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Review Article

A systematic review of supported standing programs

Leslie B. Glickman*, Paula R. Geigle and Ginny S. Paleg[1]
University of Maryland School of Medicine, Department of Physical Therapy and Rehabilitation Science, Baltimore, MD, USA

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Abstract. *Objective*: The routine clinical use of supported standing in hospitals, schools and homes currently exists. Questions arise as to the nature of the evidence used to justify this practice. This systematic review investigated the available evidence underlying supported standing use based on the Center for Evidence-Based Medicine (CEBM) Levels of Evidence framework.
Design: The database search included MEDLINE, CINAHL, GoogleScholar, HighWire Press, PEDro, Cochrane Library databases, and APTAs Hooked on Evidence from January 1980 to October 2009 for studies that included supported standing devices for individuals of all ages, with a neuromuscular diagnosis. We identified 112 unique studies from which 39 met the inclusion criteria, 29 with adult and 10 with pediatric participants. In each group of studies were user and therapist survey responses in addition to results of clinical interventions.
Results: The results are organized and reported by The International Classification of Function (ICF) framework in the following categories: b4: Functions of the cardiovascular, haematological, immunological, and respiratory systems; b5: Functions of the digestive, metabolic, and endocrine systems; b7: Neuromusculoskeletal and movement related functions; Combination of d4: Mobility, d8: Major life areas and Other activity and participation. The peer review journal studies mainly explored using supported standers for improving bone mineral density (BMD), cardiopulmonary function, muscle strength/function, and range of motion (ROM). The data were moderately strong for the use of supported standing for BMD increase, showed some support for decreasing hypertonicity (including spasticity) and improving ROM, and were inconclusive for other benefits of using supported standers for children and adults with neuromuscular disorders. The addition of whole body vibration (WBV) to supported standing activities appeared a promising trend but empirical data were inconclusive. The survey data from physical therapists (PTs) and participant users attributed numerous improved outcomes to supported standing: ROM, bowel/bladder, psychological, hypertonicity and pressure relief/bedsores. BMD was not a reported benefit according to the user group.
Conclusion: There exists a need for empirical mechanistic evidence to guide clinical supported standing programs across practice settings and with various-aged participants, particularly when considering a life-span approach to practice.

Keywords: Supported standing program, supported standing equipment, supported standing device, tilt table

1. Introduction

Supported standing programs, using various assistive devices, are commonplace in pediatric practice settings (including schools, daycare centers, and private homes) [1–5] and for adults with spinal cord injuries (SCI) [2,5]. While the use of supported standing programs appears routine, questions arise as to the nature

*Corresponding author: Leslie B. Glickman, PT, PhD, Director of Post-Professional Programs, Assistant Professor, 100 Penn Street, 205A, Baltimore, MD 21201, USA. Tel.: +1 410 706 4543; Fax: +1 410 706 6387; E-mail: lglickman@som.umaryland.edu.
[1]Based on research completed for DScPT capstone project.

Table 1
Database or search engine, search terms, and study findings (retrieved and selected)

Database or search engine	Search terms	# of studies retrieved	# of studies selected for review
Medline	stand and cerebral palsy	46	35
	stander and cerebral palsy	6	6
	standing and spinal cord injury	196	42
	upright positioning	25	22
	stander and child	37	26
	passive standing	26	26
	spina bifida	0	
	meningomyelocoel	0	
HighWire Press	supine stander	1	1
	prone stander	12	12
	passive standing	56	37
	prone board	3	3
Pedro	Stander	0	0
	standing and cerebral palsy	12	12
	whole body vibration	10	10
Hooked on Evidence (APTA)	Stander	2	2
	standing and cerebral palsy	12	12
	standing and spinal cord injury	6	6
	whole body vibration	24	10
	spina bifida	0	
	meningomyelocoel	0	
Google Scholar	stander and cerebral palsy	262	45
Total studies (excluding duplicates)		**487**	**112**
Studies included			**39 (10 pediatric; 29 adult participants)**
Studies excluded		**73**	

of the evidence used to justify this practice. There is clearly a need for a mechanistic understanding of the supported standing evidence and relationship to clinical practice.

A systematic review of supported standing programs for a variety of age groups was conducted. Studies were evaluated and categorized using the Center for Evidence-Based Medicine (CEBM) Levels of Evidence (http://www.cebm.net/?o=1116). The outcomes were classified using the International Classification of Functioning, Disability, and Health (ICF) model (http://www.who.int/classifications/icf/en).

2. Purpose of study

The purpose of this systematic review was to determine the available evidence underlying supported standing programs. While the initial purpose was to explore in depth the literature on pediatric participants, it soon became clear that there were a greater number of studies with adult participants. This finding offers potential application across all age spans as individuals with a primarily pediatric diagnoses transition into adulthood as well as to inform pediatric practice.

3. Methods

3.1. Data identification, extraction, and sorting

Several databases and search engines (MEDLINE, CINAHL, GooglesScholar, HighWire Press, PEDro, Cochrane Library databases, and APTA Hooked on Evidence) were searched using a uniform set of search terms between January 1980 and October 2009. Table 1 provides the database or search engine, the search terms, and studies retrieved and selected for review. The search terms chosen were accepted terminology for standing, standing equipment, typical diagnostic categories of individuals who use standers, Guide to Physical Therapist Practice [6] terminology, and HCPCS codes (Healthcare Common Procedure Coding System: http://www.nls.org/av/FAQ's%20HCPCS.pdf).

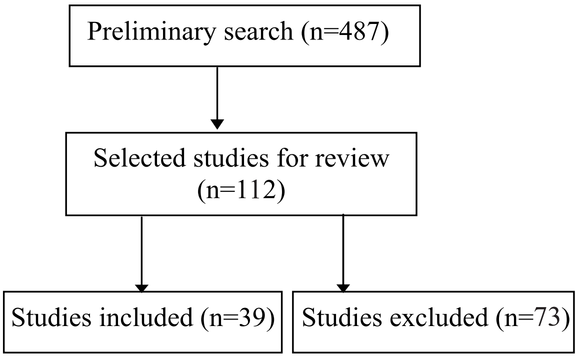

Fig. 1. Data sorting decisions; © UMB 2009 All rights reserved.

Of the 487 identified study abstracts, we extracted 122 published in English in peer-reviewed journals using human participants of all ages, gender, neuromuscular diagnoses, and functional status for further analysis. The extracted group was reviewed in their full text versions (if available) and included if a supported standing device (equipment) was used and the data from those participants was interpreted (analyzed) separately from other interventions (exercise, wheelchair positioning, sleep systems, surgery, drugs, etc) and available in full text (Fig. 1).

3.2. *Data categorization*

The studies of interest were further reviewed and assigned a level of evidence independently by two investigators using the CEBM framework with discrepancies decided by a third investigator, a clinical researcher serving as the expert investigator (Table 2). The CEBM framework levels range from 1–5, with 1 the highest level of evidence [systematic review of randomized controlled trials (RCT)] and 5 the lowest level [expert opinion without critical appraisal]. Level 5 studies were excluded because they have the greatest degree of subjectivity. Utilizing categories 1-4, the following suppositions were followed while evaluating the reviewed studies:

1. Source authors' exact terminology describing the study design or type, the category of participant ages (children or adults), or diagnosis was accepted as true.
2. Studies with no comparison participant(s) and a design that was a descriptive analysis of the participant(s) before and after an intervention classified as "case report" (for a single participant) or "case series" (for more than one participant). All were categorized at Level 4.
3. Survey research categorized at Level 2c if there was a pilot survey with reported validity and reliability. Survey studies using a novel survey tool without reported validity and reliability yet methodology with rigorous analysis, were categorized at Level 3b. Studies employing a novel survey tool without reported validity and reliability and holding limited methodology and analysis description were categorized at Level 4.

3.3. *Study types and participants* (*criteria*)

From the 112 studies of interest, we included 39 and excluded 73 for this review based on the CEBM criteria and our assumptions for evaluating the evidence and the following inclusion/exclusion criteria:

Inclusion criteria:

1. Published between January 1980 and October 2009 available in full text from English language peer-reviewed journals.
2. Used supported standing equipment or device (supine stander, prone stander, tilt table, upright stander, long leg braces, stand-up wheelchair, standing frame, standing box, oscillating stander, whole body vibration platform in combination with a standing frame)
3. Involved participants with neuromuscular diagnoses.
4. Measured a systemic response to standing (physiological, psychological, or functional) independent of other positioning devices (wheelchairs, sleep systems, etc.)
5. Reported survey answers from users and or PTs on perceived outcomes from use of supported standing equipment or devices
6. Included the same data set information from two published studies, if both studies were reconsidered by the authors using different criteria.

Exclusion criteria based on reading full text studies (See Table 3):

1. Categorized at CEBM Level 5 (expert opinion).
2. Published as a professional presentation abstract only.
3. Covered a systematic review or literature review only.
4. Provided no comparative data before and after an intervention and or outcome measures.
5. Included typical participants exclusively (not a part of control group).

Table 2
Oxford centre for evidence-based medicine levels of evidence (http://www.cebm.net/?o=1116)

Level	Therapy/prevention, aetiology/harm	Prognosis	Diagnosis	Differential diagnosis/ symptom prevalence study	Economic and decision analyses
1a	SR (with homogeneity*) of RCTs	SR (with homogeneity*) of inception cohort studies; CDR† validated in different populations	SR (with homogeneity*) of Level 1 diagnostic studies; CDR† with 1b studies from different clinical centres	SR (with homogeneity*) of prospective cohort studies	SR (with homogeneity*) of Level 1 economic studies
1b	Individual RCT (with narrow Confidence Interval‡)	Individual inception cohort study with > 80% follow-up; CDR† validated in a single population	Validating** cohort study with good††† reference standards; or CDR† tested within one clinical centre	Prospective cohort study with good follow-up****	Analysis based on clinically sensible costs or alternatives; systematic review(s) of the evidence; and including multi-way sensitivity analyses
1c	All or none§	All or none case-series	Absolute SpPins and SnNouts††	All or none case-series	Absolute better-value or worse-value analyses ††††
2a	SR (with homogeneity*) of cohort studies	SR (with homogeneity*) of either retrospective cohort studies or untreated control groups in RCTs	SR (with homogeneity*) of Level >2 diagnostic studies	SR (with homogeneity*) of 2b and better studies	SR (with homogeneity*) of Level >2 economic studies
2b	Individual cohort study (including low quality RCT; e.g., < 80% follow-up)	Retrospective cohort study or follow-up of untreated control individuals in an RCT; Derivation of CDR† or validated on split-sample§§§ only	Exploratory** cohort study with good††† reference standards; CDR† after derivation, or validated only on split-sample§§§ or databases	Retrospective cohort study, or poor follow-up	Analysis based on clinically sensible costs or alternatives; limited review(s) of the evidence, or single studies; and including multi-way sensitivity analyses
2c	"Outcomes" Research; Ecological studies	"Outcomes" Research		Ecological studies	Audit or outcomes research
3a	SR (with homoge- neity*) of case-control studies		SR (with homogeneity*) of 3b and better studies	SR (with homogeneity*) of 3b and better studies	SR (with homogeneity*) of 3b and better studies
3b	Individual Case-Control Study		Non-consecutive study; or without consistently applied reference standards	Non-consecutive cohort study, or very limited population	Analysis based on limited alternatives or costs, poor quality estimates of data, but including sensitivity analyses incorporating clinically sensible variations.
4	Case-series (and poor quality cohort and case-control studies§§)	Case-series (and poor quality prognostic cohort studies***)	Case-control study, poor or non-independent reference standard	Case-series or superseded reference standards	Analysis with no sensitivity analysis
5	Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles"	Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles"	Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles"	Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles"	Expert opinion without explicit critical appraisal, or based on economic theory or "first principles"

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The majority of the 39 outcome studies were clinical trials with a small number of participants (generally, under 50) that described or compared supported standing use with another intervention or took measurements before, during, and/or after the use of the standing device. Five of the studies were based on survey data, with 58 to 386 participants. A few randomized controlled trials existed with a designated control group, acknowledged randomization of participants, with or without single or double blinding.

Table 3
Excluded studies by author with reasons for exclusion (73 studies)

Study	Level 5	Before 1981	No use of supported stander	Professional presentation abstract only	Systematic or lit review	No comparative data or outcome measures	Typical partici-pants
Abramson & Delogi 1960		×					
Ahlborg et al., 2006			×				
Aukland et al. 2004				×			
Bahjaoui-Bouhaddi et al. 1998							×
Bakewell 2007	×						
Behrman, 2002					×		
Birkhead et al. 1964		×					
Bleck, 1980			×				
Bottos et al., 2001						×	
Brogen 1985	×						
Bubenko et al., 1984	×						
Chad et al., 1999			×				
Comarr, 1955		×					
Cybulski 1986			×				
Daniels et al. 2005	×						
Dauty et al., 2000			×				
Deshpande & Shields, 2004							×
Finke & Muldoon, 2003	×						
Fontana et al., 2005			×				
Garrett et al., 2008				×			
Gear et al, 1999	×						
Gontkovsky & Huff, 2005						×	
Gould et al., 1955		×					
Green, 1993	×						
Gudjonsdittor & Stemmons-Mercer, 2002a			×				
Hägglund etal., 2005						×	
Harvey, 2003						×	
Hawran & Biering-Sorensen, 1996			×				
Henderson, 2002			×				
Henderson, 1997			×				
Henderson, 1995			×				
Hendrie, 2005	×						
Huston 2001*							
Issekutz et al., 1966	×						
Ivey et al., 1981	×						
Ivey et al., 1980	×						
Jesinkey et al., 2003				×			
Jones et al., 2002				×			
Katz et al., 2006					×		
Kay, 1973	×						
Kim, 1961			×				
Kreutz, 2000						×	
Larson, 2000				×			
Lee & Lynn, 1990	×						
Machek & Cohen, 1955			×				
Macias, 2005					×		
Miedaner & Finuf, 1993				×			
Mogul-Rothman 2002	×						
Molinar, 1993	×						
Motloch, 1983	×						
Nash et al., 1990	×						
Naslund, 2007				×			
Otzel et al., 2008					×		
Paleg & Mauricio, 2000	×						
Phelps, 1959			×				
Pin, 2007						×	

Table 3, continued

Study	Level 5	Before 1981	No use of supported stander	Professional presentation abstract only	Systematic or lit review	No comparative data or outcome measures	Typical partici-pants
Poutney et al., 2002						×	
Ragnarsson et al., 1981			×				
Ruys, 1988	×						
Sergeeva et al., 1978		×					
Stuberg, 1991	×						
Tanaka							
Tepper, 1938		×					
Thompson et al., 2000			×				
Tihanyhi et al., 2007			×				
Torvinen et al., 2003			×				
van den Tillaar, 2006			×				
Vlychou et al., 2003			×				
Wilhite, 1954		×					
Wilton, 1977	×						
Wood & Tromans, 2001			×				
Yeh et al., 2001			×				
Zabel et al., 2005				×			

*Huston (some citations show Huston as the sole author of a study with the same title and publication date as Eng, 2001. Per discussion with Eng (Oct 2009), only one article was published and the true reference is Eng et al. (2001).

3.4. Organization of key data

Primary outcome data were sorted using the ICF classifications:

b4: Functions of the cardiovascular, haematological, immunological, and respiratory systems

b5: Functions of the digestive, metabolic, and endocrine systems

b7: Neuromusculoskeletal and movement related functions

Combination of d4: Mobility, d8: Major life areas and Other activity and participation

These classifications support the American Physical Therapy Association's (APTA) position (http://www.apta.org/AM/Template.cfm?Section=Home&TEMPLATE=/CM/ContentDisplay.cfm&CONTENTID=50081). We also made the following decisions related to our interpretation of the ICF classification system:

1. Cardiopulmonary functions measured included b410 Heart, b415 Blood vessel, b420 Blood pressure, b440 Respiration and b455 Exercise tolerance (ICF b4).
2. BMD is listed as b598, a metabolic function, since there is no category for bone strength. The ICF model makes it difficult to include consideration such as calcium intake, nutritional status, thyroid function, and all the other factors that could contribute to BMD (ICF b5).
3. Bowel/Bladder included b525 Defecation and d530 Toileting (ICF b5).
4. Pressure relief/bedsores included b810 Protective functions of the skin, b820 Repair functions of the skin, b830 Other functions of the skin and s810 Structure of areas of skin (ICF b5).
5. Range of motion was included under b710 Mobility of joint functions; Muscle Strength and Function included b730 Muscle power, b760 Control of voluntary movement, b770 Gait pattern, b789 Movement (ICF b7).
6. Hypertonicity included b735 Muscle tone, b750 Motor reflex and b765 Involuntary movement. Balance was listed under b235 Vestibular functions (ICF b7).
7. Psychological well-being included b130 Energy and drive functions, and d820 School education (ICF Combination).
8. Activities and participation included: d430 Lifting and carrying objects, d440 Fine hand use d445 Hand and arm use, d449 Carrying, moving and handling objects, d450 Walking, d455 Moving around and d855 Non-remunerative employment (ICF Combination).
9. Activities if daily living (ADLs) were classified under d230 Carrying out daily routine (including simulated self feeding) (ICF Combination).

4. Results

See individual Tables 4–7 with primary results by specific ICF classifications for pediatric and adult par-

Table 4
ICF- b4 (Functions of the cardiovascular, haematological, immunological, and respiratory systems) Adult participants only

Author	Design	Level	Population	Intervention	Outcome measures	Primary results
Luther et al. (2008)[9]	RCT with single blinding	2b	$N = 9$ unconscious adults w/TBI	Used conventional tilt × 1 table & tilt table with integrated stepping device × 1	# of syncopes/presyncopes (orthostatic hypotension, tachypnea, increased sweating) during interventions	Significantly more presyncopes on tilt table w/o than on the one with integrated stepping device at tilts of 50 or 70 degrees respectively
Faghri & Yount (2002)[7]	RCT	2b	$N = 28$ (14 healthy adults & 14 adults w/SCI)	30 min stationary standing & 30 min dynamic standing with FES for subjects with SCI	Stroke volume, cardiac output, HR, arterial blood pressure, total peripheral resistance (TPR) during supine-pre sitting, sitting-pre standing, & 30 min of standing	For subjects with SCI, significant reductions in systolic blood pressure, diastolic blood pressure, & mean arterial pressure in sitting to standing & stationary standing & maintained during dynamic standing. For healthy subjects values maintained during standing sessions. During 30 min of stationary standing, significant reductions in stroke volume, cardiac output all subjects, while peripheral resistance increased. During 30 min of dynamic standing, both groups maintained haemodynamics at pre-standing values except for reduction in stroke volume at 30 min of standing
Faghri et al. (2001)[8]	RCT	2b	$N = 14$ adults w/SCI	30 min upright with & w/FES in stander compared to standing w/o FES	Stroke volume, cardiac output, HR, arterial blood pressure, total peripheral resistance (TPR), & rate pressure product (RPP)	Cardiac output, stroke volume, & BP significantly decreased during passive standing, but maintained during FES standing, RPP & HR increased with FES standing
Eng et al. (2001) [2]	Survey	2c	$N = 126$ adults w/SCI	17-item survey on use of standers, effects, & perceived benefits	Subjective responses to survey organized into several categories	30% engaged in prolonged standing (40 min/session); Perceived benefits: circulation, akin integrity, reflex activity, bladder/bowel function, digestion, pain, sleep, fatigue; cost a deterrent
Edwards & Layne (2007)[10]	Case series	4	$N = 4$ adults w/SCI	Exercise program with dynamic weight-bearing device (DWB)	EMG, HR, & BP before & after intervention	Subjects actively responded to exercises during DWB w/positive physiologic changes in EMG, HR, & BP
Jacobs et al. (2003)[11]	Case series	4	$N = 15$ adults w/SCI	Protocol for system of FES vs frame-supported passive standing	HR, open circuit spirometry, EKG, & metabolic activity before & after intervention	Significant improvement in pO2 for FES vs passive standing & lower HR in passive standing vs FES

ticipants, then Table 8 for the results summary by CEBM levels, and Table 9 for a summary of user outcomes. Studies are not mutually exclusive to one category because of the multiple purposes of several studies, particularly the surveys.

b4: Functions of the cardiovascular, haematological, immunological, and respiratory systems (all adult participants) (See Table 4)

Six studies were identified in this category from Level 2b to 4. At Level 2b, there were three RCTs. At Level 2c, there was one survey. At Level 4, there were two case series. Participants included adults with spinal cord injury and traumatic brain injury and compared to healthy adults, with sample sizes ranging from 9 to 28 participants and 126 adult stander users for the survey. A tilt table with and without integrated stepping, standing devices with and without functional electrical stimulation (FES), and a dynamic weight-bearing

Table 5a
ICF – b5 (Functions of the digestive, metabolic, and endocrine systems) Pediatric participants

Author	Design	Level	Population	Intervention	Outcome measures	Primary results
Caulton et al. (2004)[14]	RCT (assessor blinded)	1b	$N = 52$: 26 children w/ CP; 26 normal children	50% increase in regular standing duration or control (no increase in regular standing duration) groups over 9-month period	Pre- & post-trial vertebral & proximal tibial vTBMD measured with quantitative computed tomography (QCT) before & after intervention	Intervention group showed a 6% mean increase in vertebral vTBMD; no change observed in mean proximal tibial vTBMD.
Ward et al. (2004)[12]	RCT (double blinded)	2b	$N = 20$ children w/disabling conditions: 10 WBV; 10 control	Standing on active or placebo devices, 10 min/day, 5 days/wk X 6 months	Three dimensional quantitative computed tomography before & after intervention	WBV group increased proximal tibial BMD; control group decreased proximal tibial BMD; vspine BMD change greater in WBV group; diaphyseal bone & muscle parameters did not show a response to treatment
Taylor (2009)[13]	Survey	2c	$N = 386$ school-based physical therapists	20-item on factors in the prescription and implementation of standing frame programs	Subjective responses to survey organized into several categories	58.7% rated pressure relief as most important benefit of standing; rated as very important or important: increasing bone strength
Kecsemethy et al. (2008)[4]	Case series	4	$N = 20$ w/CP	Quantified weight bearing in a passive stander for 30 min/ session, 4–6 sessions, 8 wks, total of 108 sessions, comparing 2 standers	Tilt angle, foot plates with load cells measure % of body weight during standing	Variable weight loads during standing from 37–101% of body weight; factors identified: type of stander and inclination; difference in body wt varied as much as 29%
Herman et al. (2007)[3]	Case series	4	$N = 19$ w/CP	Quantified weight bearing in a passive stander for 30 min/ session, 3–6 sessions, 2 wks, total of 110 sessions	Tilt angle, foot plates with load cells measure % of body weight during standing	Variable weight loads during standing from 23–102% of body weight, mean of 68%
Gudjonsdottir & Stemmons-Mercer (2002b)[34]	Case series	4	$N = 4$ pre-school children w/severe CP	Phase one: stood 30min/day 5x/wk X 8wks, 2 subjects in prone stander, 2 in oscillating stander Phase two: all subjects had 3 sessions on both standers	BMD of lumbar spine, proximal & distal femur before & after intervention	BMD increased in both subjects in oscillating stander and one subject in passive stander

Table 5b
ICF – b5 (Functions of the digestive, metabolic, and endocrine systems) Adult participants

Author	Design	Level	Population	Intervention	Outcome measures	Primary results
Ben et al. (2005)[30]	RCT (assessor blinded)	1b	$N = 20$ adults w/SCI	36 bouts (30 min/bout) over 12 wks on tilt table with 1 foot on a 15-degree wedge; other foot hung free (control)	ROM measured with torque wheel, BMD measured w/DEXA scan before and after intervention	Very slight increase in BMD
Goemare et al. (1994)[19]	Cohort study	2b	$N = 53$ adults w/SCI	Divided into 3 groups: 38 w/ daily standing for at least 1 hr, 3 times/wk, & 15 w/no standing	X-ray absorptiometry at L3 & L4, proximal femur & femoral shaft, & by single-photon absorptiometry at forearm before & after intervention	Standing group had better-preserved BMD at femoral shaft but not at proximal femur, than patients **not** standing; BMD at lumbar spine (L3, L4) was marginally higher in standing group; Standing with use of long-leg braces had significantly higher BMD at proximal femur than using standing frame or standing wheelchair

Table 5b, continued

Author	Design	Level	Population	Intervention	Outcome measures	Primary results
Eng et al. (2001)[2]	Survey	2c	$N = 126$ adults w/SCI	17-item survey on use of standers, effects, & perceived benefits	Subjective responses to survey organized into several categories	30% engaged in prolonged standing (40 min/session); Perceived benefits: circulation, akin integrity, reflex activity, bladder/ bowel function, digestion, pain, sleep, fatigue; cost a deterrent
Hoenig et al. (2001)[17]	Case report	3b	$N = 1$ adult w/SCI	Stood 5x/wk X1hr/day	Symptoms of constipation; freq of bowel movements, duration of bowel care in min before & after intervention	Standing imp constipation & decreased bowel care time
Dunn et al. (1998)[5]	Survey	3b	$N = 99$ adults w/ SCI	84% used their standers 41% used stander 1-6x/wk	Novel tool Focus group may have established validity, not clear No reliability testing	21% reported decreased in UTI and inc bladder emptying w/ stander use. Amt of standing correlated with reported more regular bowel movements
Netz et al. (2007)[18]	Case series	4	$N = 13$ adults (residents of nursing home, mean of 82 years)	Supported standing device use from 13–60 sessions with mean standing time of 16 minutes	MMT, ROM, reaching tests, independent standing, distance walked w/ walker, FIM	Statistically significant improvement in sphincter control
Shields & Dudley-Javoroski (2005)	Case Report	4	$N = 1$ adult w/ SCI	Average 12 min 4x/wk at 61deg upright in standing w/c	Questionnaire every 3 months for 12 months	Reported improvements in bowel
Frey-Rindova et al. (2000)[20]	Case series	4	$N = 29$ adults w/SCI (27 male) w/ paraplegia & tetraplegia	Comparisons at 6, 12, & 24 months post injury	BMD of radius, ulna, & tibia	Significant decrease in BMD over time, greater in subjects with tetraplegia; significantly lesser loss (1.5% & 3%) in 2 subjects who performed regular standing 1 hr/4X per wk
deBruin et al. (1996)[35]	Case series	4	$N = 19$ adults w/acute SCI	13 subjects divided into 2 groups: 6 w/supported standing &treadmill walking w/BWS, 7w/regular rehab program, & control group w/no intervention	BMD measured with peripheral computed tomography & flexural wave propagation velocity with biomechanical testing method before & after intervention	Early loading in stander maintained or slowed decreased of trabecular bone
Kaplan et al. (1981)[16]	Case series	4	$N = 10$ adults w/SCI	20min 1x/day $>$ 45 deg angle on tilt table & strengthening	Calciuria measured with urine analysis before & after intervention	Standing better at decreasing calciuria than exercises, early group (within 6 months of injury) benefited more than late group (between 12 & 18 months post injury)
Walter et al. (1999)[15]	Survey	4	$N = 99$ adults w/ SCI	Respondents stood $>$ 30min/day	Same data as Dunn Novel tool Focus group may have established validity, not clear No reliability testing	Daily used led to stat sig improvement in fewer bladder infections and improved bowel regularity

Table 6a
ICF – b7 (Neuromusculoskeletal and movement related functions) Pediatric participants

Author	Design	Level	Population	Intervention	Outcome measures	Primary results
Tremblay et al. (1990)[21]	RCT	2b	$N = 22$ w/ CP; 12 experimental w/ intervention, 10 control	Standing with feet dorsiflexed on a tilt-table for 30 min vs. control group kept at rest	Torque EMG before & after intervention	Standing in dorsiflexion group had stats sig decrease in spasticity; inhibitory effects lasted up to 35 min
Semler et al., (2008)[22]	Case series	4	$N = 8$ children w/OI, types III & IV	WBV applied using vibrating platform on tilting table X 6 months 2x/day 9 min total per session WBV & 6 min total standing w/o WBV	Brief Assessment of Motor Function (BAMF), tilt angle before & after intervention	Improved BAMF; increased tilting-angle (median = 35 degrees) & increased in ground reaction force
Semler et al. (2007)[23]	Case series	4	$N = 6$ children (4w/OI type III & IV, 1 w/CP, &1 w/lumbar spine defect)	WBV applied using vibrating platform on a tilting table x 6 months 2x/day 9 min total per session WBV and 6 min total standing w/o WBV	Brief Assessment of Motor Function (BAMF), tilt angle before & after intervention	Improved BAMF score; increased tilt angle

Table 6b
ICF – b7 (Neuromusculoskeletal and movement related functions) Adult participants

Author	Design	Level	Population	Intervention	Outcome measures	Primary results
Baker (2007)[36]	RCT	2b	$N = 6$ adults w/MS (wheelchair dependent)	3x/wk X 3 for 30 min ex program in standing frame vs 3 3x/wk X 3 for 30 min ex program lying down	Ashworth, self-report spasm scale before & after intervention	Increase in range of motion of the ankle and hip with use of standing frame; downward trend in spasticity for knee flexion and ankle dorsiflexion in standing group & downward trend in reduction of spasm for both groups
Allison & Dennet (2007)[37]	RCT	2b	$N = 17$ adults w/CVA	Conventional physical therapy (PT) 45min vs. PT plus standing 45min 14-28 days	Rivermead Motor Assessment (Gross Functional Tool), Trunk Control Test & Berg Balance Scale before & after intervention	Stat sig .Berg improved, trend in Rivermead GM in PT & standing group over PT alone
Bagley et al. (2005)[38]	RCT	2b	$N = 140$ adults w/acute CVA (severe)	Usual PT vs PT plus standing 20–30 min/day X 14 days	Rivermead Mobility Index (RMI), Barthel Index, Rivermead Motor Assessment (RMA), Motor Assessment Scale (sitting & balance), Motor Trunk Control Test before & after intervention	No difference in outcome measures nor resource savings from use of Oswestry Standing Frame
Eng et al. (2001)[2]	Survey	2c	$N = 126$ adults w/SCI	17-item survey on use of standers, effects, & perceived benefits	Subjective responses to survey organized into several categories	30% engaged in prolonged standing (mean of 40 min/session) 3-4X/wk; perceived benefits: improved ability to straighten legs, decreased reflex activity, improved skin integrity
Chang (2004)[25]	Survey	3b	$N = 58$ PTs	Survey on use of standers in ICU	Response to survey items (unknown # of items)	Perceived benefits: 81% identified improved strength, 70% identified increased arousal

Table 6b, continued

Author	Design	Level	Population	Intervention	Outcome measures	Primary results
Richardson (1991)[31]	Case report	3b	$N = 1$ adult w/TBI	Tilt table regime to passively stretch Achilles tendon over 27 days after conventional PT	Pain during stretching period, ROM of ankle joint	Improved ROM and tolerance for standing
Walter et al. (1999)[15]	Survey	4	$N = 99$ adults w/ SCI	Respondents who stood > 30min/day	Same data as Dunn Novel tool Focus group may have established validity, not clear No reliability testing	Daily used led to stat sig improvement in ROM, spasticity and bedsores
Dunn et al. (1998) [5]	Survey	4	$N = 99$ adults w/ SCI	84% used their standers 41% used stander 1-6x/wk	Novel tool Focus group may have established validity, not clear No reliability testing	42% reported decreased in spasticity w/ standing Amount of time spent standing correlated w/ reported decrease in spasticity 38% reported standing improved their leg ROM
Netz et al. (2007)[18]	Case series	4	$N = 12$ adults nursing home residents	Activity program performed in standing box	MMT ROM Reaching tests Standing time Distance walked w/ walker FIM	Stat significant increase in strength in hip and knee extensors, abduction, and all ankle motions; None of the subjects could stand or walk at beginning of study, at conclusion 60% could stand independently and walked w/walker
Singer et al. (2003)[24]	Case series	4	$N = 40$ adults with TBI and contractures	Prolonged weight bearing stretches (upright on tilt table)	PROM Ashworth Scale Barry-Albright Dystonia Scale	23/40 improved PROM with standing alone Dystonia was best predictor of failure of standing alone to improve PROM
Tsai et al. (2001)[26]	Case series	4	$N = 17$ adults w/ CVA	30 min plantarflexor stretch on tilt table	MAS ROM Evoked potentials	ROM increased, plantar flexor spasticity decreased and tibialis anterior spasticity increased
Kunkel et al. (1993)[39]	Case series	4	$N = 6$ adults: 4 w/SCI, 2 w/MS	Standing time averaged 144 hrs over 135 mean days	H-reflex, deep tendon reflexes (DTR), clonus before & after intervention	No change in H-reflex, DTR, & clonus
Bohannon & Larkin (1985)[29]	Case series	4	$N = 20$ adults w/CVA & other	Stood 30 min, 5–22 sessions, 2–6X/wk	Goniometry before & periodically before stretch	Increased passive ankle dorsiflexion (mean of 8 degrees for entire period)
Odeen & Nutsson (1981)[40]	Case series	4	$N = 9$ adults w/SCI	Stood 30 min for 4 days (8 sessions): 3 conditions: stretch in supine, standing with dorsiflexors stretched & loaded & standing with plantarflexors stretched & loaded	EMG to measure resistance to passive movements at 3 different speeds	Spasticity decreased with all conditions, but decreased most standing with plantarflexors stretched & loaded
Shields & Dudley-Javoroski (2005)	Case Report	4	$N = 1$ T10 adult w/ SCI	Average 12 min 4X/wk at 61° upright in standing wheelchair	Questionnaire every 3 months for period of 12 months	Reported improvements in spasticity
Bohannon (1993)[28]	Case report	4	$N = 1$ adult w/SCI	Tilt table standing, 5 non-consecutive days at 80° X 30 min	Modified Ashworth (MAS) & pendulum testing before & after intervention	Decreased spasm & spasticity

Table 7a
ICF – Combination d4 (Mobility), d8 (Major life areas), and Other activity and participation (Pediatric participants)

Author	Design	Level	Population	Intervention	Outcome measures	Primary results
Noronha et al. (1989)[32]	Case series	4	$N = 10$ children w/CP: (2 groups)	Two sets of tests of hand function while sitting & prone standing	Rate of manipulation measured w/Jebsen-Taylor Hand Function Test & Hohlstein test for quality of grasp on each subtest of Jebsen-Taylor test in both positions	No significant diff on Jebsen-Taylor test; for simulated feeding & picking up small objects performed significantly faster in prone standing

Table 7b
ICF – Combination d4 (Mobility), d8 (Major life areas), and Other activity and participation (Adult participants)

Author	Design	Level	Population	Intervention	Outcome measures	Primary results
Eng et al. (2001)[2]	Survey	2c	$N = 126$ adults w/SCI	17-item survey on use of standers, effects, & perceived benefits	Subjective responses to survey organized into several categories	30% engaged in prolonged standing (40 min/session); Perceived benefits: circulation, skin integrity, reflex activity, bladder/bowel function, digestion, pain, sleep, fatigue; cost a deterrent
Chang (2004)[25]	Survey	3b	$N = 58$ PTs	Survey on use of standers in ICU	Response to survey items (unknown # of items)	70% identified increased arousal
Dunn et al. (1998)[5]	Survey	3b	$N = 99$ adults w/SCI	42-item survey on use of standers, effects, & perceived benefits	Subjective responses to survey organized into several categories	Decreased spasticity w/ standing correlated with amount of time in standing
Walter et al. (1999)[15]	Survey	3b	$N = 99$ adults w/SCI	42-item survey on use of standers, effects, & perceived benefits	Same data as Dunn Novel tool Focus group may have established validity, not clear No reliability testing	Daily stander use led to statistically significant improvement in ROM, spasticity, & bedsores
Nelson & Schau (1997)[33]	Case report	4	$N = 1$ adult w/ CP	Client work seated vs in stander vs unsupported standing	Work output measure in 3 positions	Subject performed more "work" while in stander than other two conditions
Riek et al. (2008)[41]	Case series	4	$N = 5$ adults w/ SCI	Standing frame compared to sitting rest posture, weight relief raises, transfers, & standing depression lifts for shoulder position	Flock of birds magnetic tracking to measure 3-dimensional positions of the scapula, humerus, & thorax during various activities	Standing in frame results in less scapular anterior tilt & greater glenohumeral external rotation than standing depression lifts & weight relief raises

Table 8
Summary of intervention studies sorted by CEBM levels and outcomes

ICF outcome	Subjects	CEBM Level and source w/ positive outcomes	CEBM Level and source w/ negative outcomes	CEBM Level and citation w/ no difference
Cardiopulmonary ICF b4	Adults (>21)	II [9] II [7,8] IV Edwards 10	II [7–9]	
BMD ICF b5 Functions of the digestive, metabolic and endocrine systems	Adults (>21)	II[19] II[19] III[35] IV[16]		I[30] II [16] IV [40]
	Children (0-21)	I1[14] II[12] IV[34]		I [30] II [13,14]
Bowel ICF b5	Adults (>21)	II[2,18] III[5,15,17] IV[27]		
Hypertonicity ICF b7	Adults (>21)	II[39] II [2] III[5,15,31] IV[26,33,41]	II [39]	II[35] IV[40]
Range of Motion b710 Mobility of joint functions	Adults (>21)	I[30] II[2,36] III [5,15] IV[18,28]	I [30]	IV[40]
Muscle Strength & Function ICF d4	Adults (>21)	IV[33] IV [41] IV[18]		I [39] II[36,37]
	Children (0-21)	II[21] IV[22,23,32]		II [20]

Table 9
Summary of user/therapist outcomes sorted by CEBM levels and results

Outcome	User/Therapist	CEBM Level and source w/ positive outcomes	CEBM Level and source w/ negative outcomes	CEBM Level and citation w/ no difference
Cardiopulmonary ICF b4	Adults w/ SCI who used a stander regularly	II[2]		
BMD ICF b5 Functions of the digestive, metabolic and endocrine systems	School-based PTs	II[13]		
Bowel and Bladder ICF b5, d5	Adults w/ SCI who used a stander regularly	II[25] III[2,5,15,17] IV [18,27]		III[5]
Pressure relief/bedsores ICF b5	School-based PTs Adults w/ SCI	II[2,13] III[5,15,25]		
Muscle Strength and Function ICF b7	Acute Care PTs in an ICU	III [25]		
Range of Motion ICF b7	Acute Care PTs in an ICU School-based PTs Adults w/ SCI	II[13] II [2,26] III [5,15,25] IV [r24]		III[5]
Hypertonicity ICF b7	Adults w/ SCI who used a stander regularly	II[2,26] II [2,15,25] IV [27]		III[5]

standing device comprised the interventions. Outcome measures (pre/post) included EKG studies, heart rate (HR), blood pressure (BP) and measures of hemodynamics (snycopes, tachypnea, orthostatic hypotension, and cardiac measures) for the interventions. For the stander users, measures were their perceived benefits of use.

A surprising finding indicated passive supported standing alone had negative systemic effects on the cardiovascular system [7–11]. Both the individuals without SCI and those with SCI showed a decrease in cardiac output and stroke volume with 30 minutes of passive standing, but stroke volume decreased less for individuals without SCI [7]. Of the three Level 2b studies, two found combining FES with standing significantly improved the cardiovascular systems' responses to standing in participants with SCI through the prevention of orthostatic hypotension [7,11]. Both the Level 4 studies concurred that "active" standing (using FES or voluntary movements) resulted in more stable hemodynamics than with the use of passive standing alone [10, 11]. The user survey noted 30% engaged in an average of 40 minutes/session of regular standing with the following perceived benefits: well being, circulation, skin integrity, reflex activity, bowel ad bladder function, digestion, sleep, pain and fatigue. Equipment cost was a deterrent [2].

b5: Functions of the digestive, metabolic, and endocrine systems

Seventeen studies from Level 1b to 4 were identified in this category, six with pediatric and 11 with adult participants (See Tables 5a and b).

Pediatric participants: At Level 1b and 2b, there was one study each. At Level 2c, there was one study (a survey). At Level 4, there were three studies. In this category, the number of participants ranged from four to 53 and included, typical children, children with "disabling conditions [12]", and children with CP for the clinical studies and 386 school-based PTs for the survey. Three of the six studies focused on BMD and two investigated the amount of body weight borne through the lower extremities during standing. Two of the studies had a control group of typical children. Interventions included use of a tilt table or standing devices (static, vibrating, and oscillating) over a period of time up to nine months with a frequency of daily to five times/week. Intervention study outcomes measured BMD, percent of body weight exerted against load cells, tilt angle, and type of standing device. The survey of school based PTs measured their perceived benefits and outcomes of standing frame programs.

Of significance from the survey was respondent ranking of the following top three reasons for using standers: to provide pressure relief from sitting, promote social interaction, and improve bone strength [13]. For the RCT studies, there was significant increase in vertebral BMD but not tibial BMD [12,14]. The addition of whole body vibration (WBV) to supported standing activities improved BMD at the proximal tibia in children with CP, one of the two sites most at fracture risk for these children [12]. Two studies noted variable weight loads from 23 to 102% of body weight dependent on body alignment in the stander [3,4] and type of device [3].

Adult participants: At Level 1b and 2b, there was one study each. At Level 3b there were two studies, a case report and a higher level survey. At Level 4, there was another case report, one survey, and four case series. In this category, the number of participants ranged from one to 99 adults with the diagnosis of SCI primarily. For the surveys, the participants were regular stander users.

Findings from the surveys reflected user perceived outcomes, including a positive effect on digestion (bowel and bladder) as well as decreased time needed for bowel care [2,5,16]. These findings were similar to results from two intervention studies [17,18]. The most significant finding from the non-survey studies: participants using long-leg braces in the standing device had significantly higher BMD at the proximal femur than those who did not stand using braces [19]. Standing on a tilt table decreased calciuria more than exercise for the group of individuals with SCI during the 1st six months post injury [16]. There was a statistically significant improvement in strength, standing, walking, and sphincter control after use of a standing support device in adult residents of a nursing home [18]. One study found less reduction in BMD in two participants with SCI who used a regular standing routine versus those who did not have one [20].

b7: Neuromusculoskeletal and movement related functions

Twenty studies were identified in this category from Level 2b to 4, three with pediatric and 16 with adult participants (See Tables 6a and b).

Pediatric participants: At Level 2b, there was one study. At Level 4, there were two studies. Participants included children with CP and OI ranging from six to 22 in number. Outcome measures included EMG, tilt angle, percent of body weight on supporting limbs during standing, and the Brief Assessment of Motor Function (BAMF). Interventions included supported standing with and without ankles in a dorsiflexed position, with and without WBV, and ability to tolerate increased tilt table angle. Important findings included a statistically significant decrease in spasticity of plantarflexors [21] and improved BAMF scores [22,23].

Adult participants: At Level 2b, there were three studies. At Level 2c, there was one study, a survey. At Level 3b, there were two studies. At Level 4, there were ten studies. Participants included one to 140 adults with primarily the diagnoses of SCI, CVA, TBI, and MS and 58 PTs for the survey.

For the clinical studies, interventions included routine PT programs and specific standing programs with or without a focus on specific activities, and varied attention to specific ankle positions. Outcome measures included Ashworth, modified Ashworth, self reported spasm scale, Barry-Albright Dystonia scale (BAD), deep tendon reflexes (DTR), EMG, pendulum test, evoked potentials, ROM, manual muscle tests, specific functional measures [Functional Independence Measure (FIM)], Rivermead, Berg balance test, physiologic measures, pain tolerance to the upright position, and other tests.

The most common findings from the clinical studies were increased ROM and decreased hypertonicity. One study of the residents of a nursing home who performed exercises in a standing box showed increased hip and lower extremity strength and improved ability to stand independently and walk using a walker [18]. The user surveys, reported improved ROM, decreased spasm and spasticity, and improvement in strength [2,5,15,24]. In the survey of PTs in the ICU, 94.8% felt the purpose was to "facilitate weight bearing [25]." From the case series, findings included decreased spasm and spasticity [26–28] and improved ROM [20,24,29,31].

Other: Combination of d4: Mobility, d8: Major life areas and Other activity and participation

Seven studies were identified in these categories from Level 2c to 4, one with pediatric and six with adult participants (See Tables 7a and b).

Pediatric participants: At Level 4, there was one study. Participants were children with CP (10 participants). Outcome measures were tests measuring quality of hand function and grasp. The most significant finding was greater speed in picking up small objects and simulated feeding [32].

Adult participants: At Level 2c, there was one study. At Level 3b, there were three studies (surveys). At Level 4, there were two studies. Participants for the clinical studies were from 1 to 126 adults with SCI and TBI. For the surveys, participants were 99 stander users and 58 PTs working in an intensive care unit (ICU). Intervention measures were user and PT surveys on use of standers and perceived benefits as well as shoulder position and work activities in a standing frame.

User survey findings included benefits from perceived value from the use of supported standers related to ROM, psychological factors, bowel and bladder function, pressure relief/bed sores, and hypertonicity [2,5]. The most significant findings for the case report was improved work output [33]. The most significant finding from the PTs was increased arousal with standing, in addition to changes previously noted in ICF b7 [25].

5. Discussion: Clinical practice and research implications

After systematically reviewing the supported standing pediatric and adult literature based on ICF classifications and CEBM categories, conclusions were difficult to draw as the literature varied greatly in study design, intervention, and outcome measures. Table 8 summarizes the results by CEBM levels for pediatric and adult participants. For all participants, the available information moderately supports the beneficial impact upon BMD and indicates potentially positive outcomes for improving range of motion, spasticity, and bowel function. Because of the variable weight loads borne through the feet in supported standing, therapists must consider body alignment, angle of inclination, and type of stander in relationship to goals of the standing program. There was a potentially negative cardiopulmonary side effect from standing in participants with SCI. With the exception of ROM, the supported standing perceived outcomes and benefits reported by therapists and stander users were not consistent with the non-survey literature-measured outcomes. Therapists and stander users felt supported standing had positive effects on weight bearing, pressure relief, ROM, and psychological well being.

The apparent limitations of the supported standing body of knowledge include lack of study design rigor, limited standardization of supported standing protocols, and large variance in outcome measures. Clinical practice is difficult to replicate via research, but practitioners should seek a closer alignment and understanding of the relationship between mechanistic outcomes and clinical goals. Future supported standing clinical investigations need to define intervention outcomes in a more rigorous manner, particularly for pediatric participants, considering the following:

1. Quantified weight bearing on the axial skeleton and lower extremities and postural alignment, with the use of force transducers, scales, and loading devices to show actual lower extremity weight bearing.
2. Dosage of standing programs including duration, position, frequency, equipment utilized, and tasks performed during standing.
3. Outcome measures addressing specific ICF areas including behavioral and cognitive abilities combined with the physiological and functional skill areas utilized currently.
4. Outcome measures for each participant group, for example BMD in children with CP at sites where fractures usually occur:
5. FES and or WBV combined with supported standing, to enhance outcomes.

Using evidence-based practice, it is currently challenging to construct a standing protocol prescription for a given participant, and equally complicated to select optimal targeted outcomes. Considerations for practicing therapists are to combine the results of this systematic review with sound clinical judgment based on supported stander usage rationale in their particular setting.

Limitations of this systematic review included potential reviewer subjectivity in the interpretation of results, offset by the use of three reviewers, variable sets of studies identified on repeated search attempts offset by multiple searches performed on several dates, and reviewer choices for classification schema to sort the data and interpret the results, offset by taking into consideration professional organizational recommendations and generally-accepted practice.

Conflicts of Interest

None reported.

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