capacity of CPC, and enhance the coordination consistency between the visual feedback and other SPB factors.

Balance adjustment of muscle strength and muscle tension

Sitting-posture balance depends on good TCA; the child with trunk muscle strength and muscle tension abnormalities would acquire an abnormal sitting posture through the compensatory method. Therefore, the therapy would mainly enhance the muscle strength of the weak side to achieve the purpose of bilateral balancing. Lumbar dorsal muscle strength training could help to improve the child's sitting postures of forward leaning or arched sitting; abdominal strength training could help to improve the child's sitting postures of peripatellapexy or hand-backward-bracing.

The training methods of the lumbar dorsal muscle strength were: *bridge movement*: the child, in the supine position, would positively raise the hips from the treatment couch, and keep the pelvis in the horizontal position; if the child lacks the capacity to raise the hips, the therapist could gently pat the affected-side hip to help the child to extend the hip up to the maximum amplitude, and then keep it for 5 to 10 seconds; *swallow movement*: the child is put in the prone position, with both legs straight and both upper limbs placed in the back, then simultaneously contracts the lumbar dorsal muscle, the upper limb muscle and the lower limb muscle to try the best to make the upper chest and lower limbs leave the bed for 5 to 10 seconds.

The training methods of the abdominal strength involved: *sit-up*: the child is in the supine position, with both hands holding the head and both lower limbs on the bed and then the child positively lifts the upper torso until he/she sits up. *Leg rise in the supine position*: the child is in the supine position, with both legs straight, then both legs are lifted alternately 70−80° and maintained for 5–10 seconds. *Bicycle riding in the supine position*: the child is in the supine position, then lifts both legs to perform the active movement with the bicycle-riding action, and does each movement for 10 seconds. As for the child with increased torso muscle tension, it should firstly be performed to reduce the torso muscle tension, which usually used the methods of "ball-holding", paravertebral point-pressing *etc*. As for inadequate torso muscle tension, the problem could be solved through fast knocking method to improve muscle tension. For the femoral adductor spasm, which would then result in the unstable base surface in the sitting position because the thurl could not sufficiently expend outward, the adductor drafting technology could be enhanced to relieve the spasm. For the iliopsoas muscle spasm-induced pelvic leaning-forward, it should strengthen the iliopsoas drafting to improve the spasticity and reduce the pelvic anteversion angle. As for the tight hamstring-induced pelvic leaning-backward, it should strengthen the hamstring drafting to improve the pelvic retroversion.

Training of TCA

The abdominal controlling ability could be strengthened through the supine head rising and abdominal breathing *etc*. The lying-sitting exchange and opposite direction movement training could be done to enhance the centripetal and centrifugal muscle contraction control capacities of the trunk inflexion muscles; double-bridge or single-bridge exercise could be carried out to improve the trunk stretching controlling ability. The child could sit on the Bobath ball, with both hands on the knees, while the therapist controls the child's pelvis with both hands for the protective stretch training forward, backward and sideways to improve the child's active movements of trunk extension and lateral flexion, aiming to achieve the greater abilities of stability coordination and self-control in the sitting posture, and facilitate the protective stretching response in the sitting posture. The child could ride on the rolling drum, which was selected according to the length of the child's lower limbs, in order to promote the child's torso stability and convolution motion in the sitting posture. The torso turning training was also strengthened to promote the trunk convolution and the coordinated movements of the trunk muscles; simultaneously, the upper limbs all-directional stretching exercise in the sitting posture should be strengthened.

Core stability training

The core muscle group refers to the muscles which distribute throughout the whole torso, control the all-directional spinal movements, and maintain the spinal stability, the spinal curvature degree and the pelvic connections, including such superficial motion muscles as the rectus abdominis, the gluteus maximus and the erector spinae muscles, and such deep stabilization muscles as the transverse abdominal muscle, the obliquus externus abdominis, the obliquus internus abdominis, the multifidus muscle, the diaphragm, the quadratus lumborum and the pelvic base muscle. The spinal core stability training could improve the TCA, and the training methods were: both upper limbs supporting in the prone position, unilateral upper limb supporting in the prone position, upper limbs post-elbow supporting and lifting the pelvis in the supine position, side supporting, both knees kneeling transferring to one knee kneeling, hip-knees bending pelvic rotation training under the upper limbs post-elbow supporting in the supine position, horse stance *etc*. It could also draw assistance from the Bobath ball, the balancing plate, the rollers and other equipment to enhance the purpose of core stability training.

Pelvic controlling ability training

Pelvic rotation movement: the child is in the supine position then the therapist holds the bilateral iliac crests of the child, helping the child's pelvis to perform the alternating rotary motion toward the contralateral upper direction. *Pelvis training of leaning forward, backward and sideways*: the child sits on the Bobath ball with the therapist's hands bilaterally on the child's waist then make the Bobath ball lean 10−30° in four directions, so that the child could automatically adjust the sitting posture for the pelvis leaning training. *Crawling training*: the crawling training could not only prevent and improve the hip-surrounding muscle spasm, but also improve the overall pelvic stability, increase the thurl loading capacity and controlling capability. *Knee-walking*: trains the child to shift, move and lean the pelvic gravity centre left and right, inducing the pelvic girdle to perform the opposite movement against the trunk; knee-kneeling to knee-kneeling conversion training and the opposite direction training could enhance the dynamic controlling capability.

Assessment programmes

The enrolled children performed the SPB functional assessment with the static stability assessment module on the Tecnobody balancing instrument, and the assessment results were used as the base to develop the individualized rehabilitation exercise prescription. One treatment course was eight weeks, with four weeks as the hospital rehabilitation phase and four weeks as the family rehabilitation phase. Three courses later, the above assessment methods were repeated for the SPB functional assessment of the child, and the obtained data were analysed statistically.

Evaluation method

Standard posture for the assessment: the balancing plate was placed on the sitting platform, adjusting the height of the foot supporters so that the child's knee would flex at 90°–100°. The hip position of the child was adjusted, so that the child's greater trochanter of the femur could locate on the A3−A5 axis of the balancing plate; the child's feet were placed as wide as the shoulder. The child should keep the position of chin up and chest out. The upper limbs were naturally placed bilaterally on the thighs.

Evaluation process: Before the evaluation, the child should be kept in a quiet room with uniform brightness and suitable temperature, avoiding noise and visual disturbance, the operating procedures should be explained to the child, who should sit for five minutes to be adaptive to the environment. Then the child was placed on the balancing plate in a relaxed mood with eyes looking straight ahead at the 1 m solid marker, keeping the child's visual stability, and avoiding the moving target in the child's vision field. The detection time was 30 seconds. After 30 second eyes-open evaluation, the child closed the eyes for the 30-second eyes-closed evaluation. The total evaluation time was one minute. After the test, the average centres of pressure (COP) of the X-axis and Y-axis, the posture stability parameters (the standard deviation of the forward-backward function, the standard deviation of the left-right function, the average velocity of the forward-backward movement, the average velocity of the left-right movement, the sports oval area and the sport length) were determined. The evaluation was performed once in the morning and afternoon of the same day, respectively, and all the parameters were the average of two-time determination.

Statistical analysis

All the data were analysed with SPSS 13.0 statistical software. The intergroup quantitative data before and after the treatment used the paired *t*-test, with $p < 0.05$ considered as the statistically significant difference.

RESULTS

Comparison of eyes-open truncal stability parameters

By comparing the eyes-open COP-related parameters of the CPC in the static sitting posture before and after the treatment, the improvement of truncal stability control with visual compensation could be identified. Table 1 showed that the COPs were less than those before the treatment in the fields of the standard deviation of forward-backward and left-right swing amplitude, the average velocities of forward-backward and left-right directions, the movement length and area, and the differences were statistically significant ($p < 0.05$).

Comparison of eyes-closed truncal stability parameters

By comparing the eyes-closed COP-related parameters of the CPC in the static sitting posture before and after the treatment, the improvement of truncal stability control without visual compensation could be identified. Table 2 shows that the COPs were less than those before the treatment in the fields of the standard deviation of forward-backward and left-right swing amplitude, the average velocities of forward-backward and left-right directions, the movement length and area, and the differences were statistically significant ($p < 0.05$).

Comparison of Y-axis average COP

The Y-axis average COP of the balancing plate represented the COP displacement in the forward-backward direction; the SPB study before treatment revealed that the CPC did not exhibit the significant left-right displacement, while the forward-backward displacement significantly leaned forward, namely the gravity leaning forward. In this study, the comparison of the Y-axis average COPs before and after the treatment in children indicated that the TCA training could adjust the forward-backward displacement of CPC in the sitting posture (Table 3).

Table 3: Comparison of Y-axis average centres of pressure (COP) before and after the treatment ($\bar{x} \pm s$)

Cerebral palsy group	Eyes-open	Eyes-closed
Before	30.55 ± 24.20	34.40 ± 22.25
After	23.35 ± 18.96	30.10 ± 20.74
P	0.021	0.006

DISCUSSION

Controlling posture and obtaining motion-function are two landmarks in the body's complex movements, playing a significant role in a series of complex movements (11). As the body's centre, the TCA is the foundation of the limbs' movements and all other activities. Being the key link in the human biological motion chain, the torso plays a vital role in the action performance and energy transference during the movements. The torso is composed of multi-skeletal muscles, with multiple joints and complex structures. During movements, torso balancing and stability will affect the performance of a variety of actions (12). The mechanism of the motion controlling disorders in CPC is not very clear; some people thought that it might be connected with the interactions of nerve, endocrine, nutrition and mechanical factors during the skeletal muscle growth, as well as with the imbalance of the contraction and stretching mechanisms of the skeletal muscles (13). Also, some scholars suggested that there was damage or injury when the brain was still immature in CPC, leading to the neural controlling circuits disorders, thus the posture controlling disorders would happen because of the weakened feed-forward- and feedback-regulation when adjusting the position (14). Truncal stability is the prerequisite for the maintenance of the daily postures, and very important for life, study and work. The abnormal postures and the unstable trunk control in the sitting posture of the CPC would bring great pain to the parents. Among the CPC's gross motor functions, the achievement of TCA would be a milestone. Therefore, how to improve the TCA of CPC faster and greater would be the test and challenge against cerebral palsy rehabilitation. It would be very difficult for CPC to be trained for more than 20 minutes with the balancing instrument because of unstable emotion, crying, non-cooperation or fatigue, so it would be difficult to rely solely on the balancing instrument training to achieve sat-

Table 1: Comparison of eyes-open centres of pressure (COP) parameters before and after the treatment ($\bar{x} \pm s$)

Cerebral palsy group	COP standard deviation of forward-backward	COP standard deviation of left-right	Average velocities of forward-backward (mm/s)	Average velocities of left-right (mm^2)	Motion ellipse area (mm)	Movement length (mm/s)
Before	2.45 ± 1.35	3.05 ± 1.82	5.70 ± 2.70	5.85 ± 3.10	60.65 ± 32.63	183.50 ± 84.12
After	1.85 ± 1.04	2.10 ± 1.41	4.30 ± 2.45	4.10 ± 3.14	52.20 ± 30.43	149.55 ± 77.20
P	0.030	0.014	0.012	0.003	0.008	0.000

Table 2: Comparison of eyes-closed centres of pressure (COP) parameters before and after the treatment ($\bar{x} \pm s$)

Cerebral palsy group	COP standard deviation of forward-backward	COP standard deviation of left-right	Average velocities of forward-backward (mm/s)	Average velocities of left-right (mm/s)	Motion ellipse area (mm^2)	Movement length (mm)
Before	4.25 ± 2.15	5.95 ± 2.95	8.80 ± 4.66	9.10 ± 4.82	93.40 ± 41.90	255.90 ± 119.07
After	3.30 ± 1.78	4.25 ± 1.74	7.00 ± 4.20	7.00 ± 4.01	82.75 ± 41.57	217.60 ± 103.85
P	0.022	0.001	0.007	0.001	0.001	0.000

isfactory results. While physical therapy (PT) technology could mobilize the CPC's enthusiasm through the therapist's initiative, the treatment process could improve the active participating abilities and interests of the CPC through games or matches among CPCs of the same group, and thus better train their posture controlling ability.

The Tecnobody balancing instrument is a comprehensive training system, using the visual feedback to perform the human balancing training. Through the self-balancing sensation and the dynamic feedback from the balancing instrument towards the posture swing in the sitting posture, the patient could send various degrees of feeling and composite sense stimuli to the brain centre, then adjust the body's centre of gravity control in the sitting posture, so that the patient's imbalance status could be adjusted and corrected, and the damaged nervous system could promote the reconstruction of the balance and coordination function to improve the TCA. At the same time, it could enhance the patient's training initiative, interest and enthusiasm, and accelerate the improvement of the patient's SPB function. The Tecnobody is widely used in the assessment (15) and training (16) of the balance function in patients with stroke and multiple sclerosis, and has achieved good results. In this study, based on the conventional PT technology training, the balancing instrument training was added at the same time. The Tecnobody balancing instrument was used to quantitatively assess the TCA of CPC before and after the treatment, and the results revealed that no matter the existence of visual compensation (eyes-open and eyes-closed), the TCA parameters (COP parameters) were better than those before the treatment, with statistically significant difference (Tables 1 and 2). After training, the forward-backward displacement during the CPC's trunk control shortened, and the results were statistically significant (Table 3). Thus, the combination of the Tecnobody balancing instrument and PT technology could effectively improve the TCA of CPC, and could be used in the objective and quantitative assessment of clinical trunk control. Physical therapy technology is the international conventional cerebral palsy rehabilitation technology in training TCA in the sitting posture, which mainly adjusts the trainings of muscle strength, muscle tension, and trunk and pelvic stability. The core muscle group, including the rectus abdominis and the erector spinae, plays an important role in the stabilization of the spine and the pelvis, and, in rehabilitation medicine, PT technology has early been applied to the rehabilitation of patients with low back pain (17, 18). In recent years, more and more people have introduced the core stability training into the rehabilitation of CPC, and have achieved good results (19, 20). The results of this study were consistent with the above literature. The PT technology could fully mobilize the CPC's initiative, reduce passive activities, and the therapist could subjectively obtain the CPC's defects, and thus design the specific actions, from simple to complex, for the training. And PT operation was simple, easy to understand, with strong practicability, easy to be accepted by the CPC, and the parents could easily learn the specific treatment measures for home-based rehabilitation therapy. Therefore, the results of the combination of the above methods would be better than that of the single method.

CONCLUSION

The combination of the balancing instrument training and PT technology could improve the TCA of CPC. The balancing instrument could also objectively and quantitatively record the degrees of the CPC's trunk controlling disorder, thus providing important clinical significance in detection and rehabilitation guidance.

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