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Article

The effect of core strength combined with sensory integration training on the walking ability of children with cerebral palsy

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Abstract: Objective: To compare the influence of core strength training combined with sensory integration training and routine rehabilitation training on the walking ability of children with cerebral palsy, and to provide a basis for the selection of reasonable rehabilitation training for them. **Methods:** Thirty children with cerebral palsy aged 7–12 years were randomly divided into an experimental group (15) and a control group (15), with the former conducted for 8 months of core strength training and sensory integration training three times a week, and the latter conducted for the same period of conventional rehabilitation therapy training three times a week. Besides, the research respectively investigates the gross motor function measure (GMFM), parameters of gait, physiological consumption index as well as the balance and postural control of the children in the two groups before and after the training. **Results:** (1) The scores of GMFM-D and GMFM-E are increased in the experimental and control groups after the intervention, with the former achieving higher scores than the latter ($p < 0.01$); (2) All parameters of gait improved in both groups after the intervention, the experimental group showing better improvement than the control group in terms of stride length, width, left and right support phases and swing phase($p < 0.05$) (3) The physiological consumption index of the experimental group was significantly lower after training ($p < 0.05$). (4) The COP of the experimental group was remarkably higher than that of the control group after training ($p < 0.05$). **Conclusion:** Core strength combined with sensory integration training and conventional rehabilitation training can improve the motor function and walking capacity of children with spastic cerebral palsy, but the former method has a better intervention effect.

Keywords: children with cerebral palsy; core strength training; sensory integration training; walking ability

1. Preface

Cerebral Palsy (CP) is a group of persistent central motor and postural developmental disorders and restricted movement syndromes [1], characterized by central motor deficits and postural abnormalities, resulting in hypokinesia and sensory dysfunction. Spastic Cerebral Palsy (SCP) accounts for over 70% of all cases of CP [2]. Most children with SCP are able to stand independently. Traditional physiotherapy techniques such as muscle strengthening, balance control and assisted walking are often used to restore and improve motor function and walking ability in children with SCP. However, the effectiveness is influenced by the treatment method, movement intensity and the professional level of the therapist [3]. The key to sensory integration training is to control sensory input, focusing on tactile, vestibular and proprioceptive stimulation in the deep senses. The central nervous system integrates the three sensory information and rapidly extracts useful information. In this way, it can better cope with balance defects caused by changes in motor position, thus improving their motor stability [4]. Studies have shown that children with CP are with higher motivation and better intervention results when sensory integration training is conducted in games [5]. Therefore, based on traditional core strength training, sensory integration training was designated for school-age children with CP who were given motor rehabilitation training for 8 months. After comparing the effects of conventional rehabilitation training and core strength combined with sensory integration training on the walking ability of children with CP, an experimental basis is provided for choosing the appropriate motor rehabilitation training method for children with CP.

2. Objects and research methods

2.1. Research object

Inclusion criteria for objects: (1) Patients with SCP aged 7–12 years old, living in Xuzhou city (2) Be rated as Grade I-II with Gross Motor Function Classification System (GMFCS) (3) Children with SCP having normal intelligence or mild intellectual disability who are able to walk independently for more than 6 m (4) With sufficient time to complete the experiment during the period.

This paper mainly analyzes the effects of different training methods on the walking ability of children with cerebral palsy. Children aged 7–12 were selected as the research subjects because children in this age group have relatively good development, certain cognitive abilities and cooperation, can better accept instructions and complete training tasks, and are convenient for measuring and evaluating various walking abilities.

Exclusion criteria: (1) Patients with diseases related to heart, liver and kidney (2) Patients suffering from other mental illnesses or severe epilepsy (3) Patients without enough time to receive the test. Finally, thirty-two eligible subjects (16 of each sex) were selected and randomly divided into a control group and an experimental group according to the male to female ratio (1:1). During the experiment, one female participant in the control group and one in the experimental group dropped out of the research. Based on the statistical analysis of the basic information of the subjects before the intervention, no significance was found between the groups, as shown in **Table 1**.

Table 1. The basic information of the subjects.

Group	Age (years)	Height (cm)	Body weight (kg)	Lower limb length (cm)	FAC
Control group	9.82 ± 2.68	139.94 ± 14.46	34.53 ± 7.87	26.31 ± 2.17	30.89 ± 6.01
Experimental group	8.27 ± 2.74	129.60 ± 17.32	30.27 ± 11.00	26.20 ± 3.38	31.52 ± 4.39

2.2. Research methods

2.2.1. Exercise prescription

Exercise content: The control group was required to undergo regular rehabilitation training for 8 months and take exercise lessons for 60 min three times a week. The exercise included foot and ankle joint distraction, passive standing abduction training whose aim is to distract the thigh adductors, kneeling training, lunge station whose aim is to promote hip extension, single-leg squat, gait training with the assistance of weight loss robots, etc. General rehabilitation gymnastics and sports games are also necessary.

In the experimental group, with reference to Positive Sensory Integration Therapy written by Professor Wen-Te Chen from Taiwan, the training programs include skateboard crawling, playing big ball, playing small tactile ball, passing wobbly balance table, using round wooden suspension cable, and riding balance bicycle. The group members should undergo standard sensory integration function training in a one-to-one manner strictly according to schedule [6]. At the same time, core strength training was conducted, including training to improve breathing disorders, training to improve trunk-pelvis motor control, training to improve trunk gyration, training to enhance coordination of lumbar and abdominal muscles, training to increase abdominal muscle strength and training to relieve muscle tension. The training was conducted three times a week for 60 min each time, of which 30 minutes for sensory integration and 30 min for core strength training, and the intensity and content of the training could be adjusted according to the degree of sensory integration disorder of each child during 8 months.

Frequency and periodicity: 60 min of training will be conducted every Tuesday, Thursday and Saturday from 4:00–5:00 p.m. for 8 months, the equivalent from March to October 2021.

Address: Xuzhou Special Children's Treatment and Rehabilitation Center.

2.2.2. Test indicators

(1) Gross motor function measure

The Gross Motor Function Measure (GMFM-88) [7] was used to reflect the walking ability of children with CP, and the test was performed once before and once after the training for each of the two groups of subjects. Area D, which represents children's standing function, and area E, which represents children's walking ability, were selected for comparison of GMFM scores before and after the training. In this study, the standing zone (Dimension D of Gross Motor Functional Measure, GMFM-D) and the walking, running and jumping zone (Dimension E of Gross Motor Functional Measure, GMFM-E), which are related to walking mobility function, were selected to respectively calculate the scores before and after training.

GMFM-D score: namely standing zone scores. This is a 13-item measurement of children's ability to maintain various standing positions, to move from different positions to a standing position, and to perform specific tasks while maintaining a standing position.

GMFM-E scores: namely walking, running and jumping zone scores. This is a 24-item measurement of children's ability to perform a variety of walking activities, perform specific tasks (e.g., walking up and down stairs or kicking a ball), and perform a variety of jumping movements for a variety of movements that all begin in a standing position.

(2) Spatio-temporal gait parameters

In this study, the paper mainly analyzed walking speed and walking distance of the temporal and spatial gait parameters. Walking speed: The 10 Meters Walking Test (10MWT) was used to test the speed. The children were required to complete the test three times at the appropriate and fastest speeds on a 10-meter distance walkway, and the average speed was taken to calculate the children's self-selected walking speed.

(3) Energy consumption

The Physiological Consumption Index (PCI) was used to evaluate the energy consumption of the children during walking. A heart rate meter was used to test the child's heart rate before and after the 6-min walk test, and the results were obtained between the immediate heart rate at the end of the exercise and the resting heart rate was divided by the walking speed, which can be used as a method to determine the child's energy consumption during walking [8].

The physiological expenditure index (PCI) is a simple method to assess energy expenditure through heart rate and walking speed. During the 6-min walk test (6MWT), children's resting heart rate (HR_rest) and immediate heart rate at the end of walking (HR_walk) were measured, and walking speed was recorded at the same time. PCI=$\frac{\text{HR\_walk}-\text{HR\_rest}}{Walking\ speed}$, A lower PCI value reflects high walking efficiency and low energy expenditure, while a higher PCI value indicates greater energy expenditure.

(4) Balance and posture control

A three-dimensional posture control system produced by Motek, the Netherlands, was used to obtain data on the child's stability limits in a total of eight directions, and the Center of Pressure (COP) envelope area was calculated by the software.

2.3. Statistical methods

All experimental data were processed using SPSS25.0 software, and the results were expressed in the mean ± standard deviation (±SD). In addition, the independent samples *T*-test and paired samples *T*-test were used to test the differences between the data before and after the training, with a significant difference of $P < 0.05$.

3. Results

3.1. Changes in gross motor function before and after the intervention

Table 2. Change in GMFM scores before and after intervention.

	GMFM-D Discernibility Value		**GMFM-E Discernibility Value**	
	Pre-intervention	Post-intervention	Pre-intervention	Post-intervention
Experimental group	22.15 ± 6.63	27.15 ± 7.22*#	34.88 ± 10.02	43.75 ± 10.68*
Control group	20.76 ± 6.12	23.11 ± 6.69*	35.34 ± 11.61	37.25 ± 11.91

Note: * indicates $P < 0.05$ compared with post-intervention within the group; # indicates $P < 0.05$ compared with experimental groups.

According to **Table 2**, intra-group comparison: After the intervention, discernibility value of GMFM-D and GMFM-E in the experimental group were higher than before. $P < 0.05$ Discernibility value of GMFM-D in the control group was also significantly higher than before. Inter-group comparison: After the intervention, discernibility value of GMFM-D in the experimental group was significantly higher than that in the control group, $P < 0.05$. Moreover, before the intervention, no statistical significance was found in the data. This shows that core strength and sensory integration training has a better effect than conventional rehabilitation training in improving the standing and walking functions of children with cerebral palsy. The improvement of GMFM score means that the motor function of children with cerebral palsy has been substantially improved.

3.2. Changes in spatio-temporal gait parameters before and after the intervention

According to **Table 3**, the changes in gait parameters before and after the intervention were significant in the experimental group in terms of stride length, stride width, left and right support phases and swing phase ($p < 0.05$); Whereas in the control group, only the stride length was significantly different ($p < 0.05$). The comparison between the two groups showed significant differences in stride length, stride width, left and right support as well as swing phases ($p < 0.05$). The overall improvement in gait of the experimental group showed that core strength and sensory integration training can help children with cerebral palsy form a gait pattern that is closer to normal, thereby improving their walking efficiency and stability.

Table 3. Changes in various parameters of gait before and after the intervention.

	Experimental group (*n* = 15)		**Control group (*n* = 15)**	
	Pre-intervention	Post-intervention	Pre-intervention	Post-intervention
Stride length (cm)	45.24 ± 13.21	61.14 ± 14.55*	44.44 ± 13.11	53.36 ± 12.11*#
Stride period (s)	1.44 ± 0.41	1.57 ± 0.35	1.47 ± 0.36	1.47 ± 0.38
Step width (cm)	8.86 ± 1.55	7.05 ± 1.33*	8.49 ± 1.12	8.19 ± 1.03#
Walking speed (m/s)	0.45 ± 0.23	0.53 ± 0.33	0.46 ± 0.32	0.47 ± 0.14
Left support phase (%)	75.55 ± 7.24	70.45 ± 7.12*	75.84 ± 7.45	75.60 ± 12.06#
Right support phase (%)	74.64 ± 8.77	68.97 ± 6.65*	73.62 ± 8.17	74.16 ± 11.51#
Left oscillating phase (%)	24.36 ± 5.54	30.69 ± 4.96*	23.87 ± 4.57	24.46 ± 4.33#
Right oscillating phase (%)	25.35 ± 3.28	30.72 ± 4.35*	26.91 ± 4.74	25.82 ± 4.77#

Note: * indicates $P < 0.05$ compared with post-intervention within group; # indicates $P < 0.05$ compared with experimental groups.

3.3. Changes in energy expenditure before and after the intervention

According to **Table 4**, intra-group comparison: PCI was lower in the two groups after the intervention $P < 0.05$; inter-group comparison: Comparing the two groups after the intervention, $P < 0.05$. While before the intervention, there was no statistical significance in the data. **Table 4** shows the changes in PCI of the two groups of children before and after the intervention. The PCI of both the experimental and control groups decreased after the intervention, but the decrease in the experimental group was greater, indicating that its energy consumption was lower. This result shows that core strength and sensory integration training can not only improve the motor function of children with cerebral palsy, but also effectively reduce their energy consumption when walking, thereby improving their quality of life and exercise endurance.

Table 4. Changes in physiological exertion indices before and after the intervention.

	Control group	Experimental group
Pre-intervention	99.00 ± 79.09	98.90 ± 76.33
Post-intervention	65.40 ± 36.38*	33.20 ± 18.10*#

Note: * indicates *P* < 0.05 compared with post-intervention within group; # indicates *P* < 0.05 compared with experimental groups.

3.4. Changes in balance and postural control before and after the intervention

According to **Table 5**, intra-group comparison: after the intervention, the COP of the two groups was lower, $P < 0.05$; inter-group comparison: after the intervention, the control group was compared with the experimental group, $P < 0.05$. While before the intervention, there was no statistical significance in the data.

Table 5. Changes in children's COP before and after the intervention.

	Control group	Experimental group
Pre-intervention	153.43 ± 28.97	139.90 ± 42.99
Post-intervention	163.19 ± 28.10*	216.25 ± 52.47*#

Note: * indicates *P* < 0.05 compared with post-intervention within group; # indicates *P* < 0.05 compared with experimental groups.

4. Discussion

4.1. Effects of different rehabilitation trainings on gross motor and Spatio-temporal gait parameters of children with CP

Spatio-temporal gait parameters and gross motor are important indicators to reflect the motor ability of children with CP. However, different rehabilitation trainings have different effects on these children. Booth's study proves that functional gait training has a more positive effect on walking speed than standard physical therapy (effect size is 0.79, $p = 0.04$), and it was also beneficial for walking endurance and gait-related gross motor function [9]. Moreau's study suggests that gait training is the most effective intervention to improve the gait speed of children with CP. Even if the dose is appropriate, strength training cannot improve gait speed effectively. Speed training, electromyographic biofeedback training and whole body vibration can effectively improve gait speed in individual studies, which is worthy of further investigation [10]. Besides, Burnfield's research has proved that the immediate effect of core strength combined with sensory integration training on spatio-temporal gait parameters and gross motor function of SCP children is better than that of conventional physical therapy and other weight-loss walking trainings, but the research on long-term efficacy is not sufficient [11]. In summary, different trainings and rehabilitation methods have different intervention effects on children with CP, which may be related to the intervention time, intensity, and content.

It can be found from this study that after 8 months of rehabilitation trainings, the spatio-temporal gait parameters and gross motor function of the two groups were raised, but in the core strength combined with sensory integration training group, the improvement of gross motor function of D area and E area of GMFM was significantly better than that of the treatment group. It can be found that the core strength combined sensory integration training can reinforce the vestibular function, proprioception and stability of core muscle. Thus, this method can boost the body control ability and balance ability, and is more conducive to strengthening the gross motor function and walking ability of children with CP.

In addition, according to the results, the two groups have different degrees of enhancement in stride length, cycle, width, speed and other indicators after 8 months of rehabilitation trainings. This indicates that the set rehabilitation trainings can enhance the proprioception and the control ability of the pelvis and trunk of children with CP, intensify their functions of separation and coordination of both sides of pelvis, and promote the rotation of the pelvis and the movement of the body's center of gravity. Only when the stability of the pelvis and trunk is strengthened, can the lower limbs be driven forward with the regular rotation of these parts of body, helping children's gait gradually transform to the normal state. Although this method has a better long-term effect on gross motor function than conventional physical therapy, its maintenance effect on walking speed is not obvious, which may be related to the treatment time and intensity of this training.

4.2. Effects of different rehabilitation trainings on energy consumption of children with CP

Energy consumption can be used to evaluate the efficiency of exercise intervention and rehabilitation. Under normal conditions, children with CP have higher energy consumption while standing than normal children. This research proves that both the experimental group and the treatment group have lower PCI than before, and the former has significantly lower PCI than that of the latter. Lee's study suggests that seven-day physical exercise has a positive impact on the energy consumption of school-age children with CP, and participation in physical activity is positively correlated with the better quality of their lives [12]. In addition, Provost [13] finds that two-week intensive weight support treadmill training twice a week can accelerate the walking speed of children aged 6–14 years and reduce energy consumption. In addition, Katz-Leurer's study proves that 6 weeks of "family-based" physical activity raises balance ability and reduces energy consumption in children aged 7 to 13 years with CP [14].

In conclusion, physical exercise with different duration periods from 7 days to 6 weeks has different influences on the energy consumption of children with CP. In this research, the experimental group and the treatment group have significant differences in the value of PCI, which indicates that compared with conventional physical therapy, core strength combined sensory integration training has a more long-term curative effect on the balance and energy consumption of SCP children. Due to persistent neuromotor dysfunction, SCP children need long-term activity-based mobility training to maximize the recovery of motor function. In order to enhance lower limb motor function and coordination, core strength combined with sensory integration training promotes the compensation and reorganization of the central nervous system through high-intensity repetitive exercise to form a correct sensory-motor nerve pathway. The method can help SCP children to restore long-term and stable walking movement function and reduce unnecessary energy consumption. This result is similar to that of Aurich-Schuler et al. [15], although the damaged neural area of the brain cannot be completely repaired, the function of this area can be compensated by its neighbor. Furthermore, long-term and high-intensity repetitive trainings are crucial to promote myelin regeneration and the production of new synapses.

4.3. Effects of different rehabilitation trainings on balance and posture control of children with CP

Dynamic balance ability refers to the ability of human body to control the center of gravity and adjust posture during the transformation of various postures or movements, and gait is an important indicator of it. A gait cycle refers to the duration between one heel touches the ground and that heel touches the ground again, and it can be divided into two phases according to time phase: support phase and swing phase. The support phase represents the contact time between the bottom of the foot and the supporting surface, accounting for about 60 % of the gait cycle; the swing phase is the time that the bottom of the foot leaves the supporting surface, accounting for about 40 % of the cycle [7]. For the walking support phase, the stability of the supporting surface (ankle), limbs (knee and hip) and trunk are necessary for maintaining balance. Any disorder in those parts may lead to impaired or lost gait stability, resulting in abnormal gait, and even lead to loss of balance and fall [16]. The gait cycle of normal children is basically the same as that of adults. However, children with CP must maintain balance by increasing foot support time due to the persistence of primitive reflexes, hypertonic muscle tension, poor body control and balance ability, and low speed and accuracy of postural change.

According to this study, the COP test results of the two groups are significantly increased compared with those before trainings, reaching a significant level after 8 weeks of rehabilitation trainings ($P < 0.05$). Based on the intra-group comparison, the COP test results of the experimental group were significantly higher than those of the treatment group ($P < 0.05$). The result indicates that compared with conventional physical therapy, core strength combined with sensory integration training can enhance children’s balance control ability. This is consistent with the conclusion of a randomized controlled study by Wallard et al. [17] in 2018. SCP children can do better in posture reorganization under balance control after being trained with core strength combined with sensory integration training. And this method can improve the inherent bloc pattern, enabling standing and walking postures to approach normal state [18]. Good posture enables SCP children to reduce unnecessary energy consumption during walking and raise children ‘s walking endurance effectively.

5. Conclusion

This study focused on children with cerebral palsy and compared the effects of core strength combined with sensory integration training and conventional rehabilitation training on their walking ability. Research results show that both training methods can improve the motor function and walking ability of children with cerebral palsy to a certain extent, but the effect of core strength combined with sensory integration training is more significant. This comprehensive training method not only effectively improved the standing and walking functions of children with cerebral palsy, as shown by the GMFM-D and GMFM-E scores, but also significantly optimized their gait parameters, including step length, step width, support phase and The swings are equalized, making their gait more normal. In addition, this training method also significantly reduced the energy consumption of children with cerebral palsy during walking, which was manifested by a greater decrease in PCI values. In summary, core strength combined with sensory integration training provides a more effective rehabilitation training method for children with cerebral palsy, which not only helps to improve their motor functions, but also improves their walking efficiency and stability, reduces energy consumption, and thus Have a positive impact on their quality of life.

Ethical approval: Not applicable.

Conflict of interest: The author declares no conflict of interest.

References

1. China Society of Rehabilitation Medicine Specialized Committee on Pediatric Rehabilitation, China Disabled Persons Rehabilitation Association Specialized Committee on Pediatric Cerebral Palsy Rehabilitation, China Cerebral Palsy Rehabilitation Guidelines Editorial Committee. Chinese guidelines for rehabilitation of cerebral palsy (2015) Part 1. Chinese Journal of Rehabilitation Medicine.2015, 30(7):747-754.
2. Wu M, Kim J, Gaebler-Spira DJ, et al. Robotic resistance treadmill training improves locomotor function in children with cerebral palsy: a randomized controlled pilot study. Arch Phys Med Rehabil, 2017, 98(11):2126-2133.
3. Damiano DL, Stanley CJ, Alter KE. Task-specific and functional effects of speed-focused elliptical or motor-assisted cycle training in children with bilatera-l cerebral palsy: randomized clinical trial. Neurorehabil Neural Repair, 2017, 31(8):736-745.
4. Jang SH, Lee JH. Impact of sensory integration training on balance among stroke patients: sensory integration training on balance among stroke patients. Open Med (Wars). 2016, 11(1):330-335.
5. Kantor J, Hlaváčková L, Du J, Dvořáková P, Svobodová Z, Karasová K, Kantorová L. The Effects of Ayres Sensory Integration and Related Sensory Based Interventions in Children with Cerebral Palsy: A Scoping Review. Children (Basel). 2022, 9(4):483.
6. Chen Wende (Guidebook for children with learning disability) Sensory Integration Positive Therapy. China Children and Adolescents Publishing House, 1996, 12-13.
7. Li Jianan, Meng Dianhuai. Clinical application of gait analysis. Chinese Journal of Physical Medicine and Rehabilitation, 2006, 28(7):500-503.
8. Kitatani R, Ohata K, Takahashi H, et al. Reduction in energy expenditure duri-ng walking using an automated stride assistance device in healthy young adults. Arch Phys Med Rehabil. 2014, 95(11):2128-2133.
9. Booth ATC, Buizer AI, Meyns P, Oude Lansink ILB, Steenbrink F, van der Krogt MM. The efficacy of functional gait training in children and young adults with cerebral palsy: a systematic review and meta-analysis. Dev Med Child Neurol. 2018 Sep; 60(9):866-883.
10. Moreau NG, Bodkin AW, Bjornson K, Hobbs A, Soileau M, Lahasky K. Effectiveness of Rehabilitation Interventions to Improve Gait Speed in Children With Cerebral Palsy: Systematic Review and Meta-analysis. Phys Ther. 2016 Dec; 96(12):1938-1954.
11. Burnfield JM, Cesar GM, Buster TW, et al. Walking and fitness improvements in a child with diplegic cerebral palsy following motor-assisted elliptical inter-vention. Pediatr Phys Ther.2018, 30(4):1-7.
12. Lee J, Suk MH, Yoo S, Kwon JY. Physical Activity Energy Expenditure Predicts Quality of Life in Ambulatory School-Age Children with Cerebral Palsy. J Clin Med. 2022, 11(12):3362.
13. Provost B, Dieruf K, Burtner PA, Phillips JP, Bernitsky-Beddingfield A, Sullivan KJ, Bowen CA, Toser L. Endurance and

gait in children with cerebral palsy after intensive body weight-supported treadmill training. Pediatr Phys Ther. 2007, 19(1):2-10.

14. Katz-Leurer M, Rotem H, Keren O, Meyer S. The effects of a 'home-based' task-oriented exercise programme on motor and balance performance in children with spastic cerebral palsy and severe traumatic brain injury. Clin Rehabil. 2009, 23(8):714-24.
15. Aurich-Schuler T, Grob F, van Hedel HJA, et al. Can Lokomat therapy w-with children and adolescents be improved? An adaptive clinical pilot trial com-paring Guidance force, Path control, and FreeD .J Neuroeng Rehabil.2017, 14(1):76-89.
16. Ran Maoqun, Xiao Nong, Ren Yongping, et al. Computer-aided three-dimensional gait evaluation of muscle strength and pelvic control in children with cerebral palsy. Chinese Tissue Engineering Research, 2012, 16(39):9279-9282.
17. Wallard L, Dietrich G, Kerlirzin Y, et al. Effect of Robotic-assisted gait rehabilitation on dynamic equilibrium control in the gait of children with cerebral palsy. Gait Posture.2018, 60(1):55-60.
18. Farris RJ, Quintero HA, Murray SA, et al. A Preliminary Assessment of Legged Mobility Provided by a Lower Limb Exoskeleton for Persons with Par-aplegia. IEEE Trans Neural Syst Rehabil Eng. 2014, 22(3): 482-490.