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Effect of walking aids and foot orthoses on energy expenditure in children with cerebral palsy: a systematic review

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Background
Walking aids and ankle–foot orthoses (AFOs) are designed to address gait problems. These devices are common among children with cerebral palsy (CP), as those children's ability to ambulate is a big concern for their parents, and its improvement is considered primary focus of therapeutic modalities addressing motor disorders of this population. However, empirical support for walking aids and AFO is limited. The aim of this review was to assess the quality of research on the effect of walking aids and AFO on energy expenditure in children with CP.
Materials and methods
Four electronic databases using predefined terms were searched by two independent reviewers. All study designs except case reports were included. Nineteen studies involving 509 participants met inclusion criteria and were involved in this review.
Results
Heterogeneity was observed across included studies in measurement, implementation, and study rigor.
Conclusion
There is a need for high-quality studies to draw a clear conclusion on the effect of walking aids and AFO on energy expenditure in children with CP; the typical flaws of existing studies included weak experimental designs, insubstantial treatment outcomes, and high risk of bias.

Keywords:
cerebral palsy, energy expenditure, orthosis, systematic review, walking aids

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Introduction

Cerebral palsy (CP) is a familiar cause of postural and movement disorders among children, which are caused by damage of immature brain. Children with CP have pathological changes of musculoskeletal system. Disorders of balance, muscle tone, and strength are considered primary impairments that are related to central nervous system damage. However, joint deformities and muscle contractures occur in response to musculoskeletal growth and primary impairments and are termed as secondary impairments. All of these impairments allow children with CP to walk with inefficient pattern [1].

Ankle–foot orthoses (AFOs) have been recommended to enhance the dynamic gait efficiency of children with CP [2]. Many authors reported the effectiveness of different types of AFOs on gait kinematics and kinetics [2,3], as well as functional performance, in children with CP [4].

Energy expenditure is the amount of oxygen consumed during physical exertion. The change in energy expenditure during activity reflects the metabolic cost of muscles, from moving the body against gravity and from accelerating and decelerating different body parts [5]. The appropriate use of walking aids improves efficiency, stability, and posture. Walking aids include canes, crutches, and walkers [6].

There is a strong relation between the degree of motor disorders and energy cost of walking [7]. Children with CP often begin their walking later than normal children [8] and walk with a higher energy cost and slower speed [9].

Independent mobility is important for participation, activity, and self-sufficiency, all of which decrease dependence on caregivers. Efficiency and safety are considered essential factors for selecting methods of mobility suited to different environmental conditions [10].

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It is essential to measure energy consumption because of its role in the evaluation of functional ability as the quantification of energy expenditure; at the same time, walking provides objective data to assist in the evaluation of children with walking disabilities as well as effectiveness of therapeutic modalities, such as walking aids, orthoses, rehabilitation programmes, and surgical treatments [11].

A previous study performed on AFO and on different types of walkers concluded that high-quality studies are still required to support evidence-based decisions concerning the use of AFOs [12]; low quality of existing evidence and the heterogeneity prevent the recommendation of one walker type over the other, and well-designed studies are needed to provide clinical recommendations [13].

Therefore, there was a need for further research to provide adequate evidence to inform clinical recommendations, with adequately powered studies and careful design to minimize bias.

The purpose of this review was to assess the quality of present research on the effect of walking aids and AFOs on energy expenditure in children with CP.

Materials and methods

Literature search

The authors underwent a training programme for online search to be able to perform the searching process in different databases. The following databases were searched to identify relevant published studies: the Cochrane Library, Scopus, PubMed, and the Web of Science. Those databases were searched by using the following keywords: energy expenditure, gait, walking aids, walkers, foot orthosis, CP, diplegia, and hemiplegia. Several search strategies were developed to accommodate the databases.

Study selection and eligibility criteria

Studies were included if they met the following criteria:

Participants

Children with different types of CP of both sex aged up to 18 years old were included. Methodology: studies that investigated the immediate or long-term effect of lower limb orthoses or any type of assisted walking aid on energy expenditure were involved. Study design: all research designs except case reports were accepted.

Language

Full-text papers in English were included.

Data extraction

Two authors (Abd El-Hakiem Abd El-Nabie and Abd El-Aziz) extracted the following items from the included articles: (a) the author and year of publication; (b) information on the population, describing numbers of included children by diagnosis, age, and sex; (c) study design; (d) methodology, including the type of intervention or assessment, technique of its application, and its duration; (e) measured outcomes as explained by their authors; and (f) results. The extracted data are grouped into two tables: Table 1 related to articles that evaluated the effect of orthosis on energy expenditure [14–23], whereas articles investigating the effect of assisted walking aids, for example, a Walk Aide foot drop stimulator, walkers, sticks, a robotic-assisted gait trainer, and a flexible derotator, on energy expenditure [24–31], were presented in Table 2.

Assessment of methodological quality

Methodological quality in the current systematic review was evaluated by the PEDro scale. This ten-item instrument is a valid measurement of methodological quality of clinical trials. The items are scored as present (1) or absent (0) [32]. Two reviewers (Abd El-Hakiem Abd El-Nabie and Abd El-Aziz) independently assessed the methodological quality of included studies, and discrepancies between them were resolved by consultation with the third author (Elshennawy) to reach the final decision. After each item was classified as ‘present’ or ‘absent’, the total score of each study was calculated as the sum of ‘present’ responses (Table 3). As reported by Foley *et al.* [33], the methodological quality was considered to be ‘excellent’ when studies scored from 9 to 10 on the PEDro scale, whereas studies scoring from 6 to 8 were considered ‘good’ quality, studies with 4 and 5 scores were graded as ‘fair’ quality, and studies with a score below 4 were classified as ‘poor’ quality.

Level of evidence

The level of evidence of all included studies was scored according to the modified Sackett scale (Tables 3 and 4). This five-level scale is used to determine the strength of evidence regarding the intervention (Table 4) [34].

Results

Literature search

The search strategy revealed 981 articles from previously mentioned databases, as follows: Cochrane Library (304), Scopus (70), PubMed

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Table 1 Study design, sample details, methods and results for orthoses

References	Design	Participants	Methodology	Outcome measures	Results
Bhise *et al.* [14]	Cross-sectional	*N*: 41 normal children and 41 children with spastic diplegic cerebral palsy	Exp.=diplegic children, some of them using conventional AFOs and some without conventional AFOs; PCI was measured for both at their chosen velocities over four consecutive lengths of a 12.5 m walkway	PCI	For normal children, PCI was the same in shoes and barefoot
		Age (years): 6–18	Cont.=normal children; PCI was measured barefoot and in shoes	BMI	For diplegic children, PCI was lower with AFOs than without AFO
		Sex: not identified	PCI was calculated from walking speed and heart rate for each child		PCI for spastic diplegic children with and without AFOs is higher than PCI for normal children ($P<0.05$)
Kerkum *et al.* [15]	Pre–post experimental study	*N*: 15 children with spastic cerebral palsy	Exp.=Each child wore a hinged VAFO with adjustable stiffness (rigid, stiff, and hinged) for 3 months, and the intended outcome were assessed before and after the treatment period while walking with the optimized VAFO and walking with shoes only to individually select the optimal stiffness	Walking energy cost	A significant 9% decrease in net EC (P=0.077) was found for walking with the optimized VAFO compared to shoes only
		Age (years): 6–14	Cont.=no control group	Daily walking activity	Daily activity remained unchanged
		Sex: 11 male and 4 female		Knee angle and ankle power (gait biomechanics were assessed by 3D-gait analysis)	Knee flexion instance was reduced by 2.48 (P=0.006)
Kerkum *et al.* [16]	Pre–post experimental study	*N*: 15 children with spastic cerebral palsy	Exp.=Each child wore each configuration of VAFO stiffness for 4 weeks. Outcomes were assessed at baseline (with shoes only), then assessed after each configuration of VAFO was work	Kinetic and kinematic parameters of lower limb	Speed was significantly lower while walking with VAFOs (P=0.016)
		Age (years): 6–14	Cont.=no control group	Walking energy cost	All VAFOs decreased the knee flexion angle at contralateral toe-off, midstance, and timing of KEpk (P=0.025)
		Sex: 11 male and 4 female			Ankle power generation and work were preserved only by the spring-like VAFOs
					All VAFOs decreased the net energy cost compared with shoes-only, but no differences were found between VAFOs
Uckun *et al.* [17]	Cross-sectional study	*N*: 48 children with cerebral palsy	Exp.=Children lower extremity orthoses and were grouped according to type of orthosis they used. The energy expenditure was assessed during the wearing of the following orthoses: solid PAFO, articulated PAFO, GRAFO, plastic and metallic KAFO and metallic AFO	Energy expenditure	It was found that plastic orthoses ensured energy efficiency during walking, and this effect was most significant in patients using solid PAFOs (P=0.008)
		Age (years): 9–13	Cont.=no control group		
		Sex: 27 male and 21 female			
Brehm *et al.* [18]	Retrospective	*N*: 172 children with cerebral palsy (hemipleg, diplegia and quadriplegia)	Exp.=children were using a SAFOs or PLS orthoses, and the intended outcomes were measured at 2 sessions with 10 min rest in between first one during	Oxygen consumption	The following was found with AFO use: Speed was increased by 9% ($P<0.001$)

(*Continued*)

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Table1 (*Continued*)

References	Design	Participants	Methodology	Outcome measures	Results
			barefoot walking and the second one during wearing AFO on the same day		
		Age (years): 4–18	Cont.=no control	Walking speed	NN-cost was reduced by 6% (P=0.007)
		Sex: 103 male and 69 female		Biomechanics of gait	NN-cost pct was reduced by 9% (P=0.022)
					The Gait Index was unchanged (P=0.607)
					Subgroup analysis showed the following: Significant-improvement in NN-costpct only for quadriplegics (20%, P=0.004). whereas it remained unchanged for hemiplegic and diplegic children
					Knee flexion angle in stance phase and in terminal swing were significantly improved (P=0.013 and 0.022, respectively)
Balaban *et al.* [19]	Cross-sectional within group	N: 11 children with hemiplegic cerebral palsy.	Exp.=Children wore an HAFO on the involved side for at least 2 months; each HAFO was custom made by the same orthotist for the individual child prior to participation in this study. Gait parameters and energy expenditure were assessed barefoot for baseline gait assessment and while wearing the HAFO for each child	Kinematic and kinetic gait parameters by motion analysis	Walking spestride length and single were improved during the wearing of AFO compared with barefoot walking
		Age (years): 7.18 +1.1	Cont.=no control group	Energy expenditure=walking energy expenditure	Double support time was decreased with AFOs while there was no change in cadence
		Sex: 7 male and 4 female			Ankle dorsiflexion was significantly increased at initial contact, midstance and midswing
					Knee flexion was decreased at initial contact
					Oxygen consumption was significantly reduced during AFO walking
Buckon *et al.* [4]	Cross-sectional within group	*N*: 16 children with diplegic cerebral palsy	Exp.=children participation in the study lasted 1 year and involved four visits: a baseline assessment after 3 months of no AFO wear, and an assessment at the end of each AFO 3-month wearing period. Each AFO configuration (HAFO, PLS and SAFO) was worn daily for 6–12 h and removed at night for 3 months	Kinematic and kinetic gait parameters, assessed with a six-camera Vicon 370 system (Oxford Metrics Ltd, Oxford, UK).	The three configurations of AFO
		Age (years): 4 years 4 months to 11 years 6 months	Cont.=no control group	Energy expenditure	Improved ankle kinematics in stance-increased step/stride length while the cadence was decreased
		Sex:10 male and 6 female		Functional motor skills	Decreased energy cost of walking
				Upper limb function and Upper Limb Speed and Dexterity	Improved walking jumping, and running skills coordination of upper extremities; and fine motor speed/dexterity
					There was no change in the quality of gross motor skill performance or mobility independence
					There were no significant differences in the following

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Table1 (*Continued*)

References	Design	Participants	Methodology	Outcome measures	Results
Smiley *et al.* [20]	Cross-sectional within group	*N*: 14 children with diplegic cerebral palsy	Exp.=children wearing solid, articulated and PLS AFOs that were fabricated and fit prior to gait analysis without training period and shoes alone. A baseline assessment was conducted before wearing an orthosis and during wearing different types of AFOs. Assessment was conducted in a single day	Gait kinematics and temporospatiaparameters by motion analysis with 6 3D cameras	
		Age (years)= 6.9–16	Cont.=no control group	Brace preference	Stride length, cadence. velocity and energy efficiency index
		Sex : 8 male and 6 female		Energy efficiency index	Articulated AFO was preferred by eight children
					Six diplegic children preferred posterior leaf spring
					No one of the children preferred solid AFO
Buckon *et al.* [21]	Cross-sectional within group	*N*: 30 children with spastic hemiplegic cerebral palsy	Exp.=children who were participated in the study were using AFO or indicated for using AFO. Each child was randomly to one of three sequences of AFO use: HAFO, SAFO, PLS; SAFO, PLS, HAFO; and PLS, HAFO, SAFO. Each AFO configuration (HAFO, PL and SAFO) was worn daily for 6–12 h and removed at night for 3 months. Assessments were performed barefoot or with shoes on and at the end of each 3-month period	Ankle range of motion by goniometer	PLS and HAFO improved passive ankle dorsiflexion and normalized rocker function of ankle. HAFO was the most effective in controlling knee hyperextension instance, while PLS was the most effective in promoting knee extension in stance
		Age (years): 4–18	Cont.=no control group	Gait analysis by a six-camera Vicon 370 system	Greatest improvement in energy consumption was documented by using HAFO and PLS
		Sex: 21 male and 9 female		Energy consumption	Improvements in functional mobility were greatest in the HAFO and PLS
				Functional motor skills by using the Functional Skills–Mobility dimension of the Paediatric Evaluation of Disability	
				Inventory	
Maltais *et al.* [22]	Cross-sectional within group	*N*: 10 children with diplegic cerebral palsy	Exp.=children were using hinged AFO participated in the study and the measured outcomes were measured during sitting and with AFO on and off during steady state treadmill walking at three speeds: 3 km/h	Metabolic and cardiopulmonary responses=oxygen cost of walking (cardiovascular and ventilatory costs of walking)	During the wearing of AFO
		Age (years)=9.0±6 2.1 SD	Cont.=no control group	Gross motor skills=GMFM	Net oxygen uptake was (*P*=0.05) reduced by 8.9% at 3 km/h and by 5.9% at 90% of FWS
		Sex=8 male and 2 female			Net pulmonary ventilation was (*P*=0.05) lower by 10.3% but only at 3 km/h
					Net HR and respiratory exchange ratio did not affect at any speed
Mossberg *et al.* [23]	Cross-sectional within group	*N*: 18 children with diplegic cerebral palsy	Exp.=children wearing bilateral conventional ankle–foot orthoses and energy expenditure was measured without	PCI	PCI was lowered with AFO compared without orthoses

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Table1 (*Continued*)

References	Design	Participants	Methodology	Outcome measures	Results
			AFO and during the wearing of AFO while walking for five minutes at a freely chosen speed		
		Age (years)=3–14	Cont.=no control group	Heart rate by telemetry device	Ambulation HR, velocity and distance travelled were not significantly different between two trials
		Sex=10 male and 8 female		Velocity by recording distance travelled each minute	

Cont, control; EE, energy expenditure index; Exp, experimental; GMFM, Gross Motor Function Measure; GRAFO, ground reaction foot orthosis; HAFO, hinged ankle–foot orthosis; HR, heart rate; KAFO, knee-ankle–foot-orthosis; PAFO, polyethylene ankle–foot orthosis; PCI, Physiological Cost Index; PLS, posterior leaf spring; SAFO, solid ankle-foot orthosis; VAFO, ventral shell ankle–foot orthosis.

(449), and Web of Science (158). Thirty-six duplicated articles out of 981 were found when the results from all databases were combined and screened for duplicate. The reviewers screened titles and abstracts of the remaining 945 articles independently, and the result of this screening was 53 included articles. Fifty-three articles were filtered on the basis of full-text; 34 were excluded because they were outside the scope, because the children's diagnosis was not CP or outcome of interest was absent, or, in one case, the full-text paper was not available, as shown in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow chart (Fig. 1). The remaining 19 studies formed the basis for the current systematic review.

Characteristics of the studies

There was some variability among included studies regarding characteristics of participants (diagnosis and age), study design, methodology, outcome measures, and assessment methods.

Characteristics of participants

The children, who ranged from 3 to 18 years of age, were diagnosed with diplegic, hemiplegic, quadriplegic, and triplegic CP of different levels of severity. Both sexes were represented (261 boys and 173 girls). Two studies, namely, those of El-Shamy *et al.* [24] and Bhise *et al.* [14], did not identify sex distributions of their subjects.

Study designs

The included articles had a variety of study designs. There were 12 studies with cross-sectional design [4,14,17,19–23,27,28,30,31], two pre–post experimental studies [15,16], one RCT [24], one clinical trial [25], one case-series study [29], and two retrospective studies [2,18], as shown in Tables 1 and 2.

Methods

All studies in the current systematic review examined the effect of different types of lower limb orthoses (different configurations of AFO [4,14–16,18–23], plastic and metallic knee-AFO [17] or the effect of assisted walking aids (anterior and posterior walkers [27,28,30,31], walking sticks [29], robotic-assisted gait training [25], flexible derotator [26] and Walk Aide foot drop stimulator [24]) on energy expenditure in children with CP. All included studies can be classified into the following types: (a) studies that investigated the immediate effect of lower limb orthoses [14,17,18,20,22,23] or assisted walking aids [28,30,31] on energy expenditure, in which energy expenditure was assessed during the wearing of orthotic devices or during the usage of assisted

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Table 2 Study design, sample details, methods and results for assisted walking aids

References	Design	Participants	Methods	Outcome measures	Results
El-Shamy *et al.* [24]	RCT	*N*: 34 children with hemiplegic cerebral palsy	Exp.=received functional electrical stimulation by using the Walk Aide foot drop stimulator in addition to traditional exercise programme, 3 days/week for 3 months	GSTPs	-The gait parameters improved after treatment in the study group more than control group as the following
		Age (years): 8–12	Cont.=received only the traditional exercise programme, which included neurodevelopmental techniques, muscle stretching, strengthening exercises, proprioceptive training, and balance and gait training, for 3 months (1 h/day for 3 days/week)	Energy expenditure was measured with a breath-by-breath method using an open-circuit indirect calorimeter	Stride length, cadence, speed, cycle time, and stance phase percentage were 0.74 m, 119 steps/min, 0.75 m/s, 0.65 s, 55.9%) and 0.5 m, 125 steps/min, 0.6 m/s, 0.49 s, 50.4%, respectively
		Sex: not mentioned			Energy expenditure was improved post treatment in the study group more than the control group
Peri *et al.* [25]	Clinical trial	*N*: 7 4 children with diplegic cerebral palsy and 3 normal children)	Exp.=received robot-assisted gait training (training with the paediatric version of Lokomat) and traditional physical therapy programme	Energy expenditure per minute	The trend of the energy expenditure per minute was increased while the trend of the energy expenditure per
		Age (years): 6–18	Cont.=healthy participants (no treatment)	Energy expenditure per step	Step was decreased accordance to the control group
		Sex: 6 male and 1 female		6-min walk test	After treatment, 6 min walk test showed an increased in the walked distance from 199.5 (226.7–223.2 m (191.8 m)
Marcucci *et al*. [26]	Retrospective	*N*: 30 (22 diplegic children, three right-sided hemiplegic children, four tetraparetic children and one triplegic child)	Exp.=used flexible derotator that consists of two straps attached to an abdominal belt and two thigh bands and the straps are placed in a spiral position in order to prevent poor posture for 6 h/day for 1 year	Bone parameters (deg.)	In the flexible derotator group after the treatment procedure
		Age (years): 6–9	Cont.=did not wear flexible derotator	Functional parameters (gait distance (m), mean gait speed (m/min) was measured during a 5-min gait test during which the child was required to walk up and down a 20-metre test track as many times as possible	The right femoral anteversion and right and left external tibial torsion were improved ($P<0.05$)
		Sex=17 male and 13 female		EEI	Gait speed and distance were significantly increased ($P<0.05$) EEI was significantly decreased ($P<0.05$) There were no differences between the initial and final examinations in the control group
Konop *et al.* [27]	Cross-sectional study	*N*: 10 children with diplegic cerebral palsy	Exp.=children used posterior walker and upper extremity kinetics were evaluated after 30 days, same evaluation process repeated on anterior walker. Resting HR was calculated before gait analysis while walking HR was measured after gait analysis to determine EE	GTSPs (walking speed, cadence, step length, and stride length)	Medial JRF in the wrist, the inferior and superior JRFs in the shoulder and the posterior
		Age (years): 8–18	Cont.=no control	Energy expenditure resting HR and walking HR)	JRF in the elbow were strongly correlate during the use of anterior walker

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Table2 (*Continued*)

References	Design	Participants	Methods	Outcome measures	Results
		Sex: 3 male and 7 female		Upper limbs kinetics (joint reaction forces	EEIHR was higher with the use of anterior walker
				JRF and moments JRM	Several kinetic variables correlated well with temporal and stride parameters, as well as the EEIHR
					During the use of anterior walker there were significant correlations ($r>0.80$; $P<0.005$) in JRFs rather than moments
Strifling *et al*. [28]	Cross-sectional	*N*: 10 children with diplegic cerebral palsy	Exp.=the children were evaluated at 2 separated visits; at visit 1, children used posterior walker, while at visit 2, children used anterior walker	GTSPs: (walking speed, cadence, step length, and stride length)	There was no difference in energy expenditure, walking speed or stride length between the two walker types
		Age (years): 5–18	Cont.=no control group	Energy expenditure: (heart rate and energy expenditure index)	With the posterior walker use, there was a reduction in anterior torso tilt and the shoulder extension and elbow flexion were increased
		Sex: 7 female and 3 male		Upper limb kinematics	
Toms *et al*. [29]	Case series	*N*: 8 children with cerebral palsy	Exp.=The researchers designed prototypes of a walking stick and a tripod called Multi positional Paediatric Walking Aids for the children. The study was divided into four periods AABA, Prototypes were used during period (B) four used sticks and four used tripods and each child had been assessed at the beginning of the study and every 4 weeks. Children tested using either multi positional walking aids (period B) or conventional walking aids (period A)	(1) Energy during walking using (PCI)	PCI was improved when the children used the prototypes of walking stick
		Age: 4–11	Cont.=no control	(2) Motor abilities using (a) (GMFM-88) and (b) (GMPM)	The results of GMFM-88 and GMPM improved only for some children
		Sex: 2 male and 6 female		(3) Hand/forearm position recorded on a visual analogue scale	The hand/forearm position of the stick users was improved at assessment 4
				(4) Parent/child questionnaire	
Park *et al*. [30]	Cross-sectional within group	*N*: 10 diplegic cerebral palsy children	Exp.=children using anterior and posterior walker. Ambulation with anterior and posterior walker use was practised for 1 month before evaluation so that children were familiarized with both walkers. Children tested two times, one time with each walker, in random order	Temporospatial variables and kinematic values in sagittal plane measured by motion analysis system	No differences were found between both types of walkers in walking velocity and cadence
		Age (years): 7–12	Cont.=no control group	Oxygen cost=energy expenditure by KBI-C	During the usage of the posterior walker, flexion angles of the trunk, hip and knee were lowered while step length and single support time were elevated
		Sex:6 male and 4 female			Double support time was longer by anterior walker

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Table2 (Continued)

References	Design	Participants	Methods	Outcome measures	Results
					The oxygen cost was decreased during the wearing of posterior walker
Mattsson and Andersson [31]	Cross-sectional study	*N*: 10 diplegic cerebral palsy children	Exp.=children walking with anterior walker and posterior walker. All children walked at self-selected speed for 4 min on ground level in a circle 70 meters for 4 min During the first trial, the children used their own walker then they were assigned randomly to complete test with anterior or posterior walker then in the second part of assessment the child used the other walker	Walking speed	No differences were found in walking speed, oxygen cost of walking and perceived exertion between both types of walkers
		Age (years): 8–17	Cont.=no control group	Oxygen cost of walking	Posterior walker was preferred by most of the children
		Sex: 8 male and 2 female		Perceived exertion=measure heart rate by telemetric device	

6 min WT, 6-min walk test; Cont., control; EEI, energy expenditure index; Exp., experimental; GMFM, Gross Motor Function Measure; GMPM, Gross Motor Performance Measure; GRAFO, ground reaction foot orthosis; GTSPs, gait temporal and stride parameters; HR, heart rate; JRF, joint reaction force; JRM, joint reaction moment; PCI, Physiological Cost Index.

walking aids and (b) studies that examined the long-term or cumulative effect of orthoses [4,15,16,19,21] or assisted walking aids [24–26,29] on energy expenditure, in which lower limb orthosis or assisted walking aids were applied for a specific duration (weeks or months). In these studies, energy expenditure was evaluated before and after treatment.

Types of outcome measured

Although energy expenditure was the outcome of interest in the present systematic review, there were other measured outcomes in the included studies, for example, kinematic and kinetic gait parameters [4,16,18–21,23,24,26–28,30,31]; gross motor skills [4,21,22,29]; metabolic and cardiopulmonary responses [22]; upper limb speed, dexterity, and kinematics [9,28]; joint angles, power, daily walking activity, and range of motion [15,21]; bone parameters [26]; joint reaction force and moments [27]; BMI and perceived exertion [14]; brace preference [20]; performance on the 6-min walking test [25]; and hand/forearm position [29].

Measurement of energy expenditure

Energy expenditure can be measured with different methods. In the present systematic review, all studies were accepted regardless of the method of measuring energy expenditure. Methods of measuring energy expenditure in the included studies were as follows: the energy expenditure index method [17,18,20,26,28] or the Physiological Cost Index method [4,14,23], in which energy expenditure was measured by subtracting the maximum heart rate from the resting heart rate and divided by speed of walking; an open-circuit indirect calorimeter [19,24] or portable breath gas analysis system [15,16,18,22,30,31] which assess energy expenditure by measuring the amount of oxygen consumption; the dilution model [4,21]; and a SenseWear Armband (Table 5) [25]. Table 5 shows methods of measuring energy expenditure in the included studies.

Level of methodological quality

The score of each study on the PEDro scale is presented in Table 3. The mean score of the 19 studies was 3.736. One study was given a score of 6 [24], one study obtained a score of 5 [23], nine studies had a score of four [15–17,21,26–28,30,31], and the remaining eight studies scored 3 [4,14,18–20,22,25,29]. One of the included studies represented 'good' quality [24], 10 studies were 'fair' quality [15–17,21,23,26–28,30,31], and eight studies were 'poor' quality [4,14,18–20,22,25,29]. The criteria of a blinded therapist (criterion five) and intention-to-

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Table 3 Level of evidence and methodological quality

References	Random allocation of subjects	Concealed allocation	Similarity at baseline	Blinded subjects	Blinded therapists	Blinded assessors	More than 85% follow-up	Intention-to-treat analysis	Between-group statistical analysis	Point and variability estimates	Total score on PEDro scale	Level of evidence according to modified Sackett
Maltais *et al.* [22]	No	No	No	No	No	No	Yes	No	Yes	Yes	3	2
Park *et al.* [30]	Yes	No	No	No	No	No	Yes	No	Yes	Yes	4	2
Marcucci *et al.* [26]	No	No	Yes	No	No	No	Yes	No	Yes	Yes	4	3
Mattsson and Andersson [31]	No	No	Yes	No	No	No	Yes	No	Yes	Yes	4	2
Peri *et al.* [25]	No	No	No	No	No	No	Yes	No	Yes	Yes	3	2
Smiley *et al.* [20]	Yes	No	No	No	No	No	No	No	Yes	Yes	3	2
Mossberg *et al.* [23]	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	5	2
El-Shamy *et al.* [24]	Yes	Yes	Yes	No	No	Yes	No	No	Yes	Yes	6	1
Kerkum *et al.* [15]	No	No	No	Yes	No	No	Yes	No	Yes	Yes	4	4
Balaban *et al.* [19]	No	No	No	No	No	No	Yes	No	Yes	Yes	3	2
Buckon *et al.* [21]	Yes	No	No	No	No	No	Yes	No	Yes	Yes	4	2
Buckon *et al.* [4]	Yes	No	No	No	No	No	No	No	Yes	Yes	3	2
Uckun *et al.* [17]	No	No	Yes	No	No	No	Yes	No	Yes	Yes	4	2
Bhise *et al.* [14]	No	No	No	No	No	No	Yes	No	Yes	Yes	3	2
Strifling *et al.* [28]	No	No	Yes	No	No	No	Yes	No	Yes	Yes	4	2
Brehm *et al.* [18]	No	No	No	No	No	No	Yes	No	Yes	Yes	3	3
Konop *et al.* [27]	No	No	Yes	No	No	No	Yes	No	Yes	Yes	4	2
Kerkum *et al.* [16]	No	No	Yes	No	No	No	Yes	No	Yes	Yes	4	4
Toms *et al.* [29]	No	No	No	No	No	No	Yes	No	Yes	Yes	3	4

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treat analysis (criterion eight) were not met by all included studies. On the contrary, the criteria of between-group statistical analysis (criterion nine) and estimation of point and variability measures (criterion 10) were satisfied by all included studies.

Table 4 Modified Sackett scale

Level 1	RCTs with a PEDro score ≥6
Level 2	RCTs with a PEDro score <6, cohort studies and non-RCTs
Level 3	Case–control studies
Level 4	Pre–post or postintervention studies and case series
Level 5	Case reports, clinical consensus or observational studies

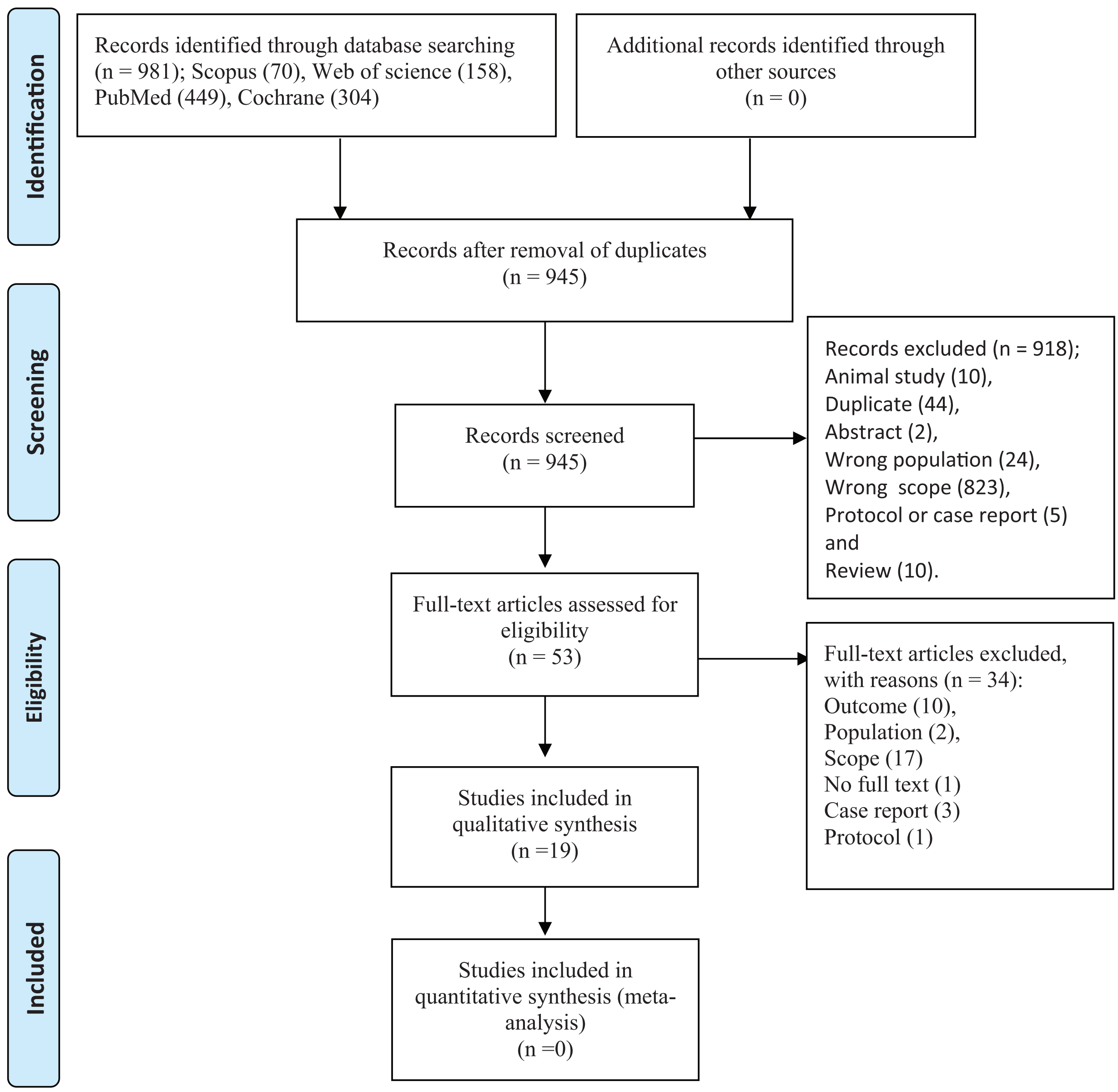
Level of evidence

According to the modified Sackett scale, one study [24] was ranked on level one, 13 studies were on level two [4,14,17,19–23,25,27,28,30,31], two studies were on level three [18,26], and three studies were on level four [15,16,29].

Discussion

Our search in literature revealed moderate-quality to low-quality evidence on the effect of assisted walking aids and foot orthoses on energy expenditure in children with CP. The current systematic review

Figure 1



Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow chart.

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Table 5 Methods of measuring energy expenditure in the included studies

References	Measurement of energy expenditure
Maltais *et al.* [22]	Oxygen cost of walking
Park *et al.* [30]	Oxygen cost measured by KBI-C (portable oxygen)
Marcucci *et al.* [26]	Energy Expenditure Index method: heart rate beats/m)/average speed
Mattsson and Andersson [31]	Oxygen cost of walking measured by an argon dilution method described by Linnarsson *et al.* (1989)
Peri *et al.* [25]	Energy expenditure per minute
	Energy expenditure per step assessed by SenseWear Armband
	Energy expenditure per minute
	Energy expenditure per step
	6-min walk test
Smiley *et al.* [20]	Energy expenditure index method (maximum heart rate minus resting heart rate divided by walking speed (beats/min)
Mossberg *et al.* [23]	Physiological Cost Index (the resting heart rate was subtracted from the ambulation heart rate and the difference divided by the walking speed
El-Shamy *et al.* [24]	Energy expenditure measured with a breath-by-breath method using an open-circuit indirect calorimeter
Kerkum *et al.* [15]	Oxygen uptake measured by a portable breath gas analysis system
Balaban *et al.* [19]	Oxygen consumption measured by an open-circuit indirect calorimeter
Buckon *et al.* [21]	Sensor Medics 2900 metabolic cart using dilution model
Buckon *et al.* [4]	Sensor Medics 2900 metabolic cart using dilution model
Uckun *et al.* [17]	Energy expenditure index method
Bhise *et al.* [14]	Physiological Cost Index (calculated from maximum HR, resting HR, and Speed)
Strifling *et al.* [28]	Energy expenditure index method
Brehm *et al.* [18]	Oxygen consumption measured by breath-by-breath gas analysis
Konop *et al.* [27]	Energy expenditure index method
Kerkum *et al.* [16]	Oxygen uptake measured by a portable breath gas analysis system
Toms *et al.* [29]	Physiological Cost Index

aimed to collect this evidence by using systematic methods for search and evaluating best available studies on the benefit of assisted walking aids and foot orthoses for children with CP, based on clinically relevant outcomes including different methods of measuring energy expenditure, kinematic and kinetic gait parameters, and functional motor skills.

Energy expenditure among children with CP is very important as children with CP consume more energy during ambulation and they have lower physical activity levels and lower energy requirements than do typically developing children [35].

Figueiredo *et al.* [12] performed a descriptive review of literature about the effect of AFOs on gait in children with CP. They reported that studies with high-quality methods are still desired to support evidence-based decisions on the use of AFOs for those children. As, studies included flaws such as; lack of randomization procedures, lack of parity among groups and no masking of subjects, therapists, and examiners, except for one blinding was mentioned for examiners [12]. Consequently, there has been little progress in the quality of evidence since the last published review on orthoses. Instead of, we found that it is important to address other assisted walking aids used by children with CP to clarify its effect on energy expenditure because they were not addressed in any other systematic reviews. It should be borne in mind that ambulation with assisted walking aids is incorporated into daily life, so energy conservation is a major issue when choosing walking aids [30].

Different mechanisms have been suggested to clarify the advantage of foot orthoses for children with CP; one of them is the improvement of energy expenditure after using foot orthoses. Because the use of foot orthoses results in normal ankle motion during stance phase, this might lead to increased stability, with decreases in mechanical power and reduction in O_2 cost of walking [36].

Another explanation mentioned when using other assisted walking aids like walkers revealed that posterior walker gives children with CP more stability as it decreases flexion angles of trunk, hips, and knees and gives more upright posture for them [37].

This review analyzed 19 studies; most of them were a cross-sectional design. This design enables researchers to estimate the prevalence of increased energy expenditure in children with CP and gave the best opportunities to know the different treatment modalities used to improve it. Studies with cross-sectional design provide a 'snapshot' of characteristics and outcomes associated with it, at a specific time [35]. Results of all included studies in this systematic review were consistent and agreed that foot orthoses and other assisted walking aids may improve energy expenditure in children with CP.

This review found moderate-quality to low-quality evidence supporting the use of foot orthoses and other assisted walking aids for children with CP; it also highlighted the variation in use of assisted walking aids and foot orthoses (types, duration, and technique of application), outcomes, and follow-up in the

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included studies. This clinical heterogeneity (characteristic of participants, absence of allocation concealment and blinding, small sample sizes, and wide variability) restricted the comparison between results of these studies and made meta-analysis inapplicable.

According to this results of PEDro scale, we had only two studies with moderate methodological quality and 17 studies with low quality. This might be owing to the absence of blindness in studies, which may be affected by the type of intervention used.

Conclusion

Results of the current review revealed moderate-quality to low-quality evidence, and they were consistent and agreed that foot orthoses and assisted walking aids can improve energy expenditure in children with CP.

Recommendation

Well-designed and high-quality studies on the effect of foot orthoses and assisted walking aids on energy expenditure in children with CP are still needed to provide strong evidence.

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Conflicts of interest

There are no conflicts of interest.

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