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Effectiveness of task-specific training for improving balance performance in children with cerebral palsy (CP): a narrative systematic review

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Abstract

Introduction. A body of research has focused on helping children with disabilities stay physically active. As poor balance has been found as a major limitation in physical activities, a systematic review exploring balance intervention programs is warranted.
Methods. The primary aim of this is to systematically evaluate evidence for the effect of task-specific training to improve balance outcomes in ambulant children with cerebral palsy. Seven databases were searched for studies involving ambulant children with cerebral palsy (4–15 years old); balance TST; and balance-related outcomes. The quality of the studies was appraised using the JBI Critical Appraisal Checklists for risk of bias, study design, and quality of evidence. Continuous data were transformed and summarised using standardised mean difference and 95%CI.
Results. Seven randomised controlled trials met the inclusion criteria. The risk of bias was deemed low in most of the studies. Due to heterogeneity of study design and outcome measures, a narrative synthesis was conducted. Positive between-group effects favouring TST were found across the six studies (BBS d = 1.528, 95% CI = 0.7747–2.2813) and follow-up (BBS d = –1.667, 95% CI = –2.459 ÷ –0.874). Despite poor reporting of motor learning strategies, repetitive practice, feedback, and task modulation strategies were used consistently in balance TST.
Conclusions. TST could be recommended to be a part of an intervention programme to improve balance performance in children with CP. However, more studies with rigorous study design and adequately powered implementation of a more fun task-oriented training programme are needed.
Key words: task-oriented, balance, children, cerebral palsy

Introduction

Cerebral Palsy (CP) is the most common cause of disability in childhood, and the overall prevalence of CP has remained constant at 2.11 of 1000 live births in recent years [1]. CP is caused by non-progressive lesions of the immature brain which are no longer active when the diagnosis is made [2]. However, these lesions are contributed to several changes or additional manifestations overtime during the developmental process [2]. Motor and postural disorders are persisting throughout the lifetime, causing functional limitations and gait disorders. According to the International Classification of Functioning, Disability and Health (ICF) model, poor balance and postural control are impairments in body structure and functions [3]. These impairments have been identified as one of the major mobility limitations contributing to the vulnerability to injury while doing regular and physical activities [4]. Particularly, lower balance confidence is correlated to avoidance and restriction of physical activity and community participation [5]. Therefore, programmes should be designed as a part of preparing participation in physical activities for children with disabilities [6]. Additionally, It is recommended that the programme should be designed according to Rosenbaum and Gorter's [7] recommendations: therapeutic intervention for children should address the functional skills; engagement with family; fun, meaningful, and involve interactive activities with peers.

Compared to typically developing children, the development of postural control in some children with CP is significantly delayed by multiple forms of disorganisation and adaptation in the neuromotor system related to postural control [8]. According to de Graaf-Peters et al. [8], the severity of CP determines the extent to which they can control and adjust their posture against postural perturbation. It has been found that children with less severe forms of CP show an intact direction-specific postural adjustment. However, they show multiple forms of dysfunctions in their capacity to fine-tune the postural activity to task-specific conditions [8, 9]. While balance is imperative to feel stable, secure, and safe in doing activities, most adults with CP experience physical and balance deterioration [10]. These balance problems affect their capacity to be active in their daily life or participate in fun activities that they enjoy.

The development of postural control depends on the child's age and the nature of the postural task. Particularly, in school-aged children, the acquisition of the fine-tuning of the basic postural pattern depends on the difficulties of the postural task and the variation of the external multi-sensory input [8]. Several studies of children with CP explain that repeated balance perturbations and balance tasks resulted in improvements in the direction-specific postural adjustment, the postural muscle recruitment, and the modulation of muscle contraction [11]. Therefore, task-specific training (TST) is a recommended neuromotor intervention to train patients with postural control problems, including children with CP [12].

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Task-specific training to improve balance

Task-specific training (TST) uses the principle of motor learning and neuroplasticity [13]. The given tasks are designed using a goal-directed approach. During TST, children are trained to find effective strategies to control balance and coordinate movements. They are repeatedly exposed to a balance task under the right constraint (task and environment) until more stable coordination and controlled movement are developed. The balance task involves weight shifting in different static (in a fixed posture) and dynamic (in motion) conditions. The tasks could be standing on a foam surface with eyes closed or performing dual-task conditions, such as walking while carrying a toy [12]. The prescribed tasks should also address children's functional and meaningful skills, and also fun, involving engagement with their family and peers [7, 14].

Aims of the review

TST has shown potential as a promising intervention for children with disabilities to gain balance skills [15, 16]. While systematic reviews investigating the effectiveness of TST have been published, according to recent searches in the PROSPERO and the Cochrane Library databases, there is no current review specifically evaluating its effects on functional balance performance in children with CP. Toovey et al. [15] evaluated TST to improve gross motor function while Dewar et al. [16] reviewed all interventions to improve postural control, including TST but only two studies were included. Finally, Rensink et al. [17] evaluated TST in stroke patients. The primary aim of this systematic review is to evaluate the effectiveness of TST on functional balance performance during standing and walking in ambulant children with CP. The secondary aims are to compare the effectiveness of TST with other interventions and to identify the strategies used in task-specific training (TST) to improve balance.

Subjects and methods

Systematic review

This systematic review explores studies that investigate the effects of balance task-specific training, the strategies shaping the interventions, and the factors that influence the treatment. Data were synthesised following Popay et al. [18], who developed four steps: (1) developing a theory of how the intervention works, why and for whom; (2) developing a preliminary synthesis of the findings of the included studies; (3) exploring relationships in the data; and (4) assessing the robustness of the synthesis. These steps were conducted to minimise bias and to enhance the transparency of this review.

Search strategy

Searches were conducted on the AMED, Medline, Embase, Cinahl, Web of Science, Cochrane Library, and ASSIA databases between December 2020 and January 2021 (Appendix 1). The search terms were devised according to previous reviews about TST [15, 17]. Remaining related terms were searched through Medical Subject Headings (MeSH) and non-MeSH subject headings. The search strategy was consulted with an expert librarian and revised accordingly. The search strategy comprised the following keywords:

1. Cerebral palsy (MeSH Term)
2. Task? oriented OR Task?specific OR Task?related OR Task?based OR Goal-based OR Goal?directed OR Goal-oriented OR Functional skill OR Functional training OR Activity? based OR Activity focused OR Motor learning
3. Balance OR Postural stability OR Postural control

The keywords were searched separately and in combination. The results were restricted to full text in the English language. Due to a lack of studies meeting this criterion, the date of publication was not limited, and the results were reported based on the searches conducted with the above search strategy.

Selection criteria

Studies were included if they met all the following criteria:

1. Level of evidence: randomised controlled trials (RCTs) and controlled trials (CT).
2. Population: ambulant children with CP (Gross Motor Function Classification System (GMFCS) I-IV) between 2 and 18 years old.
3. Intervention: TST targeting balance improvement. The intervention could be described as a motor learning approach, activity-based training, goal-based training, and/or functional skill training.
4. Comparison: another intervention or no intervention.
5. Outcomes: balance outcomes.

Exclusion criteria: TST with a combined intervention approach (e.g. robotics, treadmill training, resistance training, virtual reality, or botulinum toxin A) to isolate the effect of TST; grey literature, or non-English language studies.

Study selection

Study selection, data extraction, and quality assessment were completed by authors 1 and 2. Author 3 or 4 served as a third author to resolve any disputes. If the abstract contained uncertainty for inclusion, the full text was retrieved for further evaluation.

The JBI Critical Appraisal Checklists were utilised for the quality assessment of each included study [19]. The following nine criteria were evaluated: a) randomisation method, b) concealed treatment allocation, c) baseline similarity of study groups, d) blinding of assessors, e) cointerventions, f) compliance, g) dropout rate, h) reliability and timing of the outcome assessment, and i) intention-to-treat analysis. Computer-generated random number tables or sealed envelopes were considered adequate randomisation methods. Allocation using the date of birth, date of admission, or alternation was excluded. Concealed treatment allocation had to utilise random assignments generated by an independent person (centralised randomisation). Particularly, compliance with the interventions had to be not less than 75%. Also, the dropout rate had to be not more than 25% for follow-up. The details about the outcome measurements had to be reported. The timing of the outcome assessment had to be identical for all outcome measurements and all study groups [19]. The nine criteria for the assessment of the methodological quality were deemed as 'yes', 'no', or 'unclear' in a case of ineligible reporting. Studies were deemed to be of high quality if they met at least six of nine of the quality criteria.

Data extraction

Data from the included studies were extracted using a modified form of the Joanna Briggs Institute (JBI) Data Extraction Form for Experimental/Observational Studies [20]. The extracted data included the study methodology; study population, sample size, participants' demographics and baseline characteristics; content of the interventions and control conditions; outcomes, and times of measurements relevant to the review question and objectives.

Data analysis

To evaluate the existence of the heterogeneity between the studies, the findings were categorised into five categories: settings, demographics, prescribed tasks, outcome measures, and statistical analysis [18]. The differences in the studies (especially in the demographics, prescribed tasks, and outcome measures) were found to be not suitable for meta-analysis. Therefore, a narrative review of the findings was conducted to answer the questions [18]. To ensure complete reporting of the intervention, the components of template for intervention description and replication (TIDier) checklists and guides were adopted [21]. The description of underlying motor learning strategies; materials and procedures; who provided the intervention; modes of delivery; types of location; schedule, duration, intensity and dosage; and assessment of adherence were reported. The size of the intervention effect was calculated using a standardised mean difference. The interpretation of effect size is according to Lenhard and Lenhard [22] as follows: no effect (d = 0–0.1); small effect (d = 0.2–0.4); medium effect (d = 0.5–0.7); and large effect (d = ≥ 0.8).

Ethical approval

In this systematic review, we did not directly collect data from human participants or animals. Our research primarily relied on publicly accessible documents and existing evidence.

Results

A search of databases identified 3,541 results. Of these, 3,439 were excluded following the review of the title and the abstract, as either they did not apply the task-specific training or did not measure the balance outcomes (Table 1). A total of 102 papers were retrieved for further examination. Twenty-one papers were appraised critically. Seven papers met the study criteria (Figure 1).

Table 1. Description of included studies

Year	First author	Study design / JBI LoE	CP (n)	Age range, mean, and SD (years)	GMFCS level	Task-specific training	Comparison	Outcomes measures	
								balance	other outcomes
2013	Kumban et al. [27]	RCT/II	Total = 21 E = 10 C = 11	E = 12.3 ± 2.6 C = 12.4 ± 2.4	E = I–II = 60%, III = 40% C = I–II = 55%, III = 45%	routine physiotherapy + sit-to-stand task training	routine physiotherapy	PBS, FRT	functional movement (FTSST, MAS)
2013	Grecco et al. [25]	RCT/II	Total = 33 E = 16 C = 17	E = 6.8 ± 2.6 C = 6.0 ± 1.5	E = I = 31%, II = 50% III = 19% C = I = 47%, II = 53%	overground walking	treadmill training	BBS, Tekscan MatScan® System	functional mobility, gross motor function, functional performance
2014	El-Kafy and El-Basatiny [23]	RCT/II	Total = 30 E = 15 C = 15	E = 8.9 ± 0.77 C = 8.7 ± 0.71	E = I = 40%, II = 60% C = I = 47%, II = 53%	traditional PT program + dynamic postural stability training	traditional PT program	Biodex Balance System	gait parameter evaluation
2014	El-Shamy and El-Kafy [24]	RCT/II	Total = 30 E = 15 C = 15	E = 10.7 ± 1.3 C = 10.5 ± 1.4	E = I = 40%, II = 60% C = I = 47%, II = 53%	traditional PT program + postural balance control training	traditional PT program	Biodex Balance System, PBS	
2015	El-Basatiny and Abdel-Aziem [26]	RCT/II	Total = 30 E = 15 C = 15	E = 11.98 ± 1.21 C = 12.5 ± 1.27	E = I = 40%, II = 60% C = I = 53%, II = 47%	traditional PT program + backward walking	traditional PT program	Biodex Balance System	
2020	Gonzalez et al. [29]	RCT/II	Total = 27 E = 14 C = 13	E = 13 ± 2 C = 12 ± 2	E = I = 57%, II = 43% C = I = 64%, II = 36%	warm-up + slackline tasks + cool down	routine physiotherapy	T-plate, medicapteurs	myoelectrical activity (SEMG), jump performance (digitest), perceived exertion (Borg Scale)
2020	Heneidy et al. [28]	RCT/II	Total = 30 E = 15 C = 15	E = 6.41 ± 0.75 C = 6.27 ± 0.72	E = I = 53%, II = 47% C = I = 60%, II = 40%	therapeutic exercise programme + TST	therapeutic exercise programme	Biodex Balance System	

RCT – Randomised-controlled trial, E – experimental group, C – control group, PBS – Paediatric Balance Scale, FRT – Functional Reach Test, FTSST – five times sit to stand test, MAS – Motor Assessment Scale, BBS – Berg Balance Scale, PT – physiotherapy training, SEMG – surface electromyography

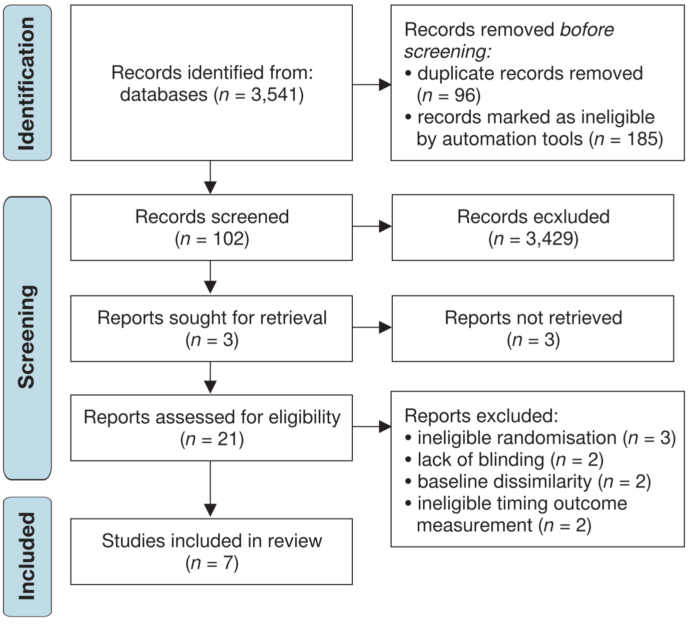

Figure 1. Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) chart of included and excluded studies

Participants

Seven RCTs were included with a total of 201 participants. There was no significant difference in terms of sex (50.75% male; 49.25% female). Age ranged from 4 to 15 years. GMFCS levels were GMFCS I (45.27%), GMFCS II (47.77%), and GMFCS III (6.96%). Spastic diplegia and hemiplegia were the most common among the participants.

Description of studies and quality assessment

Most of the studies were from Middle Eastern countries (*n* = 2), and Egypt (*n* = 2) with three further studies from Thailand, Spain, and Brazil. The studies were conducted between 2013 and 2020. The tasks of TST were varied; two studies employed dynamic balance tasks on a Biodex Balance System [23, 24]; one involved an overground walking training [25]; one trained backwards walking [26]; one employed sit-to-stand [27]; one trained static and dynamic balance tasks training [28]; and one employed balance tasks on a slackline [29].

Seven studies compared TST with 'traditional', 'routine', or 'therapeutic' physiotherapy programmes. The terms were not consistent in the studies. Stretching, strengthening, treadmill training and neurodevelopmental treatment were the most common parts of the training (Table 2) [25].

The experimental intervention employed a motor learning approach [26] or motor learning strategies [23–25, 27] on the TST. Repetitive practices with feedback and task modification were the most common strategies used. TST prescribed static and/or dynamic balance challenging tasks, such as sit-to-stand, standing on an unstable platform, and walking on a slackline (Table 3). Most of the TST was conducted by physiotherapists, however, their level of expertise was not reported. Three of five studies employed the TST in an individual format, while the remaining studies did not clearly state whether their intervention was in a group or individual format [23, 24, 26]. Overall dosage time ranged from 1 to 6 hours over 1.5–4 months.

Outcome measure

Seven studies used six balance outcome measures (Table 1). Kumban et al. [27] used a validated test, the Functional Reach Test, to measure anterior displacement within a fixed base of support or static standing balance (inter-rater reliability [ICC = 0.98] and intra-examiner reliability [ICC = 0.92]). Balance control during daily activities or functional balance was measured using the Paediatric Balance Scale and Berg Balance scale in two and one study, respectively (inter-observer reliability [ICC ¼ 0.98], and intra-observer [ICC ¼ 0.98]). Two studies used a force platform to evaluate directional weight-

Table 2. Quality assessment of the included studies

Study	JBI checklist									
	selection bias		performance bias		detection bias		attrition bias	statistical methods	quality	
	true randomisation	allocation concealment	similarity at baseline	participant blinding and therapist blinding	identical treatment	outcome assessor blinding	equality and reliability of outcome measurement	complete outcome data	statistical methods	overall bias
Kumban et al. [27]	+	+	+	–	+	+	+	unclear	+	high
Grecco et al. [25]	+	+	+	–	+	+	+	unclear	+	high
El-Kafy and El-Basatiny [23]	+	+	+	–	+	+	+	+	+	high
El-Shamy and El-Kafy [24]	+	+	+	–	+	+	+	+	+	high
El-Basatiny and Abdel-Aziem [26]	+	+	+	–	+	+	+	+	+	high
Gonzalez et al. [29]	+	+	+	–	+	+	+	+	+	high
Heneidy et al. [28]	+	+	+	–	+	+	+	+	+	high

Table 3. Components of TST for included studies

Study	TST intervention	Key characteristics of TST interventions: overall approach: goal-directed	overall approach: motor learning approach	motor learning strategies reported: feedback	cognitive strategies	repetitive Practice	task modulation	environmental modulation	dual-task training	Dosage	Setting	TiDier Component: procedure	format	providers	adherence reported?
Kumban et al. [27]	sit-to-stand task training			√		√	√			20 minutes/ session 3 sessions/ week for 6 weeks	School	Children were instructed to flex the hip and move the trunk forwards until the shoulder was vertically above the knee joints, and finally to stand up	unclear	school PT	Yes
Grecco et al. [25]	overground walking			√		√	√			30 minutes/ session 2 sessions/ week for 7 weeks	PT clinics	Children were instructed to walk at a comfortable, self-selected pace for the first and last 5 minutes, and were encouraged to increase the speed for the final 20 minutes	unclear	PT	Yes
El-Kafy and El-Basatiny [23]	dynamic postural stability training			√		√	√			2 hours/ session 3 sessions/ week for 8 weeks	PT clinics	Children were required to stand barefoot, without support while controlling their body movement and balance to maintain a cursor on the centre of a circular grid as much as possible	individual	NS	Yes
El-Shamy and El-Kafy [24]	dynamic limit of stability (DLS) training			√		√	√			2 hours/ session 3 sessions/ week for 12 weeks	NS	Children were required to stand bare feet on a Biodex Balance System without support and look straight at a visual feedback screen. Trials were performed 3 times with 5 minutes of rest and trained at 2 levels of dynamic stability (static and level 12).	individual	NS	No
El-Basatiny and Abdel-Aziem [26]	backward walking training	√	√	√		√	√			1 hour 25 minutes/ session 3 sessions/ week for 12 weeks	PT clinics	A child was instructed to take a step backwards between parallel bars. The PT guided the child to walk in the correct pattern. The difficulty increased from 'with assistance', to 'no assistance', then to 'away from the parallel bars'	individual	experi-enced PT	No
Gonzalez et al. [29]	slackline tasks	√				√	√			30 minutes/ session 3 sessions for 6 weeks	NS	A child was instructed to perform static and dynamic balance tasks on a slack rack. The difficulty of tasks gradually increased every week. The task was started with 4 balance tasks in a standing position in the first week, 4 standing balance tasks and 2 walking tasks in the second week, a walking task on the remainder of the weeks with a decreased level of assistance from the therapist.	individual	PT	Yes
Heneidy et al. [28]	balance TST		√	√		√	√	√		90 minutes, session 3 sessions/ week 16 weeks	outpatient clinic	Children were required to do tasks-oriented activities as follows: sit-to-stand; standing and reaching in different directions, distances, and heights; stepping forwards, sideways, and backwards; heel raising and lowering; and climbing up and downstairs.	individual	PT	Yes

PT – physiotherapy or physiotherapist, NS – not stated shifting in a fixed standing position or static postural stability [29, 31]. Four studies utilised a computerised multiaxial platform system, the Biodex Balance System, to calculate directional weight-shifting within the platform and overall postural stability at different levels of instability [23, 24, 26, 28].

Balance outcomes and effects

Generally, T1 (baseline) was followed by T2 (6–16 weeks) and followed up by T3 (4–6 weeks) [25, 27, 28]. In four studies, the Biodex Balance System (BS) was used to evaluate the postural stability in twelve levels of dynamic platform tilt (level 12 is the most stable and level 1 is the least stable) [23, 24, 26, 28]. Improvements in postural stability are associated with lower scores in the Biodex BS. Large negative effects favouring the TST at T2 were found at level 8 (Biodex BS d = –0.785, 95%CI = –1.528 ÷ –0.042) and larger effects at level 7 (Biodex BS d = –2.661 95%CI = –3.644 ÷ –1.679) by El-Kafy and El-Basatiny [23]. Also, these results were similar to El-Basatiny and Abdel-Aziem [26] who found large negative effects on the overall stability favouring the TST at T2 at both level 12 (Biodex BS d = –0.841 95%CI = –1.588 ÷ –0.094) and level 7 (Biodex BS d = –0.822 95%CI = –1.567 ÷ –0.076). Similarly, these large negative effects on the overall stability index of the TST group at T2 were also found at level 8 (Biodex BS d = –2.2778, 95%CI = –3.1967 ÷ –1.3589) by Heneidy et al. [28]. El-Shamy and El-Kafy [24] also found overall large positive effects on overall directional control (%) favouring the TST at T2 at both static level (Biodex BS d = 18.771 95%CI = 13.968–23.575) and level 12 (Biodex BS d = 19.442 95%CI = 14.471–24.414). Overall, the between-group effects on the postural stability were positive for the TST groups in four studies.

The functional balance was measured with the Paediatric Balance Scale (PBS) in two of six studies [24, 27]. Large positive effects favouring the TST were found by El-Shamy and El-Kafy [24] at T2 (PBS d = 78.494 95%CI = 58.62–98.369). Similarly, positive small-to-medium effects at T2 in children with GMFCS I–II (PBS d = 0.4391 95%CI = –0.7061–1.5842; FRT d = 0.5251 95%CI = –0.6259–1.676) and positive large effects in children with GMFCS III (PBS d =1.4112 95%CI = –0.0563–2.8788; FRT d = 1.0261 95%CI = –0.3715–2.4237) favouring the TST group were found by Kumban et al. [27]. Overall positive effects were also found at T3 of this study. The Berg Balance Scale (BBS) was used in one study by Grecco et al. [25]. This measure, however, is not specific to assessing balance function in children. In this study, Grecco et al. [25] also found large positive effects at T2 (BBS d = 1.528 95%CI = 0.7747–2.2813) and T3 (BBS d = –1.667 95%CI = –2.459 ÷ –0.874) favouring the treadmill group. Altogether, the between-group effects on the functional balance were positive for the TST groups in the three studies. However, one study found that treadmill training resulted in higher positive between-group effects than TST to improve functional balance.

Two studies measured static postural stability with a pressure platform (PP) [29, 31]. The movement of the centre of pressure (COP) was measured in two directions (anteroposterior, AP; mediolateral, ML). Improvements in static postural stability are correlated with lower scores in the movement of COP [32]. Grecco et al. [31] conducted this measurement in two conditions: eyes-opened (EO) and eyes-closed (EC). Medium-to-large negative effects (PP ML-EO, d = –0.9825 95%CI = –1.6842 ÷ –0.2808; PP ML-EC, d = –0.5471 95%CI = –1.2222–0.128) favouring the treadmill group at T3 were found by Grecco et al. [31]. Similarly, González et al. [29] found large negative effects in the overall movement of COP (PP, d = –1.597 95%CI = –2.4637 ÷ –0.7302) and in the ML direction (PP ML-EO, d = –2.1103 95%CI = –3.052 ÷ –1.1687) favouring the TST group at T2. Collectively, the between-group effects for static postural stability were positive for the TST groups in the two studies.

Fall risk was evaluated in a study by El-Shamy and El-Kafy [24]. A large decrease in the probability to fall favouring the TST group was found at T2 at both static levels (BiodexBS Fall d = –1.698 95%CI = –2.533 ÷ –0.863) and level 12 (BiodexBS Fall d = –2.914 95%CI = –3.941 ÷ –1.886). Large negative effects in time to complete the test were also found at T2 at both levels of stability (BiodexBS Time Static d = –125.67 95%CI = –157.476 ÷ –93.863; BiodexBS Time lvl 12 d = –52.013 95%CI = –65.193 ÷ –38.832). See the supplementary data for the full data extraction report.

Training strategies

This study also aims to identify strategies used to balance TST. Due to the poor description of the motor learning strategies and heterogeneity in the interventions and outcome measures, there are limitations in drawing definite conclusions. However, this study discusses prominent characteristics of balance TST. One anticipated finding was that repetitive practice, feedback, and task modulation strategies were used consistently in balance TST. Although the training dosage and period varied, surprisingly, TST with a higher dosage (total 24 hours) had a similar effect size to TST with a lower dosage but a longer period of training (total 51 hours) [23, 26]. TST with the highest dosage and longer period of training (total 72 hours) were found to have the largest positive effects [24, 28]. Visual or verbal feedback was the most commonly used strategy. While it was suggested that the feedback potentially improved the task acquisition, the role and the application of feedback were poorly explained. Thus, it is difficult to replicate the feedback and determine its benefit [24, 27]. While task contexts and motor challenges were variable throughout the studies, increasing the task difficulty was the most used strategy, except for one using the number of repetitions in a session as a parameter in the task progression [27]. Another important finding was that the largest postural stability outcomes were found when the task involved a conditioned perturbation and was goal-oriented. These results corroborate the finding of the growing evidence for interventions improving balance for children with CP [16]. The theoretical assumption on how the TST can improve balance in children with CP was illustrated in Figure 2.

Intervention replicability

Three studies reported that the intervention providers were physical therapists [25, 27–29]. However, only one study specified the years of expertise [26]. Two studies did not report the providers [23, 24]. All included studies explained the format of the intervention and the comparison intervention. Participant adherence was only reported in three studies, while provider adherence was not reported in the studies (Table 2) [25–27].

Discussion

This systematic review and narrative synthesis aimed to evaluate the effectiveness of TST to improve balance performance. The search strategy identified seven high-quality studies. All of the seven studies were found to have a low risk

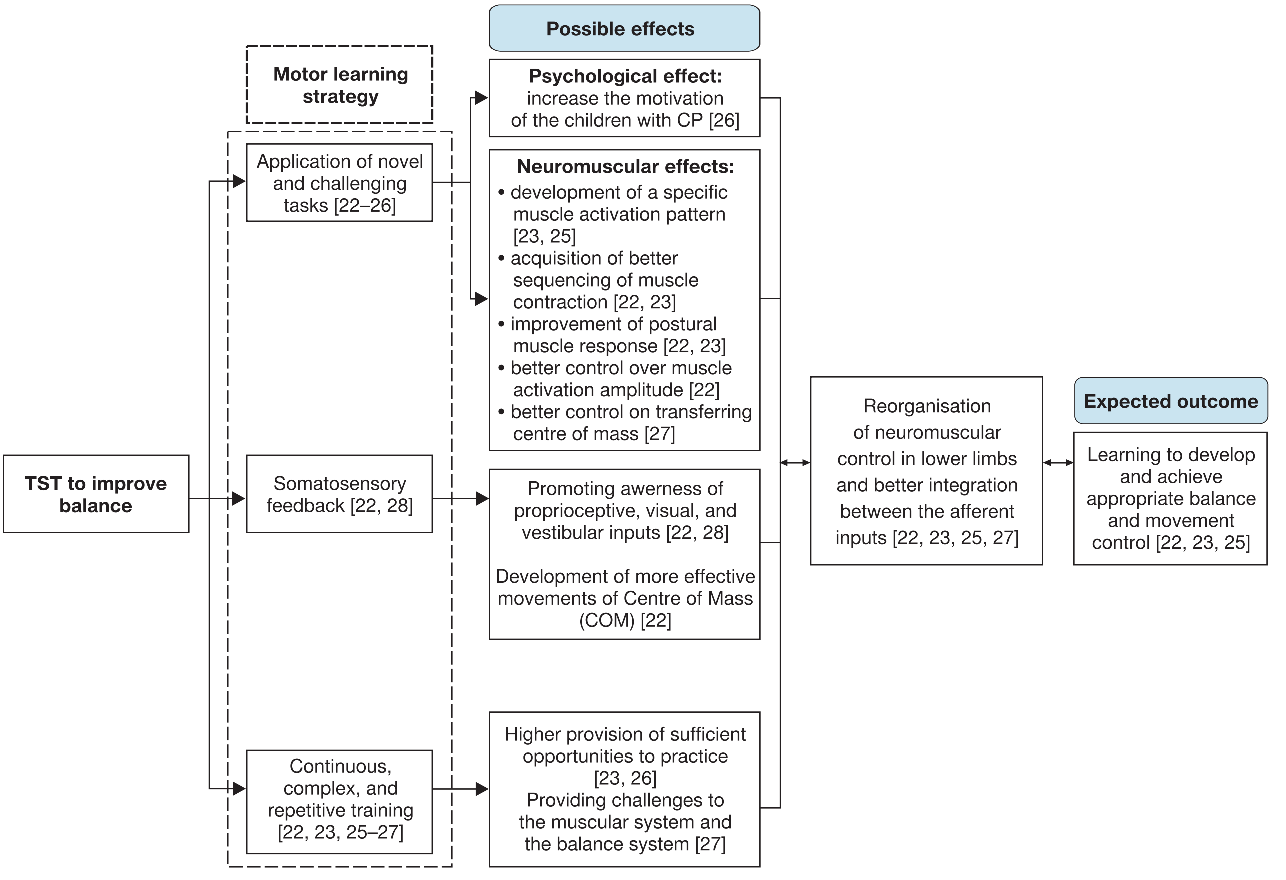

Figure 2. A theoretical model outlining the chain of causal effect on how TST can improve balance

of bias using the JBI Critical Appraisal Checklists. In four RCTs, TST was compared with traditional or routine physiotherapy training programmes, and the between-group effects on the postural stability outcome, measured with Biodex BS, showed large positive effects favouring TST [23, 24, 26, 28]. Retention of the positive between-group effects of TST was maintained for at least six weeks. The balance tasks were practised in static (maintaining balance in one position) and dynamic (backwards walking) conditions, also involving functional tasks (sit-to-stand, reaching, and climbing stairs). The strategies used in the TST were repetition, feedback (visual and verbal), and task difficulty modulation. Visual feedback from the Biodex BS was mainly used to guide the children in maintaining balance on the platform. During functional balance task training, verbal instruction from the therapists plays an important role. The positive effects were explained as a result of the reorganisation of neuromuscular control and improvement in somatosensory awareness. Thus, the children achieved appropriate balance and movement control (Figure 2).

Overall, high-quality evidence reported small to large positive effects of TST to improve functional balance in children with GMFCS I–II. Kumban et al. [27] found that children with GMFCS III had larger positive effects than those with GMFCS I–II [5, 27]. This suggested that TST may give different effects on functional balance according to their level of gross motor function. The strategy involved practising tasks in static conditions and functional activity tasks such as sit-to-stand and overground walking. This finding is in line with the previous review by Dewar et al. [16], who supported a training programme that addressed functional goals to improve postural control.

For additional balance outcomes, the evidence found positive effects of TST in decreasing fall risk. According to the previous review by Hadjistavropoulos et al. [33], the fall risk is highly correlated with balance confidence. Furthermore, Towns et al. [5] found that higher balance confidence would lead to a higher tendency to participate in physical activity in youth with CP because fear of falling and embarrassment due to falls were prominent contextual factors for children with CP to avoid participating in physical activity [5]. The findings in this review, therefore, recommended that TST can be applied in designing a programme to decrease the risk of falling in children with CP.

Concerning the secondary aim of this study, when TST was compared to other interventions, TST showed conflicting effects. Most studies favoured TST, except for Grecco et al. [25], which favoured the treadmill group. The TST conducted by Grecco et al. utilised an insufficient training dosage of 7 hours for balance training. This duration falls short of the recommended minimum of 10–30 hours, as outlined by Dewar et al. [16]. This implies that an adequate training dosage is important to the successful balance TST programme. Unexpectedly, treadmill training without body weight support had been found to have greater within-group effects in improving functional balance than TST. In line with the previous systematic review by Toovey et al. [15], this review found the possibility that the combination of TST with another approach, such as treadmill training, may bring greater benefit than pure TST to improve balance in ambulant children with CP.

The prescribed balance tasks in the current evidence were given in static and dynamic conditions, and also included functional daily tasks. However, there was no adequate clarification if the prescribed tasks were what the children found fun and meaningful. Further studies designing balanced TST based on the children's preferences and functional demands are required. It is recommended that the balance tasks or activities are fun and fulfilling for the children with CP [7].

Limitations

The evidence in this study had been evaluated to be high-quality evidence based on the pre-determined criteria. However, the studies have some methodological limitations, resulting in the risk of bias. Four of the studies did not report sample size calculations, with three studies reporting this [27–29]. The outcome data from all included studies have very wide CIs, which suggests inadequate sample sizes, resulting in limited precision in estimating the effects [23–29]. Poor reporting of the studies contributed to reducing the robustness of the findings, thus restricting the practicality of the implementation. The Biodex BS was utilised in four studies [23, 24, 26, 28], while the BBS was employed in one study [25]. The Biodex BS has never been tested for validity and reliability in the population of children [34]. While the BBS has been recommended as a balance measurement tool for children with CP, it is important to note that its original intent was for the elderly and post-stroke population [35]. Thus, balance improvement in children may not be adequately measured using these tools.

This review explicitly included studies evaluating TST interventions to improve balance outcomes in children with CP. Due to study design issues and heterogeneity of the included studies, this review could not conduct a meta-analysis. Furthermore, publication bias was not assessed in this review. Finally, only English-language studies were included. Thus, non-English and grey literature may have been missed.

Conclusions

Most of the studies found that TST brings medium-to-large positive effects on static, dynamic, and functional balance. Additionally, large positive effects of decreasing fall risk were revealed. Although neurodevelopmental treatment (NDT) was consistently found to be less effective than TST, sound recommendations on whether TST is superior to other interventions cannot be reached. Therefore, studies with a more robust design and consistent reporting are needed to draw relationships between motor learning strategies and postural balance outcomes.

The importance of keeping children with disabilities active has been recognised. To reduce a major limitation in physical activities, balance intervention programs are essential [4, 7]. Thus, a definitive evidence base is crucial to establish specific recommendations. More studies with rigorous study designs and adequately powered samples are required. Consistent and clear reporting on interventions and results is imperative to allow adequate reproducibility and evidence synthesis. Further studies also need to be conducted to validate the Biodex BS in the population of children. Studies employing a combination of balance TST with games, virtual reality, and adapted sports are suggested to bring fun and meaningful training for children with CP. Limitations related to intervention heterogeneity and inadequate application of balance strategies in TST should be explored further.

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Conflict of interest

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Data sharing statement

Data relating to the quantitative synthesis are available on request.

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Appendix 1. Web of Science search results

Search term	Results	Search number
(1) Cerebral palsy	28,136	#1
(2) Task oriented	21,654	#2
(3) Task specific	84,802	#3
(4) Task related	118,527	#4
(5) Task based	254,697	#5
(6) Goal based	195,259	#6
(7) Goal directed	38,944	#7
(8) Goal oriented	18,072	#8
(9) Functional skill*	11,904	#9
(10) Functional training	28,637	#10
(11) Activity based	637,383	#11
(12) Activity focus*	175,095	#12
(13) Motor learning	27,955	#13
(14) #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10 OR # 11 OR #12 OR #13	1,367,526	#14
(15) Balance	621,700	#15
(16) Standing	280,788	#16
(17) Walking	152,871	#1768,476
(18) Postural stability	7,013	#18
(19) Postural control	16,501	#19
(20) #15 OR #16 OR #17 OR #18	1,046,747	#20
(21) #1 AND #14 AND #20	630	#21
(22) #1 AND #13 AND #18; Refined by language = (English) and type of study	512	#22