Effectiveness of Exercise on Functional Mobility in Adults with Cerebral Palsy: A Systematic Review

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ABSTRACT

Purpose: We identified evidence evaluating the effect of exercise on functional mobility in adults (aged 18 y or older) with cerebral palsy (CP). **Method:** An exhaustive search was conducted using the electronic databases PubMed, MEDLINE, CINAHL, PsycINFO, SPORTDiscus, and Cochrane Database of Systematic Reviews from the earliest available evidence (1975) to the present (January 2016) for studies whose participants were ambulatory adults with CP receiving conservative treatment to address functional mobility limitations. Two independent reviewers agreed on the eligibility, inclusion, and level of evidence of each study. The Maastricht-Amsterdam List (MAL) was used to assess evidence quality. **Results:** Five of the six studies included were randomized controlled trials, and one was a pre-post case series. Interventions included whole-body vibration, treadmill training without body-weight support, rhythmic auditory stimulation, dynamic balance and gait activities, progressive resistance training, and interactive serious gaming for balance. All studies were considered high quality, as indicated by their MAL scores. Four studies showed no statistical difference and trivial effect sizes between the intervention and the control group. Rhythmic auditory stimulation and interactive serious gaming were found to be statistically significant in benefiting adults with CP. **Conclusions:** Evidence of the effect of exercise on functional mobility for ambulatory adults with CP is lacking. A need exists for quality research to determine the best interventions for adults with CP to maximize functional mobility.

Key Words: cerebral palsy; exercise; gait; mobility limitation; postural balance; systematic review.

RÉSUMÉ

Objectif : recenser les données probantes sur l'efficacité de l'exercice sur la mobilité fonctionnelle des adultes (18 ans et plus) atteints de paralysie cérébrale (PC). **Méthode :** une recherche exhaustive a été menée dans les bases de données électroniques PubMed, MEDLINE, CINAHL, PsycInfo, SPORTDiscus et Cochrane Database of Systematic Reviews à partir des données les plus anciennes (1975) jusqu'à aujourd'hui (janvier 2016) sur des études menées auprès d'adultes ambulatoires atteints de PC recevant un traitement conservateur pour leur mobilité fonctionnelle réduite. Deux examinateurs indépendants ont convenu de l'admissibilité, de l'inclusion et du niveau de données probantes de chaque étude. La liste de critères Maastricht-Amsterdam (MA) a été utilisée pour évaluer la qualité des preuves. **Résultats :** cinq des six études incluses étaient des essais randomisés et l'autre était une série de cas avant/après. Les interventions incluaient des vibrations transmises à l'ensemble du corps, un entraînement sur tapis roulant sans support du poids corporel, une stimulation auditive rythmique, des activités d'équilibre dynamique et de démarche, des exercices progressifs de musculation et des jeux interactifs d'équilibre. Toutes les études étaient de grande qualité, comme l'indique leur score de la liste de critères MA. Quatre études n'ont montré aucune différence statistique et ont montré une ampleur de l'effet négligeable entre l'intervention et le groupe témoin. La stimulation auditive rythmique et les jeux interactifs ont montré des bienfaits significatifs d'un point de vue statistique chez les adultes atteints de PC. **Conclusions :** il n'y a pas suffisamment de données probantes sur l'effet de l'exercice sur la mobilité fonctionnelle des adultes ambulatoires atteints de PC. Des recherches de qualité sont nécessaires pour déterminer les interventions les plus efficaces pour améliorer la mobilité fonctionnelle des adultes atteints de PC.

Cerebral palsy (CP) is an umbrella term used to classify individuals with non-progressive lesions of the immature brain, characterized by movement difficulty and postural instability.¹ Individuals with CP may experience a variety of concomitant health conditions as a result of their diagnosis, including muscle spasticity, movement disorders, difficulty with motor planning and control, and cognitive impairments. In 2001, the World Health Organization introduced the *International Classification of*

Functioning, Disability and Health (ICF) model² as a framework for patient management. The *ICF* defines a person by his or her participation roles rather than by his or her disease or illness. This approach emphasizes the interplay among the health condition, contextual factors, community activities, and access to health care to optimize functioning and participation in each patient's own environment.³ The shift from "fixing" a person's impairments to promoting functional activity

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Figure 1 ICF model applied to patient care for an adult with CP seeking PT because of decreased functional mobility. ICF = International Classification of Functioning, Disability and Health; CP = cerebral palsy; PT = physical therapy.

and participation in areas of importance to the patient⁴ was intended to improve the quality of patient care and is critical when treating patients with lifelong disabilities (LLDs). This model allows health care providers to consider a dynamic approach to patient care, thereby improving quality of life, patient outcomes, and patient satisfaction. Figure 1 illustrates the ICF model applied to adults with CP.

Advances in medical care allow individuals with LLDs, such as CP, to live further into adulthood than ever before.^{5,6} Although the lesion that causes CP is non-progressive, individuals with CP characteristically experience progressive declines in function throughout their lifetime.⁶ With increasing age, they often experience an increase in activity limitations, caused in part by decreased mobility, which is commonly manifested by difficulty with walking,⁷ negotiating stairs, and maintaining postural stability. As a result of activity limitations, in combination with other physical changes and psychosocial factors throughout their lives, individuals with CP experience a decrease in participation in typical life activities, such as post-secondary education, gainful employment, and creating a family.⁸

Medical care for adults with CP should include episodes of physical therapy (PT) aimed at addressing the limitations in activity experienced in adulthood to pre-

vent a decline or abatement in participation. However, because community resources are limited—transportation may be infrequent, increased difficulty in obtaining gainful employment and health care costs can impose financial restrictions, and practitioners may be unfamiliar with their specialized needs⁵—adults with CP who would benefit from PT often do not seek care.

Currently, there is no formalized pathway for the transition from pediatric to adult health care⁶ and no consensus on which PT interventions best help to improve or maintain functional mobility for ambulatory adults with CP. Particularly important aspects of functional mobility are gait components, dynamic postural stability on a variety of terrains, and stair negotiation. Because interventions for adults with CP necessitate a different focus than those for the typical patient without an LLD, physical therapists must be equipped to address the specific limitations experienced by adults with CP.⁶ Having limited information about interventions for adults with CP may lead to a decrease in the quality of health care a physical therapist provides and a subsequent decrease in quality of life for these patients.

Most research done in the field of CP relates to children and adolescents, leaving a gap in the literature regarding appropriate interventions strictly for adults with CP. One piece of current literature has specifically

examined the effects of progressive resistance training to strengthen people with CP aged 6–47 years,⁹ but it focused more on impairments to body structure than limitations on functional activity or restrictions on participation. Another systematic review published in 2010 revealed that only a few studies on PT interventions had been done with adults with CP, and even fewer were of good methodological quality. That systematic review assessed the use of all varieties of physiotherapeutic interventions for adolescents and adults with CP, but it did not incorporate dimensions of the *ICF* model.¹⁰ To our knowledge, there is no current systematic review that specifically evaluates the best interventions for preventing and decreasing activity limitations in adults with CP while incorporating important aspects of the *ICF* model.

The goal of this systematic review was to identify the available evidence for PT interventions to address functional mobility limitations such as ambulation, stair negotiation, and dynamic postural stability in ambulatory adults with CP aged older than 18 years.

METHODS

Eligibility criteria

The eligibility criteria for selection were as follows: (1) Participants had a diagnosis of CP, were ambulatory, and were aged 18 years or older; (2) participants had received conservative treatment such as PT, resistance training, or gait training; (3) studies reported results in terms of gait speed or velocity or reported outcomes using one of the following gait- or mobility-related outcome measures: 6-minute walk test (6MWT), 10-metre walk test (10MWT), Gross Motor Function Measure (GMFM), or Berg Balance Scale (BBS); (4) the publication was a randomized controlled trial, a controlled trial, a cohort study, a case-control study, or a pre-post study; and (5) data for participants aged 18 years or older were available independently in studies that also included children and adolescents.

Search

An exhaustive online search was completed using PubMed, MEDLINE, CINAHL, PsycINFO, SPORTDiscus, and the Cochrane Database of Systematic Reviews. The search spanned from the earliest available time (1975) to January 2015 and was rerun in January 2016. A hand search was also conducted using available reference lists and journal articles.

A systematic search strategy was formulated with the help of a professional librarian using the keyword *cerebral palsy*, in combination with variations on *gait*, *mobility limitation*, *postural balance*, *exercise*, *physical therapist*, and *adults*. Limiters used were *humans* and *English*. Studies were evaluated using a stepwise approach by title, abstract, and full text, in that order, by two independent reviewers (SH, HL), and consensus was reached for inclusion. Available data were extracted independ-

ently by the reviewers (SH, HL) from the included articles using a table format that included prospective patient or population, intervention, comparison, outcomes, and study design. One author was contacted independently for additional data relevant to this review.¹¹

The characteristics of each included study were collected, including the participants' demographics, the intervention(s) performed, and the study design. When conducting a systematic review, it is important to consider the quantity and quality of the evidence that is included. The 19-item Maastricht-Amsterdam List (MAL) was used to assess the quality of evidence of each study because it accommodates both randomized and non-randomized designs. According to a study published in 2008, the MAL has positive face validity, criterion validity, and reproducibility among physical therapists, and, despite its limitations in internal consistency, content validity, and construct validity, it remained the best tool for the purpose of this systematic review.¹² Each article in this review was scored by two independent reviewers (NK, KW) using the MAL. When the reviewers' scores differed, the mean score was calculated and assigned as the final score.

In addition to the quality assessment, the reviewers reported the level of evidence of each article, assessed according to the hierarchy published on the University of Oxford's Centre for Evidence-Based Medicine (CEBM) website. This hierarchy assigns a letter and number "grade" based on the presence or absence of a control group, randomization, and CIs, among other characteristics. The highest level of evidence is level 1a, and the lowest is level 5.¹³ For example, a level 1b grade would be given to a randomized controlled trial with narrow CIs, and a level 4 grade would be given to a case series, poor-quality cohort study, or case-control design.

The principal summary measures were measures of central tendency (e.g., means, SDs, medians, and ranges). The data reflect mean change scores, SDs, and *p* values either between groups^{11,14–16} or, if these data items were not initially reported, within groups.^{17,18}

Between-group differences^{11,14–16} and within-group differences^{17,18} were also calculated, in a manner that was independent of sample size, to reflect the true magnitude of change. These values were interpreted according to Cohen's interpretation of effect size to assess the benefit and magnitude of that benefit in interventions. This interpretation classifies a trivial effect size as being 0.0–0.1, small as 0.2–0.4, moderate as 0.5–0.7, and large as 0.8–2.0 or more.¹⁹

RESULTS

Study selection

The initial search yielded 205 eligible articles for review: 43 from PubMed; 96 from the Cochrane Database; and 66 from MEDLINE, CINAHL, PsycINFO, or SPORTDiscus. An additional 2 articles were found via a manual

search. After 11 duplicate records were removed, 162 articles were excluded by title and 23 by abstract. As a result, 11 full-text articles were then assessed for eligibility. Five articles were excluded after a full-text review: 2 case reports, 2 that did not use a conservative intervention, and 1 in which all participants were aged younger than 18 years. A total of 6 articles thus fulfilled the inclu-

sion criteria and were reviewed.^{11,14–18} A flow diagram, Figure 2, illustrates this process.

Quality assessment

The final quality assessment score for each study is included in Table 1, and Table 2 provides a detailed description of each study. The two reviewers initially disagreed on 9 of the 109 items assessed, resulting in 92%

Figure 2 PRISMA flow diagram of findings.
PRISMA = Preferred Reporting for Systematic Reviews and Meta-Analyses.

Table 1 Patient, Intervention, Comparison, and Outcome Characteristics

Author (year) and type	Participants	Intervention: frequency, type, and duration	Setting and provider	MAL score	LOE score
Ahlborg et al. ¹⁷ (2006), RCT	<i>n</i> = 14; WBV = 7; RT = 7 Aged 21–41 y; 8 M, 6 F 14 with diplegia GMFCS* I–III	3 × /wk for 8 wk WBV: 6 min in static standing with hips and knees in 50° of flexion RT: 3 sets of 10–15 reps. in a leg press device up to 70% 1RM	Not reported	13.9	1b
Chrysagis et al. ¹⁴ (2012), RCT	<i>n</i> = 5; SOC = 2; Exp. = 3 Aged 18–19 y; 3 M, 2 F Diplegia or tetraplegia GMFCS I–III	45-min. sessions, 3 × /wk for 12 wk SOC: mat activities, balance, gait training, functional gross motor activities Exp.: static stretching, walking on treadmill without BWS	School for students with disabilities; experienced physical therapist	16.5	1b
Kim et al. ¹⁵ (2012), RCT	<i>n</i> = 28; RAS = 15; NDT = 13 Mean age = 27.3 y, SD = 1.7; 17 M, 11 F Bilateral spasticity GMFCS not reported	30 min, 3 × /wk for 3 wk RAS while walking based on gait characteristics Gait training using NDT	RAS performed by music therapist, NDT by specialized physical therapist	14.0	1b
Morgan et al. ¹⁶ (2014), RCT	<i>n</i> = 17; Interv. 1 = 8, Interv. 2 = 9 Aged 19–53 y; 10 M, 7 F Unilateral spasticity, bilateral spasticity, mixed, ataxic GMFCS I–III	1.5 hr, 1 × /wk for 8 wk Interv. 1: guided relaxation, meditation, mindfulness, seated yoga, tai chi Interv. 2: dynamic balance in standing and stepping, dynamic gait, PRT of LE	Outpatient program Interv. 1: allied health assistant Interv. 2: physical therapist	15.5	1b
Taylor et al. ¹¹ (2013), RCT	<i>n</i> = 26; SOC = 15; Exp. = 11 Aged 18–22 y; gender not reported Diplegia GMFCS II–III	2 × /wk for 12 wk SOC: PT and usual recreational activities Exp.: PRT	Community gym under supervision of physical therapist	16.5	1b
Jaume-i-capó et al. ¹⁸ (2014), pre–post design	<i>n</i> = 9; before–after study Aged 27–57 y; 7 M, 2 F Tetraplegia, tetraparesis, tetraparesis and hydrocephalus, mixed, CP with moderate to severe psychomotor retardation GMFCS I–II	20 min, 1 × /wk for 4 wk Serious gaming for balance rehab	Not reported	10	4

MAL = Maastricht-Amsterdam List; LOE = level of evidence; RCT = randomized controlled trial; WBV = whole-body vibration; RT = resistance training; M = male; F = female; GMFCS = Gross Motor Function Classification System; reps. = repetitions; 1RM = one repetition maximum; SOC = standard of care; Exp. = experimental; BWS = body-weight support; RAS = rhythmic auditory stimulation; NDT = neurodevelopmental treatment; Interv. = intervention; PRT = progressive resistance training; LE = lower extremity; PT = physical therapy; CP = cerebral palsy.

*GMFCS is a standardized tool to stratify individuals with CP into one of five levels. Each level is defined by an individual's ability to perform various motor activities, including walking, negotiating stairs, and using a wheelchair. A higher level (level 1) indicates that an individual is mostly independent but may use various means of assistive equipment for distances within the community. A lower level (level 5) indicates that an individual depends on a caregiver and the primary means of mobility is a power or manual wheelchair.

Table 2 Maastricht-Amsterdam List Quality Assessment Criteria & Scores

Author (year), Reviewer	Subtotal internal validity criteria	Subtotal descriptive criteria	Subtotal statistical criteria	Final score (%)
Randomized clinical trials				
Maximum score available	11	6	2	19
Eligible criteria	b1 b2 e f g h i j l n p	a c d k m1 m2	o q	
Ahlborg et al. ¹⁷ (2006)				
1	b1 b2 g h i l n p = 8	a c d k m1 = 5	o q = 2	15 (79)
2	b1 g i j l n = 6	a c d k m1 = 5	o q = 2	13 (68)
Average	7	5	2	13.9 (73.5)
Chrysagis et al. ¹⁴ (2012)				
1	b1 b2 f g h i j l n p = 10	a c d k m1 m2 = 6	o q = 2	18 (95)
2	b1 b2 f g i j l n = 8	a c d k m1 = 5	o q = 2	15 (79)
Average	9	5.5	2	16.5 (87)
Kim et al. ¹⁵ (2012)				
1	b1 b2 g h i l n p = 8	a c d m1 = 4	o q = 2	14 (74)
2	b1 b2 g i j l n p = 8	a c d m1 = 4	o q = 2	14 (74)
Average	8	4	2	14.0 (74)
Morgan et al. ¹⁶ (2014)				
1	b1 b2 g i j l n p = 8	a c d k m1 m2 = 6	o q = 2	16 (84)
2	b1 b2 g i j l n = 7	a c d k m1 m2 = 6	o q = 2	15 (79)
Average	7.5	6	2	15.5 (81.5)
Taylor et al. ¹¹ (2013)				
1	b1 b2 f g h i j l n p = 10	a c d k m1 m2 = 6	o q = 2	18 (95)
2	b1 b2 g i j l n = 7	a c d k m1 m2 = 6	o q = 2	15 (79)
Average	8.5	6	2	16.5 (87)
Non-randomized clinical trial				
Maximum score available	7	5	2	14
Eligible criteria	f g h i j l n p	a d k m1 m2	o q	
Jaume-i-capó et al., ¹⁸ 2014				
1	f g j l n = 5	a d m1 = 3	o q = 2	10 (71)
2	f g j l n = 5	a d m1 = 3	o q = 2	10 (71)
Average	5	3	2	10 (71)

agreement; therefore, the average of the two scores was taken as the final value. This did not result in a difference in whether a study was classified as low or high quality. In calculating the maximum score, average scores ranged from 10 to 16.5. All six studies were considered to be of high quality (MAL score ≥ 10 for controlled studies, ≥ 7 for non-controlled studies). The lowest quality study, a pre-post case series, received a score of 10 and was still considered to be of high quality for a non-randomized clinical trial.¹⁸

Level of evidence

The level of evidence for each article was reported according to the hierarchy published on the CEBM website¹³ (see Table 1). Five articles^{11,14–17} were classified as level 1b (individual randomized controlled trials with

narrow CIs), and one article¹⁸ was classified as level 4 (a case series, poor-quality cohort, or case-control study).

Study characteristics and results

Table 1 summarizes the characteristics of the studies included. Data from participants aged 18 years and older were extracted, and a detailed description of each study is provided. Five of the studies were randomized controlled trials with either a treatment and control group^{11,14,16} or two different treatment groups.^{15,17} All reported control groups received the standard of care for the study or the typical PT intervention for that setting. No true control groups receiving no treatment at all were reported. One pre-post case series was included.¹⁸ Three of the studies used participants who were young adults (aged 18–27 y, SD = 2.5),^{11,14,15} and three studies used participants

Table 3 Between-Group Effect Sizes of Mean Change Scores or Endpoint Values

Author (year), study design	Outcome measure	Intervention group 1		Intervention group 2		<i>p</i> -value	Effect size	Benefit
		Standard mean change score	SD	Standard mean change score	SD			
Chrysagis et al. ¹⁴ (2012), treadmill training without body weight support compared with conventional physical therapy	GMFM	3.260	2.800	2.440	2.130	0.73	0.160 (trivial)	ND
	Gait speed (m/min)	2.280	3.220	4.930	11.910	0.79	0.150 (trivial)	ND
Kim et al. ¹⁵ (2012), RAS compared with NDT	Gait velocity—comfortable speed (m/s)	RAS 0.10	0.030	NDT–0.100	0.030	<0.001	0.960 (large)	In favour of RAS
Morgan et al. ¹⁶ (2014), balance activities compared to seated yoga, tai chi, meditation, relaxation	Gait speed—comfortable speed (cm/s)							
	Wk 0–8	0.300	9.400	3.300	7.000	>0.05*	0.030 (trivial)	ND
	Wk 0–24	0.300	15.700	3.200	16.900	>0.05*	0.000 (trivial)	ND
Taylor et al. ¹¹ (2013), progressive resistance training compared with control receiving “usual care”†	6MWT (m)							
	Wk 0–12	367	112	386	139	0.70	0.075 (trivial)	ND
	Wk 0–24	376	114	373	146	0.95	0.011 (trivial)	ND
	Self-selected walking speed (m/s)							
	Wk 0–12	0.900	0.400	0.900	0.300	1.00	0.000 (trivial)	ND
	Wk 0–24	0.900	0.300	0.900	0.400	1.00	0.000 (trivial)	ND
	GMFM-E (%)							
	Wk 0–12	68.100	21.500	66.300	20.900	0.83	0.042 (trivial)	ND
	Wk 0–24	66.900	20.000	65.000	24.500	0.83	0.0042 (trivial)	ND

* Authors' interpretation based on written report. No specific values reported.

† Calculated as standardized mean difference of endpoint values.

GMFM = gross motor function measure; ND = no difference; RAS = rhythmic auditory stimulation; NDT = neurodevelopmental treatment; 6-MWT = 6-minute walk test; GMFM-E = Gross Motor Function Measure, Part E.

ranging from their early 20s to their late 50s.^{16–18} Participants in two studies had spastic diplegia;^{11,17} in one, they had spastic tetraplegia;^{14,18} in another, they had bilateral spasticity.¹⁵ Two studies included participants with various types of spasticity.^{14,16,18} Three studies included participants who were at Gross Motor Function Classification System (GMFCS) levels I–III;^{14,16,17} one study included participants at GMFCS levels II–III;¹¹ in another, participants were at GMFCS levels I–II;¹⁸ and one study did not report GMFCS levels.¹⁵

Individual interventions and the results of each study varied greatly. The first study used an unconventional method of whole-body vibration (WBV) in static standing with the intervention group, and the control group participated in resistance training.¹⁷ This study did not demonstrate statistically significant within-group differences when comparing resistance training with WBV ($ps = 0.50$ and 0.72 , respectively). Despite the lack of statistically significant differences, the authors of this study reported that they found clinically significant decreasing spasticity in knee extensors in the WBV group

as well as an improvement in the participants' gross motor function.

In the second study, the control group received the standard of care—mat, balance, and gait activities—and the intervention group participated in treadmill training without body-weight support.¹⁴ The study found no statistically significant differences between the groups when using the GMFM and gait speed to assess outcomes ($ps = 0.730$ and 0.789 , respectively) and only trivial effect sizes. The third study compared two intervention groups: one that received rhythmic auditory stimulation (RAS) while walking and one that received neurodevelopmental treatment (NDT).¹⁵ This study concluded that there were statistically significant differences ($p < 0.001$) and a large effect size (0.960) in favour of using RAS. The authors also reported clinically significant improvements in participants' functional gait parameters. The fourth study compared the difference between using guided relaxation, meditation, seated yoga, and tai chi and using dynamic balance and gait activities in standing and found no statistically ($p > 0.050$) or clinically significant findings between the two interventions.¹⁶

Table 4 Within-Group Effect Sizes with Endpoint Values

Author (year)	Outcome measures	Reported measure of change				Effect size	Benefit	
		Pre-assessment		Post-assessment			WBV	RT
Ahlborg et al. ¹⁷ (2006) WBV training compared with RT		WBV, median (range)	RT, median (range)	WBV, median (range)	RT, median (range)	n/a	WBV	RT
	6MWT	384 (386)	215 (495)	376 (356)	237 (512)		<i>p</i> = 0.72	<i>p</i> = 0.50
	GMFM-E*	69 (71)	57 (64)	72 (75)	61 (58)		<i>p</i> = 0.06	<i>p</i> = 0.31
Jaume-i-capó et al. ¹⁸ (2014) pre-post case series using serious gaming	BBS, mean (SD)	29.500 (3.900)		34.100 (2.200)		0.588, moderate	In favour of intervention (<i>p</i> = 0.002)	

*Data for WBV and RT are percentages, not scores.

WBV = whole-body vibration; RT = resistance training; n/a = not applicable; 6MWT = 6-minute walk test; GMFM = Gross Motor Function Measure, Part E; BBS = Berg Balance Scale.

The fifth study compared typical PT activities as the standard of care for PT and usual recreational activity with a progressive resistance training program and found no statistically significant differences between the groups ($ps = 0.703$ – 1.000). Effect sizes were trivial.¹¹ However, in the original study, the authors had reported a clinically significant positive effect of resistance training on the psychosocial aspects of participants' lives. The last study, a pre-post case series, assessed each participant's response to an interactive "serious" game in which the user participated in therapeutic balance-and-attention video game-like activities for balance rehabilitation.¹⁸ This study demonstrated that interactive serious gaming had a statistically significant ($p = 0.002$) effect on participants and a moderate effect size (0.588). The statistical results and effect sizes for the six included studies are provided in Tables 3 and 4.

DISCUSSION

Six studies included in this systematic review on the effective of exercise on functional mobility in adults with CP. All six of these studies were assessed as being of high quality. Two of the studies showed statistically significant differences in the effect of interventions on functional mobility^{15,18} as well as moderate¹⁸ to large¹⁵ effect sizes in favour of the experimental group. Interactive serious games were shown to have a meaningful effect on improving balance in adults with CP, as measured by improvements in BBS scores after receiving the intervention.¹⁸ The use of serious gaming for rehabilitation and improving functional mobility is currently being studied and has been supported for two neurologic populations at this time: people receiving post-stroke rehabilitation^{20–23} and children and adolescents with CP.^{24,25}

RAS proved to be more effective than traditional NDT methods for correcting gait patterns in ambulatory adults with CP, as indicated by an increase in gait speed.¹⁵ The

literature supported the use of RAS for PT rehabilitation and improvement of functional mobility with other neurologic populations, including people with Parkinson's disease^{26–31} and those undergoing post-stroke^{32,33} rehabilitation. The four remaining studies showed no statistically significant differences and trivial effect sizes between the control and experimental groups.^{11,14,16,17}

Although not all studies demonstrated statistical significance in their interventions, some of the studies reported clinical significance in other areas. Kim and colleagues^{15(p.912)} discussed the fact that participants also showed improvements in functional "gait measures such as cadence, walking velocity, stride length, step length, stride time, and step time." Taylor and colleagues¹¹ concluded that it is important to recognize the positive effect that resistance training has on the psychosocial aspects of life, such as body image and self-efficacy. Ahlborg and colleagues,¹⁷ who compared WBV with resistance training, reported a significant decrease in spasticity in the knee extensors in the WBV group after the intervention period as well as an increase in gross motor function.

These findings are clinically relevant because of the increasing population of ambulatory adults with CP and the lack of consensus about the best PT interventions to use to help them maintain important aspects of their functional mobility and to prevent limitations on their activity and restrictions on their participation. This systematic review shows that not enough quality research has been done in relation to clinically applicable interventions for adults with CP. Serious gaming and RAS were found to be beneficial, but they may not be applicable in all clinical settings.

The studies we used had two main limitations: the lack of blinding of participants in the original research and missing information about how co-interventions were avoided.^{11,15–17} Regarding blinding, the care provider

was not blinded in any of the studies reviewed,^{11,14–18} and the patient was not blinded in four of the randomized studies;^{11,14,16,17} this could lead to bias on the part of care providers and patients. No disclosure of information about co-interventions could decrease assurance that the results of a study occurred solely because of that intervention and not secondarily, because of external factors.

This review itself has two main limitations. The first is the lack of available high-quality evidence to include in the review, as demonstrated by the authors' decision to limit the review to studies with a higher level of evidence. For example, much of the literature available on adults with CP consisted of single-case reports and therefore did not meet the inclusion criteria for this review. A second limitation relates to quantity: An overwhelming lack of evidence relating specifically to interventions for adults with CP for improving functional mobility, combined with low sample sizes, may be reflected in the lack of statistically significant *p* values. We could not conduct a meta-analysis of the data because of the lack of consistency in how principal summary measures were reported in different studies and because one study¹⁷ reported data in medians and ranges.

CONCLUSION

Literature on the effects of PT intervention on functional mobility and prevention of limitations in activity and restrictions on participation in adults with CP is currently lacking. Serious interactive games were shown to have a meaningful effect on improving balance, and RAS proved to be more effective than NDT in correcting gait patterns.^{15,18} In the future, research should focus on the development of activity-focused interventions for adults with CP and how they assist with preventing and decreasing activity limitations. Studies should also ensure that interventions are driven by clients' needs, preferences, and participation and that they can be used in a variety of environments.

KEY MESSAGES

What is already known on this topic

Both the quality and the quantity of research available on adults with CP and effective PT intervention to prevent limitations on activity and restrictions on participation into adulthood is currently lacking. Much of the literature published to this point on adults with CP has focused on the effects of resistance training and strengthening, but little research has been done to relate these interventions to aspects of functional mobility across dimensions of the *International Classification of Functioning, Disability and Health* model.

What this study adds

This study aimed to identify gaps in the literature and to provide insight into the most effective PT interven-

tions for adults with CP aged 18 years and older to help them maintain functional mobility throughout adulthood and thereby prevent limitations on their activity and restrictions on their participation.

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